ASAE EP460 FEB04
Commercial Greenhouse Design and Layout

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1 Purpose and scope

This Engineering Practice presents information and data for the design, construction, and layout of commercial size greenhouses. Wind, snow, and crop loads are covered. Bench systems and utility requirements are discussed. Environment control system design is covered in ASAE EP406.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Engineering Practice. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Engineering Practice are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Standards organizations maintain registers of currently valid standards.

ANSI/NFPA 70-1993, *National Electrical Code*
ANSI/UL 94-1990, *Tests for Flammability of Plastic Materials from Parts in Devices and Appliances*
ASAE EP288.5 DEC92, *Agricultural Building Snow and Wind Loads*
ASAE EP406.1, *Heating, Ventilating and Cooling Greenhouses*
ASTM D635-91, *Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position*
ASTM E82-91, *Test Method for Determining the Orientation of a Metal Crystal*
ASTM E162-90, *Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source*
ASTM E662-92, *Test Method for Specific Optical Density of Smoke Generated by Solid Materials*
NGMA, *Design Loads in Greenhouse Structures*
NGMA, *Glazing Standards*

3 Definitions

3.1 foundation: The structural element between the building and the ground. It must safely transfer gravity, uplift and overturning loads to the ground such as those from snow, crops, and wind.

3.2 footing: The support for the foundation wall. Its size depends on the weight of the wall, structure and other gravity loads, and the supporting soil type.

3.3 pier: A column of concrete, masonry, or pressure treated lumber used to support greenhouse individual frame members.

3.4 single span greenhouse: An independently erected greenhouse set apart from other structures. The roof can be either pitched or arched.

3.5 lean-to greenhouse: A greenhouse structure which is attached to another building along the ridge line.

3.6 gutter-connected greenhouse: A series of two or more single span greenhouses joined together at the eave by a drain gutter. Interior walls are usually eliminated.

3.7 temporary greenhouse: A structure used for short term production, overwintering or hardening of plants. It is usually glazed with transparent plastic film.

3.8 headhouse: A building, attached to a greenhouse or free-standing, used as a work and storage area. It usually contains the office, lavatories, utilities, employee rest area, storage space, potting and/or shipping area.

3.9 glazing: The light transmitting material used to cover the greenhouse frame.

3.10 light transmittance: The ratio of the light passing through a glazing material to the light incident upon it.

3.11 thermal radiation transmittance: The ratio of the heat that is radiated through a glazing material to the thermal radiation incident upon the inside surface.

3.12 spectral transmittance: The transmission of light in the various regions of the spectrum.

3.13 purlin: Longitudinal members of the framework that support the glazing material on the roof.

3.14 truss: Structural framework used to support the roof.

3.15 girts: Longitudinal members of the framework that support the glazing material on the walls.

3.16 bow/hoop: Pipe or tubing framework shape used to support the glazing.

3.17 range: A series of single span greenhouses, usually interconnected, or two or more sections of gutter-connected greenhouses.

4 Design load

4.1 The design load includes the weight of the structure (dead load), loads (equipment, etc.) associated with building use (live load), and loads from snow and wind.

4.2 Use the actual weights of building materials and system components to estimate the dead load. All fixed services equipment such as heating, ventilating, air circulation, electrical, lighting, watering, and energy conservation blankets should be included if supported by structural members. Long term crops such as tomatoes and cucumbers supported by the structure are also considered as dead loads.

4.3 Live loads are temporary loads produced by the use and occupancy of the greenhouse and shall include the weight of repair crews and hanging plants if left in place for less than 30 d. Live loads should also include dynamic loads from materials handling and irrigation equipment.

4.4 Snow load is based on expected ground accumulation (see ASAE EP288), roof slope, single or double glazing, individual houses or gutter connected and whether heated or unheated. Air inflated, double polyethylene covered houses, if maintained above 10 °C (50 °F), should be considered as single glazing. Particular attention should be paid to the potential from unbalanced loads due to drifting and sliding snow from another roof. The slope of gutters must allow for run-off of rain and snow melt from gutter connected roofs.

4.4.1 In areas of snow, a minimum distance of 3.0 m (10 ft) should be provided between greenhouses to allow for snow accumulation and to prevent sidewall crushing from snow sliding off the roof.

4.5 Wind load should be based on the 50 yr mean recurrence interval map (see ASAE EP288) and should be calculated as total greenhouse load and as individual component loads.

4.5.1 Since the deadweight of most greenhouses is very small, special attention should be given to insure that anchorage to the ground is secure enough to resist the upward lift force created by the wind.

4.6 The minimum design loads for greenhouse mainframes in table 1 should be used for reference only. Actual design values should be calculated for each greenhouse.

Table 1 – Minimum design loads for greenhouse mainframe*)

Load description	Minimum value kg/m^2	lb/ft^2
Dead—		
pipe frame, polyethylene cover	10	2
truss frame, lapped glass	25	5
supported crops—tomatoes, cucumbers, etc.	20	4
Live—workers, repair materials	25	5
Snow—10 °C (50 °F) minimum greenhouse temperature	75	15
Wind—load acts perpendicular to surfaces	50	10

*) See annex A for further details.

4.7 In design of a greenhouse frame the most unfavorable combination of loads should be used.

5 Materials and methods of construction

5.1 Foundations

5.1.1 If the primary greenhouse frame consists of members spaced 1.2 m (4 ft) or greater, pier foundations are adequate. A curtain wall can be used to close the area between piers. If primary frame members are spaced less than 1.2 m (4 ft), a continuous masonry or poured concrete wall should be used.

5.1.2 The footing should be set below frost level or to a minimum depth of 600 mm (24 in.) below the ground surface whichever is greater. Consult building code for local requirements. It should rest on level, undisturbed soil, or adequately compacted fill. Individual pier footings should be sized to fit the load and soil conditions. The pier can be of reinforced concrete, galvanized steel, treated wood, or concrete masonry. The wall between piers can be poured or precast concrete, masonry, fiber reinforced cement panels, aluminum clad insulating board, or any moisture and decay resistant material. A continuous foundation wall should be set on a poured concrete footing. The wall can be concrete or masonry. A 150 mm (6 in.) wall is usually sufficient for building spans up to 7.3 m (24 ft). Use a 200 mm (8 in.) wall for wider building spans. Typical foundation construction details are shown in figure 1 with pier footing dimensions given in table 2.

5.1.3 Engineering data is not available for the load carrying capacity of pipes driven into the ground to support pipe frame (hoop) greenhouses.

5.2 Floors. Gravel, pea stone, and trap rock make a good floor material. A thickness of 150 to 200 mm (6 to 8 in.) is needed for drainage and weed control. Where a hard, smooth surface is desired a 50 to 75 mm (2 to 3 in.) thickness of porous concrete can be used. This is made from uniform sized aggregate and a cement water paste. Aisles and heavy traffic areas should be concrete or asphalt. Thickness depends on the traffic load but usually 75 to 100 mm (3 to 4 in.) is sufficient. Concrete walks should have a broom finish for safety. Floors should slope to assure surface drainage and be sufficiently even to prevent puddling.

5.3 Frame

5.3.1 Materials. Wood, steel, aluminum, and reinforced concrete have been used to build frames for greenhouses. Some frames use combinations of the materials. Wood must be painted or otherwise preserved for protection against decay and also to improve light conditions within the buildings. Preservatives should be used to protect any wood in contact with soil against decay but they must be free of chemicals that are toxic to plants or humans. Creosote and pentachlorophenol treated wood should not be used. Chromated copper arsenate, CCA, and ammoniacal copper arsenate, ACA, are waterborne preservatives that are considered safe to use where plants are grown. Heartwood of redwood or cypress has natural decay resistance.

5.3.2 Wood frames include post beam and rafter systems, posts and trusses, glued laminated arches, and rigid frames. Steel and aluminum are used for posts, beams, girts, purlins, trusses, and arches. Frames may be aluminum or steel or a combination of the two materials. Aluminum and hot-dipped galvanized steel are comparatively maintenance free as is, but both materials must be protected from direct contact with the ground to prevent corrosion. White paint on either material will improve the light reflection in a greenhouse. The rate of heat loss through steel or aluminum is much higher than through wood, so metal frames may need special insulation. Composite materials are sometimes used, such as a trussed beam of wood and steel or a member made of fiberglass reinforced plastic.

5.3.3 Structural form. The greenhouse with a straight sidewall and a gable roof is the most common shape and has advantages in framing and in space utilization. Post and beam, post and truss, and arches are used to form the gable structure (see figure 2).

5.3.4 The part circle arch or quonset type frame is easily formed from rolled sections of steel or aluminum or from glue laminated wood. It makes better structural use of frame material than a gable building, but in some applications there is unused space because of the curvature of sidewalls.

5.3.5 The gothic arch frame can be formed from metal sections or glue laminated wood. With proper design it can provide adequate sidewall height without loss of strength. Any of the forms can be used to build a single span greenhouse or a large range of gutter-connected units.

5.3.6 The ridge and furrow or gutter-connected greenhouse consists of several single span houses connected together. The advantages include greater uninterrupted interior growing space and lower heating costs per unit area covered. Heat should be provided immediately below the gutter to prevent any snow accumulation.

5.3.7 Structural joints. There must be adequate fasteners at sill plate and ridge to resist loads from any direction. A snow load acts downward but a wind load can act in any direction. Sills should be bolted to the foundation and metal connectors should be used to secure the wall frame to the sill. Metal connectors should be used at the plate and ridge also.

5.4 Covering materials

5.4.1 Since light is often the limiting factor in plant growth, light transmittance of glazing materials should be as high as practical (see table 3). In most materials the transmitted light is direct, but in some materials such as fiberglass reinforced plastic a high percentage is diffused. Structural support members reduce installed glazing transmission values.

5.4.2 Glazing materials do not transmit all wavelengths equally. This can affect plant growth and flowering. Figures 3 and 4 give spectral transmission curves for typical greenhouse glazing materials as determined in laboratory tests.

5.4.3 Thermal radiation transmittance is important in evaluating heat loss from a greenhouse during cold weather. Most published heat transfer values include radiation and conduction effects in a single coefficient.

5.4.4 Material selection and application

5.4.4.1 Glass. This traditional long life material has been improved by increasing pane size and strength. Construction costs have been reduced through use of extruded glazing bars, bar caps, and strip caulking. Double and triple glazing systems are available to reduce heat loss.

5.4.4.2 Acrylic structural sheet. Extruded double skinned sheets that contain an internal rib add two surfaces providing some additional thermal insulation. Sheet sizes of 1.2 m (4 ft) wide by lengths to 12 m (40 ft) and several thicknesses are available. Installation is made using extruded attachment components.

5.4.4.3 Polycarbonate structured sheet. It is similar in configuration and installation to the acrylic material. Sheets as wide as 2.4 m (8 ft) are available. To resist yellowing and reduced light transmission, coated or treated material should be used. The coated side must face to the outside.

5.4.4.4 Fiberglass reinforced plastic. Large corrugated sheets and several thicknesses are available. Surface erosion may require recoating every 5 to 6 yr to retain high light transmittance.

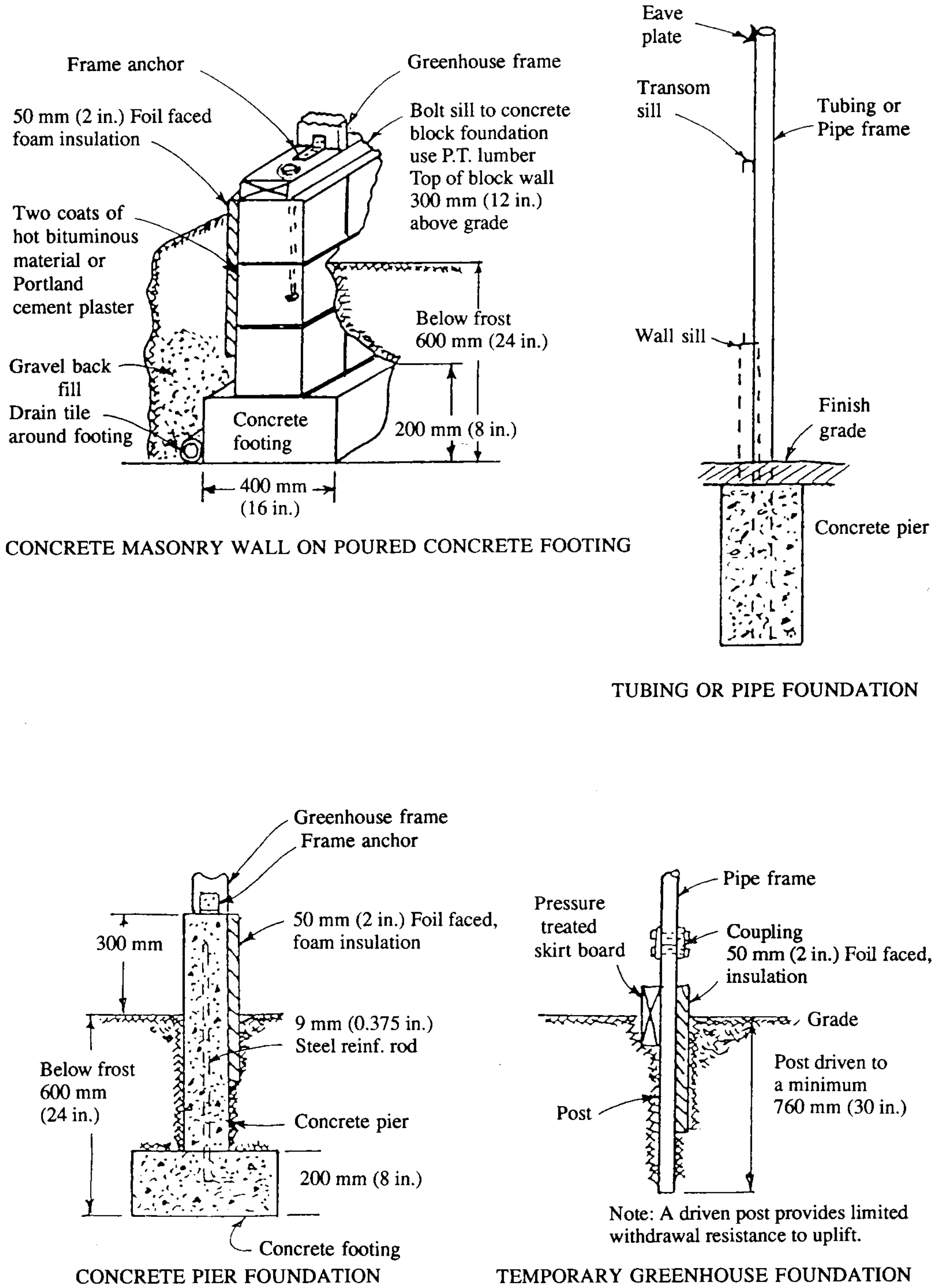

Figure 1 – Typical foundations for greenhouses

5.4.4.5 Polyethylene film. It is the most common covering material because of low cost and large sheet size. Agricultural grades are good for temporary covering for less than one year. Ultraviolet inhibited, stronger copolymer plastic is available in 2 or 3 yr life. IR absorbing films reduce heat loss. Application generally consists of a double layer with air inflation between the layers from a small squirrel cage blower. Air pressure should be maintained at 50 to 75 Pa (0.2 to 0.3 in.) H_2O.

5.4.4.6 Polyvinyl fluoride film. This is a long-life film with high light transmission and strength. Maximum width is 3.2 m (10.5 ft) unless heat sealed. Application is with aluminum extrusions or steel frames.

5.4.4.7 Most plastic glazing materials are available with a surfactant on the inside surface to reduce condensation droplet formation.

5.4.5 Fire safety is important in selection and use of glazing materials. Tests under ASTM D635, E82, E162, E662, and ANSI/UL 94 have been used. Building codes specify those tests considered to provide most useful results. Insurance company or independent laboratory tests are desired. Consult local building codes for special applications; such as, garden centers, schools, and institutions.

Table 2 – Pier footing diameters for average soil for design gravity loads*) Check for uplift due to wind

Greenhouse span (m)	Pier spacing (m)					
	1.2	1.8	2.4	3.0	3.7	4.6
	Pier dia (mm)					
6.1	150	230	300	300	300	380
7.3	230	230	300	300	380	380
8.5	230	300	300	380	380	460
9.5	230	300	300	380	380	460
11.0	230	300	380	380	460	†)
12.2	300	300	380	380	460	†)
14.0	300	380	380	460	460	†)
18.3	300	460	460	460	†)	†)

Greenhouse span (ft)	Pier spacing (ft)					
	4	6	8	10	12	15
	Pier dia (in.)					
20	6	9	12	12	12	15
24	9	9	12	12	15	15
28	9	12	12	15	15	18
32	9	12	12	15	15	18
36	9	12	15	15	18	†)
40	12	12	15	15	18	†)
46	12	15	15	18	18	†)
60	12	18	18	18	†)	†)

*)12 205 kg/m^2 (2500 psf) average bearing capacity
†)Requires special design

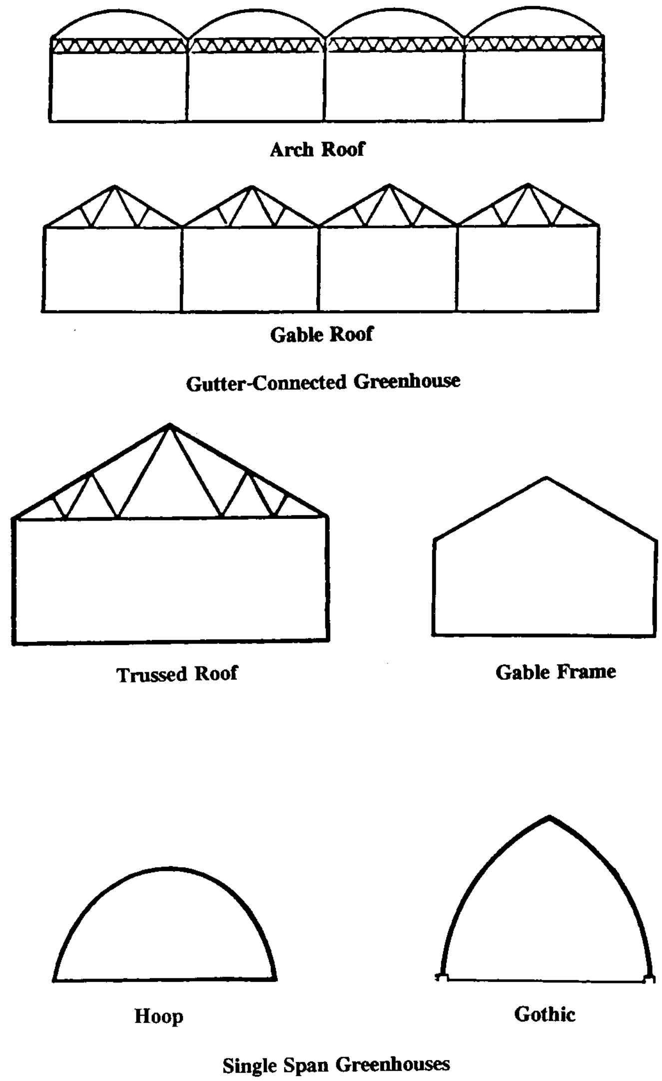

Figure 2 – Some typical greenhouse frames

6 Site selection and layout

6.1 Site selection

6.1.1 Zoning regulations control the use of land and promote health, safety, and welfare of a community. Frontage and side yard distances, size and type of structure that can be built, and location of driveways are usually specified. Contact the local zoning enforcement officer to determine if a permit is needed.

6.1.2 Building codes govern the construction, alteration, repair, and demolition of buildings and structures with the intent to insure public safety, health, and welfare. Contact the local building official to determine if a permit is needed.

6.1.3 Location with respect to highways should also be considered. Location on a high traffic count road or near a residential area can increase business for a retail operation. Access to a major highway is desirable for a wholesale business.

6.1.4 The site should be located away from industrial and vehicular pollution to prevent plant injury from possible pollutants and to ensure high light levels.

6.1.5 The functional and environmental operation of a greenhouse can be affected by the building site selected. Ground slope for drainage of water is important. Greenhouses should be placed on a gravel base 150 mm to 300 mm (6 to 12 in.) above grade. Swales between greenhouses are necessary to direct the water from the area. A topographic map of the area will indicate surface drainage routes. A permit may be needed to drain onto neighboring property. Check culvert sizes downstream from installations. Soil permeability and depth to water table may affect the potential for ground-water contamination from fertilizers and pesticides.

6.1.6 The ideal greenhouse site would have a slight southerly facing slope ($<$ 3%) for good winter light and protection from northerly winds. A nearly level area for greenhouses reduces materials handling problems.

6.2 Site layout

6.2.1 The following planning factors should be considered in developing a layout:

— locate the headhouse to the north of the greenhouse to reduce shading;

— locate windbreaks at least 30 m (100 ft) away to the side of the prevailing winter winds to reduce energy consumption;

— separate supplier and customer traffic. Provide for convenient customer parking;

— locate and screen any residence to insure privacy;

— place the outdoor storage area where there is convenient access for materials delivery and movement to the work area;

— locate the retail sales area to keep customers away from the production area to reduce chances for disease introduction and prevent interruption of work routines.

6.2.2 The layout of the greenhouse range will depend to some extent on the crop or crops to be grown. Two basic systems are in use.

6.2.2.1 Single span greenhouses can be left separate or the end walls attached to a central headhouse. Expansion or contraction of the operation can be accomplished easily by moving each greenhouse into or out of production as needed. They can be operated with different environments depending on plant needs. More heat is required per unit of floor area than with a gutter-connected greenhouse.

6.2.2.2 The gutter-connected range keeps all growing space inside one

Table 3 – Properties of typical glazing materials

Material	Thickness mm (in.)	Estimated life (yr)	Light*) (PAR) transmittance (%)	Overall heat transfer (U-value) w/m^2 °C (btu/hr °F ft^2)	Advantages	Disadvantages
Glass	double strength	30	88	6.3 (1.1)	Superior resistance to heat, UV, abrasion. Low thermal expansion.	Low impact resistance. Heavy
Glass—low iron	3.175 (0.125)	30	90–92	6.3 (1.1)	Superior resistance to heat, UV, abrasion. Low thermal expansion.	Heavy
Glass—double pane (sealed)	25.4 (1.000)	30	71	3.0 (0.5)	Superior resistance to heat, UV, abrasion. Low thermal expansion.	Heavy
Acrylic—structured sheets	8, 16 (0.315, 0.630)	20+	83	3.5 (0.6)	Superior UV+weather resistance. Lightweight	High expansion—needs gasketed extrusions. Flammable. Low impact resistance.
Polycarbonate—structured sheets	6, 8 (0.236, 0.315)	15	79	3.5 (0.6)	High impact resistance.	High expansion
Fiberglass reinforced plastic, FRP		10–15	88	5.7 (1.0)	Strong	Yellows with age. Flammable. Recoating needed every 5 to 6 yr.
Ultraviolet stabilized polyethylene film, PE	0.00016, 0.00024 (0.004, 0.006)	2–3	87	6.3 (1.1)	Large sheets, easy installation. Low cost.	Short life
Polyethylene film IR absorbing	0.00016, 0.00024 (0.004, 0.006)	3	82	5.7 (1.0)	Large sheets, easy installation. Low cost.	Short life
Polyvinyl fluoride film, PVF	0.0008, 0.00016 (0.002, 0.004)	>10	92	5.7 (1.0)	High impact resistance, UV resistant.	Narrow sheet size

*)Photosynthetically active radiation, 400 to 700 nm at zero incidence angle.

building, and a central heating plant can easily serve all areas. A minimum area of 1860 m^2 (20,000 ft^2) should be considered to efficiently use materials and equipment. It may not be as easy to expand or contract space use as with single span greenhouses. A headhouse can

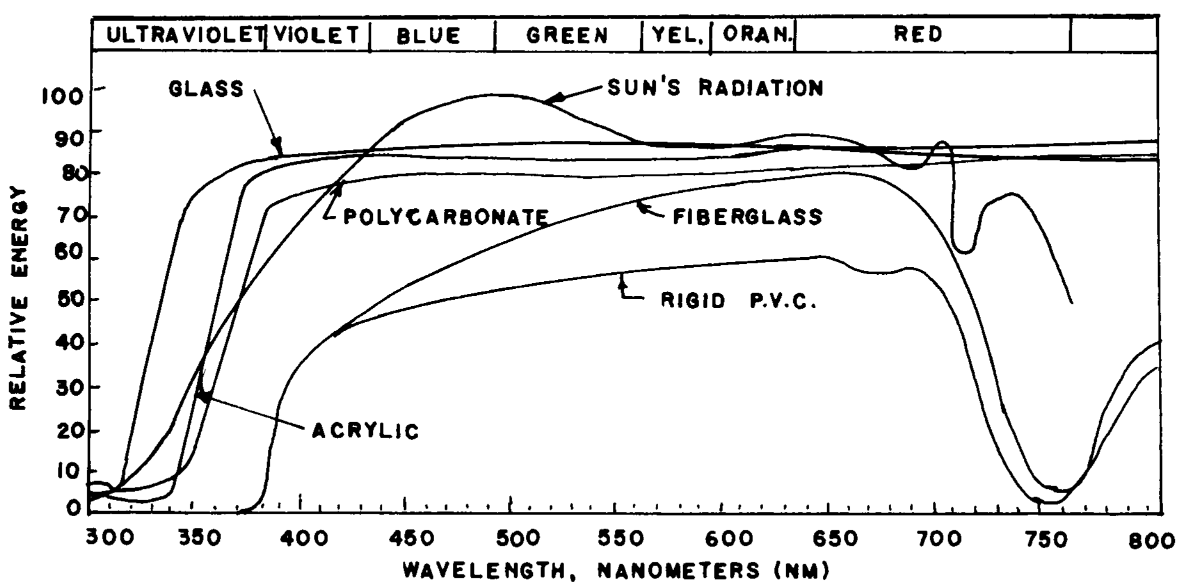

Figure 3 – Spectral transmittance of selected rigid greenhouse covering materials

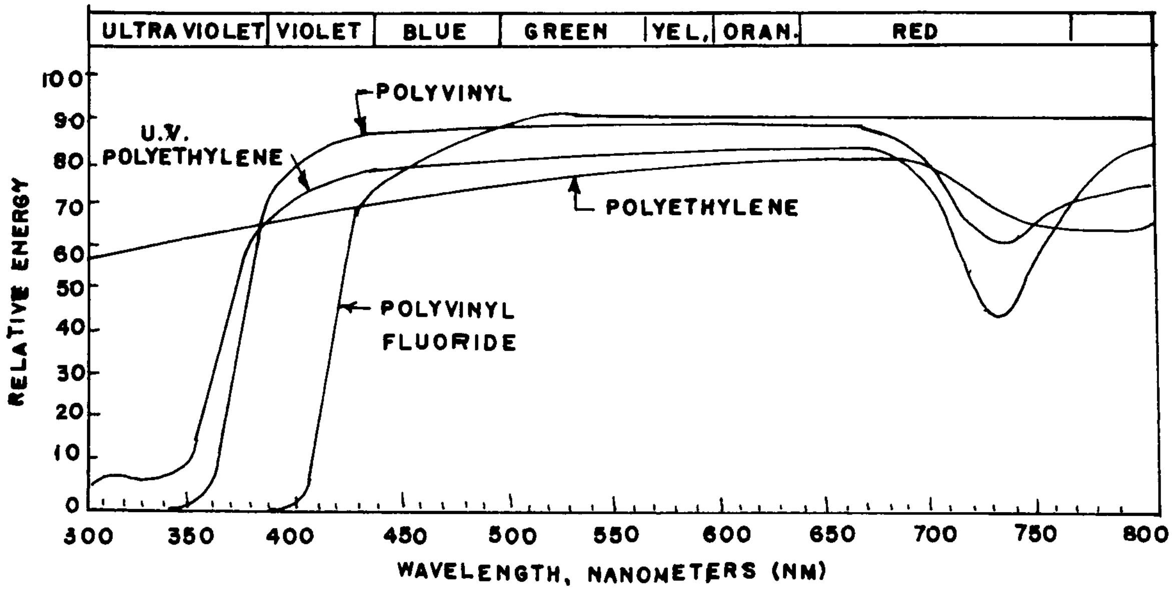

Figure 4 – Spectral transmittance of selected film greenhouse covering materials

be attached to the end or sides, or in large operations a central location reduces travel distance for plants and personnel.

6.2.3 The ridge in either single span greenhouse or a gutter-connected range should run east-west in areas above 40 deg N latitude to transmit maximum winter sunlight to the plants. Gutters shading the same area during each day may result in uneven growth in some plants. The potential for uneven growth in east-west ridge orientation is a tradeoff against general reduction in winter light if ridges run north-south.

6.2.4 Throughout the planning process provisions should be made for expansion. Land should be available for additional greenhouses and headhouse area. Water, electrical, and environment control systems should be installed to allow for expansion.

6.3 Headhouse and storage facilities

6.3.1 A headhouse should be built to house the office, utilities, work areas, employee areas, storage, and shipping.

6.3.2 The size of the headhouse can be approximated from table 4. This value should be adjusted depending on the indoor storage needed and the amount of mechanization used.

6.3.3 A good headhouse layout helps the system operate smoothly and efficiently. Materials flow should be such that there is a minimum of handling or cross traffic in moving the components through the system.

6.3.4 Although it is often impractical to store all growing media under cover, it is convenient to have some of it protected from rain and snow. The amount of space needed is determined by the type of operation, kind of media being used, and the local climate. Calculate space requirements based on the amount that is needed for one crop or a specific time period.

Table 4 – Sizing the headhouse

Greenhouse size		Approximate headhouse area needed per 93 m^2 (1000 ft^2) of greenhouse area	
m^2	ft^2	m^2	ft^2
930 to 3700	10,000 to 40,000	14	150
3700 to 7400	40,000 to 80,000	9	100
over 7400	over 80,000	7	75

6.3.5 Locate the storage area for bulk materials and truck loads where there is good access by an all weather road. Allow adequate space for trucks to turn and back. The storage should be located close to the work area to reduce handling time and costs.

6.3.6 Provide drainage in the storage area. Materials stored without cover should drain quickly. Provide a paved area for handling with a bucket loader or fork lift.

6.3.7 A clear span storage building allows freedom of movement for tractors and trucks and allows arrangement of equipment to be easily changed. For ease in maneuvering tractors and trucks, a minimum width of 7.3 m (24 ft) should be used. For larger operations, buildings 18 to 24 m (60 to 80 ft) are common.

6.3.8 Once the layout within the building has been established, service and personnel doors can be located. Service doors should be a minimum of 0.6 m (2 ft) wider than the largest piece of equipment. Headroom should be a minimum of 3.6 m (12 ft) with higher ceilings desirable if bucket loaders are to be used. For convenience, locate a personnel door next to an overhead door.

6.3.9 Concrete floors inside the building and paved areas outside make movement of vehicles easy in all types of weather. Elevate building floors at least 150 mm (6 in.) above outside grade, and slope the ground surface away from the walls or doorways. Provide drainage for roof gutters and snow melt.

7 Interior layout

7.1 The choice between production on the floor or on benches depends on the crop and the production schedule. Benches are usually provided for pot plant production. Bedding plants are generally grown on the floor. Beds, either ground or raised, are needed for cut flowers.

7.1.1 Benches improve labor efficiency, permit more effective display and inspection, and assist air circulation.

7.1.2 Bench arrangement depends on dimensions of the greenhouse, walkways, and doors and on materials handling and heating system type and location.

7.1.3 Total aisle space should be less than 25% of the total floor area.

7.1.4 Longitudinal arrangement with benches extending the length of the house permits continuous runs of water lines, heat pipes, and plant support systems. Width of bench can be up to 0.9 m (3 ft) for tending

Table 5 – Sizing the electrical system

Greenhouse size m²	ft²	Electrical service entrance size*)		amps/volts
TO	460	TO	5,000	60/240
460	1 860	5,000	20,000	100/240
1 860	2 800	20,000	30,000	150/240
2 800	3 700	30,000	40,000	200/240
3 700	7 400	40,000	80,000	400/240
7 400	11 150	80,000	120,000	600/240
11 150	14 860	120,000	160,000	400/240
14 860	18 580	160,000	200,000	600/240
18 580	27 870	200,000	300,000	800/240

*)Excluding plant lighting and heavy machinery.

from one side and 1.8 m (6 ft) when aisles are on both sides. Minimum aisle width should be 500 mm (20 in.).

7.1.5 A peninsular arrangement with one main center aisle extending the length of the greenhouse and perpendicular side aisles usually results in more growing space. A main aisle width of 0.9 to 1.5 m (3 to 5 ft) and side aisles of 400 to 600 mm (16 to 24 in.) should be used.

7.1.6 Movable benches allow the use of all the area except one or two work aisles. Bench tops are supported on rollers and allowed to move sideways 450 to 600 mm (18 to 24 in.) to provide a work aisle. Connections for water, heat, and electrical systems that are attached to the bench must be made flexible.

7.1.7 Benches can be fabricated of wood, metal, or plastic with either a solid or mesh bottom.

7.1.8 Benches should be placed at a convenient height above the floor, usually 600 to 900 mm (24 to 36 in.).

7.1.9 Beds are usually on the floor and have sides made from concrete or pressure treated lumber. The depth of the bed should be sufficient to contain adequate soil for the crop, usually 200 to 300 mm (8 to 12 in.).

8 Utilities

8.1 Electricity

8.1.1 An adequate electrical supply and distribution system should be provided to serve the environment control and mechanization needs of the greenhouse. Contact the local supplier to determine availability and the best location for the service drop. Once this is done a plan for the distribution system can be developed.

8.1.2 To determine the size of the service drop, the size and number of motors and other electrical components should be known. Unless special equipment or plant lighting is to be used, the size given in table 5 should be adequate.

8.1.3 The distribution system within the greenhouse/headhouse area shall meet ANSI/NFPA 70 and any local codes. Watertight boxes, UF wire, and ground fault interrupters may be required.

8.1.4 Provisions should also be made for an alarm system to indicate when a power interruption has occurred or an environment control system has failed. An auxiliary generating system should be available and installed with the proper transfer switch to prevent feedback of power to the utility lines. Locate the electrical service supply, auxiliary power, switches, and distribution system inside or adjacent to the headhouse.

8.1.5 Utility lines should be buried to improve appearance, avoid damage, and reduce hazards. Electric, phone, and fuel lines should be buried at least 450 mm (18 in.) deep to avoid damage from surface traffic. Water and sewage lines should be placed below frost. Location of the utility lines should be recorded on a map for future reference.

Table 6 – Estimated maximum daily water requirements

Crop	L/m²	Gal/ft²
Bench crops	16.3	0.4
Bedding plants	20.4	0.5
Pot plants	20.4	0.5
Mums, hydrangeas	40.7	1.0
Roses, tomatoes	28.5	0.7

8.2 Water

8.2.1 The amount of water needed each day throughout the year depends on the area to be watered, crop grown, weather conditions, time of year, and whether the heating or ventilating system is operating. For most of the US, the maximum requirement during the summer is about 2000 L per 100 m^2 (500 gal per 1000 ft^2) per watering (see table 6).

8.2.2 The water system for the greenhouse should have the capacity to supply the total daily needs in a 6 h application period. This allows the plants to be watered during the morning and early afternoon and with time for the foliage to dry before sunset. Tempered water may be desirable on some plants during the winter.

8.2.3 The peak use rate is the maximum flow rate during the 6 h period (8 am to 2 pm) needed to determine pump capacity, pipe size, type of distribution system, and storage tank size.

8.2.4 Ground water is usually the most reliable source of water. It is available from drilled wells, dug wells, springs, and some community water systems. Surface water from ponds, lakes, and streams can also be used, but precautions must be taken to insure against contamination injurious to the plants.

8.2.5 If peak use rates exceed the maximum water supply yield, some type of intermediate storage is needed. Storage tanks should be large enough to hold at least one day's water needs. Ponds are common in rural areas and for larger nurseries. Evaporation losses can be reduced by constructing the pond 3.0 to 4.6 m (10 to 15 ft) deep. Consult the local Soil Conservation Service office or consulting engineering firm for pond design information.

8.2.6 Water may contain impurities that adversely affect the growth of plants. Chemical tests should be made by an approved testing laboratory and the results analyzed by a horticulture specialist.

8.3 Fuel

8.3.1 A dependable supply of fuel for heating is needed.

8.3.2 Where possible, dual fuel supply (oil/gas, etc.) and appropriate heating equipment should be provided.

8.4 Where possible, design utility systems for easy expansion.

Annex A
(informative)
Bibliography

The following documents are cited as reference sources used in development of this Engineering Practice.

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