APPENDIX C

DETERMINING AND MINIMIZING WIND SPEED OVER COLLECTOR AND POOL SURFACES

INTRODUCTION

It is important to minimize the rate at which cool or cold ambient air flows over the surfaces of swimming pools, spas or unglazed solar collectors. This may be done by locating them in areas that are naturally protected from the wind or by building one or several wind screens if natural wind protection is not available Under either condition it is important for the solar designer or installer to estimate as accurately as possible the wind speeds likely to occur at the site during the pool heating season (which may not be concurrent with the design or installation period). The information in this appendix may be used to make the required estimates

AIRPORT WIND SPEEDS

Table C.1* gives average monthly wind speeds at 10 meter elevations (32.8 ft) at the airports near 12 Florida cities.

C.2 DIRECTION OF THE WIND

Figure C identifies prevailing monthly wind directions (and approximate speed) for eleven of those same cities

*Table C.1, Figure C.1 and Figure C.2 are from Chapter 3 (by Subrato Chandra, Michael Houston and Philip Fairey) of FSEC's "Principles of Low Energy Building Design in Warm, Humid Climates".

Table C.1

Monthly Average Wind Speeds for Florida Cities

CITY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Apalachicola	8.4	8.8	9.0	8.7	7.8	7.2	6.6	6.7	8.1	8.1	8.1	8.0	8.0
Daytona Beach	9.1	9.9	10.1	9.9	9.2	8.4	7.6	7.3	8.7	9.5	8.8	8.8	8.9
Fort Myers	8.5	9.1	9.4	9.0	8.2	7.4	6.8	6.8	7.7	8.5	8.2	8.2	8.2
Jacksonville	8.4	9.4	9.4	9.1	8.6	8.3	7.5	7.2	8.1	8.6	8.1	8.2	8.4
Key West	12.0	12.0	12.5	12.8	10.8	9.8	9.9	9.5	9.9	11.4	12.0	12.0	11.2
Lakeland	7.3	7.8	7.8	7.7	6.9	6.2	5.7	5.5	6.6	7.2	6.9	6.9	6.9
Miami	9.4	10.1	10.4	10.7	9.5	8.2	7.8	7.8	8.1	9.4	9.5	9.1	9.2
Orlando	9.0	9.8	10.0	9.5	8.8	8.2	7.4	7.3	7.8	8.8	8.7	8.7	8.7
Pensacola	9.0	9.4	9.7	9.3	8.5	7.5	6.8	6.6	7.7	8.0	8.2	9.0	8.3
Tallahassee	7.7	7.9	8.4	7.5	6.8	6.4	5.7	5.6	6.4	6.9	6.6	6.9	6.9
Tampa	8.9	9.5	9.8	9.6	9.1	8.3	7.5	7.3	8.1	9.0	8.7	8.8	8.7
West Palm Beach	9.8	10.3	10.7	10.9	9.6	8.1	7.5	7.6	8.5	10.1	10.0	10.0	9.4

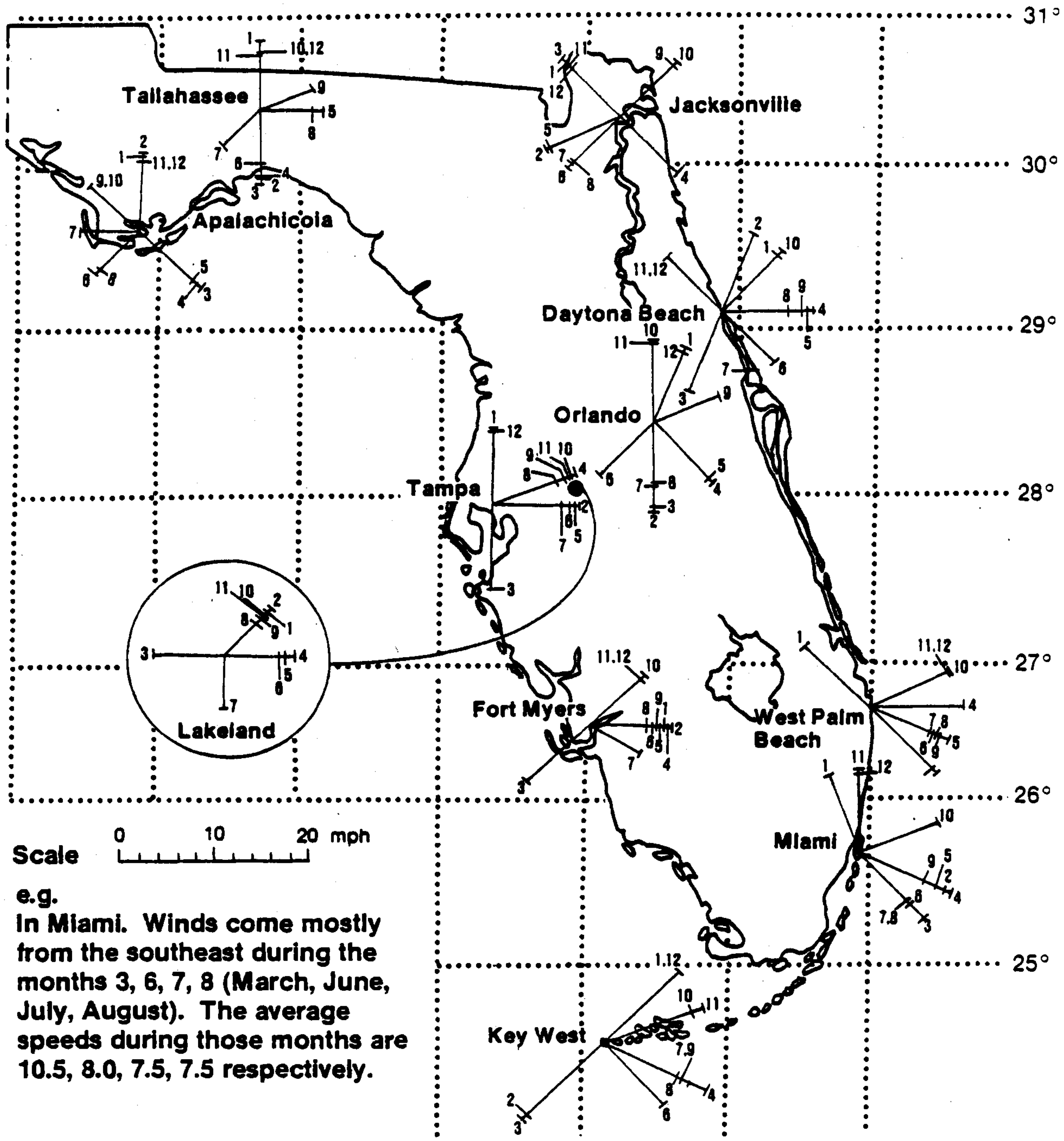


Figure C.1

Florida Average Wind Speeds and

Prevailing Directions for Each Month

C.3 EFFECT OF MICROGEOGRAPHY ON WIND SPEED

Figure C.2 gives correction factors which may be used to modify those the airport wind speeds to make them applicable other generic locations and heights above the ground near the reporting locations.

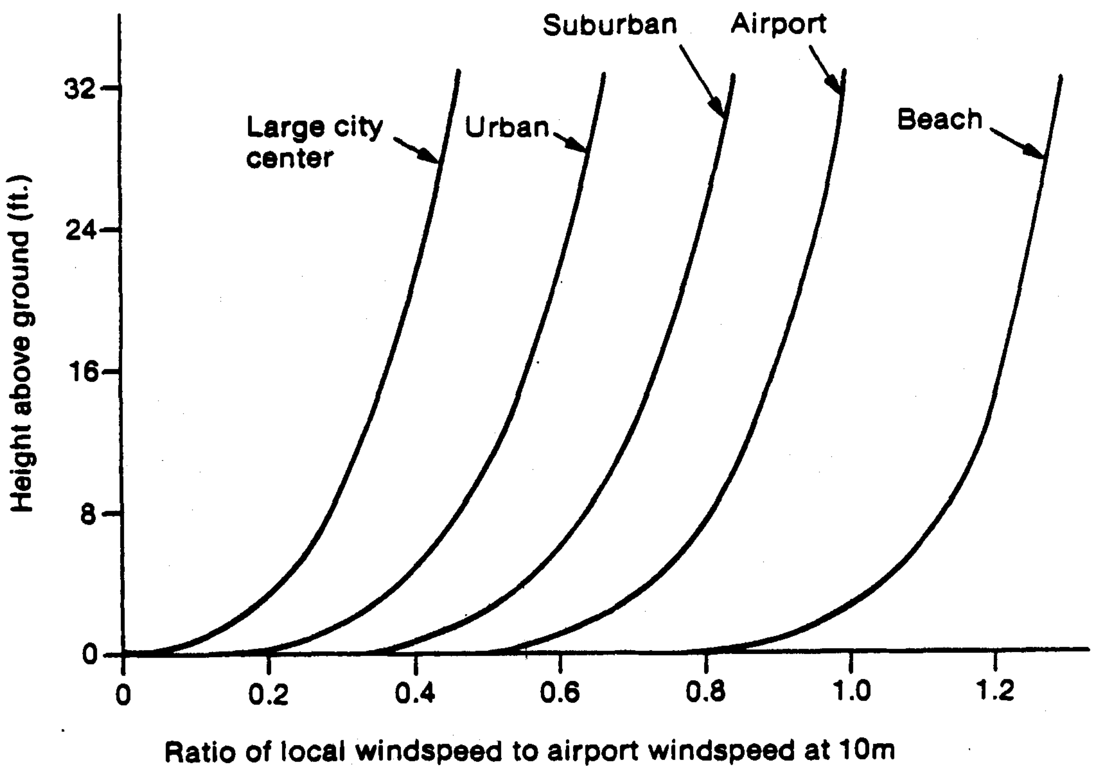


Figure C.2

Ratio of Local Windspeed to Airport Windspeed at 10m

Windspeed Variation with Height for Different Terrains

At this point it my be well to run through the solution to a hypothetical problem in order to illustrate the use of the information contained in Table C.1 and Figures C.1 and C.2.

Sample Problem

What is the average January wind speed and prevailing direction which may be expected 16 ft above ground level at an exposed Daytona Beach oceanfront motel site?

Solution

Figure C.1 contains prevailing wind direction information. From the line identified as #1 (January) for the Daytona Beach area, the direction is from the NE. The length of the line indicates that the wind speed is about 9 mph. The wind speed is more accurately obtained from Table C.1. The January wind speed at the airport 10 meters (about 33 ft) above the ground = 9.1 mph. The wind speed at 16 ft at the airport = .9 x 9.1 = 8.2 mph. On the beach at 16 ft elevation the wind speed is 1.2 x 9.1 = 10.9 mph. The correction factors .9 and 1.2 are found on the horizontal axis of Figure C.2. The curves on that figure are representative of geographic microclimates and the figures on the vertical axis represent the height (in ft) above the ground.

The above process relates the reported wind speed information -- Table C.1 and Figure C.1 -- to a nearby generic location and a specific elevation above the ground by the use of correction factors contained in Figure C.2.

C.4 VARIATIONS OF WIND SPEED WITH TIME OF DAY

Unfortunately, an examination of hourly wind speeds indicates that for all Florida cities those wind speeds occurring during the sunshine hours between 9 a.m. and 5 p.m., and during the October thru March pool heating period, are about 1.25 times the 24-hour daily average.

Table C.2 contains the wind speed ratios for three representative Florida cities: Jacksonville (north), Orlando (central), and Miami (south).

Table C.2
Ratio of 9 a.m. - 5 p.m. to 24-Hour Average Wind Speeds

	Jacksonville	Orlando	Miami
Oct	1.23	1.32	1.23
Nov	1.23	1.27	1.30
Dec	1.22	1.20	1.28
Jan	1.26	1.20	1.21
Feb	1.26	1.25	1.25
Mar	1.27	1.35	1.32

An hourly wind speed profile for a January day in Miami is presented in Figure C.3.

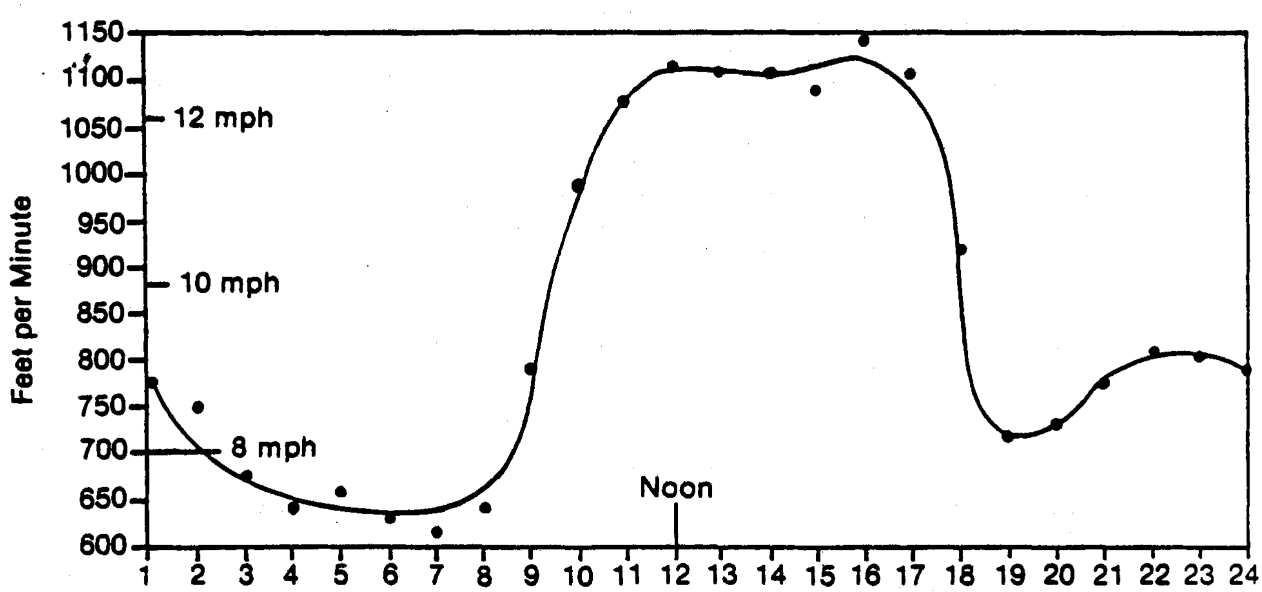


Figure C.3

Typical Hourly Wind Speed Profile

(January, Miami, Fla.)

Continuation of Sample Calculations

We now may refine our calculations of the wind speed at the Daytona Beach site so as to evaluate the wind speed during the <u>operational hours</u>

a solar pool heating system The wind speed during the 9 a.m. - 5 p.m period is: 10.9 x 1.26 = 13.73 mph (the 1.26 ratio factor corresponds to January in Jacksonville)

Availability of Climatological Data

Detailed climatological data (which was used to develop Table C.1) is available for a nominal price for many cities throughout the United States It may be obtained from

National Oceanic and Atmospheric Administration (NOAA)
Environmental Data and Information Service
National Climatic Center
Federal Building
Ashville, NC 28801

WIND BEHAVIOR DURING COLD SNAPS

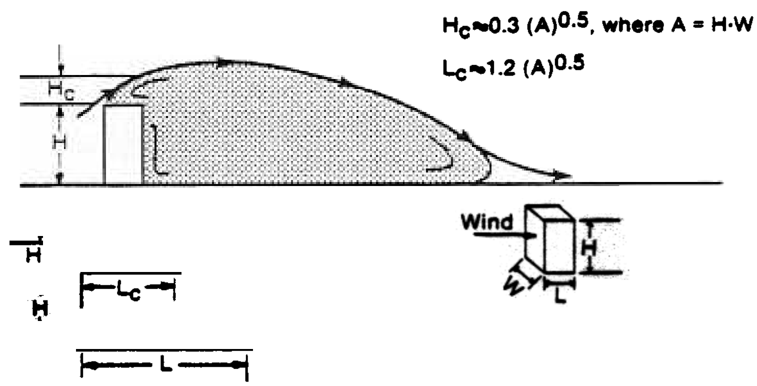
During severe cold snaps the daytime wind speed increases in all Florida cities, though the coastal ones are the most severely effected. A quantitative evaluation of the increase is not required for an unfortunate reason The efficiency with which unglazed solar pool heating systems operate during cold, windy periods is so low that whether the airflow over their surfaces s 10 mph or 20 mph is, in most cases, an academic consideration.

THE EFFECT OF BUILDINGS ON WIND SPEED

The calculations that have been introduced to this point do not account for the effects of man-made structures. The next few paragraphs, tables and figures deal with those effects in sufficient detail for most unglazed collector array design and installation purposes.

"Air flow around buildings is complicated and erratic." "Buildings of even moderately complex shape, such as L-shaped structures formed by two rectangular blocs, may generate flow patterns too complicated to generalize for design " Both of these statements appear on the first page of chapter 14 "Air Flow Around Buildings" of the 1981 edition of the ASHRAE Handbook of Fundamentals The solar designer or installer should recognize the limitations that those disclaimers impose on the accuracy of the following series of wind speed calculations

An examination of Figure C.4 discloses that the proper selection of a rooftop location will place an array of solar collectors in an eddy zone where they will escape the full force (and thus cooling effect) of cold winter winds



Dimensions of Recirculation Cavity

Ratio of building Width and height	Cavity Height, H_C	Cavity Length, L_C
Less than 8:1	$0.3\ (HW)^{0.5}$	$1.2\ (HW)^{0.5}$
Greater than 8:1	0.85 x smaller of H or W	3.4 x smaller of H or W

Figure C.4

Effect of Rectangular Buildings on Air Flow

It also discloses that a ground location in the lee of a building affords the same sort of protection

Figure C.5 shows that on large buildings the airflow reattaches itself to the building skin downwind from the eddy zone The eddy zone is indicated by reverse airflow arrows.

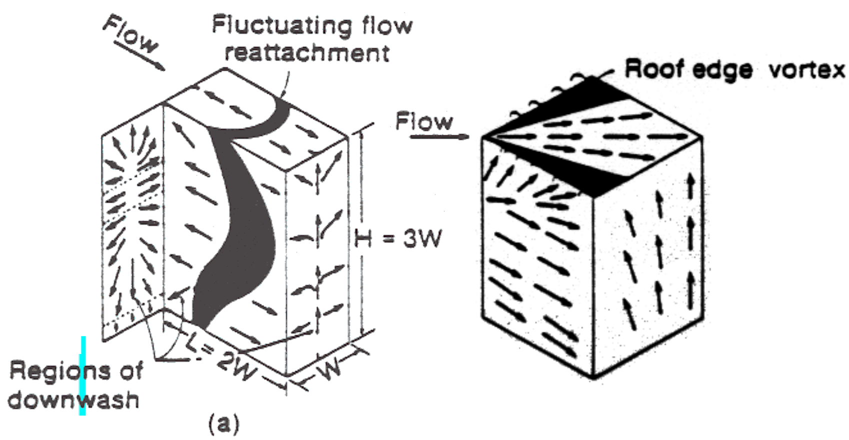


Figure C.5

Surface Flow Patterns

The table contained in Figure C.4 allows calculation of the height and length of the eddy cavity on the roof of a rectangular building Collector locations should be selected that avoid either the darkened zones shown in Figure C.5 or areas downwind of them

Figure C.6 shows relative air speeds over the flat roof of several building configurations when the wind directions are as indicated.

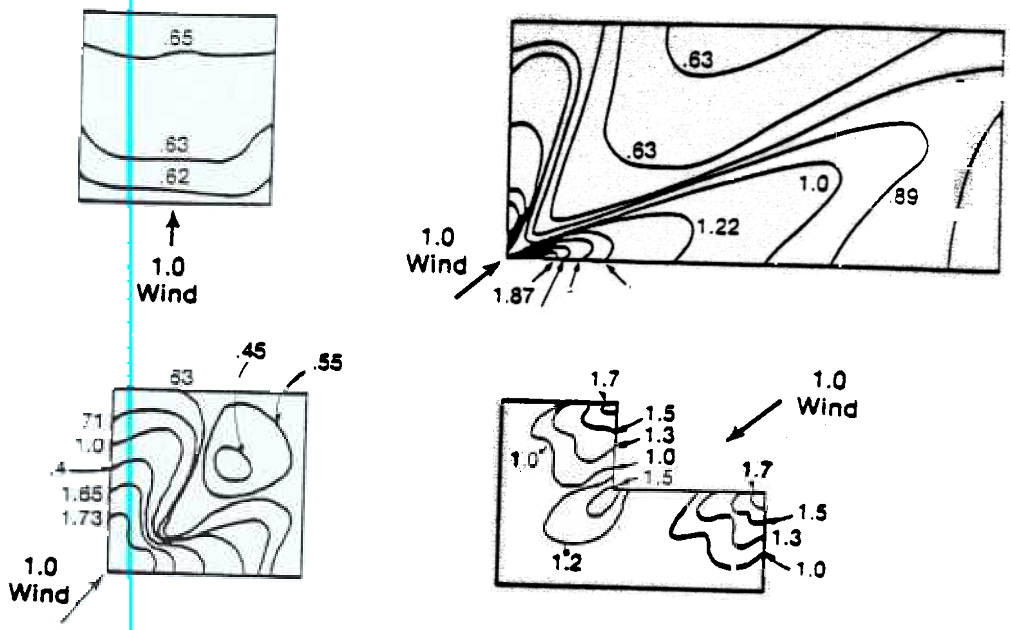


Figure C.6

Relative Wind Speeds on Flat Roofs

The airflow over pitched-roofed buildings is shown in Figure C.7

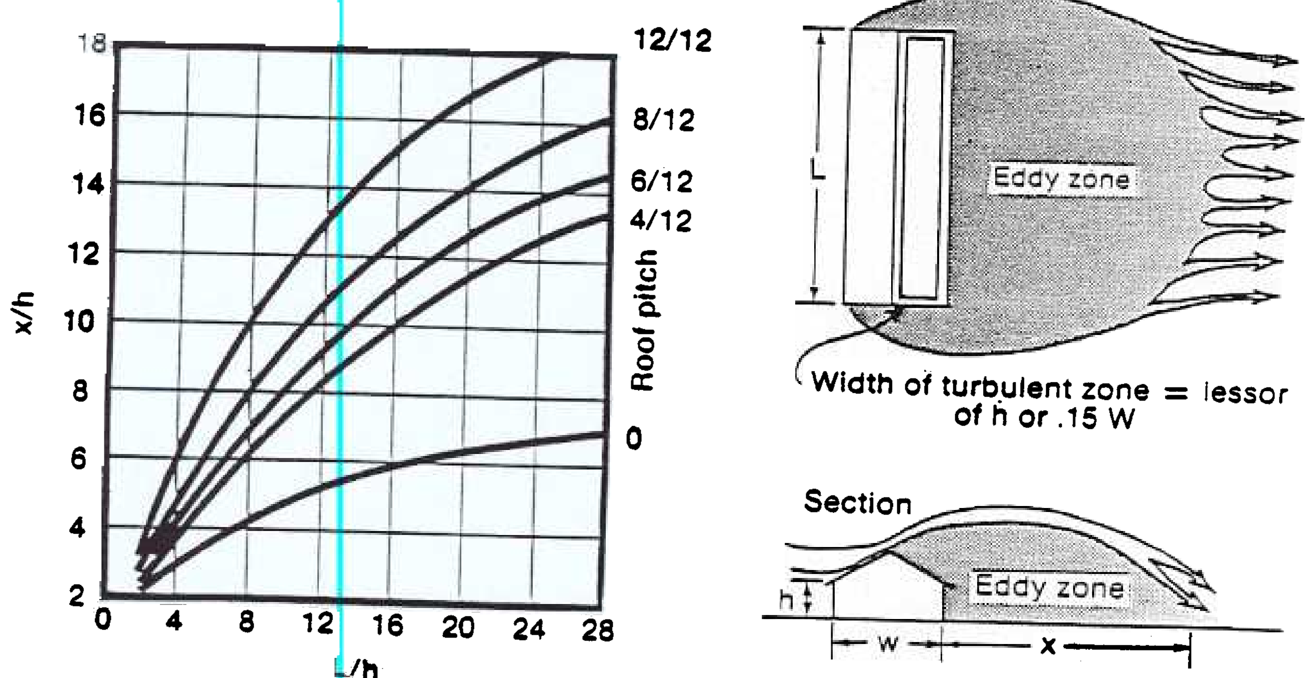


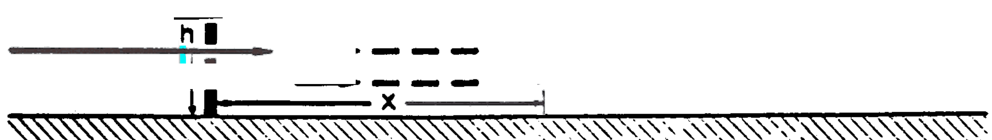
Figure C.7

Airflow Over Pitched Roof Buildings

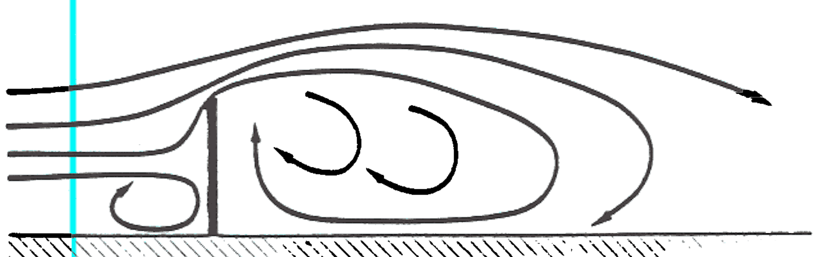
wind speed on the downwind roof is relatively constant (except for severe edge effects caused by the overhangs) and has a value of about 71 of the free-flow airspeed (providing that the roof ridge is at a right angle to the wind direction

C.7 WIND SCREENS

Figure C.8 shows the effect of a wind screen on airflow patterns and speeds Agricultural interests believe that a wind screen with 30-50% porosity reduces the wind speed to about ¼ of the speed upwind of the screen for a distance downwind of 12 times the screen height (except for zones immediately downwind of the pores). The lower porosity (30%) lowers the mean down-screen airspeed but reduces the effective length of shelter. A nonporous parapet or wind screen may introduce large, strong eddys that actually increase the rate of airflow in some locations immediately downwind of the barrier.



Wind screen with a porosity of 30 - 50%
x = 12h



Non-porous wind screen

Figure C.8

Agricultural wind screens usually are tall tree rows which sometimes for miles across otherwise flat land The solar designer or installer deals with a different situation. Buildings are very likely to introduce primary turbulence and eddys and the wind screens used are relatively short (40-80 ft) fences that are typically only 3-6 ft high Consequently a more conservative estimate of the protection afforded by wind screens probably is called for

FSEC senior scientist Dr. Subrato Chandra has made a number of in depth studies of airflow in and around buildings. He recommends the inclusion of a downwind distance of four times the wind screen height in the protected zone and an airspeed reduction factor of three to evaluate the quality of protection offered.

If multiple wind screens are installed, care must be exercised to prevent solar shading

WIND SPEED CONVERSION TABLE

Table C.3 may be used to convert between the units which are commonly used to report wind speed.

Table C.3
Relationships Among Wind Speed Units

MPH	KNOTS	FPM	M/S
1	.9	88	.45
3	2.6	264	1.34
5	4.3	440	2.24
7	6.0	616	3.13
9	7.8	792	4.02
10	8.7	880	4.47
11	9.6	968	4.92
13	11.3	1144	5.81
15	13.0	1320	6.71

Continuation of Sample Calculations

We already have calculated an average, daytime, January wind speed of about 13 3/4 mph on the Daytona Beach oceanfront. What is the best location for an unglazed solar array on a new motel installation? buildings are tc be parallel to the beach with their long axis running N-S Their length is 80 ft, their depth is 65 ft, and the height of their roof is 16 ft above the ground. There is a 3-ft parapet surrounding the roof.

Step 1 Evaluate the wind conditions during the months when pool heating is required

A motel pool in Daytona Beach may need heating from early November thru late March Wind direction and speeds for those months may be evaluated by using the procedures outlined in the previous sample problem. The results are summarized in Table C.4.

Table C.4
Wind Data for Daytona Beach

	Wind Direction	Airport Wind Speed/mph	Site Wind Speed/mph
Nov	NW	8.8	13.28
Dec	NW	8.8	13.28
Jan	NE	9.1	13.73 (previously calculated)
Feb	N-NE	9.9	14.93
Mar	S-SW	10.1	15.24

Site-specific wind speeds for November, December, February and March may be estimated by ratio from the previously calculated January values

$$\frac{13.73}{9.9} = 1.509$$

$8.8 \times 1.509 = 13.28$; etc.

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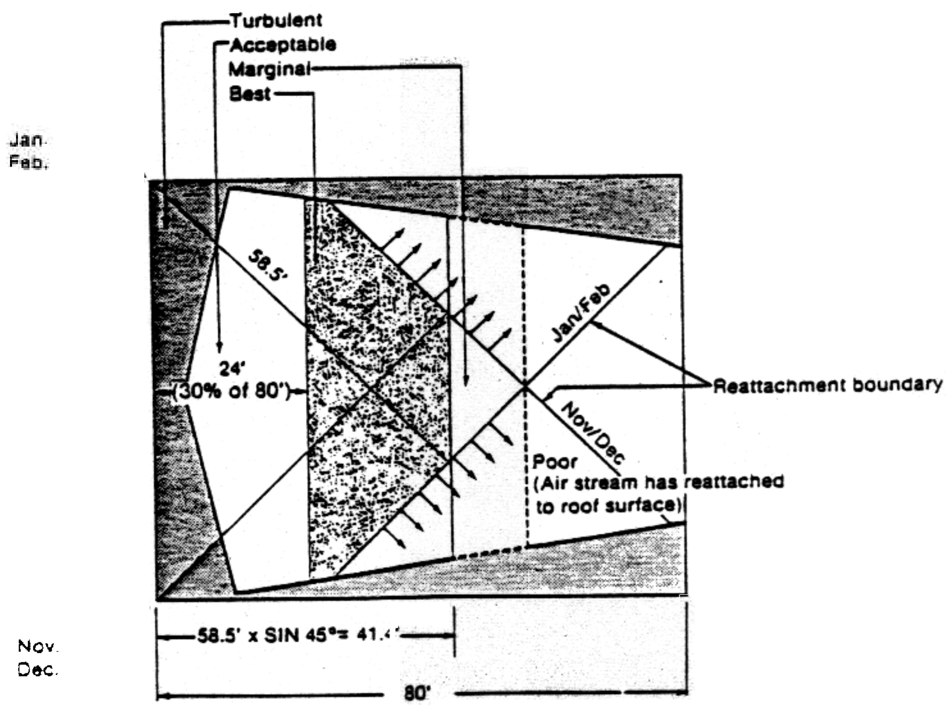

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corners of the building where the wind speeds during different months may be excessive (see Figure C.5). The proper distances from the upwind (N, E, W) edges of the roof depend upon interpretation of the factors presented in Figures C.4, C.5 and C.6. The size of the eddy bubble pictured in Figure C.4 may be approximately evaluated from Figure C.4 even though it is somewhat distorted because the prevailing Nov/Dec and Jan/Feb wind directions are at 45° to the north wall of the building. The dimensions of the eddy bubble are:

$h_c = 3(h \times w)^{.5} = .3\ ((16 + 3) \times 80)^{.5} = 11.7$ ft high;

$l_c = 1.5(h \times w)^{.5} = ((16 + 3) \times 80)^{.5} = 58.5$ ft long

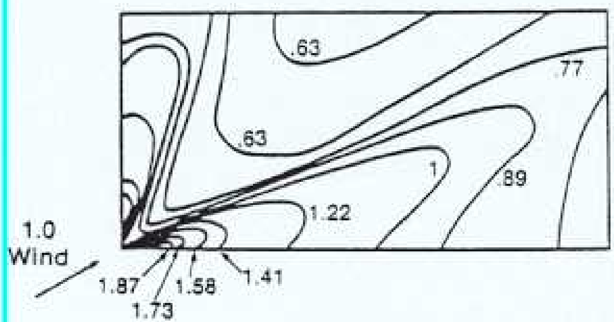
The height dimension is adequate to protect the type of collector array normally used for swimming pool heating.

The length of the eddy bubble should be measured along a 45° diagonal line from the NE (Jan/Feb) or NW (Nov/Dec) corners of the roof. A point 58.5 ft downwind of the corner is 58.5 x sine 45° or 41.4 ft downwind on a NS line Turbulent areas are depicted in Figure C.5. Figure C.6 shows a velocity ratio map which may be used to assist the solar designer or installer in the selection of the most desirable area of the roof (that with the lowest average wind speed <u>during the cold months</u>) for collector location An examination of all the factors allows us to draw a "map" such as Figure C.9

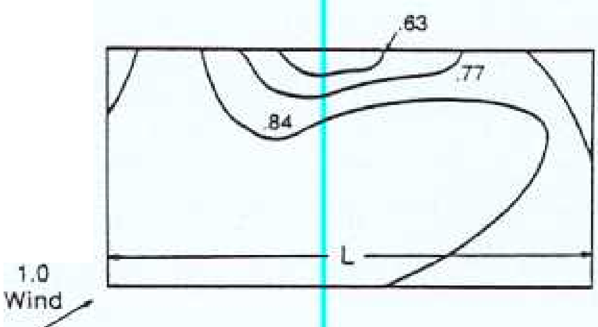
A ten-foot margin around the north, east and west edges of the roof should keep the collectors out of the turbulent zones depicted on Figure C.5 and C.6

C.9 EFFECT OF PARAPETS ON WIND SPEED

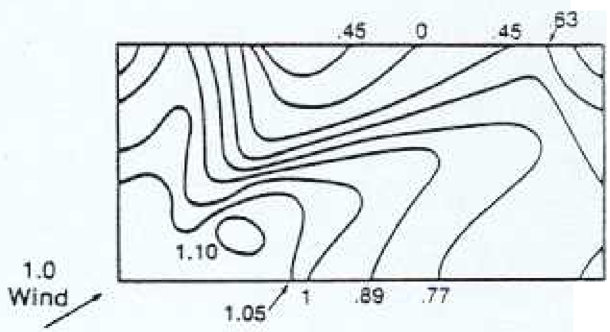
Figures C.10 a, b, and c show the effect of a parapet on the airflow distribution.



No Parapet
(a)



$h_p = L/12$
(b)



$h_p = L/24$
(c)

h_p = Parapet height
L = Building length

Figure C.10

Effect of Parapets on Wind Speed Patterns

The size of the collector array will dictate what portion of the roof will be used. If the motel pool is a small one, the entire array may be placed in the "best" zone.

Appendix D carries the hypothetical problem into sizing of the collector array.