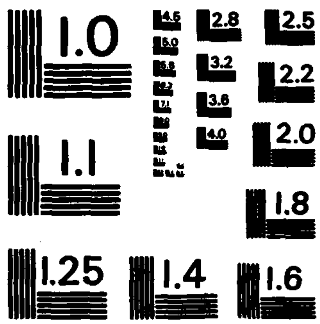
AD-A147 893 HANGAR HEATING AND ENERGY CONSERVATION MANUAL(U) NAVAL CIVIL ENGINEERING LAB PORT HUENEME CA J L ASHLEY SEP 84 AFESC/DEB-TR-84-01 1/2

UNCLASSIFIED F/G 1/5 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

3

Air Force No. DEM-TR-84-01

Special Project

2873SP

HANGAR HEATING AND ENERGY CONSERVATION MANUAL

By

J. L. Ashley

AD-A147 893

September 1984

HEADQUARTERS AIR FORCE ENGINEERING AND SERVICE CENTER
Tyndall Air Force Base, Florida 32403

NAVAL FACILITIES ENGINEERING COMMAND
Alexandria, Virginia 22332

NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California 93043

Approved for public release; distribution unlimited.

METRIC CONVERSION FACTORS

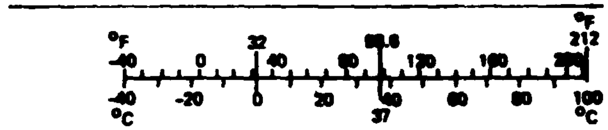
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AF No. DE TR-84-01	2. GOVT ACCESSION NO. DN687061	3. RECIPIENT'S CATALOG NUMBER AD-A147 893
4. TITLE (and Subtitle) HANGAR HEATING AND ENERGY CONSERVATION MANUAL		5. TYPE OF REPORT & PERIOD COVERED Final; Oct 1979–Sep 1983 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. L. Ashley		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS NAVAL CIVIL ENGINEERING LABORATORY Port Hueneme, California 93043		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS ZO829-01-111C
11. CONTROLLING OFFICE NAME AND ADDRESS Chief of Naval Material Washington, DC 20360		12. REPORT DATE September 1984 13. NUMBER OF PAGES 100
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Headquarters AFESC Tyndall Air Force Base, Florida 32403		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

HVAC, energy conservation, hangars

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Hangars and similar structures require large amounts of energy for space heating. Energy conservation survey techniques for hangars are defined and technical data sheets are included which provide: (1) procedures to identify energy conservation deficiencies, (2) methods to calculate annual energy losses, (3) recommend solutions, and (4) methods to calculate annual energy savings.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Library Card

Naval Civil Engineering Laboratory
HANGAR HEATING AND ENERGY CONSERVATION MANUAL
(Final), by J. L. Ashley
AF No. DED TR-84-01 100 pp illus Sep 1984 Unclassified

1. Energy conservation 2. Hangars I. Z0829-01-111C

Hangars and similar structures require large amounts of energy for space heating. Energy conservation survey techniques for hangars are defined and technical data sheets are included which provide (1) procedures to identify energy conservation deficiencies, (2) methods to calculate annual energy losses, (3) recommend solutions, and (4) methods to calculate annual energy savings.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

CONTENTS

Page

HANGAR ENERGY CONSERVATION MANUAL

INTRODUCTION

Hangars are large structures that require large amounts of energy for space heating. Headquarters Air Force Engineering and Service Center and the Naval Facilities Engineering Command funded a joint Air Force/Navy hangar heating investigation that was conducted by the Naval Civil Engineering Laboratory. This Manual is one of the results of the joint investigation.

The Hangar Energy Conservation Manual is organized into three sections: Section 1, Hangar Energy Conservation Survey Techniques; Section 2, Technical Option Sheets; and Section 3, General Equations. Section 1, Survey Techniques, is a checklist to be used in a hangar energy survey that is cross referenced to the applicable energy conservation Option Tech Sheets (Section 2). Each Tech Sheet presents a description of an energy conservation option, application feasibility criteria, survey data requirements, procedure to calculate the annual energy surveys available, option life expectancy and estimated installation cost. Section 3 is equations associated with the energy conservation Option Tech Sheets, which can be used to increase the accuracy of the annual energy savings projected by the Tech Sheets.

Four appendixes are contained in this manual. Appendix A provides information required for designers to install or design a destratification system, Appendix B provides criteria to estimate lighting system energy savings, Appendix C provides thermal properties of materials and fuel heat values, and Appendix D provides national weather data.

The procedures presented in this manual provide methods to quickly estimate the results of hangar energy conservation options. Other methods are available that produce similar results and can be utilized if so desired. Although this Manual was written for hangars, the procedures can be used for most large industrial buildings and warehouses that must be heated.

SECTION I - SURVEY TECHNIQUES

SURVEY TECHNIQUES

A hangar survey should be conducted in a systematic manner. The following seven areas need to be inspected for discrepancies that cause excessive heat loss:

1. Hangar aircraft access doors
2. Vehicle access doors
3. Personnel access doors
4. Exterior walls
5. Roof
6. Windows
7. Heating system and controls

The location and physical characteristics of all discrepancies should be recorded. Survey guidelines, with suggested correction measures, are as follows:

Item	Reference
1. Aircraft access doors	
1.1 Door seal material: good bad rubber (replace with nylon brush seals)	Tech Sheet No. 9 Tech Sheet No. 10
1.2 Door alignment: good bad (realign)	Tech Sheet No. 12
1.3 Insulation: yes (____ inches, material) no (insulate)	Tech Sheet No. 1
1.4 Surface condition: good bad (repair, seal holes, etc.)	Tech Sheet No. 2
1.5 Aircraft appendage protrusions through doors: no yes (seal)	Tech Sheet No. 11
2. Vehicle access doors	
2.1 Are vehicle access doors installed: yes no (install)	Tech Sheet No. 13
2.2 Door seal condition: good bad (repair or replace)	Tech Sheet No. 9

2.3 Surface condition: good bad Tech Sheet No. 2
(repair, seal holes, etc.)

2.4 Insulation: yes (____ inches, Tech Sheet No. 1
material) no (insulate)

2.5 Alignment: good bad Tech Sheet No. 12
(realign)

2.6 Flexible vinyl strip doors installed: Tech Sheet No. 14
yes no (install)

3. Personnel access doors

3.1 Door seal condition: good Tech Sheet No. 16
bad (repair or replace)

3.2 Surface condition: good Tech Sheet No. 9
bad (repair, seal holes, etc.)

3.3 Door insulated: yes no Tech Sheet No. 15
(insulate)

3.4 Door frequently used: no Tech Sheet No. 14
yes (install flexible vinyl Tech Sheet No. 17
strip door, entrance vestibule, Tech Sheet No. 18
or revolving door)

4. Exterior walls

4.1 Insulation: yes (____ inches, Tech Sheet No. 1
material) no (insulate)

4.2 Surface condition: good Tech Sheet No. 2
bad (repair, seal holes, etc.)

4.3 Floor/wall caulking: yes Tech Sheet No. 3
no (caulk)

4.4 Ceiling/wall caulking: yes Tech Sheet No. 3
no (caulk)

5. Roof

5.1 Insulation: yes (____ inches, Tech Sheet No. 1
material) no (insulate)

5.2 Surface condition: good Tech Sheet No. 2
bad (repair, seal holes, etc.)

6. Windows

6.1 Condition: good bad (replace broken, cracked, or missing panes) — Tech Sheet No. 6

6.2 Daytime electric lighting: no yes (reduce window area by replacement with wall/door structural material or cover with insulation) — Tech Sheet No. 5

6.3 Double glazed or storm windows: yes no (install double glazed or storm windows) — Tech Sheet No. 7

6.4 Will windows close and seal: yes no (repair, replace seals, etc.) — Tech Sheet No. 8

7. Heating System

7.1 Aircraft access door shutoff switch: yes no (install shutoff switch) — Tech Sheet No. 20

7.2 Temperature setback device: yes no (install for off-shift periods) — Tech Sheet No. 21

7.3 Ceiling level temperature 10°F greater than floor level temperature: no yes (destratify or install radiant heating system) — Tech Sheet No. 22, Tech Sheet No. 26, Tech Sheet No. 27, Tech Sheet No. 28, Tech Sheet No. 29, Tech Sheet No. 30

7.4 Central heating plant for all hangars: yes no (tune up hangar's boiler) — Tech Sheet No. 23

8. Miscellaneous

8.1 Energy efficient lighting in hangar bay: yes no (install HPS lighting) — Tech Sheet No. 25

8.2 Fluorescent office lighting: no yes (reduce wattage) — Tech Sheet No. 24

8.3 Insulation between heated/cooled and non-heated/cooled interior partitions: yes no (insulate) — Tech Sheet No. 4

8.4 Vehicle loading dock: no yes (install seals) — Tech Sheet No. 19

SECTION II - TECHNICAL SHEETS

EXTERIOR SURFACE INSULATION (Tech Sheet No. 1)

Description

Many hangars were constructed without wall or door insulation and very little roof insulation. Insulating exterior surfaces can save significant amounts of energy. In addition to reducing the amount of heat that is transmitted through the hangar walls and roof, insulation can also reduce air infiltration. Priority should be given to insulating exterior surfaces that have no insulation before adding insulation to surfaces with existing but substandard insulation.

Feasibility Requirements

Site specific but, in general, insulating exterior surfaces is feasible for all heated/cooled structures.

Survey Data Requirements

1. Average number of annual heating/cooling degree days; D_h and D_c, days-°F/yr
2. Area of exterior surfaces to be insulated; A, ft²
3. U value of existing exterior surface; U_e, Btu/ft²-°F-hr
4. U value of insulation to be added; U_i, Btu/ft²-°F-hr
5. Overall efficiency of heating/cooling system; e_h and e_c; %÷100.

Procedure

Calculate the average annual energy savings (AES) as follows:

$$AES = \frac{24 \times A \times D_h \times (U_e - U_i)}{e_h} + \frac{24 \times A \times D_c \times (U_e - U_i)}{e_c}, \text{ Btu/yr}$$

General Information

Life: 25 years
Installation Cost: Site specific

SEAL HOLES AND CRACKS IN WALLS AND DOORS (Tech Sheet No. 2)

Description

Often holes and cracks exist in hangar walls and doors caused by ground settling, corrosion, wind damage, and collisions. These holes and cracks provide a constant source for air infiltration and should always be repaired. Temporary patches can be made (duct tape, cardboard, etc.) until permanent repairs are done.

Feasibility Requirement

Always feasible for heated structures

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr

2. Area of hole or crack; A, ft^2

Procedure

Calculate the average AES from Figure 1 or as follows:

$$AES = 110\ A\ D\ \sqrt{5{,}700 + D_h},\ \ Btu/yr$$

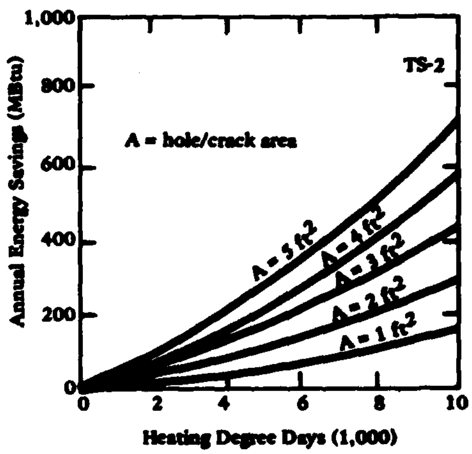


Figure 1. Annual energy savings for Test Sheet No. 2.

General Information

Life: Varies Installation Cost: Varies

SEAL WALL, FLOOR, AND ROOF CRACKS (Tech Sheet No. 3)

Description

The junction made when the wall of a hangar joins with the floor or roof is a source of air infiltration. A small crack exists at this junction that constantly lets cold outside air in and allows warm inside air to escape. This air infiltration source can be sealed by caulking the crack with one of many caulking materials available.

Feasibility Requirement

Always feasible for heated hangars.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr
2. Hangar perimeter less the width of aircraft access doors; L, ft

Procedure

Calculate the average AES from Figure 2 or as follows:

$$AES = 0.14\ L\ D\sqrt{5{,}700 + D_h},\ \text{Btu/yr}$$

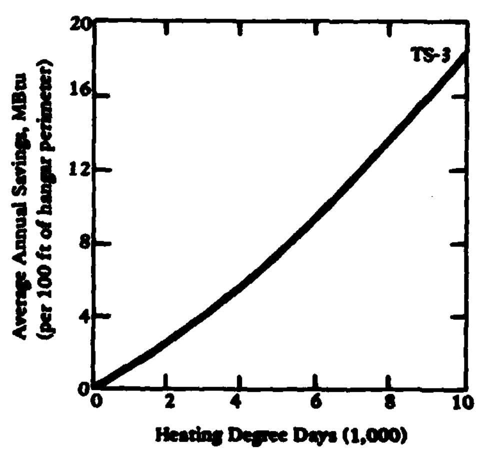


Figure 2. Annual energy savings for Tech Sheet No. 3.

General Information

Life: 10 years
Installation Cost: $15/100 ft

INSULATE BETWEEN HEATED, COOLED, AND NON-HEATED SPACES (Tech Sheet No. 4)

Description

While a hangar's exterior wall may be insulated, internal partitions between spaces may not be. Hangar bays often adjoin air conditioned office spaces. Installing insulation between these partitions can save energy, Figure 3. A vapor barrier is required to prevent water condensation.

Feasibility Requirements

Site specific. Feasible for non-insulated partitions with at least a 10°F temperature difference on each surface for 180 days or more.

Survey Data Requirements

1. Partition area; A, ft^2
2. Existing U value for partition; U_p, Btu/ft^2 - °F-hr
3. U value for insulation; U_f, Btu/ft^2 - °F-hr
4. Temperature difference across the partition; ΔT, °F
5. Duration of temperature difference; N, days/yr
6. Overall heating system efficiency; e, %÷100

Procedure

Calculate the average AES as follows:

$$AES = \frac{24\ A\ N}{e} (U_f - U_p)\ \Delta T, \text{ Btu/yr}$$

General Information

Life: 25 years
Installation Cost: Site specific

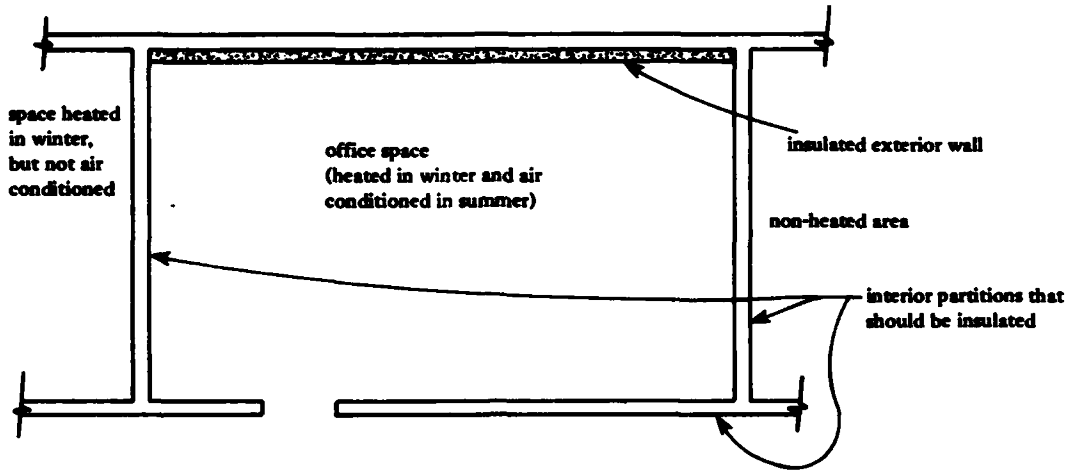


Figure 3. Hangar bay.

REDUCE WINDOW AREA (Tech Sheet No. 5)

Description

Glass windows have little insulating value and are sources of heat loss. Most activity in hangars on modern aircraft requires artificial light because natural lighting is insufficient. Reducing window area can reduce energy consumption when artificial lighting is required. Windows can be removed and replaced with wall sections or they can be covered with insulation.

Feasibility Requirements

Site specific, but reducing window area is feasible for all heated structures that require artificial interior lighting.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr

2. Window area to be reduced; A, ft^2

Procedure

Calculate the average AES from Figure 4 or as follows:

$$AES = 5.8 \, A \, D_h \text{ Btu/yr}$$

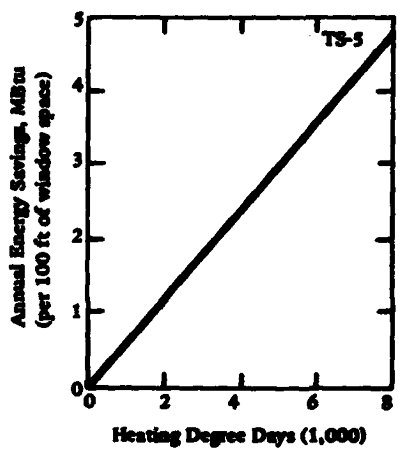


Figure 4. Annual energy savings for Tech Sheet No. 5.

General Information

Life: 25 years
Installation cost: Site specific

REPLACE BROKEN AND/OR MISSING WINDOWS (Tech Sheet No. 6)

Description

Infiltration of outside air into heated buildings is a major source of heat loss. Broken and/or missing window panes contribute greatly to air infiltration. Replacing broken or missing window panes should always receive a high priority as an energy conservation action.

Feasibility Requirement

Always feasible for heated structures.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr

2. Total area of broken or missing windows; A, ft²

Procedure

Calculate the average AES from Figure 5 or as follows:

$$AES = 110\ D_h\ A\sqrt{D_h + 5{,}700},\ \text{Btu/yr}$$

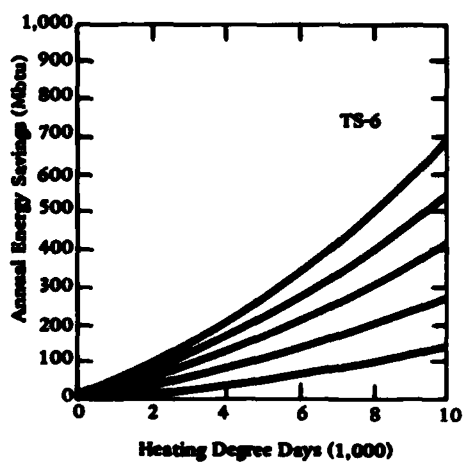


Figure 5. Annual energy savings for Tech Sheet No. 6.

General Information

Life: 15 years
Replacement cost: Variable

STORM AND DOUBLE GLAZED WINDOWS (Tech Sheet No. 7)

Description

Glass windows have little insulating value and are a heat loss source. Some hangars and other structures use windows to provide most of their interior lighting requirements. Adding storm windows or double glazed windows for natural lighting reduces the amount of heat loss and air leakage.

Feasibility Requirements

Feasible for heated structures in locations with 2,000 or more heating degree days.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr

2. Area of windows to be double glazed; A, ft^2

Procedure

Calculate average AES from Figure 6 or as follows:

$$AES = 18\ A\ D_h,\ \text{Btu/yr}$$

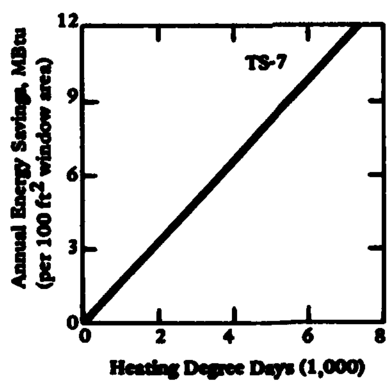


Figure 6. Annual energy savings for for Tech Sheet No. 7.

General Information

Life: 25 years
Installation Cost: Site specific

REPLACE WINDOW SEALS (Tech Sheet No. 8)

Description

Many hangar windows are opened during hot weather for ventilation. As time progresses, the windows do not seal tightly when closed and provide an air infiltration source. Often, operable windows were designed and installed with no seals or the seals have deteriorated. Adding or replacing window seals for can reduce air infiltration.

Feasibility Requirements

1. Marginally feasible for heated structures in locations with less than 2,000 heating degree days.

2. Always feasible for heated structures in locations with more than 2,000 heating degree days.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr

2. Length of window sealing required; L, ft

Procedure

Calculate the average AES from Figure 7 or as follows:

$$AES = 0.45\ L\ D_h \sqrt{5,700 + D_h}, \text{ Btu/yr}$$

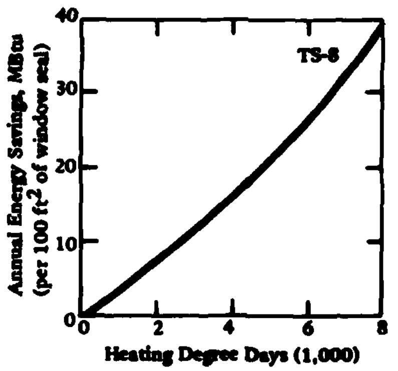


Figure 7. Annual energy savings for for Tech Sheet No. 8.

General Information

Life: 5 years
Cost: $1.00/foot

REPLACE MISSING HANGAR DOOR SEALS (Tech Sheet No. 9)

Description

Hangar aircraft access doors are a significant percentage of the structure's total vertical surface area. These doors are usually located at each end of a hangar and consist of several panels that require a seal around the perimeter of each panel. Missing seals provide a major source of air infiltration. Rubber, fire hose, and nylon brush seals are available, but the nylon brush seals are preferred.

Feasibility Requirement

Always feasible.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr

2. Total area of unsealed crack around hangar door panels; A, ft^2

Procedure

Calculate the average AES from Figure 8 or as follows:

$$AES = 105 \, A \, D_h \sqrt{D_h + 5{,}700}, \text{ Btu/yr}$$

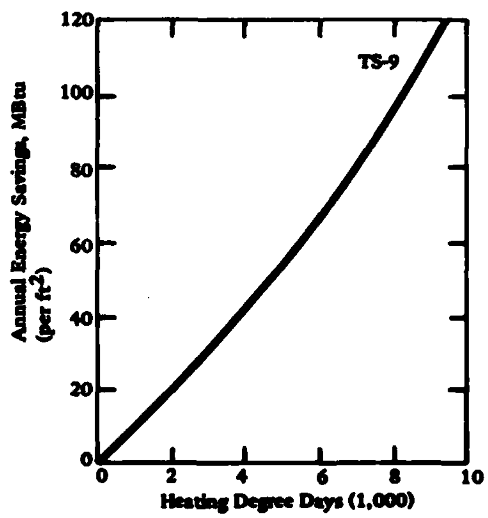


Figure 8. Annual energy savings for for Tech Sheet No. 9.

General Information

Life: (a) rubber = 2 years
(b) hose = 3 years
(c) nylon brush = 15 years
Cost: $15-$25/perimeter foot

NYLON BRUSH DOOR SEALS (Tech Sheet No. 10)

Description

Hangar aircraft access doors are a significant percentage of the structures total vertical surface area. These doors are usually located at each end of the hangar and consist of several panels that require a seal around their perimeter. Until recently only rubber or fire hose materials were available for hangar door seals. Nylon brush door seals are now available and are superior. These seals perform better and last longer than the rubber or fire hose seals. The nylon brush seal can conform to abrupt changes in surface contours and its resistance to weathering is much greater. These seals are easy to install, require no special tools, and are within the capabilities of most military bases.

Feasibility Requirement

Feasible for all heated hangars.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr

2. Total door seal length; L, ft

Procedure

Calculate the average AES from Figure 9 or as follows:

$$AES = 1,300 \; L \; D_h \text{ , Btu ft/yr}$$

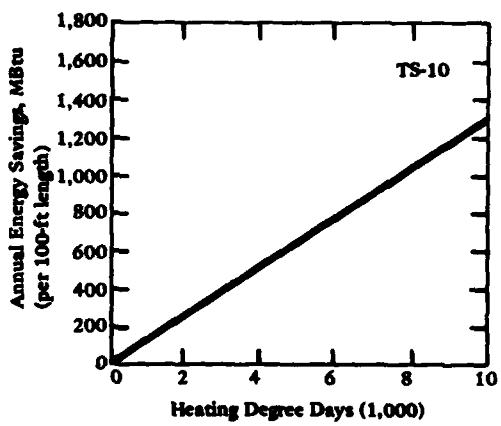


Figure 9. Annual energy savings for for Tech Sheet No. 10.

General Information

Life: Unknown, but estimated 10 to 15 years
Installation Cost: $15 to $25/foot

AIRCRAFT APPENDAGE SEALS FOR AIRCRAFT SHEDS (Tech Sheet No. 11)

Description

Sheds that do not house an entire aircraft are found at many military installations. Tail surfaces protrude through a cutout in the hangar door. Vinyl/canvas material with draw strings or flexible vinyl strip doors are used to seal the gap between the aircraft and the hangar surfaces. These seals are subjected to heavy use and are often damaged. Improperly used or damaged aircraft appendage seals are a source of hangar air infiltration, and they should be repaired or replaced. Hangar crews should be instructed in the importance of properly using aircraft appendage seals. Flexible vinyl strip doors do not seal as well as the canvas or vinyl seals with draw strings, are more expensive, and are not preferred for use as aircraft appendage seals.

Flexibility Requirement

All heated aircraft sheds.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr

2. Total gap area between aircraft appendage and hangar structure; A, ft^2

Procedure

Calculate the average AES from Figure 10 or as follows:

$$AES = 105\ A\ D_h \sqrt{D_h + 5{,}700},\ \text{Btu/yr}$$

General Information

Life: 3 to 5 years
Installation Cost: $500 to $1,000/seal

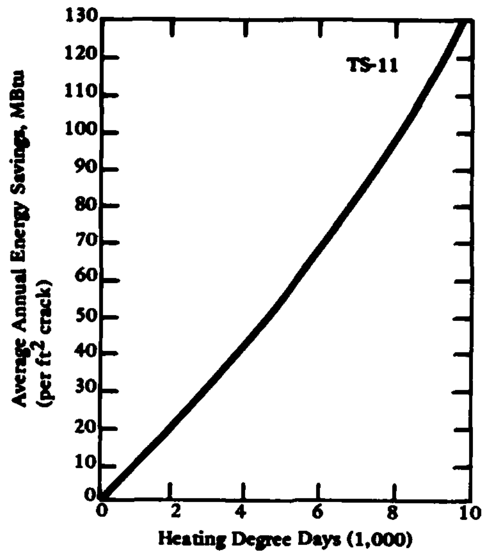


Figure 10. Annual energy savings for Tech Sheet No. 11.

MISALIGNED HANGAR DOORS (Tech Sheet No. 12)

Description

Hangar door alignment is critical if door seals are to reduce air infiltration. Misaligned doors can prevent a tight seal and create air infiltration sources. Improper door installation and/or settling effects are major sources of misaligned doors. Correcting this problem is site specific and can be expensive. An economic analysis is recommended to determine the cost effectiveness of a proposed hangar door alignment project.

Feasibility Requirement

Site specific.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr

2. Total area of crack resulting from misaligned doors; A, ft²

Procedure

Calculate the average AES from Figure 11 or as follows:

$$AES = 105\ A\ D_h \sqrt{D_h + 5{,}700},\ \text{Btu/yr}$$

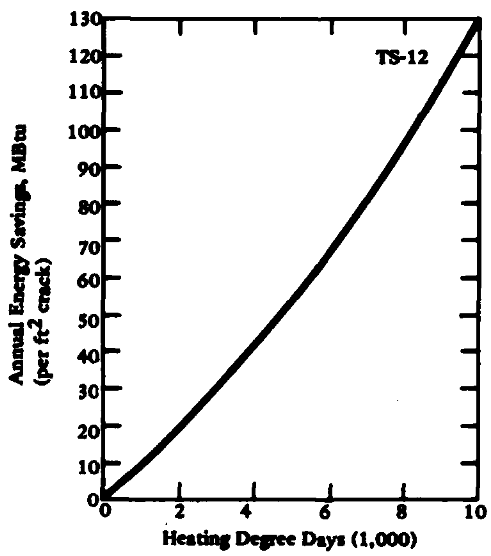


Figure 11. Annual energy savings for Tech Sheet No. 12.

General Information

Life: Site specific
Cost: site specific

VEHICLE ACCESS DOORS (Tech Sheet No. 13)

Description

Vehicles enter and leave hangars many times during the working day. Most hangars do not have a separate door for vehicles; thus, the hangar aircraft access doors are used. Usually these doors are opened 15 to 20 feet for 1 to 2 minutes per vehicle passage. During this time warm interior air is displaced by cold outside air. The installation of a separate vehicle access door can save energy by reducing the area of the opening required for vehicular traffic.

The retrofit of vehicle access doors in hangars is difficult. A wall is the preferred location; however, hangar design or usage usually requires that the vehicle door be installed in a hangar's aircraft access door. Retrofit of a vehicle access door in a hangar's aircraft access door must be done in such a way that maintains the door's structural rigidity. Overhead and roll-up doors have experienced alignment problems when retrofitted in hangar aircraft access doors. Vertically hinged doors are not alignment critical and should be considered if maintaining the rigidity of hangar aircraft access doors is critical (Figure 12).

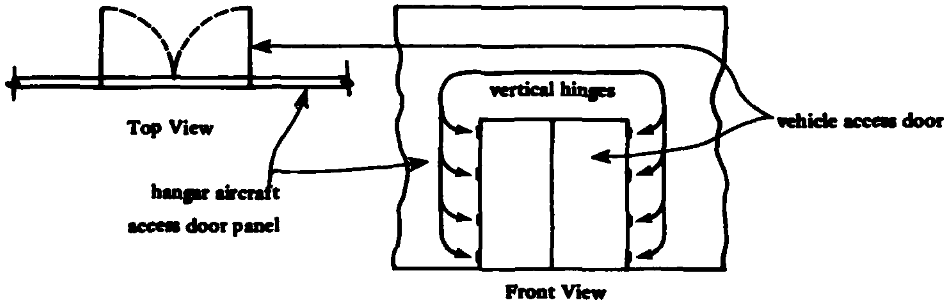


Figure 12. Vertically hinged vehicle access door.

Feasibility Requirement

See Figure 13.

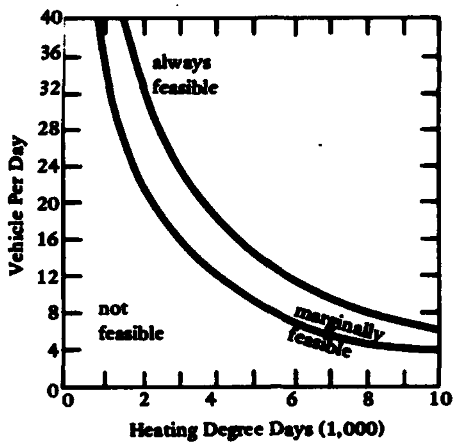


Figure 13. Feasibility requirement.

Survey Data Requirements

1. Average number of vehicles per day; P, 1/day

2. Average number of annual heating degree days; D_h, days-°F/yr

Procedure

Calculate average AES from Figure 14 or as follows:

$$AES = 48\ D_h\ P\sqrt{D_h + 5{,}700},\ \text{Btu/yr}$$

General Information

Life: 25 years
Installation Cost: $2,000 to $40,000

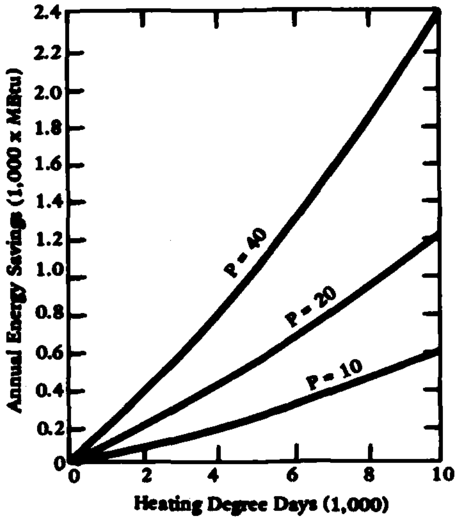


Figure 14. Annual energy savings for Tech Sheet No. 13.

FLEXIBLE VINYL STRIP DOORS (Tech Sheet No. 14)

Description

Flexible vinyl strip doors provide a method to reduce air infiltration for frequently used personnel and vehicle doors. Used properly vinyl strip doors can be very valuable, however, precautions should be taken to eliminate potential safety hazards connected with some applications. Vinyl plastic produces dense smoke when burning. Fire retardant vinyl should be used in order not to block doors during the early stages of a fire. Another hazard associated with flexible vinyl strip doors is their reaction to very high winds (in excess of 35 miles per hour). Personnel injuries have occurred during high winds, from hanging the vinyl strips wrong, and using the wrong weight of vinyl material. Care should be used for installations where foreign object damage could occur from small pieces of the door, which can break off a strip, or for applications where static electricity could present a fire hazard (explosion) or damage equipment.

Feasibility Requirement:

Site specific.

Survey Data Requirements

1. Average number of annual heating degree days, D_h, days-°F/yr
2. Average daily time door is in use; P, hr/day
3. Area of door, A; ft²

Procedure

Calculate the average AES from Figure 15 or as follows

$AES = 500 (P A D_h)$, Btu/yr

General Information

Life: 5 years
Installation cost: Site specific (approximately $8.00/ft²)

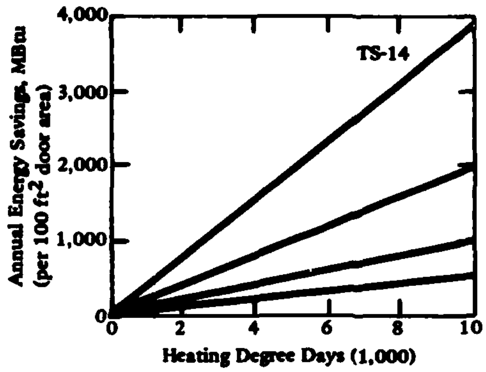


Figure 15. Annual energy savings for for Tech Sheet No. 14.

INSULATE HOLLOW STEEL EXTERIOR DOORS (Tech Sheet No. 15)

Description

Hollow steel doors are used for personnel and other entrances in many hangars and similar structures. Filling the hollow space in these doors with urethane foam insulation can reduce the energy transmitted through the door. Small holes can be drilled into one side of the door and the foam forced in.

Feasibility Requirements

Always feasible for heated structures.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr
2. Area of doors to be insulated; A, ft^2

Procedure

Calculate average AES from Figure 16 or as follows:

$$AES = 25\ A\ D_h,\ Btu/yr$$

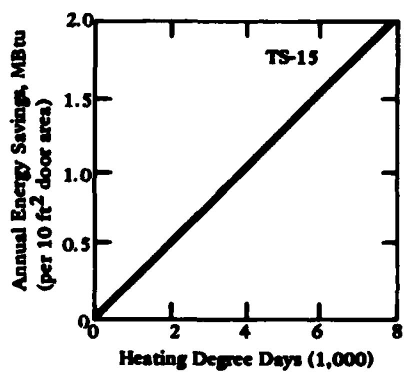


Figure 16. Annual energy savings for Tech Sheet No. 15.

General Information

Life: 25 years
Installation Cost: $3.00/ft²

PERSONNEL DOOR SEALS (Tech Sheet No. 16)

Description

Defective or missing seals on personnel doors contribute to air infiltration and should be repaired. The cost is minimal and the return can be great. Many different types of door seals are available, such as: rubber, nylon brush, bronze, felt, etc. No data are available to recommend any one type seal for personnel doors. One suggestion is to use a common seal for all personnel doors to take advantage of bulk purchase and common installation techniques.

Feasibility Requirements

Always feasible for heated hangars.

Survey Data Requirements

Average number of annual heating degree days; D_h, days-°F/yr

Procedure

Calculate the average AES from Figure 17 or as follows:

$$AES = 7.6\ D_h \sqrt{5,700 + D_h},\ \text{Btu/yr}$$

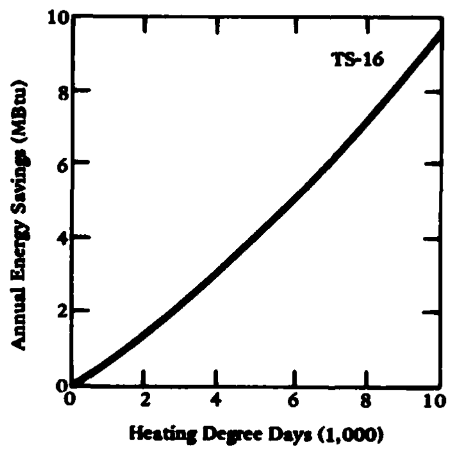


Figure 17. Annual energy savings for Tech Sheet No. 16.

General Information

Life: 5 years
Installation Cost: \$20/door

ENTRANCE VESTIBULE FOR PERSONNEL DOORS (Tech Sheet No. 17)

Description

When personnel doors are opened, heated inside air is displaced by cold outside air. Entrance vestibules limit the amount of heated air lost to the volume of the vestibule and also retard the rate of hot air displacement through open doors. In addition to saving energy, vestibules decrease drafts and serve as a shelter for people waiting on transportation, changing foul weather clothing, etc.

Feasibility Requirements

See Figure 18.

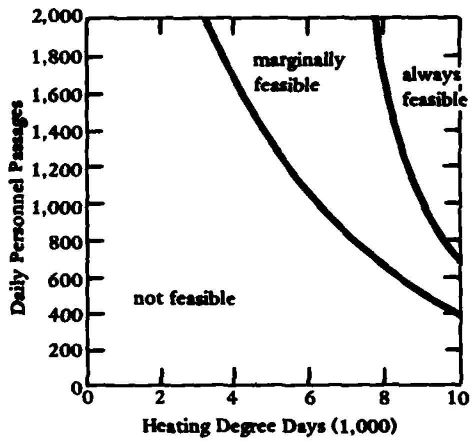


Figure 18. Feasibility requirements.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr
2. Average number of daily door openings; P_d, 1/day
3. Average time of each door opening; t, seconds
4. Door area; A, ft^2

Procedure

Calculate the average AES from Figure 19 or as follows:

$$AES = 0.00043\ D_h\ A\ P_d\ t\ (2.9\sqrt{5,700 + D_h} - 1.5\ \ 13,600 + D_h,\ Btu/yr)$$

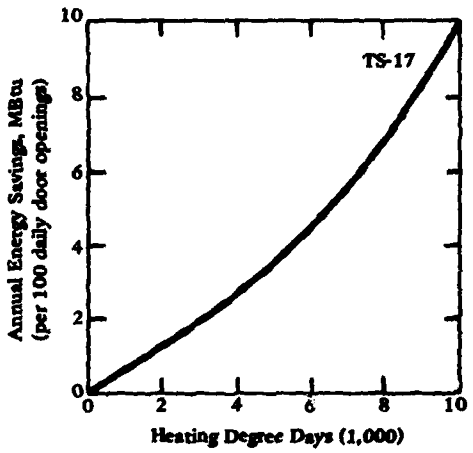


Figure 19. Annual energy savings for Tech Sheet No. 17.

General Information

Life: 25 years
Installation Cost: $7,000/door

REVOLVING PERSONNEL DOORS (Tech Sheet No. 18)

Description

Revolving doors fitted to heavily used personnel access doors, which are not located in hangar aircraft or vehicle access doors, can reduce air infiltration. These doors are expensive and should be used in hangars that have very heavy personnel traffic.

Feasibility Requirement

See Figure 20.

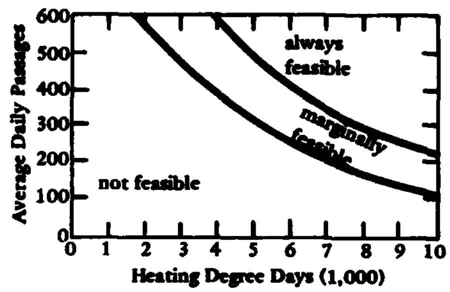


Figure 20. Feasibility requirements.

Survey Data Requirements

1. Average number of annual heating degree days, D_h, days-°F/yr
2. Average number of daily passages through door, P_p, 1/day

Procedures

Calculate the average AES from Figure 21 or as follows:

$$AES = 0.22\ P_p\ D_h \sqrt{5,700 + D_h}, \text{ Btu/yr}$$

General Information

Life: 25 years
Installation Cost: $6,500/door

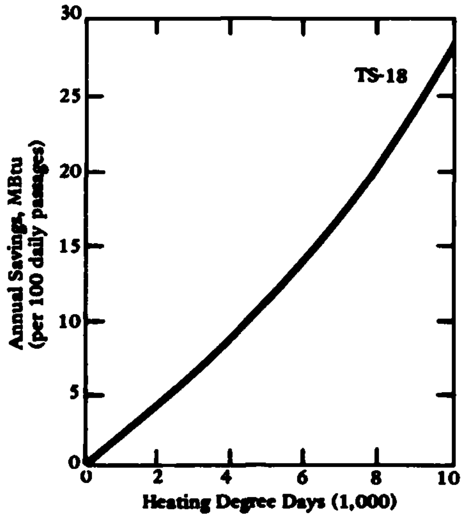


Figure 21. Annual energy savings for Tech Sheet No. 18.

LOADING DOCK SEALS (Tech Sheet No. 19)

Description

When trucks are loaded and unloaded at loading docks, large quantities of heated interior air is lost. Although few hangars have loading docks, many similar types of structures, such as warehouses, do. The installation of rubber seals around the perimeter of a loading dock door can reduce the amount of energy lost (Figure 22).

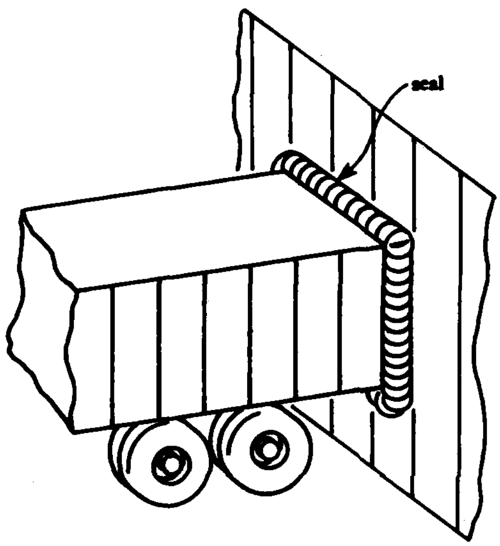


Figure 22. Loading dock seal.

Feasibility Requirements

See Figure 23.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr

2. Average number of hours per day loading dock door is open; P_h, hr/day

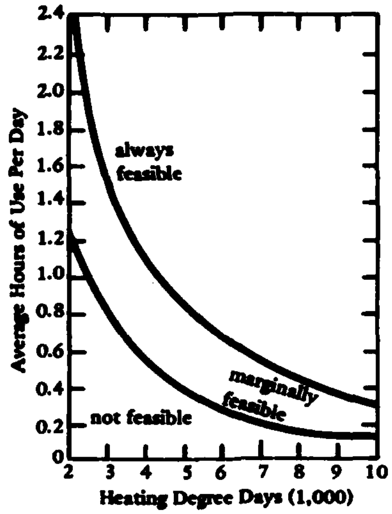


Figure 23. Feasibility requirements.

Procedure

Calculate the average AES from Figure 24 or as follows:

$$AES = 56\ D_h\ P_h \sqrt{D + 5,700},\ \text{Btu/yr}$$

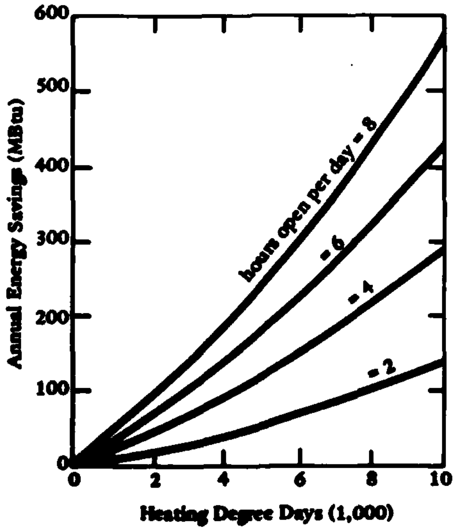


Figure 24. Annual energy savings for Tech Sheet No. 19.

General Information

Life: 5 years
Installation Cost: $25.00/perimeter foot

HANGAR DOOR HEATING SYSTEM SHUTOFF SWITCH (Tech Sheet No. 20)

Description

When an aircraft enters or leaves a hangar the heated interior air is replaced by cold outside air. Dependent upon the outside air temperature and wind velocity between 2 to 10 mintues is required for all of the heated interior air to be displaced. Typical hangar heating systems operate continuously whenever the hangar doors are open. This heated air is rapidly displaced to the outside and lost. Significant amounts of energy can be saved by not operating the heating system when the hangar doors are opened. The hangar door shutoff switch should secure only the heating systems blower and not steam or hot water. In addition, a low temperature/time override control is required which will override the shutoff switches to prevent fire protection systems from freezing during prolonged door openings in very cold weather.

Feasibility Requirements

Always feasible for heated hangars.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr

2. Area of hangar door opened; A, ft^2

3. Total average daily open time; P_h, hr/day

Procedure

Calculate the average AES from Figure 25 or as follows:

$$AES = 4.5\ D_h\ A\ P_h \sqrt{D_h + 5{,}700},\ \text{Btu/yr}$$

General Information

Life: 15 years
Installation Cost: $5,000/hangar

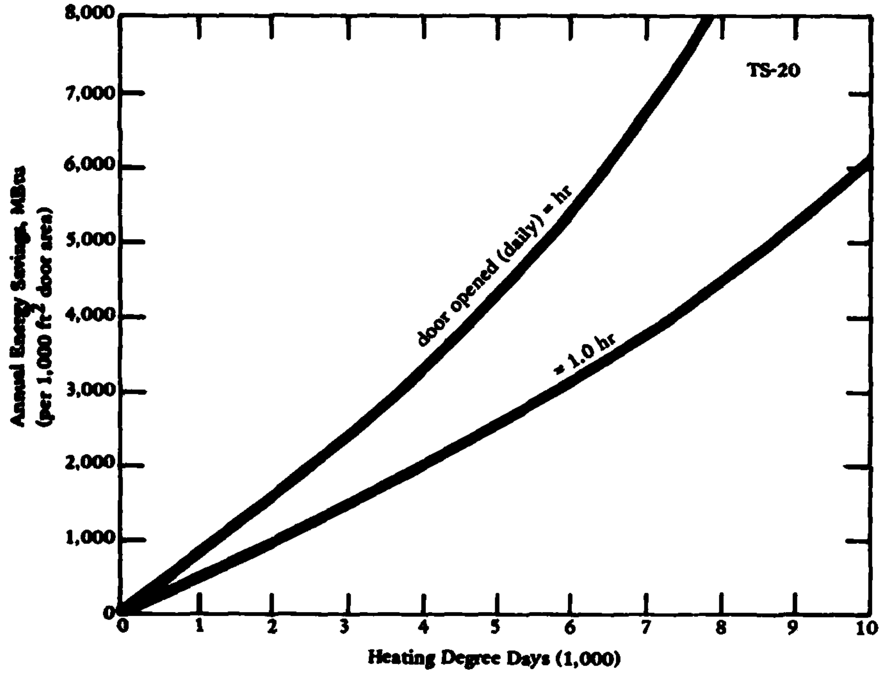


Figure 25. Annual energy savings for Tech Sheet No. 20.

TEMPERATURE SETBACK DEVICES (Tech Sheet No. 21)

Description

Working hours for many hangars are less than 24 hours per day. When daily non-work periods are 6 hours or more, temperature setback devices such as thermostats and time clocks can reduce hangar energy consumption. A temperature setback of 10°F is recommended. Temperature setback is not recommended for corrosion control hangars.

Feasibility Requirement

All heated hangars with daily non-work periods of 6 hours or more.

Survey Data Requirements

1. Daily hours of operation; H, hr/day
2. Average number of days in heating season; N/yr
3. Volume of hangar; V, ft^3
4. Roof U value; U_r, Btu/ft^2 · °F-hr
5. Wall U value; U_w, Btu/ft^2 - °F-hr
6. Roof area; A_r, ft^2
7. Wall area; A_w, ft^2
8. Heating system efficiency; e, %÷100
9. Difference between heating temperature and setback temperature; ΔT, °F

Procedure

Calculate the AES as follows:

$$AES = \Delta T\ N\ (2\text{-}4\ H)\ (0.024\ V + U_r\ A_r + U_w\ A_w)/e, \text{ Btu/yr}$$

General Information

Life: 15 years
Cost: $300 to $3,000/hangar

RADIANT HEATING (Tech Sheet No. 22)

Description

Radiant heaters emit heat in a straight, line of site, direction. Radiant heating is practical for applications where air infiltration rates are high (poor building design, frequent door openings, high ventilation requirements, etc.). Radiant heating uses infrared radiation. Air, the medium for conductive heat, is a poor absorber of infrared radiation and is not heated. Upon striking an object or person, this energy is converted into heat. Floors, walls, and other objects become warm and give off heat to the surrounding air.

Feasibility Requirements (Retrofit)

Marginally feasible: 2,000 heating degree days.

Always feasible: 3,500 heating degree days.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr
2. Extension surface area (walls and roof); A, ft^2
3. Building volume; V, ft^3

Procedure

Calculate the average AES from Figure 26 or as follows:

$$AES = D_h \, (A+0.22\ V) \text{ Btu/yr}$$

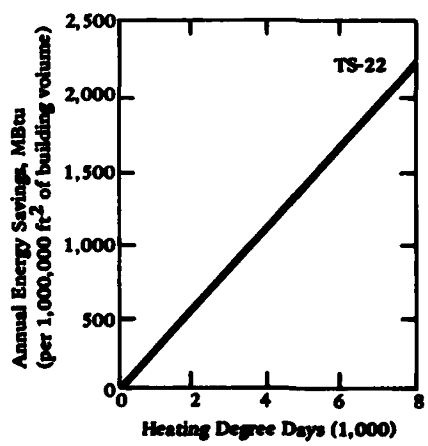


Figure 26. Annual energy savings for Tech Sheet No. 22.

General Information

Life: 25 years
Installation Cost: Site specific

BOILER TUNE UP (Tech Sheet No. 23)

Description

Many hangars and similar structures have on-site boilers for space heating (Figure 27). Boilers operate more efficiently if tuned up and adjusted annually. The boiler should be tuned up after the fire side surfaces have been cleaned, the fuel filters replaced, and the burner nozzles cleaned or replaced.

Feasibility Requirements

Always feasible.

Survey Data Requirements

1. Annual fuel consumption; G, gallons/yr
2. Type fuel (natural gas, No. 2 fuel oil, No. 6 fuel oil, JP-5, etc.)
3. Boiler combustion test kit
4. Handtools (screwdriver, wrenches, etc.)
5. Combustion efficiency calculation

Procedure

1. Measure flue gas temperature, percent of carbon dioxide, and smoke density then calculate boiler efficiency (e_1).

2. Adjust combustion controls/boiler draft to obtain highest percent of carbon dioxide in the flue gas while maintaining a smoke spot reading of one; calculate the boiler efficiency (e_2).

3. Calculate the average AES as follows:

$$AES = 150{,}000 \times G\,(e_2 - e_1),\ \text{Btu/yr}$$

General Information

Life: One heating season
Cost: 2 manhours

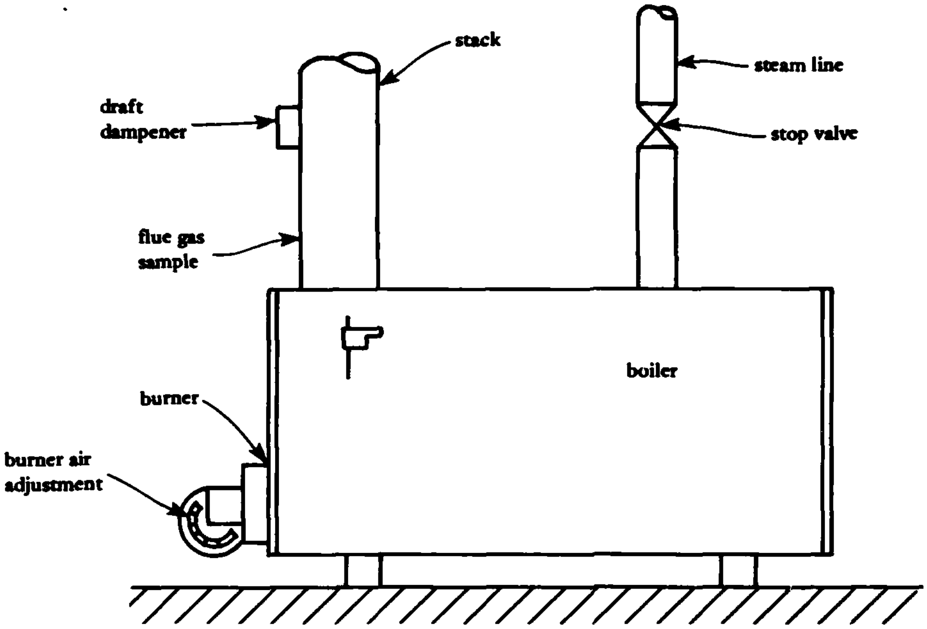


Figure 27. Boiler flue gas sample point.

LOW-WATTAGE FLUORESCENT LAMPS (Tech Sheet No. 24)

Description

Until recently lighting systems were overdesigned and produced excessive amounts of light. Most office spaces in hangars and other structures use fluorescent lamps and have excessive lighting levels. Replacing the existing fluorescent lamps with lower wattage lamps can save energy. This concept is feasible only if the low-wattage florescent lamps are used as part of a scheduled replacement program. For example, when a 50-watt fluorescent lamp needs replacing, use a 40-watt fluorescent lamp instead. The cost for the energy saving concept involves only the time required to identify lighting systems suitable for using low-wattage lamps. The actual cost should be no more than the normal cost of the replacement program.

Feasibility Requirements

Always feasible if done as part of the normal replacement program.

Survey Data Requirements

1. Number of fluorescent lamps; N

2. Number of hours used per year; H, hr/yr

Procedure

Calculate the average AES as follows:

$$\begin{aligned} AES &= 165\ N\ H,\ \text{Btu/yr, or} \\ &= 0.015\ N\ H,\ \text{kW-hr/yr} \end{aligned}$$

General Information

Life: Same as higher wattage lamps
Cost: $0.21/lamp greater than higher wattage lamps

HIGH-PRESSURE SODIUM LIGHTING SYSTEM (Tech Sheet No. 25)

Description

Some hangars are not retrofitted with energy efficient lighting systems. High-pressure sodium lighting is one method to reduce electrical consumption in hangars.

Feasibility Requirements

Feasible for hangars with 40 or more hours of operation per week.

Survey Data Requirements

1. Number of hours in use annually; H, hr/yr
2. Number of light fixtures; N_f
3. Existing lamp wattage rating; W, watts

Procedure

Calculate the average annual energy savings (AES) as follows:

AES = 4 N H W, Btu/yr or

AES = 0.00036 N H W kW-hr/yr

COLD AIR JET HANGAR DESTRATIFIER (Tech Sheet No. 26)

Description

Measurements made in Navy and Air Force hangars indicated that stratification, the formation of a hot air pocket in the structure's ceiling, is a typical condition. Tests, conducted on commercial destratifiers, did not identify any units that were practical for use in hangars. A cold air jet destratifier, developed by the Naval Civil Engineering Laboratory, was successful and was able to reduce steam consumption in one hanger by 29%. The cold air jet transfers cold floor air and discharges it as a high-velocity jet at roof level, see Figure 28. Design considerations are provided in Appendix A.

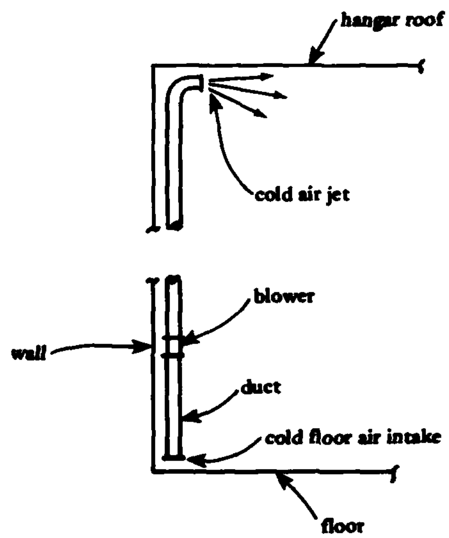


Figure 28. Coal-air jet destratifier.

Feasibility Requirements

See Figure 29.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr

2. Hangar floor area; A, ft²

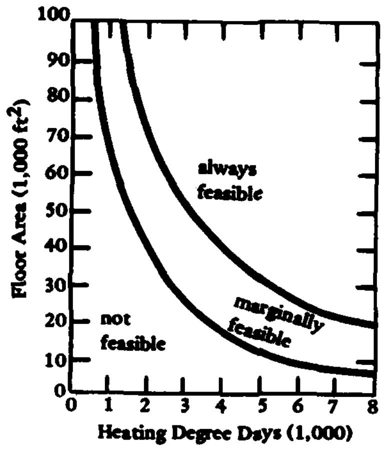


Figure 29. Feasibility requirements.

Procedure

Calculate the average AES from Figure 30 or as follows:

AES = $4.5\ A\ D_h$, Btu/yr

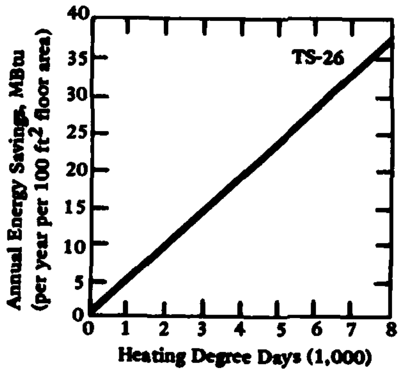


Figure 30. Annual energy savings for Tech Sheet No. 26.

General Information

Life: 25 years
Installation Cost: \$8,000 per unit (approximately 6 units required/hangar)

HANGAR DESTRATIFICATION: HEATING SYSTEM MODIFICATION (Tech Sheet No. 27)

Description

Most hangars use unit heaters mounted in the hangar's ceiling. These heaters are mounted at the lower level of the purlin in order to reduce the distance that they must blow heated air down to the floor. Unit heaters can be modified to recover some of the hot air trapped in the ceiling by running a duct from just below a hangar's roof to the unit heater's air intake, Figure 31. Since several different heating system and hangar designs have been used, the design of each heating system modification is site specific. The heating system modification is recommended for hangars with draft curtain "egg crate" sectionalized ceilings.

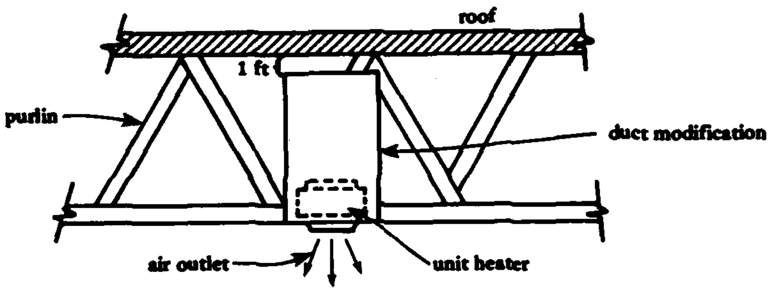


Figure 31. Heater duct modification.

Feasibility Requirements

(a) *Marginally feasible:* hangars with at least 12,000 ft^2 of floor area per unit heater located in geographic regions with at least 3,000 heating degree days.

(b) *Always feasible:* hangars with at least 16,000 ft^2 of floor area per unit heater located in geographic regions with at least 4,000 heating degree days.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr

2. Number of unit heaters in hangar; N

3. Hangar flow area; A, ft^2

Procedure

Calculate the average AES from Figure 32 or as follows:

AES = 0.55 A D_h, Btu/yr

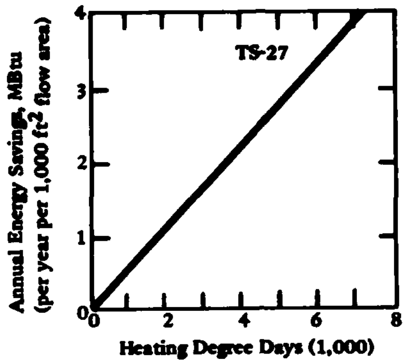


Figure 32. Annual energy savings for Tech Sheet No. 27.

General Information

Life: 25 years Installation Cost: $4,000/unit heater

DESTRATIFICATION OF STRUCTURES WITH LOW CEILINGS (15-25 FEET) USING FLOOR LEVEL AIR BLOWERS (Tech Sheet No. 28)

Description

Floor level air blowers are used to blow cold air toward the ceiling where it is mixed with the hot ceiling air, Figure 33. Floor level blowers are an effective method to destratify shops, warehouses, etc., with ceilings lower than 25 feet, and where the destratifier units can be placed away from exterior walls. The cold air blower requires approximately 25 ft^2 of floor area. Fire detection can be delayed in the early stages of a slow starting fire (such as a smoldering cigarette in trash, etc.), for this reason, destratifiers are not recommended for use when the building is unoccupied. These destratifiers can be plugged directly into existing electrical power outlets.

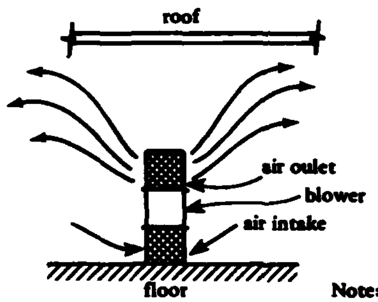


Figure 33. Floor level air blower.

Feasibility Requirement

Feasible for all heated structures with ceilings lower than 25 feet and floor space available for the units.

Survey Data Requirements

1. Average number of annual heating degree days; D_h, days-°F/yr

2. Building floor area; A, ft^2

Procedure

Calculate the average AES from Figure 34 or as follows:

$$AES = 4.5\ A\ D_h,\ \text{Btu/yr}$$

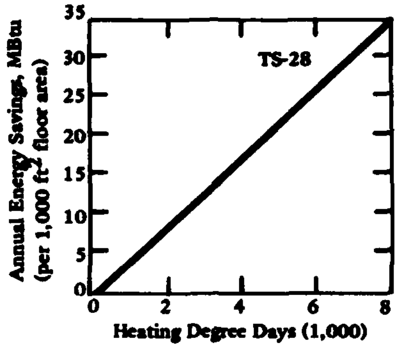


Figure 34. Annual energy savings for Tech Sheet No. 28.

General Information

Number of Units Required: floor area divided by 5,000
Installation Cost: \$20/100 ft^2 of floor area

DESTRATIFICATION OF STRUCTURES WITH LOW CEILINGS (15-25 FEET) USING CEILING FANS (Tech Sheet No. 29)

Description

Ceiling fans are used to mix the hot air pocket located in a structure's ceiling to provide a destratification effect (Figure 35). To be effective, these units must move large volumes of air and this often causes complaints of drafts, uneven temperatures, etc. Ceiling fans blow hot air to the floor where it is mixes with the cooler air. Installation costs are site specific and depend on the amount of electrical circuits that must be installed. Ceiling fans could have an adverse effect upon some fire detection systems and are not recommended for use when buildings are unoccupied.

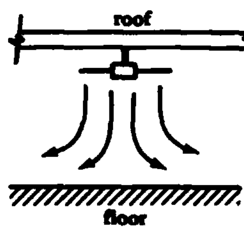


Figure 35. Ceiling fan.

Feasibility Requirement

Site specific. In general, they are feasible in structures where floor level temperatures are greater than 68°F and located in geographic regions with at least 2,000 heating degree days.

Survey Data Requirements

1. Average number of annual heating degree days, D_h, days-°F/yr

2. Building floor area; A, ft²

Procedure

Calculate the average AES from Figure 36 or as follows:

$$AES = 2\ A\ D_h,\ \text{Btu/yr}$$

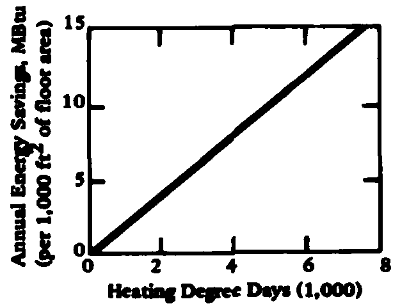


Figure 36. Annual energy savings for Tech Sheet No. 29.

General Information

Number of Fans Required, N; N = floor area/1,250
Installation Cost: \$1 ft² of floor area

DESTRATIFICATION OF STRUCTURES WITH LOW CEILINGS (15-25 FEET) USING DESTRATIFIER TUBES (Tech Sheet No. 30)

Description

The destratifier tube, Figure 37, is a small blower mounted on top of a tube or duct running from the ceiling to the floor. Hot ceiling air is transferred to the floor where it mixes with the cooler air. The effects that these tubes have on fire detectors is unknown; therefore, in the interest of safety, the destratifier tube should not be used during unoccupied periods of time, in unoccupied buildings, where personnel sleep, etc. The installation of destratifier tubes may require the installation of additional electrical circuits.

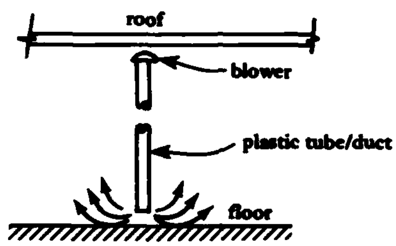


Figure 37. Destratification tube.

Feasibility Requirements

Site specific. In general, they are feasible in structures where floor level temperatures are greater than 68°F and located in geographic regions with at least 4,000 heating degree days.

Survey Data Requirements

1. Average annual heating degree days; D_h, days-°F/yr

2. Building floor area; A, ft²

Procedure

Calculate the average AES from Figure 38 or as follows:

$$AES = 0.25\ A\ D_h,\ \text{Btu/yr}$$

General Information

Number of Units Required; N; N = floor area/2,000
Installation Cost: \$100/1,000 ft² of floor area

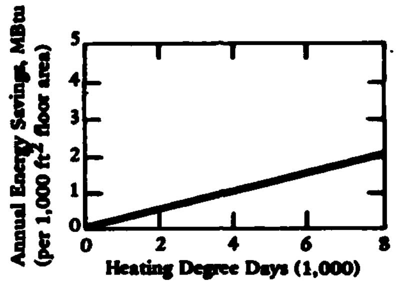


Figure 38. Annual energy savings for Tech Sheet No. 30.

SECTION III - GENERAL AND ANNUAL ENERGY SAVINGS CALCULATIONS

The annual energy savings procedures used in the Tech Sheets provide a method to estimate the energy saved by various options. The procedures provide estimates to accurately rate energy conservation options and generate preliminary project documentation. This section provides procedures that can be used if additional accuracy is required to rate projects having similar costs and energy saving characteristics, or if local conditions greatly differ from the following assumptions that were used to generate the test sheet option procedures:

(a) Average windspeed during heating season: 10 mph
(b) Duration of heating season: 150 days
(c) Overall heating plant efficiency: 70%
(d) Hangar height: 40 feet

Tech Sheet No. 1: Exterior Surface Insulation (not applicable)

Tech Sheet No. 2: Seal Holes and Cracks in Walls and Doors

$$AES = \frac{26\ D_h\ A}{e}\sqrt{79\ v^2\ H^{1/2} + 32\ H\ D/N}$$

where: AES = annual energy savings, Btu/yr

D_h = annual number of heating degree days, days-°F/yr

A = area of crack or hole, ft^2

e = overall heating system efficiency, %÷100

v = average heating season windspeed, mph

H = building height, feet

N = number of days in heating season, days/yr

Tech Sheet No. 3: Seal Wall, Floor and Roof Cracks (same as Tech Sheet No. 2 except A = L W)

where: L = crack length, feet

W = average crack width, feet

Tech Sheet No. 4: Insulate Between Heated, Cooled, and Non-Heated Spaces (not applicable)

Tech Sheet No. 5: Reduce Window Area

$$AES = \frac{24\ D_h\ A}{e}\ (U_p - U_f)$$

where: AES = annual energy savings, Btu/yr

D_h = number of heating degree days per yr, days-°F/yr

A = window area, ft²

U_p = existing U_{value}; Btu/ft²-°F-hr

U_f = final U value, Btu/ft²-°F-hr

e = overall heating system efficiency, %÷100

Tech Sheet No. 6: Replace Broken and Missing Window (same as Tech Sheet No. 2)

Tech Sheet No. 7: Storm and Double-Glazed Windows (same as Tech Sheet No. 5)

Tech Sheet No. 8: Replace Window Seals (same as Tech Sheet No. 3)

Tech Sheet No. 9: Replace Missing Hangar Door Seals (same as Tech Sheet No. 2 except that A = 0.9 A)

Tech Sheet No. 10: Nylon Brush Door Seals

$$AES = \frac{7{,}000\ D_h\ L\ U^{1.1215}}{e}$$

where: AES = annual energy savings, Btu/yr

v = average windspeed for heating season, mph

D_h = number of heating degree days per year, days-°F/yr

L = length of seal, feet

e = overall heating system efficiency, %÷100

Tech Sheet No. 11: Aircraft Appendage Seals for Aircraft Sheds (same as Tech Sheet No. 2)

Tech Sheet No. 12: Misaligned Hangar Doors (same as Tech Sheet No. 2)

Tech Sheet No. 13: Vehicle Access Doors (same as Tech Sheet No. 2 except that A = Area hangar door opening-Area of vehicle door opening)

Tech Sheet No. 14: Flexible Vinyl Strip Doors

$$AES = 1.44\ P\ A\ D_h\ (30\ v - v^{1.72})$$

where: AES = annual energy savings, Btu/yr

P = average hours flexible door is used per day, hr/day

A = area of flexible door, ft^2

D_h = number of heating degree days per year, days-°F/yr

v = average windspeed during heating season, mph

Tech Sheet No. 15: Insulate Hollow Steel Personnel Doors (same as Tech Sheet No. 5)

Tech Sheet No. 16: Personnel Door Seals (same as Tech Sheet No. 2 except that A = 0.004L where L = door perimeter, feet)

Tech Sheet No. 17: Entrance Vestibules for Personnel Doors

$$AES = \frac{0.018\ P\ D_h\ t}{60\ e}\left(A_1\sqrt{79\ v^2\ H_1^{1/2} + 32\ H_1\ D_h/N} - A_2\sqrt{79\ v^2\ H_2^{1/2} + 32\ H_2\ D_h/N}\right)$$

where: AES = annual energy savings, Btu/yr

P = average number of personnel passages per day, 1/day

D_h = heating degree days per year, days-°F/yr

t = average door open time per personnel passage, sec

e = overall heating system efficiency, %÷100

A_1 = original door area, ft^2

H_1 = height of hangar, feet

H_2 = height of vestibule, feet

v = average windspeed during heating season, mph

N = number of days in heating season, days/yr

Tech Sheet No. 18: Revolving Personnel Doors (same as Tech Seet No. 17 except that

$$A_2\sqrt{76\ v^2\ H_2^{1/2} + 32\ H\ D_h/N} = V_d/S$$

where: V_d = total volume of revolving door, ft^3

S = number of revolving door sections

Tech Sheet No. 19: Loading Dock Seals

$$AES = \frac{D\,A\,P}{e}\sqrt{79\,v^2\,H^{1/2}\,H\,D_h/N}$$

where: AES = annual energy savings, Btu/yr

D_h = heating degree days per year, days-°F/yr

P = average hours in use per day, hr/day

A = open area, ft^2

e = heating system efficiency, % ÷ 100

v = average windspeed during heating season, mph

H = building height, ft

N = number of days in heating season, days/yr

Tech Sheet No. 20: Hangar Door Heating System Shutoff Switch (same as Tech Sheet No. 19 except that AES is zero if $V \geq Q$)

V = hangar volume, ft^3

$$Q = 60\,A\,P\sqrt{79\,v^2\,H^{1/2} + 32\,H\,D_h/N}\ ,\ ft^3$$

Tech Sheet No. 21: Temperature SetBack Devices (not applicable)

Tech Sheet No. 22: Radiant Heating

$$AES = \frac{4.3\,D_h}{e}\left[\sum A_s\,U_s + 0.018\,I\,V\right],\ Btu/yr$$

where: AES = annual energy savings, Btu/yr

D_h = heating degree days per year, days-°F/yr

e = heating system efficiency, %÷100

A_s = exterior surface area, ft^2

U_s = U value of exterior surface, Btu/ft²-°F-hr

I = air infiltration rate, air changes per hour, 1/hr

V = building volume, ft³

Tech Sheet No. 23: Boiler Tune Up (not applicable)

Tech Sheet No. 24: Low-Wattage Florescent Lamps (not applicable)

Tech Sheet No. 25: High-Pressure Sodium Lighting Systems (not applicable)

Tech Sheet No. 26: Cold Air Jet Hangar Destratifier

$$AES = \frac{24\ \varepsilon\ N}{e} (T_c - T_f)\ (U_r A_r + 0.018\ I\ V)$$

where: AES = annual energy savings, Btu/yr

N = number of days in heating season, days/yr

V = hangar volume, ft³

A_r = roof area, ft²

U_r = U value of roof, Btu/ft²-°F-hr

I = air infiltration rate, air changes per hour, 1/hr

ε = destratifier efficiency, %÷100

ε = 0.9; cold jet and floor level air blower
ε = 0.11; heating system modification
ε = 0.40; ceiling fan
ε = 0.05; destratification tube

e = heating system efficiency, %÷100

T_c = air temperature at ceiling level, °F

T_f = air temperature at floor level, °F

Tech Sheet No. 27: Hangar Destratification: Heating System Modification (same as Tech Sheet No. 26)

Tech Sheet No. 28: Destratification of Strucutres With Low Ceilings Using Floor Level Air Blowers (same as Tech Sheet No. 26)

Tech Sheet No. 29: Destratification of Structures With Low Ceilings Using Ceiling Fans (same as Tech Sheet No. 26)

Tech Sheet No. 30: Destratification of Structures With Low Ceilings Using Destratifier Tubes (same as Tech Sheet No. 26)

Appendix A

DESTRATIFIER PERFORMANCE CRITERIA

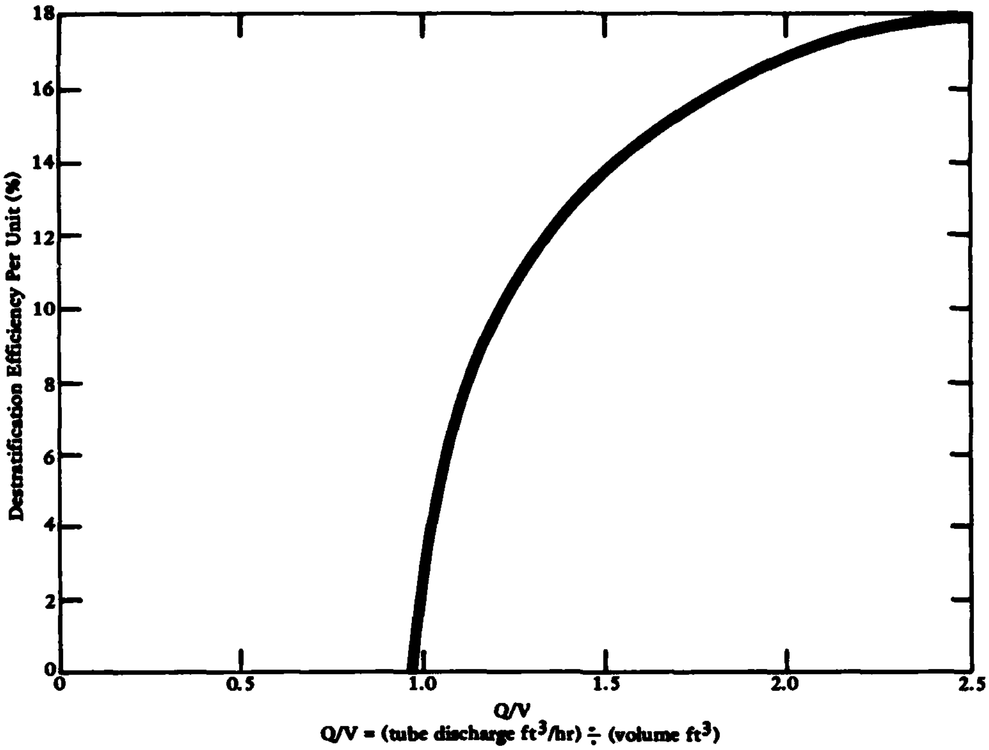


Figure A-1. Destratifier tube performance for building heights less than 25 feet.

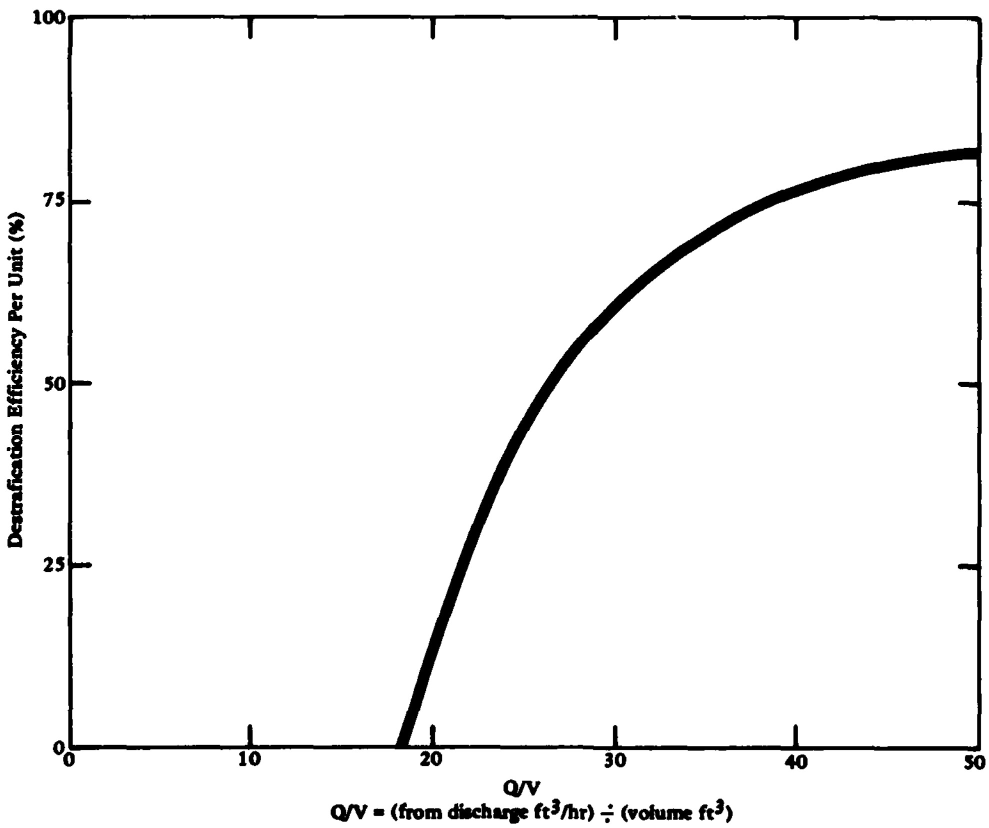
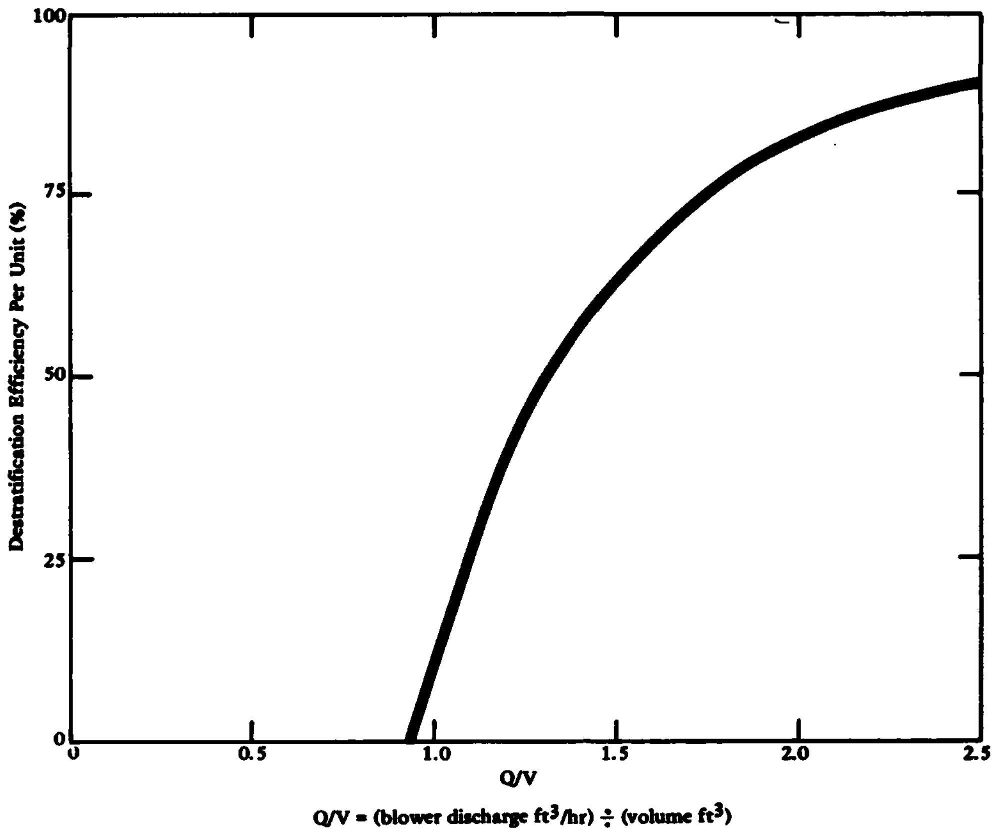


Figure A-2. Ceiling fan destratification performance for building heights less than 25 feet.



<u>Cold Air Jet Destratifier Design Considerations</u>

1. Destratifier flow: Q, ft^3/min

   Q = 0.0027 V/N, ft^3/min

   V = hangar volume, ft^3

   N = number of ceiling sections created by draft curtains or 6, whichever is greater

2. Destratifier air discharge velocity; U, ft/min

   $U = 641\ W^2/Q$, ft/min

   W = hangar width, ft

3. Destratifier nozzle diameter; D, in.

   $D = 24\ (Q/(\pi U))^{1/2}$ in.

Figure A-3. Floor air blower performance for building height less than 25 feet.

Appendix B

LIGHTING CRITERIA

RECOMMENDED LIGHTING LEVELS*

With proper attention to quality, the following light levels should be adequate for the areas cited:

(A) Circulation areas between work stations: 20 footcandles

(B) Background beyond tasks at circulation area: 10 footcandles

(C) Waiting rooms and lounge areas: 10-15 footcandles

(D) Conference Tables: 30 footcandles with background lighting 10 footcandles

(E) Secretarial Desks: 50 footcandles with auxiliary localized (lamp) task lighting directed at paper holder (for typing) as needed. In secretarial pools, 60 footcandles.

(H) Kitchens: Non-uniform lighting with an average of 50 footcandles

(I) Cafeterias: 20 footcandles

(J) Snack Bar: 20 footcandles

(K) Testing Labs: As required by the task, but background not to exceed 3 to 1 ratio in footcandles.

(L) Computer Rooms: As required by the task, (consider 2 levels: one-half and full). In computer areas, reduce general overall lighting levels to 30 footcandles and increase task lighting for critical areas for input. Too high a level of general lighting makes it difficult to read the self-illuminated indicators.

(M) Drafting: 80 footcandles at full-time work station and 60 footcandles at part-time work stations.

(N) Accounting Offices: 80 footcandles at work stations

*All levels are average ESI footcandles unless otherwise noted. Where applicable, refer to health and safety codes and Federal standards (OSHA) for minimum lighting specification.

The luminous efficacy (lumens per watt) of various light sources as compared to daylight are shown below (no allowance for ballast of luminairies):

Table B-1. Luminous Efficacy

Light Sources	lumens/watts
Low pressure sodium	183
Natural	120*
High pressure (HD)	105-120
Metal halide	85-100
Fluorescent	67-97
Mercury vapor	56-63
Incadescent	17-22

*Varies

Table B-2. Comparison of Mercury Vapor and High-Pressure Sodium Lamps

Mercury Vapor Lamp			High Pressure Sodium Lamp			Increased Lumens Per Lamp	Savings Per Lamp (watts)
Type	Total Watts Per Lamp	Lumen Output	Type	Total Watts Per Lamp	Lumen Output		
H33 (400w)	450	23,000	S50 (250w)	305	27,500	4,500	145
H37 (250w)	285	13,000	S55/56 (150w)	188	16,000	3,000	97
H39 (175w)	205	8,500	S54 (100w)	126	9,500	1,000	79

Appendix C

MATERIAL THERMAL PROPERTIES

Table C-1. U Values for Common Walls and Roofs

Description	U Value BTU/ft^2-°F
Walls	
1-inch stucco, air space, 3-inch insulation	0.083
Metal siding, 3-inch insulation, air space, metal	0.086
Surface finish, 3-inch insulation, surface finish	0.090
4-inch face brick, 2-inch insulation, 8-inch concrete block	0.100
1-inch stucco, 8-inch concrete, 1-inch insulation	0.198
Metal siding, 1-inch insulation, air space, metal	0.203
4-inch face brick, air space, 8-inch concrete block	0.237
4-inch lightweight concrete	0.240
4-inch face brick, air space, 4-inch common brick	0.335
1-inch stucco, air space	0.512
1-inch stucco, 8-inch heavy weight concrete	0.585
Roofs	
Roof terrace, acoustic ceiling	0.084
2-inch insulation, 1-inch wood, air space, acoustic ceiling	0.085
2-inch insulation, metal deck, air space, acoustic ceiling	0.095
2-inch insulation, 2-inch wood	0.112
1-inch insulation, 1-inch wood, air space, acoustic ceiling	0.120
2-inch insulation, 4-inch heavy weight concrete	0.124
1-inch insulation, 1-inch wood, air space, acoustic ceiling	0.129
4-inch lightweight concrete, air space, acoustic ceiling	0.140
4-inch lightweight concrete, air space, acoustic ceiling	0.140
1-inch insulation, 1-inch wood	0.180

Table C-2. Thermal Conductivity (k) of Industrial Insulation (Design Values) (for Mean Temperatures Indicated)

[Expressed in Btu per (hour) (square foot) (degree Fahrenheit) temperature difference per inch]

Form/Material Composition	Typical Density (lb/ft^3)	Typical Conductivity k at Mean Temp F				
		0	25	50	75	100
BLOCKS, BOARDS, AND PIPE INSULATION						
ASBESTOS						
Laminated asbestos paper	30					0.40
Corrugated and laminated asbestos paper						
4-ply	11-13				0.54	0.57
6-ply	15-17				0.49	0.51
8-ply	18-20				0.47	0.49
MOLDED AMOSITE AND BINDER	15-18					0.32
85% MAGNESIA	11-12					0.35
CALCIUM SILICATE	11-13					0.38
CELLULAR GLASS	9	0.35	0.36	0.38	0.40	0.42
DIATOMACEOUS SILICA	21-22					

(Continued)

Table C-2. Continued

Form/Material Composition	Typical Density (lb/ft^3)	Typical Conductivity k at Mean Temp F				
		0	25	50	75	100
MINERAL FIBER						
Glass						
Organic bonded, block, and boards	3-10	0.20	0.22	0.24	0.25	0.26
Nonpunking binder	3-10					0.26
Pipe insulation, slag or glass	3-4	0.20	0.21	0.22	0.23	0.24
	3-10	0.20	0.22	0.24	0.25	0.26
Inorganic bonded block	10-15					0.33
	15-24					0.32
Pipe insulation slag or glass	10-15					0.33
MINERAL FIBER						
Resin binder	15	0.25	0.26	0.28	0.29	
RIGID POLYSTYRENE						
Extruded, Refrigerant 12 exp	3.5	0.16	0.17	0.18	0.19	0.20
Extruded, Refrigerant 12 exp	2.2	0.17	0.18	0.19	0.20	
Extruded	1.8	0.21	0.23	0.24	0.25	0.27
Molded beads	1	0.25	0.25	0.26	0.28	
POLYURETHANE						
Refrigerant 11 exp	1.5-2.5	0.18	0.17	0.16	0.16	0.17
RUBBER, Rigid Foamed	4.5		0.20	0.21	0.22	0.23
VEGETABLE AND ANIMAL FIBER						
Wool felt (pipe insulation)	20		0.28	0.30	0.32	0.33

(Continued)

Table C-2. Continued

Form/Material Composition	Typical Density (lb/ft^3)	Typical Conductivity k at Mean Temp F				
		0	25	50	75	100
INSULATING CEMENTS						
Mineral Fiber (Rock, slag, or glass)						
With colloidal clay binder	24-30					0.49
With hydraulic setting binder	30-40					0.75
LOOSE FILL						
Cellulose insulation (milled pulverized paper or wood pulp)	2.5-3			0.26	0.27	0.29
Mineral fiber, slag, rock or glass	2-5	0.23	0.25	0.26	0.28	0.31
Perlite (expanded)	5-8	0.32	0.34	0.34	0.37	0.39
Silica aerogel	7.6	0.15	0.15	0.16	0.17	0.18
Vermiculite (expanded)	7-8.2	0.42	0.44	0.45	0.47	0.49
	4-6	0.38	0.40	0.42	0.44	0.46

$$\text{U Value} = \frac{\text{K Value}}{\text{Insulation Thickness (in.)}}$$

Appendix D

WEATHER DATA

Weather Data

State/City	Winter		Summer	
	Avg. DB Winter Temp	Length In Weeks	Avg. DB Summer Temp	Length In Weeks
ALABAMA				
Birmingham	41.9	16.6	80.6	32.9
Montgomery	43.5	14.1	81.1	35.3
Huntsville	40.3	18.8	80.5	30.9
Mobile	44.7	10.4	79.4	38.4
ARIZONA				
Tucson	46.2	12.4	83.5	40.1
Flagstaff	35.6	33.4	73.5	18.6
Phoenix	46.4	11.4	86.0	41.3
ARKANSAS				
Blytheville	39.5	20.4	80.5	29.7
Little Rock	41.7	18.1	81.6	31.3
Ft. Smith	40.5	18.0	81.0	30.5
CALIFORNIA				
Los Angeles	50.2	8.9	72.0	32.6
San Diego	50.5	7.0	70.9	29.8
Santa Barbara	49.6	23.9	69.7	12.2
Bishop	40.2	21.3	82.2	30.4
Barstow	42.6	20.6	83.7	32.3
San Francisco	48.2	18.4	71.1	22.2
Sacramento	46.1	19.4	79.9	28.4
COLORADO				
Denver	35.2	29.4	77.9	22.6
Colorado Springs	35.4	30.4	76.9	21.6
Trinidad	36.2	27.7	78.5	25.4
Grand Junction	36.3	27.5	80.3	23.7
DELAWARE				
Dover	38.4	25.2	77.5	23.6
Wilmington	38.2	26.0	77.5	23.7

(Continued)

Weather Data				
State/City	Winter		Summer	
	Avg. DB Winter Temp	Length In Weeks	Avg. DB Summer Temp	Length In Weeks
FLORIDA				
Pensacola	44.7	10.4	79.4	38.4
Miami	49.3	1.6	80.4	50.1
Jacksonville	45.6	8.6	80.4	41.6
Orlando	48.5	3.0	78.5	46.2
Tampa	47.0	4.0	78.5	46.0
GEORGIA				
Atlanta	41.1	19.8	78.7	30.0
Augusta	42.6	16.0	80.7	35.1
Macon	43.3	14.5	80.3	34.8
Valdosta	45.0	10.7	80.0	38.9
Savannah	44.0	12.0	80.0	38.0
IDAHO				
Boise	38.1	31.4	78.8	19.7
Pocatello	35.1	33.3	78.6	18.8
Lewiston	40.2	29.7	78.8	18.9
ILLINOIS				
Chicago	34.2	30.0	77.0	20.9
Champaign	33.3	27.3	77.9	23.6
Peoria	34.0	26.0	78.0	24.0
Rockford	32.0	29.0	77.0	21.0
INDIANA				
Fort Wayne	34.8	28.5	77.7	22.5
South Bend	34.2	29.1	77.1	21.4
Indianapolis	35.8	26.7	78.0	23.9
Terre Haute	36.8	26.2	78.7	24.8
IOWA				
Mason City	29.8	31.1	76.7	19.7
Sioux City	31.2	28.9	79.0	22.2
Council Bluffs	32.1	27.2	78.5	23.0

(Continued)

Weather Data				
State/City	Winter		Summer	
	Avg. DB Winter Temp	Length In Weeks	Avg. DB Summer Temp	Length In Weeks
KANSAS				
Dodge City	35.9	25.4	81.4	25.6
Goodland	34.3	29.1	81.0	23.6
Kansas City	36.5	23.6	80.5	25.7
Wichita	37.0	22.6	81.2	27.0
KENTUCKY				
Louisville	38.4	23.5	79.9	26.6
Covington	36.8	25.1	78.2	24.4
Hopkinsville	38.2	22.0	79.7	28.4
LOUISIANA				
New Orleans	46.4	9.4	79.8	39.6
Alexandria	43.7	13.3	81.0	37.2
Shreveport	42.6	15.2	81.8	35.2
Lake Charles	45.5	10.4	80.4	39.2
MAINE				
Portland	34.5	33.7	74.4	15.1
MASSACHUSETTS				
Boston	35.1	31.1	76.0	19.8
Springfield	34.6	30.5	76.3	20.1
MICHIGAN				
Lansing	34.0	30.4	76.0	19.5
Grand Rapids	34.4	30.5	75.0	19.0
Traverse City	33.0	32.8	75.3	17.0
Sault Ste Marie	30.2	37.0	73.4	12.8
Detroit	33.8	30.5	75.8	19.2
MINNESOTA				
Duluth	28.0	37.0	73.5	12.7
International Falls	25.5	36.8	73.8	14.1
Minneapolis	29.3	31.0	76.8	18.8

(Continued)

Weather Data				
State/City	Winter		Summer	
	Avg. DB Winter Temp	Length In Weeks	Avg. DB Summer Temp	Length In Weeks
MISSISSIPPI				
Biloxi	45.2	10.1	79.8	37.6
Jackson	43.0	14.8	81.1	35.3
Columbus	41.6	16.9	81.2	33.8
MISSOURI				
Kansas City	36.5	23.6	80.5	25.7
Columbia	36.1	24.4	80.2	25.7
Springfield	36.7	23.4	79.6	26.9
St. Louis	36.1	24.2	79.6	26.3
MONTANA				
Billings	34.6	32.1	78.1	18.4
Glasgow	27.9	33.5	77.8	17.5
Helena	32.9	36.0	76.1	15.5
Great Falls	33.8	33.8	76.6	16.9
NEBRASKA				
Omaha	32.1	27.2	78.5	23.0
Grand Island	32.6	28.6	79.4	22.7
North Platt	32.4	29.7	79.1	22.0
NEVADA				
Las Vegas	43.7	15.6	86.6	35.4
Ely	33.4	35.0	77.7	20.2
Winnemucca	36.2	31.9	80.4	22.3
Reno	35.0	33.0	79.0	21.0
NEW HAMPSHIRE				
Manchester	32.0	32.0	75.0	19.0
NEW JERSEY				
Trenton	37.5	26.9	77.1	22.9

(Continued)

Weather Data				
State/City	Winter		Summer	
	Avg. DB Winter Temp	Length In Weeks	Avg. DB Summer Temp	Length In Weeks
NEW MEXICO				
Albuquerque	39.7	23.9	80.4	27.3
Alamogordo	41.0	19.2	81.8	32.5
Clovis	38.7	23.1	79.9	29.4
NEW YORK				
Albany	33.8	30.5	76.4	19.5
Buffalo	34.5	31.1	75.0	18.8
Syracuse	34.0	30.2	76.1	19.4
New York City	38.0	27.5	76.0	20.0
NORTH CAROLINA				
Greensboro	40.1	21.6	79.0	28.1
Raleigh	41.0	20.0	79.0	30.0
Wilmington	43.6	15.2	78.5	33.6
NORTH DAKOTA				
Bismarck	27.4	33.5	77.8	18.3
Grand Forks	24.6	34.4	76.1	16.9
Minot	27.2	34.7	76.4	16.2
Fargo	27.2	35.0	77.0	17.0
OHIO				
Cleveland	34.0	29.4	76.5	21.0
Dayton	36.2	25.4	78.4	24.3
Columbus	37.8	25.5	77.6	23.8
Toledo	33.8	29.5	76.8	21.3
Cincinnati	36.8	25.1	78.2	24.2
OKLAHOMA				
Altus	39.5	19.5	83.2	31.2
Oklahoma City	38.9	20.0	81.2	29.5
Tulsa	39.0	20.2	81.7	29.7
Enid	37.9	21.6	81.9	28.4

(Continued)

Weather Data				
State/City	Winter		Summer	
	Avg. DB Winter Temp	Length In Weeks	Avg. DB Summer Temp	Length In Weeks
OREGON				
Burns	35.7	36.3	76.5	17.3
Medford	41.9	30.9	78.7	21.2
Pendleton	40.1	29.9	78.1	20.0
Portland	44.0	30.8	73.5	15.8
Eugene	44.0	30.8	74.0	15.0
PENNSYLVANIA				
Pittsburg	35.1	28.2	76.0	21.9
Scranton	35.2	29.7	76.2	20.1
Williamsport	36.4	28.9	77.2	21.0
Philadelphia	38.2	26.0	77.5	23.7
RHODE ISLAND				
Providence	37.6	28.8	74.7	18.7
SOUTH CAROLINA				
Charleston	43.3	14.2	78.7	36.0
Columbia	43.2	16.0	79.7	33.4
Myrtle Beach	43.0	15.9	77.9	32.3
SOUTH DAKOTA				
Rapid City	32.6	30.7	78.8	19.6
Huron	28.5	31.4	78.9	20.4
Sioux Falls	29.2	30.4	78.0	20.5
TENNESSEE				
Memphis	40.5	18.9	81.1	30.4
Nashville	39.3	23.3	79.7	28.4
Knoxville	39.5	21.5	80.0	29.0

(Continued)

Weather Data				
	Winter		Summer	
State/City	Avg. DB Winter Temp	Length In Weeks	Avg. DB Summer Temp	Length In Weeks
TEXAS				
Amarillo	38.1	23.0	80.4	28.4
Lubbock	39.1	20.8	80.3	30.8
Dallas	42.5	15.1	82.8	34.6
San Antonio	46.0	8.9	82.7	41.3
Corpus Christi	48.1	4.8	80.3	43.0
Houston	47.0	6.0	80.3	42.0
UTAH				
Salt Lake City	36.5	30.2	79.0	19.9
Wendover	36.7	27.7	79.7	21.6
VERMONT				
Burlington	31.3	33.1	74.8	16.7
VIRGINIA				
Richmond	40.9	20.9	77.8	26.8
Roanoke	39.8	23.4	78.9	26.3
WASHINGTON				
Seattle	43.7	37.3	70.9	9.4
Spokane	36.6	34.8	76.1	15.6
WEST VIRGINIA				
Charleston	38.4	23.7	78.4	26.1
Clarksburg	36.5	29.1	75.2	22.5
WISCONSIN				
Madison	31.5	30.7	76.9	20.2
Green Bay	31.1	33.0	75.2	17.5
Milwaukee	33.0	30.0	77.0	20.9
WYOMING				
Casper	33.6	33.5	78.3	19.2
Cheyenne	34.4	33.9	76.0	18.3
Rock Springs	31.7	35.3	75.3	16.7

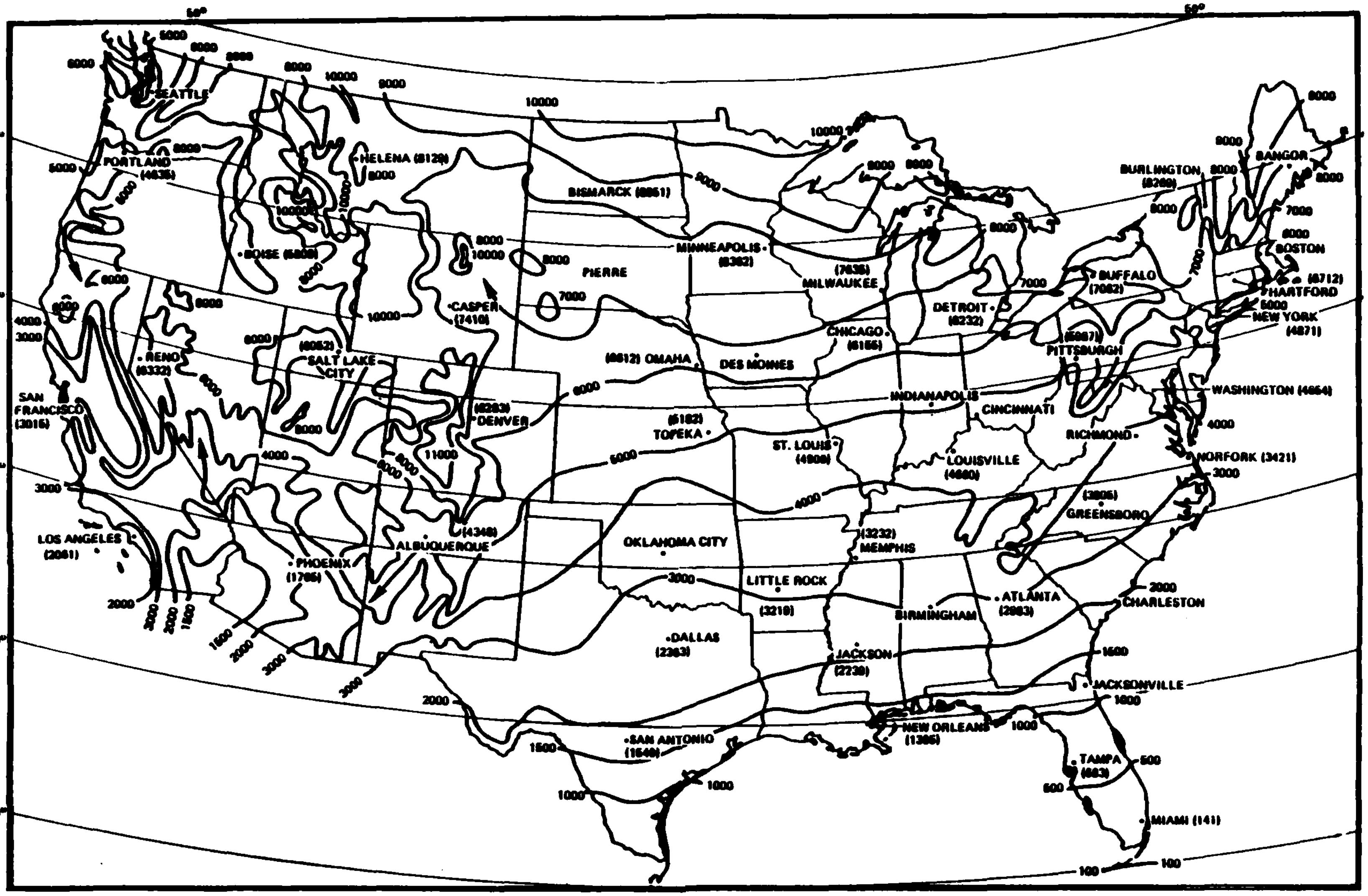


Figure D-1. Annual heating degree days (base 65°F).

DISTRIBUTION LIST

ARMY ARRADCOM, Dover, NJ; BMDSC-RE (H. McClellan) Huntsville AL; Contracts - Facs Engr Directorate, Fort Ord, CA; DAEN-CWE-M, Washington DC; DAEN-MPE-D Washington DC; DAEN-MPU, Washington DC; ERADCOM Tech Supp Dir. (DELSD-L) Ft. Monmouth, NJ; HQDA (DAEN-FEE-A); Tech. Ref. Div., Fort Huachuca, AZ
ARMY - CERL Library, Champaign IL; Spec Assist for MILCON, Champaign, IL
ARMY CORPS OF ENGINEERS MRD-Eng. Div., Omaha NE; Seattle Dist. Library, Seattle WA
ARMY CRREL G. Phetteplace Hanover, NH
ARMY DEPOT FAC ENGR, CODE SDSLE-SF, Letterkenny Army Dp, Chambersburg,
ARMY ENGR DIST. Library, Portland OR
ARMY MATERIALS & MECHANICS RESEARCH CENTER Dr. Lenoe, Watertown MA
ARMY MISSILE R&D CMD SCI Info Cen (DOC) Redstone Arsenal, AL
ARMY MTMC Trans Engr Agency MTT-CE, Newport News, VA
ARMY-MERADCOM DRDME-WC Ft Belvoir VA
ADMINSUPU PWO, BAHRIAN
ASO PWD (ENS M W Davis), Philadelphia, PA
BUREAU OF RECLAMATION Code 1512 (C. Selander) Denver CO
CINCLANT CIV ENGR SUPP PLANS OFFR NORFOLK, VA
CNM Code MAT-04, Washington, DC; Code MAT-O8E, Washington, DC; NMAT - 044, Washington DC
CNO Code NOP-964, Washington DC; Code OP 987 Washington DC; Code OP-413 Wash, DC; Code OPNAV 09B24 (H); OP987J, Washington, DC
COMNAVRESFOR Code 473, New Orleans, LA
COMFAIRMED SCE, Code N55, Naples IT
COMFLEACT, OKINAWA PWD - Engr Div, Sasebo, Japan; PWO, Kadena, Okinawa; PWO, Sasebo, Japan
COMNAVMARIANAS Code N4, Guam
COMNAVSUPPFORANTARCTICA PWO Det Christchurch
COMOCEANSYSLANT PW-FAC MGMNT Off Norfolk, VA
COMOCEANSYSPAC SCE, Pearl Harbor HI
COMSUBDEVGRUONE Operations Offr, San Diego, CA
DEFFUELSUPPCEN DFSC-OWE (Term Engrng) Alexandria, VA
DOE INEL Tech. Lib. (Reports Section), Idaho Falls, ID
DTIC Defense Technical Info Ctr/Alexandria, VA
DTNSRDC Anna Lab (Code 4120) Annapolis MD
DTNSRDC Code 4111 (R. Gierich), Bethesda MD
DTNSRDC Code 522 (Library), Annapolis MD
ENVIRONMENTAL PROTECTION AGENCY Reg. III Library, Philadelphia PA; Reg. VIII, 8M-ASL, Denver CO
FLTCOMBATTRACENLANT PWO, Virginia Bch VA
FOREST SERVICE Engr Staff Washington, DC
GIDEP OIC, Corona, CA
GSA Assist Comm Des & Cnst (FAIA) D R Dibner Washington, DC ; Off of Des & Const-PCDP (D Eakin) Washington, [illegible]
HC & RS Tech Pres. Service, Meden, Washington, DC
LIBRARY OF CONGRESS Washington, DC (Sciences & Tech Div)
MARINE CORPS BASE Code 4.01 (Asst Chief Engr) Camp Pendleton, CA; Code 406, Camp Lejeune, NC; Maint Off Camp Pendleton, CA; PWD - Maint. Control Div. Camp Butler, Kawasaki, Japan; PWO Camp Lejeune NC; PWO, Camp Pendleton CA; PWO, Camp S. D. Butler, Kawasaki Japan
MARINE CORPS HQS Code LFF-2, Washington DC
MCAS Facil. Engr. Div. Cherry Point NC; CO, Kaneohe Bay HI; Code S4, Quantico VA; Facs Maint Dept - Operations Div, Cherry Point; PWD - Utilities Div, Iwakuni, Japan; PWO, Iwakuni, Japan; PWO, Yuma AZ
MCDEC NSAP REP, Quantico VA
MCLB B520, Barstow CA; Maintenance Officer, Barstow, CA; PWO, Barstow CA
MCRD SCE, San Diego CA
NAF PWD - Engr Div, Atsugi, Japan; PWO, Atsugi Japan
NALF OINC, San Diego, CA
NARF Code 100, Cherry Point, NC; Code 612, Jax, FL; Code 640, Pensacola FL; SCE Norfolk, VA
NAS CO, Guantanamo Bay Cuba; Security Officer, Kingsville TX; Code 114, Alameda CA; Code 183 (Fac. Plan BR MGR); Code 183, Jacksonville FL; Code 18700, Brunswick ME; Code 18U (ENS P.J. Hickey), Corpus Christi TX; Code 8E, Patuxent Riv., MD; Dir of Engrng, PWD, Corpus Christi, TX
NAVAIRSYSCOM PWD Code 8P (Grover) Patuxent River, MD
NAS Lakehurst, NJ; Lead. Chief. Petty Offr. PW/Self Help Div, Beeville TX; PWD - Engr Div Dir, Millington, TN; PWD - Engr Div, Gtmo, Cuba; PWD - Engr Div, Oak Harbor, WA; PWD Maint. Cont. Dir., Fallon

NV; PWD Maint. Div., New Orleans, Belle Chasse LA; PWD, Code 1821H (Pfankuch) Miramar, SD CA; PWD, Maintenance Control Dir., Bermuda; PWO (Code 18.2), Bermuda; PWO Belle Chasse, LA; PWO Chase Field Beeville, TX; PWO Key West FL; PWO Lakehurst, NJ; PWO Patuxent River MD; PWO Sigonella Sicily; PWO Whiting Fld, Milton FL; PWO, Cecil Field FL; PWO, Dallas TX; PWO, Glenview IL; PWO, Millington TN; PWO, Miramar, San Diego CA; PWO, Oceana, Virginia Bch VA; PWO, So. Weymouth MA; SCE Norfolk, VA; SCE, Barbers Point HI; SCE, Cubi Point, R.P; Security Offr, Patuxent Riv. MD

NATL RESEARCH COUNCIL Naval Studies Board, Washington DC

NAVACT PWO, London UK

NAVAEROSPREGMEDCEN SCE, Pensacola FL

NAVAIRDEVCEN Chmielewski, Warminster, PA; PWD, Engr Div Mgr, Warminster, PA

NAVAIRPROPTESTCEN CO, Trenton, NJ

NAVCOASTSYSCEN CO, Panama City FL; Code 715 (J Quirk) Panama City, FL; Library Panama City, FL; PWO Panama City, FL

NAVCOMMAREAMSTRSTA PWO, Norfolk VA; SCE Unit 1 Naples Italy; SCE, Guam; SCE, Wahiawa HI; Sec Offr, Wahiawa, HI

NAVCOMMSTA Code 401 Nea Makri, Greece; PWD - Maint Control Div, Diego Garcia Is.; PWO, Exmouth, Australia; SCE, Balboa, CZ

NAVCONSTRACEN Curriculum/Instr. Stds Offr, Gulfport MS

NAVEDTRAPRODEVCEN Technical Library, Pensacola, FL

NAVEDUTRACEN Engr Dept (Code 42) Newport, RI

NAVENENVSA Code 111A (Winters) Port Hueneme CA

NAVEODTECHCEN Code 605, Indian Head MD

NAVFAC M & O Officer Bermuda; PWO, Brawdy Wales UK; PWO, Centerville Bch, Ferndale CA; PWO, Point Sur, Big Sur CA

NAVFACENGCOM Alexandria, VA; Code 03 Alexandria, VA; Code 032E, Alexandria, VA; Code 03T (Essoglou) Alexandria, VA; Code 04B3 Alexandria, VA; Code 04M, Alexandria, VA; Code 051A Alexandria, VA; Code 082, Alexandria, VA; Code 09M54, Tech Lib, Alexandria, VA; Code 100, Alexandria, VA; Code 1113, Alexandria, VA; Code 111B (Hanneman), Alexandria, VA; Code 112, Alexandria, VA

NAVFACENGCOM - CHES DIV. Code 403 Washington DC; Code 406 Washington DC; FPO-1 Washington, DC; Library, Washington, D.C.

NAVFACENGCOM - LANT DIV. Code 111, Norfolk, VA; Code 1112, Norfolk, VA; Eur. BR Deputy Dir, Naples Italy; Library, Norfolk, VA

NAVFACENGCOM - NORTH DIV. Code 04 Philadelphia, PA; Code 04AL, Philadelphia PA; Code 11, Phila PA; Code 111 Philadelphia, PA; ROICC, Contracts, Crane IN

NAVFACENGCOM - PAC DIV. (Kyi) Code 101, Pearl Harbor, HI; CODE 09P PEARL HARBOR HI; Code 402, RDT&E, Pearl Harbor HI; Library, Pearl Harbor, HI

NAVFACENGCOM - SOUTH DIV. Code 1112, Charleston, SC; Code 403, Gaddy, Charleston, SC; Code 406 Charleston, SC; Library, Charleston, SC

NAVFACENGCOM - WEST DIV. AROICC, Contracts, Twentynine Palms CA; Code 04B San Bruno, CA; Library, San Bruno, CA; O9P/20 San Bruno, CA; RDT&ELO San Bruno, CA

NAVFACENGCOM CONTRACTS AROICC, Quantico, VA; Contracts, AROICC, Lemoore CA; Dir, Eng. Div., Exmouth, Australia; Dir. of Constr, Tupman, CA; Eng Div dir, Southwest Pac, Manila, PI; OICC, Southwest Pac, Manila, PI; OICC-ROICC, NAS Oceana, Virginia Beach, VA; OICC/ROICC, Balboa Panama Canal; OICC/ROICC, Norfolk, VA; ROICC Code 495 Portsmouth VA; ROICC Key West FL; ROICC MCAS El Toro; ROICC, NAS, Corpus Christi, TX; ROICC, Pacific, San Bruno CA; ROICC, Yap; ROICC-OICC-SPA, Norfolk, VA

NAVHOSP PWD - Engr Div, Beaufort, SC

NAVMAG PWD - Engr Div, Guam; SCE, Subic Bay, R.P.

NAVOCEANSYSCEN Code 4473B (Tech Lib) San Diego, CA; Code 523 (Hurley), San Diego, CA; Code 6700, San Diego, CA; Code 811 San Diego, CA

NAVORDMISTESTFAC PWD - Engr Dir, White Sands, NM

NAVORDSTA PWD - Dir, Engr Div, Indian Head, MD; PWO, Louisville KY

NAVPETRES Director, Washington DC

NAVPGSCOL PWO Monterey CA

NAVPHIBASE PWO Norfolk, VA; SCE Coronado, SD,CA

NAVREGMEDCEN PWD - Engr Div, Camp Lejeune, NC; PWO, Camp Lejeune, NC

NAVREGMEDCEN PWO, Okinawa, Japan

NAVREGMEDCEN SCE; SCE San Diego, CA; SCE, Camp Pendleton CA; SCE, Guam; SCE, Newport, RI; SCE, Oakland CA

NAVREGMEDCEN SCE, Yokosuka, Japan

NAVSCOLCECOFF C35 Port Hueneme, CA

NAVSCSOL PWO, Athens GA

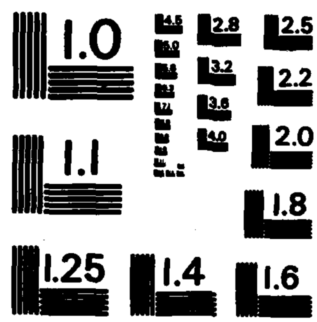
NAVSEASYSCOM Code 0325, Program Mgr, Washington, DC; Code PMS 395 A 3, Washington, DC; SEA 04E (L Kess) Washington, DC

NAVSECGRUACT PWO Winter Harbor ME; PWO, Adak AK; PWO, Edzell Scotland; PWO, Puerto Rico; PWO, Torri Sta, Okinawa
NAVSECSTA PWD - Engr Div, Wash., DC
NAVSHIPYD Code 202.4, Long Beach CA; Code 202.5 (Library) Puget Sound, Bremerton WA; Code 380, Portsmouth, VA; Code 382.3, Pearl Harbor, HI; Code 400, Puget Sound; Code 440 Portsmouth NH; Code 440, Norfolk; Code 440, Puget Sound, Bremerton WA; Code 453 (Util. Supr), Vallejo CA; Code 457 (Maint. Supr.) Mare Island, Vallejo CA; Commander, Pearl Harbor, HI; Library, Portsmouth NH; PW Dept, Long Beach, CA; PWD (Code 420) Dir Portsmouth, VA; PWD (Code 450-HD) Portsmouth, VA; PWD (Code 453-HD) SHPO 03, Portsmouth, VA; PWO, Bremerton, WA; PWO, Mare Is.; PWO, Puget Sound; SCE, Pearl Harbor HI
NAVSTA Adak, AK; CO, Brooklyn NY; Code 16P, Keflavik, Iceland; Code 4, 12 Marine Corps Dist, Treasure Is., San Francisco CA; Dir Engr Div, PWD, Mayport FL; Dir Mech Engr 37WC93 Norfolk, VA; Engr. Dir., Rota Spain; Long Beach, CA; Maint. Cont. Div., Guantanamo Bay Cuba; PWD - Engr Dept, Adak, AK; PWD - Engr Div, Midway Is.; PWO, Keflavik Iceland; PWO, Mayport FL; SCE, Guam, Marianas; SCE, Pearl Harbor HI; SCE, San Diego CA; SCE, Subic Bay, R.P.; Utilities Engr Off. Rota Spain
NAVSUPPACT CO, Naples, Italy; PWO Naples Italy
NAVSUPPFAC PWD - Maint. Control Div, Thurmont, MD
NAVSURFWPNCEN PWO, White Oak, Silver Spring, MD
NAVTECHTRACEN SCE, Pensacola FL
NAVTELCOMMCOM Code 53, Washington, DC
NAVWARCOL Dir. of Facil., Newport RI
NAVWPNCEN Code 2636 China Lake; PWO (Code 266) China Lake, CA; ROICC (Code 702), China Lake CA
NAVWPNSTA (Clebak) Colts Neck, NJ; Code 092, Concord CA; Code 092A, Seal Beach, CA
NAVWPNSTA PW Office Yorktown, VA
NAVWPNSTA PWD - Maint. Control Div., Concord, CA; PWD - Supr Gen Engr, Seal Beach, CA; PWO Colts Neck, NJ; PWO, Charleston, SC; PWO, Seal Beach CA
NAVWPNSUPPCEN Code 09 Crane IN
NCTC Const. Elec. School, Port Hueneme, CA
NCBC Code 10 Davisville, RI; Code 15, Port Hueneme CA; Code 155, Port Hueneme CA; Code 156, Port Hueneme, CA; Code 25111 Port Hueneme, CA; Code 430 (PW Engrng) Gulfport, MS; Code 470.2, Gulfport, MS; Library, Davisville, RI; NEESA Code 252 (P Winters) Port Hueneme, CA; PWO (Code 80) Port Hueneme, CA; PWO, Davisville RI; PWO, Gulfport, MS; Technical Library, Gulfport, MS
NOAA (Mr. Joseph Vadus) Rockville, MD; Library Rockville, MD
NRL Code 5800 Washington, DC
NSC Code 54.1 Norfolk, VA; SCE Norfolk, VA; SCE, Charleston, SC
NSD SCE, Subic Bay, R.P.
NSWSES Code 0150 Port Hueneme, CA
NTC SCE, San Diego CA
NUSC DET Code 5202 (S. Schady) New London, CT; Code EA123 (R.S. Munn), New London CT
OFFICE SECRETARY OF DEFENSE OASD (MRA&L) Dir. of Energy, Pentagon, Washington, DC
ONR Code 221, Arlington VA; Code 700F Arlington VA
PACMISRANFAC HI Area Bkg Sands, PWO Kekaha, Kauai, HI
PHIBCB 1 P&E, San Diego, CA
PWC ACE Office Norfolk, VA; CO, (Code 10), Oakland, CA; Code 10, Great Lakes, IL; Code 105 Oakland, CA; Code 105, Oakland, CA; Code 110, Great Lakes, IL; Code 110, Oakland, CA; Code 121.1, Oakland, CA; Code 154 (Library), Great Lakes, IL; Code 200, Great Lakes IL; Code 400, Great Lakes, IL; Code 400, Pearl Harbor, HI; Code 400, San Diego, CA; Code 420, Great Lakes, IL; Code 420, Oakland, CA; Code 424, Norfolk, VA; Code 500 Norfolk, VA; Code 500, Great Lakes, IL; Code 500, Oakland, CA; Code 505A Oakland, CA; Code 600, Great Lakes, IL; Code 610, San Diego Ca; Code 700, Great Lakes, IL; Library, Code 120C, San Diego, CA; Library, Guam; Library, Pearl Harbor, HI; Library, Pensacola, FL; Library, Subic Bay, R.P.; Library, Yokosuka JA; Production Officer, Norfolk, VA; Util Dept (R Pascua) Pearl Harbor, HI; Utilities Officer, Guam
SPCC PWO (Code 120) Mechanicsburg PA
TVA Solar Group, Arnold, Knoxville, TN
U.S. MERCHANT MARINE ACADEMY Kings Point, NY (Reprint Custodian)
USAF REGIONAL HOSPITAL Fairchild AFB, WA
USCG G-MMT-4/82 (J Spencer); Library Hqs Washington, DC
USCG R&D CENTER Library New London, CT
USDA Forest Service Reg 3 (R. Brown) Albuquerque, NM
USNA Ch. Mech. Engr. Dept Annapolis MD; ENGRNG Div, PWD, Annapolis MD; Energy-Environ Study Grp, Annapolis, MD
ARIZONA State Energy Programs Off., Phoenix AZ
CONNECTICUT Office of Policy & Mgt, Energy, Div. Hartford, CT
CORNELL UNIVERSITY Ithaca NY (Serials Dept, Engr Lib.)
FOREST INST. FOR OCEAN & MOUNTAIN Carson City NV (Studies - Library)
FRANKLIN INSTITUTE M. Padusis, Philadelphia PA

LOUISIANA DIV NATURAL RESOURCES & ENERGY Div Of R&D, Baton Rouge, LA
MAINE OFFICE OF ENERGY RESOURCES Augusta, ME
MISSOURI ENERGY AGENCY Jefferson City MO
MIT Cambridge MA (Rm 10-500, Tech. Reports, Engr. Lib.); Cambridge, MA (Harleman)
NEW HAMPSHIRE Concord NH (Governor's Council on Energy)
NY CITY COMMUNITY COLLEGE BROOKLYN, NY (LIBRARY)
NYS ENERGY OFFICE Library, Albany NY
OAK RIDGE NATL LAB T. Lundy, Oak Ridge, TN
PORT SAN DIEGO Pro Eng for Port Fac, San Diego, CA
UNIVERSITY OF TEXAS Inst. Marine Sci (Library), Port Arkansas TX
DIXIE DIVING CENTER Decatur, GA
MCDONNELL AIRCRAFT CO. (Goff) Sr Engr, Engrng Dept, St. Louis, MO
NEWPORT NEWS SHIPBLDG & DRYDOCK CO. Newport News VA (Tech. Lib.)
SANDIA LABORATORIES Library Div., Livermore CA
UNITED TECHNOLOGIES Windsor Locks CT (Hamilton Std Div., Library)

AD-A147 893 HANGAR HEATING AND ENERGY CONSERVATION MANUAL(U) NAVAL CIVIL ENGINEERING LAB PORT HUENEME CA J L ASHLEY SEP 84 AFESC/DEB-TR-84-01 2/2

UNCLASSIFIED F/G 1/5 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

PLEASE HELP US PUT THE ZIP IN YOUR MAIL! ADD YOUR FOUR NEW ZIP DIGITS TO YOUR LABEL (OR FACSIMILE), STAPLE INSIDE THIS SELF-MAILER, AND RETURN TO US.

(fold here)

DEPARTMENT OF THE NAVY

NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043-5003

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300
1 IND-NCEL-2700/4 (REV. 12-73)
0030-LL-L70-0044

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DOD-316

Commanding Officer
Code L14
Naval Civil Engineering Laboratory
Port Hueneme, California 93043-5003

INSTRUCTIONS

The Naval Civil Engineering Laboratory has revised its primary distribution lists. The bottom of the mailing label has several numbers listed. These numbers correspond to numbers assigned to the list of Subject Categories. Numbers on the label corresponding to those on the list indicate the subject category and type of documents you are presently receiving. If you are satisfied, throw this card away (or file it for later reference).

If you want to change what you are presently receiving:

- Delete – mark off number on bottom of label.
- Add – circle number on list.
- Remove my name from all your lists – check box on list.
- Change my address – line out incorrect line and write in correction (ATTACH MAILING LABEL).
- Number of copies should be entered after the title of the subject categories you select.

Fold on line below and drop in the mail.

Note: Numbers on label but not listed on questionnaire are for NCEL use only, please ignore them.

Fold on line and staple.

DEPARTMENT OF THE NAVY

NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300
1 IND-NCEL-2700/4 (REV. 12-73)
0930-LL-L70-0044

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DOD-316

Commanding Officer
Code L14
Naval Civil Engineering Laboratory
Port Hueneme, California 93043

END

FILMED

12-84

DTIC