

## 6.0 SNOW LOADS

**6.1 General:** Provisions for the determination of snow loads on greenhouse structures are described in the following subsections. The provisions apply to the calculation of snow loads for both continuously heated greenhouses and for intermittently heated or unheated greenhouses.

**6.1.1 Definitions:** The following definitions apply only to the provisions of Section 6, SNOW LOADS.

**Thermal Resistance (R):** A factor which measures a material's resistance to the transmission of heat. The smaller the R value, the greater the amount of heat a material will transmit.

**Continuously Heated Greenhouses:** A production or retail greenhouse with a constantly maintained temperature of 50 degrees F or more during winter months. Such greenhouse must also have a maintenance attendant on duty at all times or an adequate temperature alarm system to provide warning in the event of a heating system failure. In addition, the greenhouse roof material must have a thermal resistance (R) less than 2.0.

**Intermittently Heated or Unheated Greenhouse:** Any greenhouse that does not meet the requirements of a continuously heated single or double glazed greenhouse.

**6.2 Ground Snow Loads:** Ground snow loads,  $P_g$ , to be used in the determination of design snow loads for roofs of greenhouses are given in Figs. 6.1, 6.2, and 6.3 for the contiguous United States. In some areas, the amount of local variation in snow loads is so extreme as to preclude

**Table 6.1**

ALASKAN GROUND SNOW LOADS ( $P_g$ )			
Adak	30	Kotzebue	70
Anchorage	75	McGrath	80
Angoon	100	Nenan	95
Barrow	40	Nome	130
Barter Island	80	Palmer	45
Bethel	80	Petersburg	180
Big Delta	95	St. Paul Island	55
Cold Bay	20	Seward	70
Cordova	95	Shemya	25
Fairbanks	100	Sitka	60
Ft. Yukon	95	Talkeetna	230
Galena	70	Unalakleet	75
Gulkana	75	Valdez	130
Homer	60	Whitter	450
Juneau	90	Wrangell	90
Kenai	75	Yakutat	230
Kodiak	40		

meaningful mapping. In certain other areas, the snow load zones are meaningful but the mapped values should not be used for certain geographic settings, such as high country, within these zones. These areas are shown shaded in the figures.

Table 6.1 gives ground snow load values,  $P_g$ , for many locations in Alaska. Extreme local variations prohibit state-wide mapping of the ground snow loads in Alaska. Ground snow load should be taken as zero for Hawaii.

**6.3 Flat Roof Design Snow Loads:** The design snow loads,  $P_f$ , on an unobstructed flat roof shall be calculated using one of the following formulas:

$$P_f = C_{tg} C_e I P_g$$

where:

$P_f$  = flat roof design snow load (psf)

$C_e$  = exposure factor

$C_t$  = thermal factor

$C_r$  = risk factor

$P_g$  = ground snow load (psf)

**6.3.1 Exposure Factor ( $C_e$ ):** Exposure factors, which take into account the effect of wind on the design snow loading, are given in Table 6.2. The site condition chosen should be representative of that which is likely to exist throughout the life of the greenhouse.

**Table 6.2**

**SNOW EXPOSURE FACTOR ( $C_e$ )**

Roofs located in generally open terrain extending one-half mile or more from the structure	0.6
Structures located in densely forested or sheltered areas	0.9
All other structures	0.7

**6.3.2 Thermal Factor ( $C_{tg}$ ):** Thermal factors for various thermal conditions are given in Table 6.3. The thermal factor is meant to take into account the thermal resistance of the greenhouse roof glazing and the temperature conditions within the structure. The thermal condition chosen should be representative of that which is likely to exist throughout the life of the structure.

Table 6.3

THERMAL FACTOR ( $C_{tg}$ )

Thermal condition	$C_{tg}$
Continuously heated greenhouse	0.83
Unheated or intermittently heated greenhouse	1.00

Note: See Section 6.11 for definition of greenhouse thermal conditions.

**6.3.3 Importance Factor (I):** Importance factor, which take into account the consequences of failure of the various types of greenhouses, are given in Table 6.4.

**6.4 Sloped Roof Design Snow Loads:** All snow loads acting on a sloping surface shall be considered to act on the horizontal projection of that surface. The sloped roof design snow load,  $P_s$ , shall be obtained by multiplying the flat roof design snow load,  $P_f$ , by the roof slope factor  $C_s$ .

Table 6.4

IMPORTANCE FACTOR (I)

Type of Greenhouse	I
Retail greenhouses with general public access permitted	1.0
All other greenhouses	0.8

$$P_s = C_s \times P_f$$

Values of  $C_s$  for greenhouse roofs are given in Sections 6.4.1 and 6.4.2, respectively.

**6.4.1 Heated Greenhouse Roof Slope Factor ( $C_s$ ):** For unobstructed heated greenhouse roofs with slippery surface that will allow snow to slide off at the eaves, the roof slope factor shall be determined by using the formula:

$$C_s = 1 - [(a-15)/55]$$

Note: a is the angle of slope in degrees from the horizontal. Lesser slopes use no slope factor.

**6.4.2 Unheated Greenhouse Roof Slope Factor ( $C_s$ ):** For unobstructed unheated greenhouse roofs having a slope from the horizontal of 30 degrees or more, the roof slope factor

shall be determined by using formula:

$$C_s = 1 - [(a-30)/40]$$

Note: a is the angle of slope in degrees from the horizontal. Lesser slopes use no slope factor.

**6.4.3 Roof Slope Factor For Arched Roofs:** Portions of arched greenhouse roofs having a slope exceeding 70 degrees shall be considered free of snow load. The point at which the slope exceeds 70 degrees shall be considered the "eave" for such roofs. For arched roofs the roof slope factor,  $C_s$ , shall be determined from the appropriate formula in Sections 6.4.1 & 6.4.2, by basing the angle of slope on the slope line from the "eave" to the crown.

**6.4.4 Roof Slope Factor For Multiple Roofs:** For multiple folded plate, sawtooth and barrel vault roofs with parallel ridge lines, the roof slope factor ( $C_s$ ) shall be considered to be equal to 1.0 regardless of the slope of the roof. (Section 1610.5.2 BOCA National Building Code, 1993)

**6.5 Unbalanced Snow Loads:** Winds from all direction shall be considered when determining unbalanced snow loads. (Section 1610.6 BOCA National Building Code, 1993)

**6.5.1 Unbalanced Snow Load For Pitched Roofs:** For pitched greenhouse roofs with a slope less than 15 degrees, unbalanced snow loads need not be considered. For slopes greater than 15 degrees, the structure shall be designed to sustain an unbalanced uniform snow load on the lee side equal to 1.5 times the sloped roof design snow load,  $P_s$ , divided by  $C_e$  (i.e.,  $1.54 P_s/C_e$ ). In the unbalanced situation the windward side shall be considered clear of snow. Balanced and unbalanced loading diagrams are presented in Fig. 6.5.

**6.5.2 Unbalanced Snow Load For Arched Roofs:** Portions of arched roofs having a slope exceeding 70 degrees shall be considered free of snow. The **equivalent** slope of an arched roof for use in Sections 6.4.1 & 6.4.2 is equal to the slope of a line from the eave or the point at which the slope exceeds 70 degrees to the crown. If the **equivalent** slope is less than 10 degrees, unbalanced snow loads need not be considered. For **equivalent** slopes greater than 10 degrees, unbalanced loads shall be determined according to the loading diagrams in Fig. 6.6. In all cases, the windward side shall be considered clear of snow. If the ground or another roof abuts a Case II or Case III arched roof greenhouse at or within 3 ft of its eave, the snow load shall not be decreased between the 30 degree point and the eave but shall remain constant at  $2 P_s/C_e$ . This alternate distribution is shown as a dashed line in Fig. 6.6.

**6.5.3 Unbalanced Snow Load For Gutter-Connected Roofs:** The unbalanced snow load shall increase from one-half the balanced load used in Section 6.4.4 at the crown (i.e.  $0.5 P_s$ ) to three times the Section 6.4.4 balanced load divided by  $C_e$  at the valley (i.e.  $3 P_s/C_e$ ). Balanced and unbalanced loading diagrams for a gutter-connected greenhouse roof are presented in Fig. 6.7.

**6.6 Drifts on Lower Roofs:** Drift loads need not be considered on warm greenhouse roofs ( $C_t = 0.83$  or  $1.0$  in Table 6.3).

**6.6.1 Regions With Light Snow Loads:** In areas where the ground snow load,  $P_g$ , is 10 psf or less, drift loads on lower roofs need not be considered.

**6.6.2 Drifts on Lower Roof of a Structure:** In cases, such as lean-to or attached even-span greenhouses where a greenhouse abuts the wall of a higher adjacent structure, a surcharge load due to snow drifting shall be considered on the lower roof. The geometry of the surcharge load should be approximated by a triangle as shown in Fig. 6.8 where:

$h_b$  = height of balanced snow load, i.e. balanced snow divided by approximate density in Table 6.5 (ft)

$h_c$  = clear height from top of the balanced load on the lower roof to the closest point on the adjacent upper roof (ft). It is assumed that all snow has blown off the upper roof near its eave. If  $h_c/h_b < 0.2$ , drift loads need not be considered.

$h_d$  = drift height =  $2C_t P_g / C_e \delta$  (Note:  $h_d$  shall not be greater than  $h_c$ .)

$\delta$  = the appropriate density from Table 6.5 (pcf)

$L$  = length of drift, i.e. the common length of the upper and lower roofs (ft)

$w$  = width of drift (ft)

if  $L \leq 50$  ft., then  $w = 3h_d$ .

if  $L > 50$  ft., then  $w = 4h_d$ .

minimum value of  $w = 10$  ft.

$P_d$  = the drift surcharge load =  $h_d \delta$

establish surcharge loads caused by drifting on a roof within 20 ft of a higher structure that could cause snow to accumulate on it. However, the separation distance,  $S$ , between the two structures will reduce drift loads on lower roofs. The factor  $(20-S)/20$  shall be applied to the intensity of the maximum drift load to account for spacing. For separations greater than 20 ft, drift loads from the adjacent structure need not be considered.

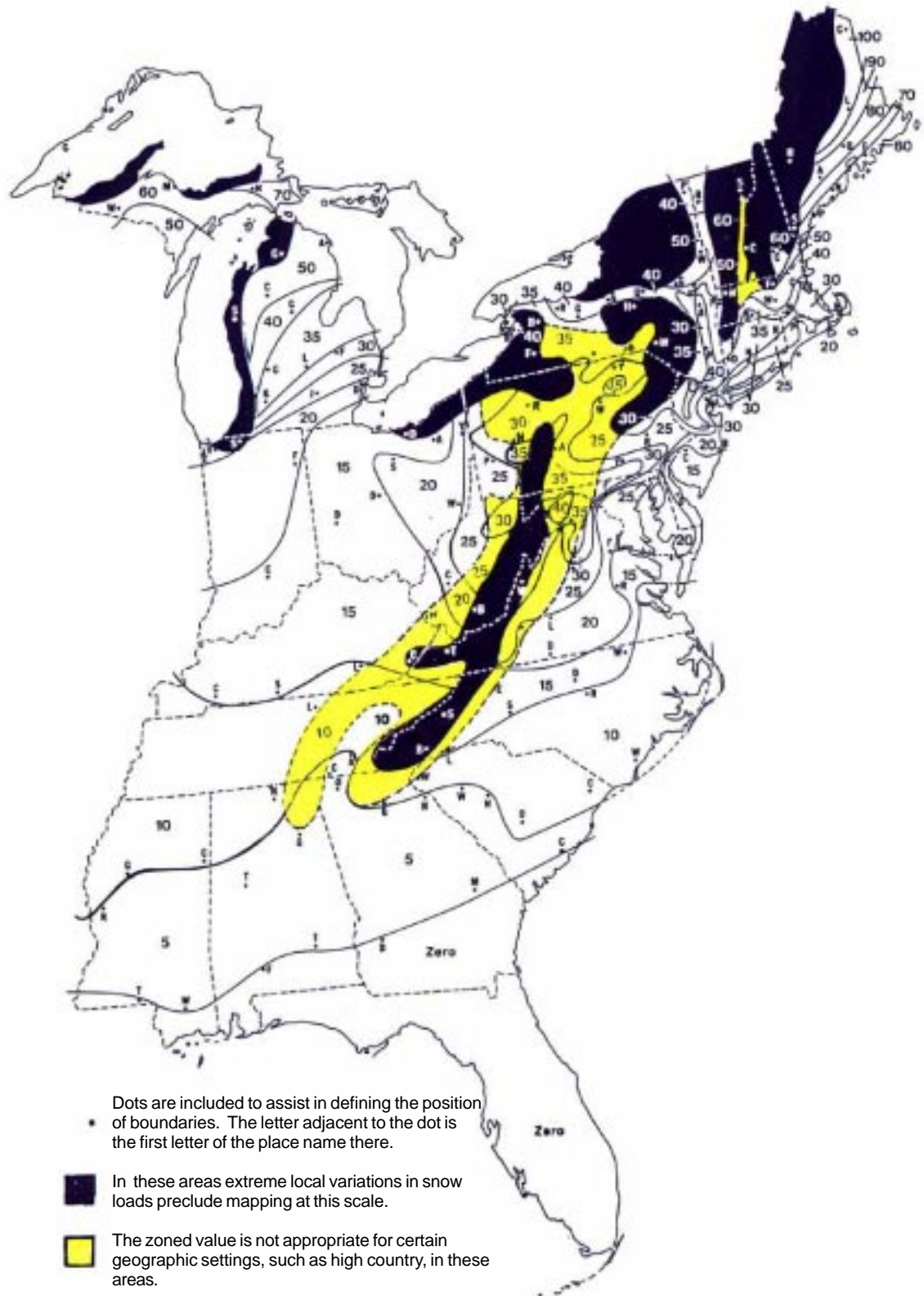
**6.7 Sliding Snow:** In situations where the snow load from a higher adjacent structure may be expected to slide onto a greenhouse roof, and where all the snow may be expected to remain on the greenhouse roof after sliding its full intensity shall be considered in the design of the greenhouse roof. This requirement applies to continuously heated as well as unheated or intermittently heated greenhouses.

**6.8 Unloaded Portions:** For all roofs, the effect of removing half the snow load from any portion of the loaded area shall be investigated.

**6.9 Extra Loads From Rain-On-Snow:** All unheated or intermittently heated greenhouse roofs shall be designed to sustain a temporary surcharge load associated with an intense rain while sustaining the design snow load.

**6.10 Drainage In Gutter Connected Roofs:** All gutters shall be provided with adequate slope and drains to allow for run off of rain and snow meltwater and to prevent ponding.

**6.6.3 Lower Roof Of An Adjacent Structure:** The methodology in Sections 6.6.1. and 6.6.2 shall also be used to



**Figure 6.1** Ground Snow Load  $P_g$ , For Eastern United States (PSF)

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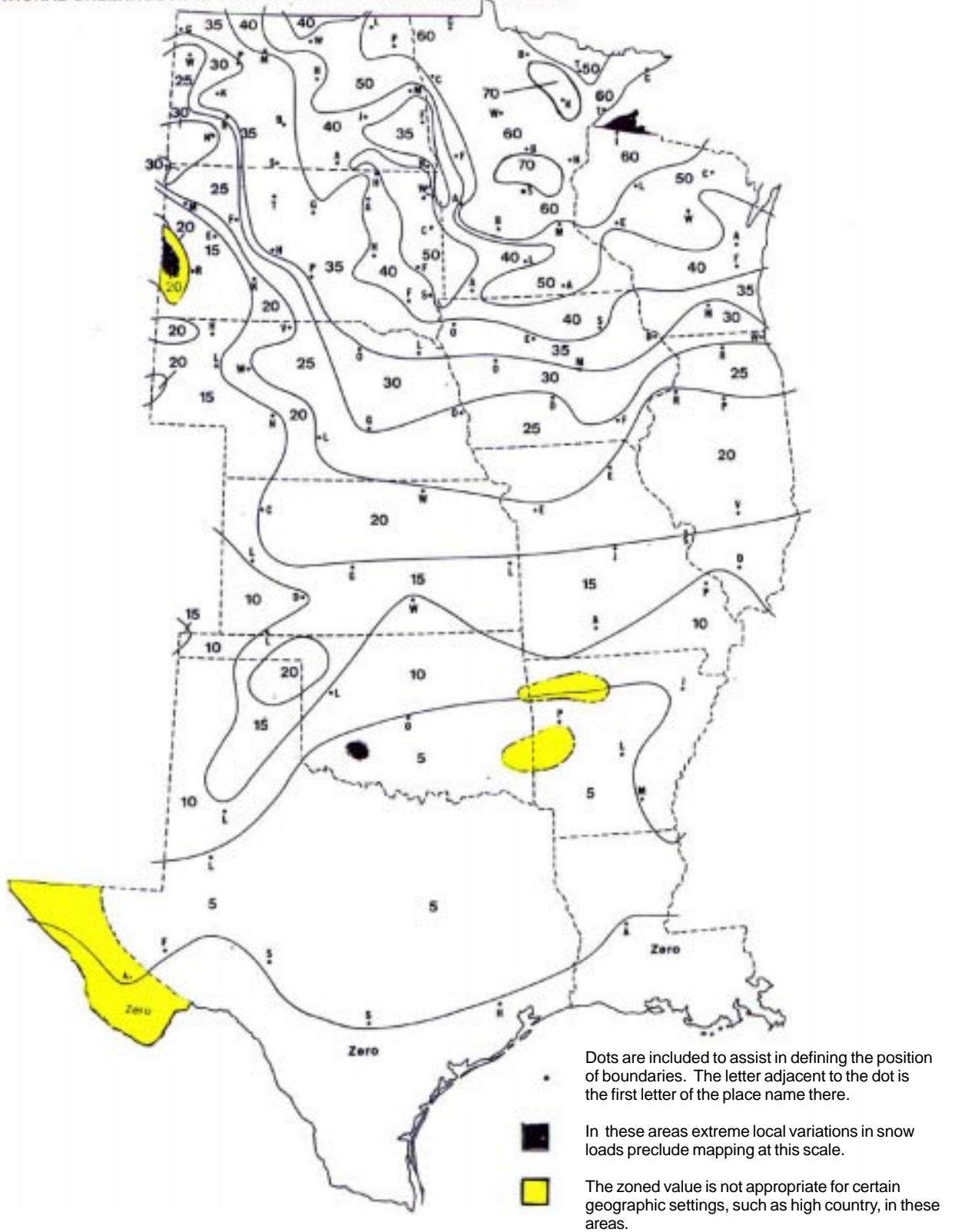
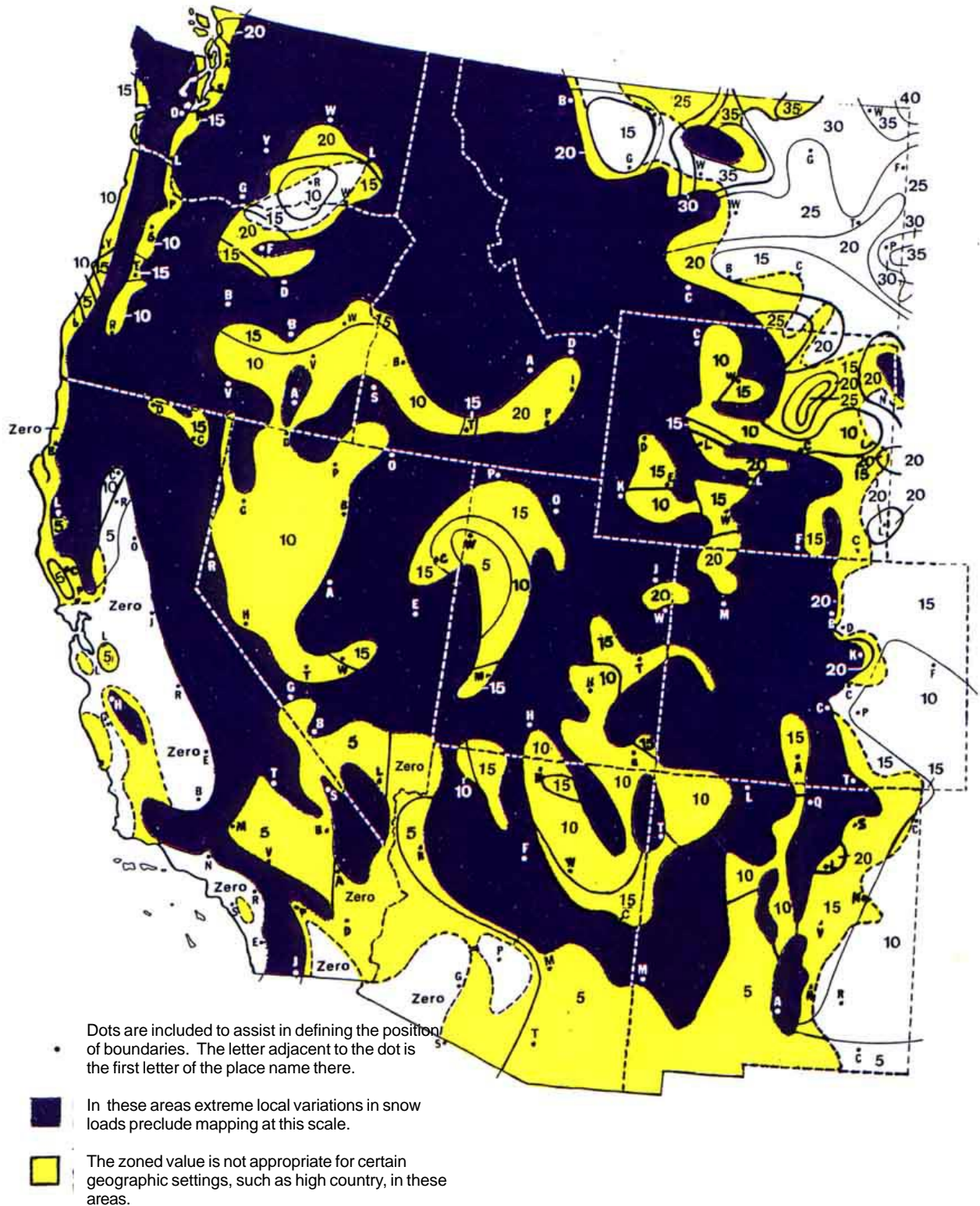


Figure 6.2 Ground Snow Load  $P_g$ , For Central United States (PSF)





**Figure 6.3** Ground Snow Load  $P_s$ , For Western United States (PSF)

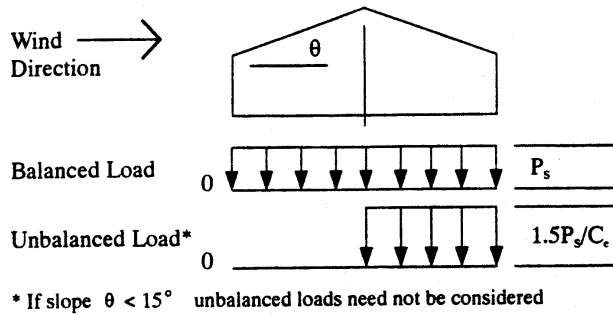


Figure 6.5: Balanced and Unbalanced Snow Loads for Pitched Roofs

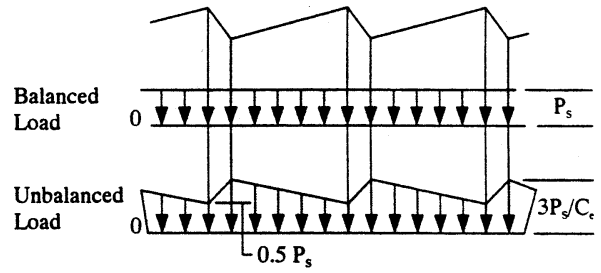


Figure 6.7: Balanced and Unbalanced Loads for Sawtooth Roof

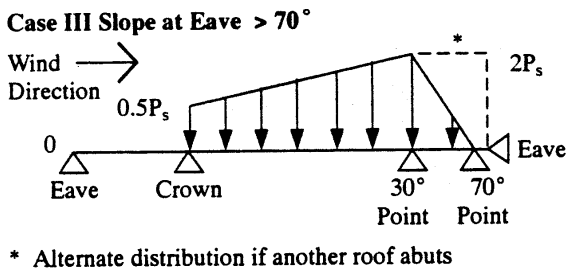
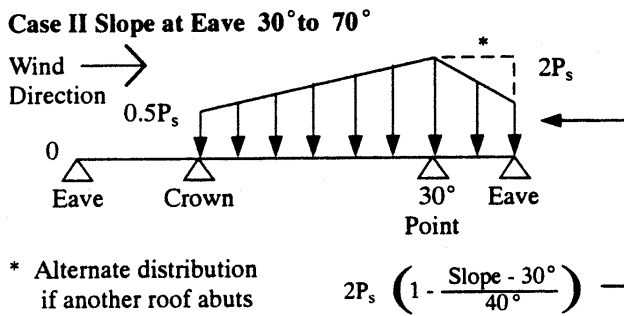
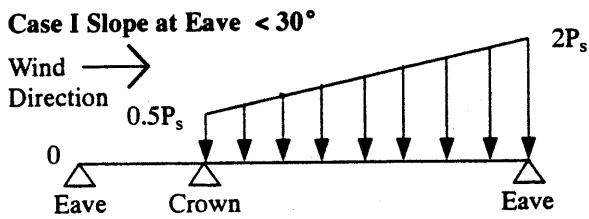
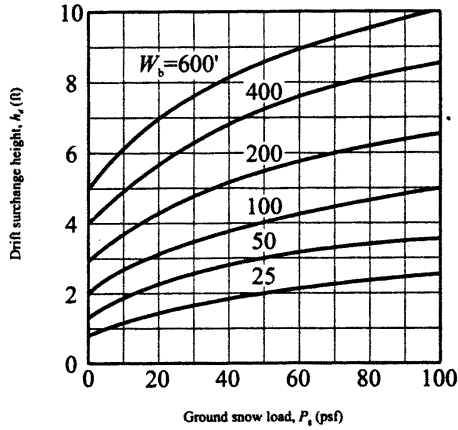


Figure 6.6: Unbalanced Load Conditions for Curved Roofs



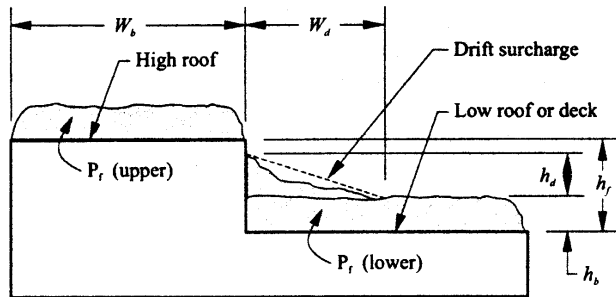
**Figure 6.8**  
**DETERMINATION OF THE MAXIMUM HEIGHT OF**  
**DRIFT SURCHARGE ( $h_d$ ) IN FEET**  
 (Figure 1610.7 BOCA National Building Code, 1993)

$$h_d = 0.43^3 \sqrt{W_b} \cdot \sqrt{P_g + 10} - 1.5$$

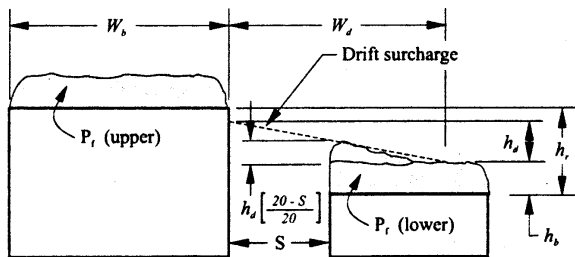
Note a. If the horizontal dimension in feet of the upper roof ( $W_b$ ) is less than 25 feet, use  $W_b$  of 25 feet.

Note b. If the horizontal dimension in feet of the upper roof ( $W_b$ ) is more than 600 feet, use equation above.

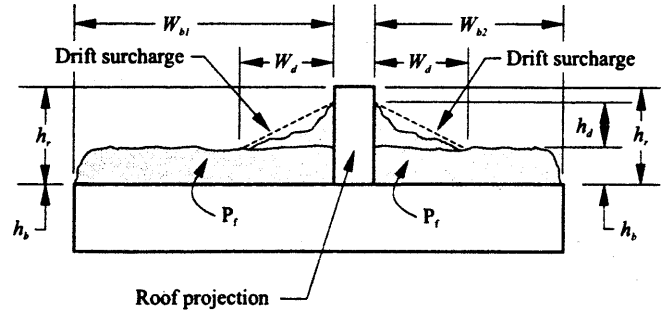
Note c.  $P_g$  = Ground snow load expressed in pounds per square foot.



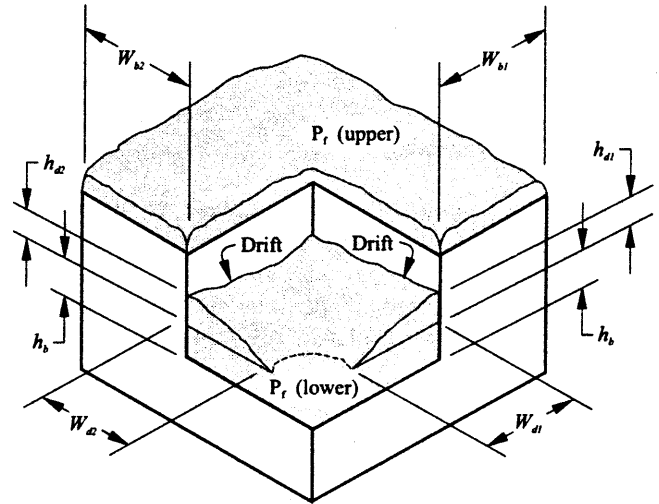
**Figure 6.9**  
**DRIFTING SNOW ON LOW ROOFS AND DECKS**  
 (Figure 1610.7.1 BOCA National Building Code, 1993)



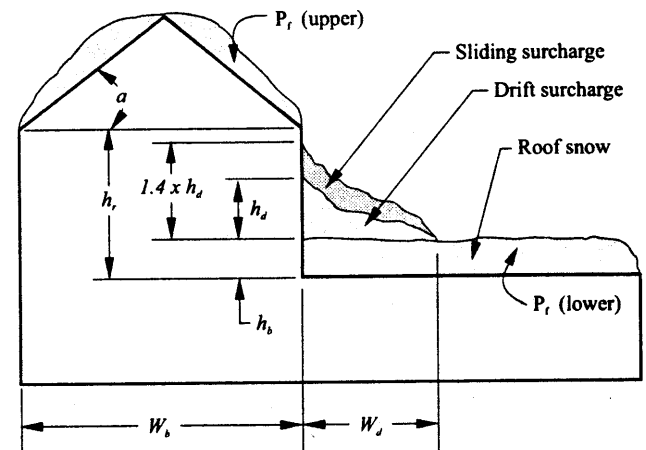
**Figure 6.10**  
**DRIFTING SNOW ONTO ADJACENT LOW STRUCTURES**  
 (Figure 1610.7.2 BOCA National Building Code, 1993)



**Figure 6.11**  
**SNOW DRIFTING AT ROOF PROJECTIONS**  
 (Figure 1610.7.3 BOCA National Building Code, 1993)



**Figure 6.12**  
**INTERSECTING SNOW DRIFTS**  
 (Figure 1610.7.4 BOCA National Building Code, 1993)



**Figure 6.13**  
**ADDITIONAL SURCHARGE DUE TO SLIDING SNOW**  
 (Figure 1610.7.8 BOCA National Building Code, 1993)



## COMMENTARY TO NATIONAL GREENHOUSE MANUFACTURERS ASSOCIATION STANDARD FOR DESIGN LOADS IN GREENHOUSE STRUCTURES

### C1 GENERAL

**C1.1 Scope:** The NGMA standard provides only load requirements for the design of greenhouse structures and their components. The effects these loads have on the structure in terms of stresses and deflections should be determined by accepted methods of analysis. Depending on the material used, the calculated values should then be compared to the allowable values as given in the current editions of the following design specifications:

1. *Specifications for Aluminum Structures* by the Aluminum Association.
2. *National Design Specification for Wood Construction* by the National Forest Products Association.
3. *Steel Construction Manual* by the American Institute of Steel Construction.
4. *Building Code Requirements for Reinforced Concrete* by the American Concrete Institute.
5. *Specification for the Design of Cold Formed Steel Structural Members* by the American Iron and Steel Institute.
6. *Glazing Manual* by the Flat Glass Marketing Association.

**C1.1.2 Limitations:** The NGMA standard is written to apply specifically to free-standing, attached even-span, lean-to, and gutter-connected greenhouses constructed at ground level. There are a variety of other greenhouse-type structures such as solar domes, skylights, A-frames, observatories, etc. which, because they are constructed on top of other structures or because of their shape, are not specifically covered by the standard. However, many of the recommendations of this standard may still be used as a guide in designing these other types of structures.

**C1.4 Additions To Existing Structures:** The designer should be aware of potential structural problems that may be created by the addition of any attached even-span or a lean-to greenhouse to an existing structure. These include the possibility of weakening the existing structure if a common wall is removed to allow access to the greenhouse and, the potential for excessive snow buildup on the lower roof of the two adjacent structures due to drifting.

### C2 COMBINATIONS OF LOADS

**C2.1 Combining Loads:** The load combinations listed cover cases of practical interest. The loads are intended for use with design specifications for conventional structural materials such as aluminum, steel, wood, concrete, glass, etc., that are used in greenhouse construction. Some of these specifications are based on allowable stress design while others employ strength design. Accordingly, no safety or load factors have been applied to the given load combinations since these depend on the design philosophy of the particular material specification.

It should be noted that earthquake loads have been omitted from the combinations to be considered in greenhouse design. This is due to the fact that current practice for earthquake design calls for the application of equivalent lateral forces to the structure. The magnitude of these equivalent lateral forces is based on the weight of the structure to which they are applied. Since greenhouses are relatively lightweight structures, the magnitude of the equivalent lateral earthquake design forces will always be less than the design wind forces and thus they need not be considered.

**C2.2 Load Combination Factors:** Most loads other than dead loads vary significantly with time. When one of these variable loads is combined with permanent load (e.g., combinations 2 through 4, in Section 2.1), its maximum probable value should be used. However, when more than one variable load is considered (e.g. combinations 5 through 6 in Section 2.1), it is very unlikely that they will each attain their maximum values at the same time. Accordingly, some reduction in the total combined load effects is appropriate. This reduction is accomplished through the specified load combination factors. It should be noted, however, that many design specifications allow a 1/3 increase in allowable stresses for load combinations which include wind. This accomplishes the same result as the factor recommended in Section 2.2. Therefore, if a 1/3 increase is allowed, the load combination factors should not be used.

### C3 DEAD LOADS

**C3.2 Weights Of Building Materials:** Table C3.1 gives the weights of several materials commonly used in greenhouse construction. The weights given are average values suitable for general use. However, when there is reason to suspect considerable deviation from the values shown, the actual weight shall be determined.

Table C3.1

WEIGHTS AND DENSITIES OF  
COMMON GREENHOUSE MATERIALS

Steel	490 PCF
Aluminum	165 PCF
Wood (dependent on type and moisture content)	35 PCF
Glass (1/8" thick)	26 oz/ft <sup>2</sup>
Glass (1/4" thick)	52 oz/ft <sup>2</sup>
Fiberglass (4 oz)	4 oz/ft <sup>2</sup>
Fiberglass (5 oz)	5 oz/ft <sup>2</sup>
Fiberglass (6 oz)	6 oz/ft <sup>2</sup>
Polyethylene (6 mil thickness)	2/3 oz/ft <sup>2</sup>

**C3.3 Weight Of Fixed Service Equipment:** Weights of fixed service equipment such as heaters, air conditioners, etc. can usually be obtained from manufacturers' literature.

**C3.4 Special Considerations:** Oftentimes, bottom chord members of greenhouse roof trusses or other interior structural members are used to permanently support suspended plant material such as hanging baskets. The designer shall anticipate these loads where they may occur and increase the design dead load accordingly.

#### C4 LIVE LOADS

**C4.1 Definitions:** Live loads, exterior or interior, are **temporary** loads produced by the use and occupancy of the greenhouse. An example of an exterior live load is the weight of workmen and materials which may be applied to a greenhouse roof during construction or repair. An example of an interior live load is the weight of suspended plant material or other hanging objects which may be temporarily supported by an interior structural member. It has been found that oftentimes interior greenhouse live loads tend to become permanent, i.e., they are left in place for extended time periods. For this reason, Section 4.1 requires that any load that is anticipated to be added to a greenhouse and left in place for a continuous time period of 30 days or more be considered a dead load for design purposes.

**C4.2 Minimum Roof Live Load:** Section 4.2 provides a method for determination of a uniformly distributed minimum live load, L, to be applied to greenhouse roofs. All

greenhouse roofs must be designed for the live load, L, or the snow load given in Section 6, whichever is greater. The method for calculation of the minimum roof live load, L, in Section 4.2 is taken directly from ANSI A58.1. The value is intended to estimate the distributed live load which might be applied to a normal building's roof by workers and equipment during construction or repair.

**C4.3 Maximum Roof Live Load:** During their lifetime, most normal roofs require reroofing or roof repairs, in which case significant temporary loads may be applied to the structure. These loads are due not only to the weight of workers, but also to the weight of conventional roofing materials (tars, felts, shingles, etc.) and tools which may be stored on the roof prior to their placement or use.

Greenhouse roofs, because they are constructed of relatively thin sheets of glazing material such as glass or fiberglass, do not fall into the category of normal roofs, i.e., they are never subjected to the construction or repair loads of men or materials that a conventional roof might experience. This is due to the fact that during the construction and repair of greenhouse roofs, scaffolding or ladders are used to place the roof glazing materials thereby eliminating the bulk of construction live load. In addition, during normal use, repairs to the greenhouse roof, if any, are usually limited to local areas and resulting live loads are concentrated in nature (Section 4.4).

Consequently, Section 4.3 limits the distributed live load, L, on greenhouse roofs to a maximum value of 15 psf. This value is based on 50 years of experience in greenhouse design and construction where a roof design load value of 15 psf has been used successfully.

**C4.4 Concentrated Loads:** The design of roof members for a concentrated load of 100 lbs is based on the fact that an average worker may have to climb on the roof during construction or repair of local areas. Similarly, the 100 lb concentrated load requirement for truss bottom chord panel points is meant to provide additional strength in the event that equipment, plants, etc., are ever hung temporarily from the panel points in local areas.

The 100 lb concentrated load value stipulated in Section 4.4 has been used successfully for over 50 years in greenhouse design and construction. It assumes that special scaffolds meant to distribute the weight of workmen are used to access greenhouse roofs for local repairs. (Many greenhouse systems are actually supplied with fasteners used to support these special scaffolds). It also assumes that the weight of a typical interior live load will be less than 100 lbs. (As an example, the weight of a single hanging basket is less than 10 lbs.).

In cases where special scaffolding is not supplied for roof

access or where an interior live load is anticipated to be greater than normal, the concentrated load requirement in Section 4.4 shall be increased to 200 lbs. In addition, in the event it becomes necessary to hang temporary concentrated live loads from bottom chord members at locations other than panel points, adequate temporary bracing members shall be provided to support these loads.

**C4.5 Partial Loading:** It is intended that the full intensity of the greenhouse roof live load,  $L$ , be considered over portions of the structure as well as over the entire structure. This partial loading requirement is necessary only when its consideration will produce higher loads and stresses in certain members than will application of the full load.

Partial length loads on a simple beam or truss will produce higher shear on a portion of the span than a full-length load. Loads on the half span of arches or on the two central quarters can be critical.

## C5 WIND LOADS

**C5.1 General:** The wind design procedure given in the standard requires calculation of two separate sets of design forces, those applied to the main wind force resisting system and those applied to individual components and glazing. The main wind force resisting system is that part of the greenhouse, such as rigid or braced frames or walls which provides lateral support to the structure when subjected to wind pressures. In attached even-span or lean-to greenhouses, the existing structure to which the greenhouse is connected may supply the main wind force resisting system. Individual components and glazing are those portions of the structure such as glass or fiberglass panels which resist the wind pressures directly and which may be subjected to locally higher pressures than those applied to the structure as a whole.

**C5.3.1 Procedure For Calculating Velocity Pressure:** The design wind speed is converted to a velocity pressure by use of the formula:

$$q_z = 0.00256 K_z (IV)^2$$

In the above formula, the constant 0.00256 reflects air mass density for certain standard conditions. The constant shall be used except where sufficient weather data are available to justify a different value. The appendix to ANSI A58.1 gives a procedure for calculating the air mass density.  $K_z$  in the above formula is the exposure coefficient which takes into account the effect terrain roughness has on velocity pressure. Values of  $K_z$  for various exposure conditions and elevations are given in Table 5.3

**C5.3.2 Selection Of Basic Wind Speed:** Values of the basic design wind speed,  $V$ , given in Fig. 5.1 (reproduced

from ANSI A58.1) were prepared from data collected at 129 U.S. weather stations. They are based upon an annual probability of 0.02 that the wind speed is exceeded (50 year mean recurrence interval). The basic design wind speed,  $V$ , is converted to a velocity pressure using the equation in Section 5.3.1.

The velocity pressure equation in Section 5.3.1 also contains another factor, the importance coefficient,  $I$ . Values of  $I$  are given in Table 5.2. The coefficient is meant to account for the importance of a greenhouse in terms of hazard to human life and damage to property. Application of the importance coefficient value of 0.95 in Table 5.2 adjusts the design wind speed,  $V$ , to an annual probability of 0.04 of being exceeded (25 year mean recurrence interval).

**C5.3.2.1 Special Wind Regions:** Special consideration shall be given to those regions where records or experience indicate that the wind speeds are higher than those reflected in Fig. 5.1 and Section 5.3.2. Some such regions are indicated in Fig. 5.1; however, all mountainous and hilly terrain, gorges and ocean promontories shall be examined for unusual conditions and the authority having jurisdiction shall, if necessary, adjust the values of  $V$  given herein to account for higher local winds. The appendix to ANSI A58.1 provides recommendations for making such adjustments.

**C5.5 Pressure Coefficients:** Pressure coefficient values given in Tables 5.5 through 5.8 were taken directly from ANSI A58.1. The values were assembled from the latest boundary layer wind tunnel and full-scale tests and from previously available literature. More complete information of the compilation of each table along with selected references is included in the appendix to ANSI A58.1.

Pressure coefficient values given in ANSI do not directly address multispans buildings such as gutter-connected greenhouses. Data compiled from wind tunnel studies and actual measurement of pressure on low rise multispans buildings indicate that the second and subsequent roof spans actually experience a reduction in the pressure applied to the first span. Therefore, if warranted, the designer of a gutter-connected greenhouse may use the pressure coefficients given in Tables 5.5 and 5.7 for design wind loads on the first roof span and he may reduce the design wind pressures on subsequent spans.

## C6 SNOW LOADS

**C6.1 General:** The procedure established in Section 6 for the determination of design snow load is as follows:

1. Determine the ground snow load for the geographic location (Section 6.2 and C6.2).

2. Generate a flat roof design value from the ground load with consideration given to:
  - a. Roof exposure (Sections 6.3.1, C6.3, and C6.3.1)
  - b. Roof thermal condition (Sections 6.3.2, C6.3, and C6.3.2)
  - c. Occupancy and function of structure (Sections 6.3.3, C6.3, and C6.3.3)
3. Consider roof slope (Sections 6.4 and C6.4)
4. Consider unbalanced loads if applicable (Sections 6.5 and C6.5.3)
5. Consider snow drifts on lower roofs if applicable (Sections 6.6 and C6.6)
6. Consider sliding snow (Sections 6.8 and C6.8)
7. Consider unloaded portions (Sections 6.9 and C6.9)

The approach to snow load design used by ANSI is to establish a load value that reduces the risk of snow-load-induced failure to an acceptably low level. As such, snow loads in excess of the design value may occur, and therefore it is necessary to consider the implications of such “excess” loads. This would seem especially important in greenhouses, which are relatively lightweight structures, and as a result, the percentage increase in total roof load due to an “excess” snow load might be substantial. However, past experience has shown that in the case of greenhouses, the “excess” loads are apparently never realized, since few, if any, snow-load-induced roof failures of normally operating greenhouses have occurred. This is most likely due to the fact that most greenhouses are continuously heated and the heat loss through the roof glazing causes snow striking the roof to melt almost immediately. Verification of this occurrence is given by the fact that snow-load-induced greenhouse roof failures that have occurred did so at times when the greenhouses were out of service and therefore were not heated and had no heat loss through the roof. Even then, the reported failures were localized, breaking through individual and isolated roof glazing panels rather than failing any of the main structural support members.

Taking advantage of this past experience with greenhouse structures subjected to snow loads, a distinction has been

made in Section 6 between continuously heated single or double glazed greenhouses and intermittently heated or unheated greenhouses. A greenhouse which meets the requirements for continuous heating (Section 6.1.1) will have a substantially reduced design snow load based on the fact that the heating will prevent an “excess” snow build-up. Greenhouses not meeting the continuously heated criteria will have a design snow load in accord with standard ANSI requirements.

To qualify as continuously heated, a greenhouse must satisfy three requirements. First, its interior temperature must be maintained at a minimum of 50 degrees F at normal planting level during winter months. Second, the greenhouse must have maintenance personnel on duty at all times or an adequate temperature alarm system to assure that the minimum temperature is maintained. Third, the total thermal resistance of the roof glazing material must be less than 1.0 for single glazed roofs and less than 2.0 for double glazed roofs, i.e., low enough to transmit the heat necessary to melt falling snow. The first two of these requirements are met by most large-scale greenhouse operations where it is necessary to keep a certain minimum temperature for the interior plant life. Virtually every greenhouse meets the third requirement since the thermal resistance of all commonly used double glazing materials is less than 2.0.

It should be noted that air inflated double polyethylene greenhouse roofs may be considered as single glazed. This is due to the fact that a minimal amount of snow striking this type of roof causes it to deflate and thus act as a single glazed roof.

**C6.2 Ground Snow Loads:** The methodology used to determine appropriate values and compile the results along with the results themselves for the ground snow load maps given in Figs. 6.1, 6.2, and 6.3 are reported in the following documents:

Redfield, R., and Tobiasson, W.  
*Snow Loads for the United States: Part I, Ground Load Statistics*  
 U.S. Army Cold Regions Research and Engineering Laboratory  
 (CRREL), Hanover, NH, 1980.

Tobiasson, W. and Redfield, R.  
*Snow Loads for the United States: Part II, Ground and Roof Loads*  
 U.S. Army Cold Regions Research and Engineering Laboratory  
 (CRREL), Hanover, NH., 1980.

The values indicated in the figures are based on an annual probability of 0.02 of being exceeded (50 year mean recur-

rence interval).

In the above mentioned report, *Snow Loads for the United States: Part II, Ground and Roof Loads*, a methodology is developed for establishing a design snow load for a specific site from meteorological information available at surrounding locations with consideration given to the orientation, elevation and records available at each location. That methodology should be used to establish design values for sites in shaded portions of Figs. 6.1, 6.2, and 6.3. It can also be used to improve upon the values presented in unshaded portions of the figures. Detailed study of a specific site may generate a design value lower than that indicated by the generalized national map. It is appropriate in such a situation to use the lower value established by the detailed study. Occasionally, a detailed study may indicate that a higher design value than the national map indicates should be used. Again, results of the detailed study should be followed.

**Table C6.1**

SITE SPECIFIC VS. ZONED  
GROUND SNOW LOADS

State	Location	Zoned Value (PSF)	Site-Specific Value (PSF)*
California	Mount Hamilton	5	45
Arizona	Chiricahua Nat. Mon.	10	30
Arizona	Palisade R.S.	5	200
Tennessee	Monteagle	15	20
West Virginia	Fairmont	40	55
Maryland	Edgemont	50	65
Pennsylvania	Blairsville	50	60
Vermont	Vernon	60	75

\* Based on a detailed study of information in the vicinity of each location according to the methodology developed in *Snow Loads for the USA: Part II, Ground and Roof Loads* (Tobiasson and Redfield, 1980)

Table C6.1 is included to emphasize the importance of considering local sitting in the shaded areas of Figs. 6.1, 6.2, and 6.3. For some locations in shaded areas of the Northeast, ground snow loads exceed 100 psf. Even in the southern portion of the Appalachian Mountains, not far from

the sites where a 15 psf ground snow load is appropriate, ground loads exceeding 50 psf may be required. Lake effect storms create requirements for ground loads in excess of 75 psf along portions of the Great Lakes. In some areas of the Rocky Mountains, ground snow loads exceed 200 psf. Local records and experience should also be considered when establishing design values.

Ground snow load values in Table 6.1 are for specific Alaskan locations only and generally do not represent appropriate design values for other nearby locations. They are presented to illustrate the extreme variability of snow loads within Alaska.

**C6.3 Flat Roof Design Snow Loads:** The minimum allowable values of  $P_f$  presented in section 6.3 for unheated or intermittently heated greenhouses acknowledge that, in some areas, a single major storm can generate loads which exceed those developed from an analysis of weather records and snow load case studies. Factors are included which account for the thermal, aerodynamic, and geometric characteristics of the greenhouse in its particular setting.

**C6.3.1 Exposure Factor ( $C_e$ ):** Except in areas where loads are increased by snow drifting, far less snow is present on most roofs than on the ground. Loads in unobstructed areas of conventional flat roofs average less than 50 percent of ground loads. The values in the standard are above average values, chosen to reduce the risk of snow-load induced failures to an acceptably low level. Because of the variability of wind action, a rather conservative approach has been taken when considering load reductions by wind.

The effects of exposure are handled on two scales. First, the equations for the contiguous United States and Alaska are reduced by basic exposure factors of 0.7 and 0.6, respectively. Second, the conditions of local exposure are handled by exposure factor,  $C_e$ . This two-step procedure generates ground-to roof load reductions as a function of exposure from 0.56 to 0.84 for the contiguous United States and from 0.48 to 0.72 for Alaska.

**C6.3.2 Thermal Factor ( $C_t$ ):** Case studies verify that more snow will be present on cold roofs than on warm roofs. Glass, fiberglass, or plastic roofs of continuously heated greenhouse structures are seldom subjected to much snow load because their high heat losses cause snow melt and sliding. The value of the thermal factor,  $C_t$ , given in Table 6.3 for continuously heated greenhouses assumes that the total thermal resistance value,  $R$ , of the greenhouse roofing material is less than 1.0 for single glazed roofs and less than 2.0 for double glazed roofs. The values are taken directly from ANSI A58.1 which requires that the roofing material have a total thermal resistance of 10 or less. For greenhouse roofs, the values are therefore conservative.

The NGMA has for years used a 15 psf snow load for design of continuously heated greenhouses having roofing materials with R values less than 1.0. Based on examination of insurance claims for greenhouse damage over the last 20 years, this value has apparently been realistic. In the isolated cases when snow has damaged greenhouses, they were normally out of operation at the time with no heat, and as discussed in Section C6.1, the failures themselves were limited to local portions of the structures.

**C6.3.3 Risk Factor ( $C_r$ ):** Risk factor,  $C_r$ , has been included to account for the need to relate design loads to the consequences of failure. Roofs of retail greenhouses where general public access is permitted, are designed using a risk factor equal to 1.0. This equates to unmodified use of the ground snow loads given in Figs. 6.1, 6.2, and 6.3 for an annual probability of being exceeded of 0.02 (50 year mean recurrence interval). All other greenhouses use a risk factor equal to 0.8. This in effect modifies the ground snow loads to an annual probability of being exceeded of 0.04 (25 year mean recurrence interval).

**C6.4 Sloped Roof Design Snow Loads:** Snow loads decrease as the slope of roofs increases. A portion of the decrease is related to the aerodynamics of snow accumulation but sliding and improved drainage are also important factors. The ability of a sloped roof to shed snow load by sliding is related to the absence of obstructions not only on the roof by also below it, the temperature of the roof, and the slipperiness of its surface. Most materials used in greenhouse roof construction can be considered slippery. All of the above factors are considered in the slope reduction factors presented in Fig. 6.4.

If the ground or another flatter roof exists near the eave of a sloped roof, snow may not be able to slide completely off the sloped roof. This may result in the elimination of snow loads on upper portions only. Lateral loads induced by such conditions should be considered.

**C6.4.4 Roof Slope Factor For Gutter-Connected Greenhouse Roofs:** Gutter connected roofs on unheated or intermittently heated greenhouses are susceptible to collecting extra snow in their valleys by snow creep and sliding and by wind drifting. Therefore, no reduction in the design load because of slope should be applied. However, if a gutter-connected greenhouse qualifies as continuously heated and if measures are made to melt snow which may accumulate in the gutters, the slope reduction factor may be applied.

Measures which are necessary to meet the requirements of this section include supplementary or other adequate heat sources beneath gutters and the construction of gutters with a total thermal resistance less than 1.0. Supplemental heat-

ers may be fin pipe or similar and need be operated only during periods of snow.

**C6.5 Unbalanced Roof Snow Loads:** Unbalanced snow loads may develop on sloped roofs because of sunlight and wind. Winds tend to reduce snow loads on windward portions and increase snow loads on leeward portions. Since it is not possible to define wind direction with assurance, winds from all directions should generally be considered when establishing unbalanced roof loads. Unbalanced snow loads need not be considered on continuously heated greenhouse roofs.

**C6.6 Drifts On Lower Roofs:** The requirements for drift loads need not be considered on continuously heated greenhouses. For unheated or intermittently heated greenhouses, however, it is extremely important to consider localized drift loads in designing roofs. Drifts will accumulate on roofs in the wind shadow of higher roofs. The affected roof may be influenced by a higher portion of the same structure or by another structure nearby if the separation is 20 ft or less. When a new structure is built within 20 ft of an existing structure, drifting possibilities should also be investigated for the existing structure. The method presented in Section 6.6.2 will establish reasonable drift loads for most situations. However, in windy treeless areas and in windy areas that experience heavy snowfalls and blizzards, snowdrifts somewhat larger than those generated by Section 6.6.2 have been measured. Local experience may prove valuable in determining the nature and extent of snow drifts on roofs in such areas.

**C6.7 Sliding Snow:** Situations which permit snow to slide onto lower roofs should be avoided. Where this is not possible, the extra load of the sliding snow should be considered. The final resting place of any snow which slides off a higher roof onto a lower roof will depend on the size, position, and orientation of each roof. Distribution of sliding loads might vary from a uniform load 5 ft wide, if a significant vertical offset exists between the two roofs, to a 20 ft wide uniform load where a low-slope upper roof slides its load onto a second roof that is only a few feet lower.

In some instances, a portion of the sliding snow may be expected to slide clear of the lower roof. Nevertheless, it is prudent to design the lower roof for a substantial portion of the sliding load to account for any dynamic effects that might be associated with sliding snow.

**C6.8 Unloaded Portions:** For greenhouse structures, the effect of removing half the design snow load from any portion is usually less severe than the effect of the entire snow load. Nevertheless, it should be considered.



**C6.9 Extra Loads From Rain-On-Snow:** The ground snow load measurements on which this standard is based contain the load effects of **light** rain-on-snow. However, since **heavy** rains percolate down through snowpacks and drain away, they are not included in the measured values. The temporary roof load contributed by a heavy rain may be significant. Its magnitude will depend on the duration and intensity of the design rainstorm, the drainage characteristics of the snow on the roof, the geometry of the roof and the type of drainage provided.

Loads associated with rain-on-snow are discussed by:

Colbeck, S.C.  
*Snow Loads Resulting From Rain-On-Snow*  
CRREL report 77-12, 1977, Hanover, N.H.

Colbeck, S.C.  
*Roof Loads Resulting From Rain On Snow - Results of a Physical Model*  
Canadian Journal of Civil Engineering, Volume 4, 1977.

The following rain-on-snow surcharge loads are suggested for design purposes:

<b>Roof Slope</b>	<b>Rain-on-Snow Surcharge (psf)</b>
1/4 in./ft	8
>1/4 in./ft	5

It is recommended that the appropriate surcharge load be applied to all final roof snow loads for unheated or intermittently heated greenhouses except where the minimum allowable flat roof design snow load exceeds  $P_f$  in Section 6.3. In that situation, the rain-on-snow surcharge load above should be reduced by the difference between the minimum allowable flat roof design snow load and  $P_f$ . For example, for a flat roof where  $P_g = 20$  psf and  $P_f = 18$  psf, the minimum allowable value of  $P_f$  (20 psf) is the design snow load. The rain-on-snow surcharge recommended for this situation would be  $8 - (20-18) = 6$  psf. The total design load considering snow (20 psf) and rain-on-snow (6 psf) would be 26 psf. If this roof had a slope of 1/4 in./ft or more, the rain-on-snow surcharge load would equal 3 psf.

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