PLAN
M-6701

GREENHOUSE HEATING REQUIREMENTS

CALCULATING HEAT LOSS A good heating system is essential to greenhouse operation. The system should be properly sized to the needs of the greenhouse under extreme weather conditions. A heat loss calculation is the first step in determining heating system capacity before selecting the system and its various components.

Greenhouse heat loss is determined by the following equation:

$$Q = \left[\frac{A_1}{R_1} + \frac{A_2}{R_2} + \dots \right] (t_i - t_o)(f_w)(f_c)(f_s)$$

Where:

Q = overall heat loss, Watts
A_1, A_2 = surface area of various components, m2
R_1, R_2 = thermal resistance of each component, M2°C/W
t_i = inside design temperature, °C
t_o = outside design temperature, °C
f_w = wind or exposure factor, (Table 2)
f_c = construction type or quality factor (Table 3)
f_s = system factor (Table 4)

EXPLANATION OF FACTORS This equation is a standard building heat loss formula, modified to account for the particular requirements of a glass building. Heat loss for any greenhouse can be readily determined by plugging the appropriate values into this equation. Following is an explanation of all items, and tables of the various factors. Design examples illustrate the use of this equation.

Q - is the overall heat loss used to determine the minimum size of heater or boiler required to maintain the inside design temperature.

A_1, A_2 - are the surface areas of the various building components such as glazing, walls and foundations (m2).

R_1, R_2 - are the thermal resistances (often called "RSI" in metric) of each construction material. Table 1 lists the RSI values for common greenhouse materials and building components. In making heat loss calculations, be sure to use the metric RSI value to match the metric units of this equation.

t_i - is the lowest inside air temperature consistent with good management or growing practice.

t_o - is the design outdoor air temperature; either the coldest expected, or the "winter design temperature" stated in the building codes for the locality.

f_w - is the wind or exposure factor. The heat loss equation is based on a 25 km/h wind speed; f_W increases 5% for every 10 km/h that the hourly wind speed is expected to exceed 25 km/h during the coldest weather, as shown in Table 2. Whether you select a sheltered or exposed location to determine fW, is very much a matter of judgement.

f_c - is the construction factor (Table 3). This factor adjusts heat loss for the type, tightness and quality of construction. It accounts for the effect of both framing and air leakage. Note that tightness and state of repair are important to heating requirements. For a 'very loose' house, this factor is relatively high and is a rough estimate at best.

f_s - is a system factor (Table 4) that relates to the type of heating system and management practices. Indoor temperature always above 20°C, heat delivered through convection tubes near the roof, or radiant heating pipes mostly overhead - these are all systems that create higher surface temperatures and/or greater turbulence, increasing heat loss. The values in Table 4 reflect this.

CANADA PLAN SERVICE

The Canada Plan Service prepares detailed plans showing how to construct modern farm buildings, livestock housing systems, storages and equipment for Canadian Agriculture.

This leaflet gives the details for a farm building component or piece of farmstead equipment. To obtain another copy of this leaflet, contact your local provincial agricultural engineer or extension advisor.

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OTHER CONSIDERATIONS This heat loss formula does not allow for solar heat gain, since it computes heat loss at night when maximum heating is required. Various methods are available to help reduce heat loss:

- double polyethylene covering
- double-wall polycarbonate or acrylic glazing materials
- night time insulating shades
- insulation of some surfaces, such as north walls
- polyethylene beads in double coverings
- improved system efficiencies and maintenance
- heat exchangers
- perimeter foundation insulation

When considering insulating some areas, such as the north wall, pay particular attention to the possible reduction of available light, as this may cause a loss in yield or quality. Some crops and management systems are more sensitive than others to light levels. For this reason, it is generally not recommended to place a double polyethylene system over existing glass houses, or to insulate north roof slopes. Insulating north walls is usually cost effective in Canada.

There are several types of heating systems that are commonly used for greenhouses. The capacity of the system selected should normally be 10 to 20% greater than that calculated by this formula, to allow a safety factor. Also, consider a larger system if expansion is contemplated, using a central heating system.

TABLE 1. THERMAL RESISTANCE OF BUILDING SYSTEMS

Material	Thickness mm	RSI value m 2C°'/W
Glazing materials		
Single glass'	3	0.15
Double glass (6 mm air space)	-	0.27
Fiberglass	-	0.16
Polyethylene	0.15	0.14
Double acrylic or polycarbonate	6 - 12	0.30 - 0.35
Air inflated, double polyethylene	-	0.25 - 0.28
Construction materials		
Asbestos cement	6	0.16
Wood (typical softwood)	25	0.30
Concrete	100	0.20
	150	0.23
Concrete block	200	0.35
Insulation 2		
Rigid polystyrene	25	0.88
Polyurethane foam	25	1.10

' RSI value for glass is for a temperature difference of 50°C; value decreases by 0.005 for each 10°C greater than 50°C, and increases when the temperature difference is less than 50°C. RSI value is for sloping roofs and increases by 10% for walls, though this difference is generally ignored.

2 RSi value for insulations is proportional to thickness and can be added to the RSI for construction materials.

TABLE 2. WIND OR EXPOSURE--FACTOR (fw)

Wind velocity (km/h)	fW
less than 25	1.00
30	1.03
40	1.08
50	1.13
60	1.18
70	1.22

TABLE 3. CONSTRUCTION FACTORS (fc)

House description	fc
All metal, tight glass, lapped	1.08
somewhat loose glass	1.15 - 1.20
Wood frame, steel gutters, tight construction	1.05
All wood bars, vents, etc.	
good, tight sealed	1.00
moderately good	1.10
loose fitting	1.20 - 1.30
Fiberglass, caulked ribs	0.95
unsealed joints	1.05 - 1.10
Polyethylene film double or single layer	0.90 - 0.95
Double acrylic or polycarbonate	0.90

TABLE 4. SYSTEM DESCRIPTION (fs)

		fs
1.	Heat supplied by unit heaters via polytubes near roof	1.15
2.	Radiation or convection pipe system, over 50% overhead	1.10
3.	System 2, with polytube circulation	1.15
4.	Radiation or convection heat near ground or below benches	1.00
* 5.	Greenhouse always below 20°C for cold operation of a glass house	0.95

* At moderately low temperatures, during cold outdoor conditions lapped joints of glass houses freeze, thus sealing the house and reducing heat loss.

EXAMPLE 1

Rectangular greenhouse, as illustrated (Fig. 1). 12 x 30 m with 2.6 m high sidewall height. Foundation 300 mm below grade and 600 mm above, insulated with 50 mm styrene foam. Lapped glass on metal frame. Outside temperature -35°C and inside temperature 15°C, exposed location with 50 km h wind. Heating by overhead unit heater connected to a polytube. Basic formula is:

$$Q_2 = \left[\frac{A_1}{R_1} + \frac{A_2}{R_2}\right] (t_i - t_o)\,(f_w)\,(f_c)\,(f_s)$$

$t_i - t_o$ = 50°C
f_w = 1.13 for 50 km h wind speed (Table 2)
f_c = 1.08 for a good lapped glass house (Table 3)
f_s = 1.15 x 0.95 overhead heat unit, but temperature kept moderately low for coldest weather (Table 4)
R_1 = 0.15 for single glass (Table 1)
R_2 = (0.16 + 1.76) = 1.92 (asbestos cement plus 50 mm foam of RSI 0.88 per 25 mm)

Area calculation:

Walls = perimeter x height
= (30 + 30 + 12 + 12) x 2.0
= 168 m2

Gable ends = width x height x 0.5 for triangular areas
= 12.0 x 3.0 x 0.5 x 2 ends
= 36 m2

Roof area = slope distance x building length
= 6.70 x 30.0 x 2 = 402 m2

Foundation = perimeter x height (height = 0.9 m above and below grade)
= (30 + 30 + 12 + 12) x 0.9
= 75.6 m2

A_1 = 168 + 36 + 402 =606 m2
A_2 = 75.6 m2

$$Q = \left[\frac{606}{0.15} + \frac{75.6}{1.92}\right] (50)(1.13)(1.08)(1.15)(0.95)$$

= 272 000 W or 272 kW

Suggested unit size is 272 + 10% = 300 kW

(NOTE: 1 kW = 3414 Btu/h)

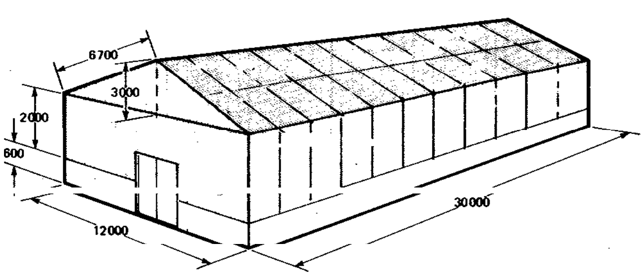

Figure 1

EXAMPLE 2

Same house with double-poly roof, fiberglass walls

Now

A1 = wall areas at R1 = 0.16 for fiberglass
A2 = foundation area at R2 = 1.92
A3 = roof area at R3 = 0.25 for double-poly fc is reduced to 1.00 (combining 0.95 for roof with 1.08 for walls)

From previous example,
A_1= 168 + 36 = 204 m2
A_2 = 75.6 m2
A_3 = 402 m2

Now:

$$Q = \left[\frac{204}{0.16} + \frac{75.6}{1.92} + \frac{402}{0.25}\right] (50)\,(1.13)\,(1.0)\,(1.15)\,(0.95)$$

=180,000 W or 180 kW; use about a 200kW heater

Changing to the double-poly roof has reduced heater size by 100 kW or about 35%. Note that the values in brackets below A_1, A_2, etc. represent the relative heat loss for each area; in fact, heat loss for each area could be calculated separately.

EXAMPLE 3

Small greenhouse (Fig. 2), 3.6 m x 4.8 m x 2.0 m sidewall freight. Insulated foundation 300 mm below grade and 600 mm above on walls. Glass structure on metal frame. Same exposure factors as EXAMPLE 1.

Wall area: (3.6 + 3.6 + 4.8 + 4.8)(1.4) = 23.52 m2

Gable ends: 1.0 x 3.6 x 0.5 x 2 = 3.6 m2

Roof area: 2.06 x 4.80 x 2 = 19.78 m2

Foundation: (3.6 + 3.6 + 4.8 + 4.8)(0.9) = 15.12 m2

A_1 = 23.52 + 3.60 + 19.78 = 46.9 m2
A_2 = 15.12 m2
R_1 = 0.15
R_2 = 1.88
t_i – to = 50°C
f_w = 1.13
f_c = 1.08
f_s = 1.15 x 0.95

Heat loss,

$$Q = \left[\frac{46.9}{0.15} + \frac{15.12}{1.88}\right] (50)\,(1.13)\,(1.108)\,(1.15)\,(0.95)$$

= 21 380 W or 21.4 kW

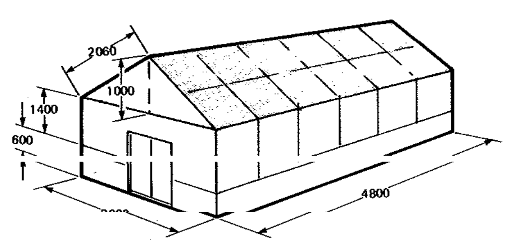

Figure 2

COMMENTS ON EXAMPLES

The following summarizes the heat loss calculations for the three examples:

Example	Greenhouse Floor area m2	Heat loss Total kW	Heat loss Per unit area W/m2
1	360	272	755
2	360	180	500
3	17.3	21.4	1240

Comparing Examples 1 and 3 of houses of similar construction, note that the heat loss per unit area is much higher for the small backyard size greenhouse than for the large commercial house. This is due to the higher ratio of surface to floor area. Small houses are less economical to heat and respond more rapidly to weather variations. Heater sizing is more critical and a greater safety factor is recommended.

The effect of a more energy efficient double-poly covering in reducing peak heat loss is evidence when comparing Examples 1 and 2.