

Foreword

The formulation of this national standard was initiated by the Agricultural Machinery Testing and Evaluation Center (AMTEC) under the project entitled “Enhancing the Implementation of the AFMA Through Improved Agricultural Engineering Standards” which was funded by the Bureau of Agricultural Research (BAR) of the Department of Agriculture (DA).

This standard has been technically prepared in accordance with PNS 01-4:1998 (ISO/IEC Directives Part 3:1997 – Rules for the Structure and Drafting of International Standards. It specifies the general requirements for greenhouse.

The word “shall” is used to indicate requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted.

The word “should” is used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required.

In the formulation of this standard reference were made to:

ASAE EP 406 ASAE Engineering Practice, Heating, Ventilating and Cooling Greenhouses. ASAE Standards 1987.

Nuess, Mike. Designing and Building a Solar Greenhouse or Sunspace. Washington.1997

OSU Extension Facts F-6700. Greenhouse Structures and Coverings. Oklahoma Cooperative Extension Service. Division of Agricultural Sciences and Natural Resources.

OSU Extension Facts F-6700. Greenhouse Floors and Benches. Oklahoma Cooperative Extension Service. Division of Agricultural Sciences and Natural Resources.

Ross S. David. Planning and Building a Greenhouse. Adapted from Fact Sheet 645 – University of Maryland Cooperative Extension Service.

Walker, J.N. and G.A. Duncan. Greenhouse Structures. University of Kentucky. College of Agriculture, Cooperative Extension Service. 1975

Walker, J.N. and G.A. Duncan. Greenhouse Benches. University of Kentucky. College of Agriculture, Cooperative Extension Service.1975

Walls, Ian G. The Complete Book of the Greenhouse. Ward Lock Limited, London. 1979.

Agricultural Innovations. Brochure on Azrom Greenhouses. AZROM Metal Industries Ltd.

Agricultural Structures – Greenhouses

1 Scope

This standard specifies the minimum requirements for site selection, functional and structural requirements of the greenhouse.

2 Definitions

For the purpose of this standard, the following definitions shall apply:

2.1**greenhouse**

structure that provide a reliable enclosure within which an environment favorable to plant growth can be attained

2.2**ridge and furrow greenhouse**

gutter connected

method of greenhouse construction where modular roof units are connected at the eave by a common gutter

2.3**cooling**

removal of heat from the interior of the greenhouse

2.4**heating**

addition of heat to the interior of the greenhouse from any energy source including the sun

2.5**shading**

prevents excess solar radiation in the greenhouse

2.6**ventilation**

process of exchanging air inside the greenhouse with outside air to control temperature, humidity, oxygen or carbon dioxide levels

2.7**mechanical ventilation**

ventilation of greenhouse using fans

2.8

natural ventilation

ventilation of greenhouse which occurs through controlled openings due to natural pressure variations inside and outside the greenhouse

Note Wind creates pressure gradients and solar energy creates vertical temperature gradients, which facilitate natural ventilation

3 Classification

Greenhouses shall be classified as follows:

3.1 Based on enclosure (total or partial)

3.1.1 Glasshouse

3.1.2 Plastic house

3.1.3 Screen house

3.1.4 Combination

3.2 Based on roof shape (Figure 1)

3.2.1 Lean-to

3.2.2 Gable

3.2.3 Flat

3.2.4 Monitor

3.2.5 Quonset

3.2.6 Saw tooth

3.2.7 Arch

3.2.8 Uneven arch

3.2.9 Arch saw

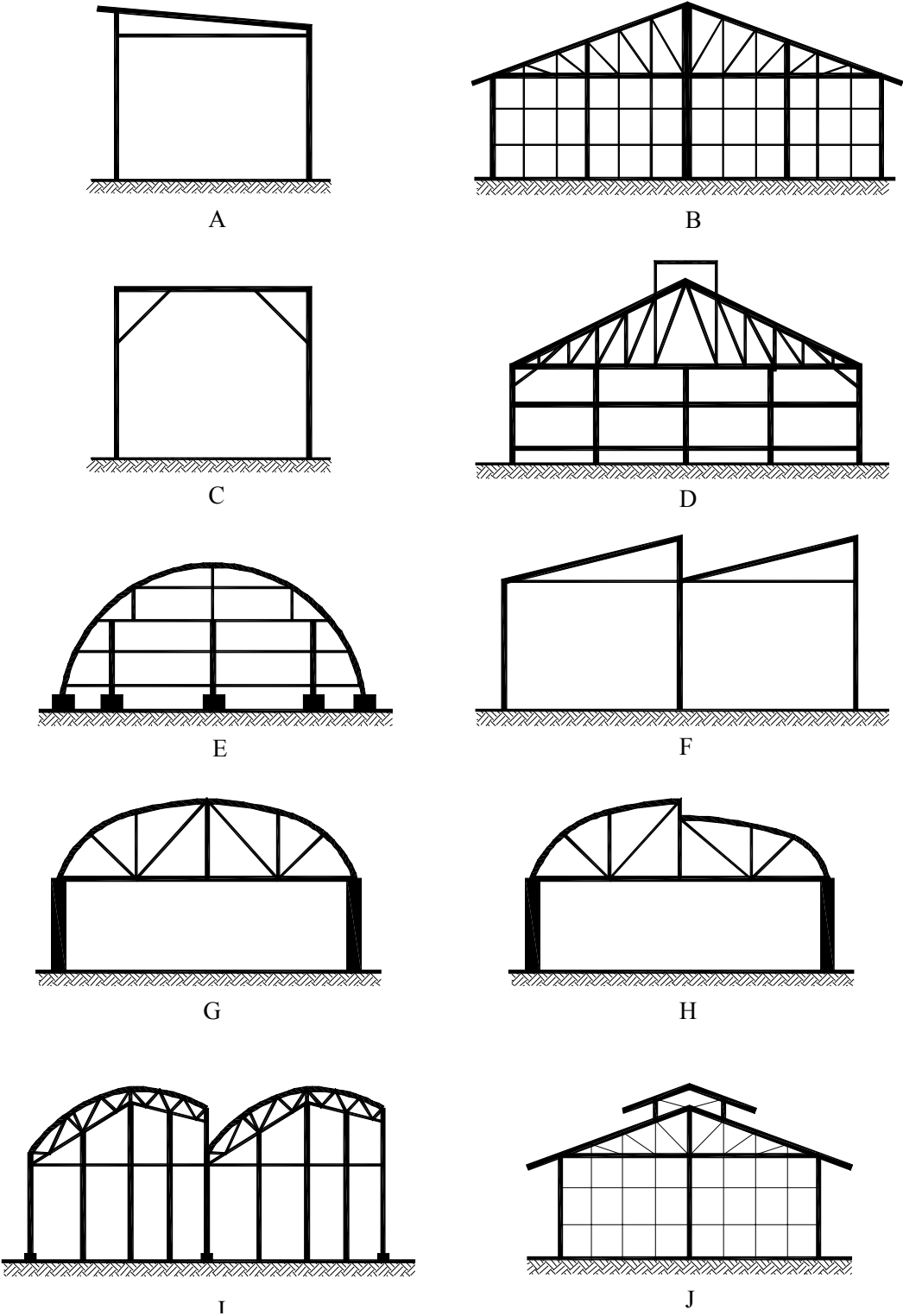


Figure 1. Roof shape: a) Lean-to; b) Gable; c) Flat; d) Monitor; e) Quonset; f) Saw tooth; g) arch; h) Uneven arch; i) Arch saw and j) Gable

4 Location

4.1 The greenhouse shall be located where it gets adequate sunlight.

4.2 The greenhouse should be placed with the ridge in a north to south orientation to reduce interior shading from the structure itself on the plants. Greenhouse that are connected together should be constructed north to south to provide even light coverage within the houses throughout the day.

4.3 The site shall be well drained.

4.4 There shall be ample supply of irrigation water.

4.5 The site shall be sheltered from excessive winds.

5 Floor area requirement

5.1 Benches

5.1.1 Bench area requirement

5.1.1.1 Benches should be up to 1.8 m wide if they are to be access from both sides, and should not exceed 0.90 m if they are accessible only from one side.

5.1.1.2 An air circulation space of approximately 160 mm shall be allowed between the sidewalls and the benches.

5.1.1.3 For fixed benches the usable space should be 66% - 75 % of the floor area while 90% for rolling benches.

5.1.2 Plant requirement

5.1.2.1 Nursery

5.1.2.1.1 Bags

Table 1 shows the population density of plants per square meter of bench. The population density will vary depending on the distance between bagged plants.

5.1.2.1.2 Pots

Table 2 shows the population density of plants per square meter of bench. The population density will vary depending on the distance between potted plants.

Table 1 – Population density per square meter of bench based on bag sizes

Bag size ^a	Population density per m ² of bench ^b	Bag size ^a	Population density per m ² of bench ^b
63.5x63.5x127 (2.5x2.5x5)	169-196	152.4x152.4x279.4 (6x6x11)	25-36
63.5x63.5x178 (2.5x2.5x7)	169-196	165x165x381 (6.5x6.5x15)	25
76.2x76.2x127 (3x3x5)	121-144	178x178x279.4 (7x7x11)	16-25
76.2x76.2x254 (3x3x10)	121-144	178x178x355.6 (7x7x14)	16-25
89x89x152.4 (3.5x3.5x6)	81-100	203.2x203.2x381 (8x8x15)	16
89x89x152.4 (3.5x3.5x11)	81-100	228.6x228.6x406.4 (9x9x16)	9-16
95.3x95.3x228.6 (3.75x3.75x9)	81	228.6x228.6x457.2 (9x9x18)	9-16
101.6x101.6x178 (4x4x7)	64-81	254x254x406.4 (10x10x16)	9
101.6x101.6x254 (4x4x10)	64-81	254x254x 457.2 (10x10x18)	9
101.6x101.6x304.8 (4x4x12)	64-81	304.8x304.8x482.6 (12x12x19)	4-9
127x127x203.2 (5x5x8)	36-49	355.6x355.6x584.2 (14x14x23)	4
127x127x254 (5x5x10)	36-49	406.4x406.4x686 (16x16x27)	4
127x127x 355.6 (5x5x14)	36-49		

^a bag sizes commercially available in mm (inches)
^b population in dense packing

Table 2 – Population density per square meter of bench based on pot sizes

Pot size ^a	Population density per m ² of bench ^b	Pot size ^a	Population density per m ² of bench ^b
10	100	170	36
11	81	180	25
12	64	200	25
13	42	230	16
15	36	250	16
16	36	300	16

^a pot size based on diameter of pots commercially available, in mm
^b population in dense packing

5.1.2.2 Production

5.1.2.2.1 Vegetables

Table 3 – Population density at recommended plant spacing for vegetables

Vegetable	Recommended plant spacing	Population density per m ² of bench
Sweet pepper	30 cm between hills (2 rows bed)	6-8
Chili	35 cm between hills (2 rows bed)	6-8
Tomato	40 cm between hills (2 rows bed)	4-6
Sweetmelon	50-60 cm between hills (2 rows bed)	4
Watermelon	50-60 cm between hills (2 rows bed)	4
Cucumber	50-60 cm between hills (2 rows bed)	4
Lettuce	15 cm between hills (4 rows bed)	24-28
Broccoli	30 cm between hills (3 rows bed)	9-12

5.1.2.2.2 Ornamentals

Table 4 – Population density at recommended plant spacing for ornamentals

Ornamentals	Recommended plant spacing		Population density per m ² of bench
	Between hills mm	Between rows mm	
Baby Aster	100 – 150	250	28-40
Chrysanthemum	120 - 250	250	16-32
Daisy	250	360 - 460	8-12
Gladiolus	60 - 80	200	60-85
Rose	300	300	9
Orchids (Vanda)	10 plants/driftwood		1-2 driftwood

5.2 Walkways

5.2.1 If the walkway will be used only as a place to stand while servicing the benches, a minimum of 0.30 m aisle shall be used for determinate crops and a minimum of 0.80 m aisle for indeterminate crops.

5.2.2 The width of the walks shall be adjusted if machinery will be used. Larger greenhouses often have 0.60 m - 0.90 m secondary aisle and 1.2 m - 1.8 m primary aisle. If a worker is in a wheelchair, 1.2 m wide aisle shall be used and ramps shall be provided for easy access.

5.3 Floor length and width

5.3.1 The length of the structure shall be determined by the number of the plants to be grown and the actual dimension of the commercially available sizes of the materials shall be

considered. The measurement shall be rounded off so that no glass will need to be cut to fill odd sash bar spacing. When figuring the length of a plastic structure, an extra 0.60 m shall be allowed to fasten the plastic properly, for glass, allow for the width of the projecting part of each sash bar plus a fraction of an inch clearance.

5.3.2 The length of the greenhouse should not exceed 50 m. For gutter connected greenhouses the total width should not exceed 50 m for well distribution of air.

6 Structure height

6.1 Building Height

6.1.1 The eave height for a gable roof greenhouse shall be at least 1.70 m with a minimum gable height of 2.4 m.

6.1.2 The eave height and the roof pitch will determine the height of the structure at the center. The height of the structure shall be equal to the eave height plus one-fourth the width.

6.2 Working height

6.2.1 The height of a greenhouse should be sufficient for the operation of machinery and the comfort of the workers. Gutter heights of 2.8 m - 3.0m are recommended for multi span houses to allow machines to move freely.

6.2.2 The height of the house in the walk areas shall not be less than 2.0 m.

6.2.3 For tall crops 2.0 m shall be the minimum height at the eaves and 2.10 m as minimum desirable height.

7 Functional and structural requirement

7.1 Foundation

7.1.1 The foundation and footings shall be able to resist uplift, overturning and downward acting loads. For permanent greenhouses, all foundations shall be of durable material and shall extend to a minimum depth of 0.45 m.

7.1.2 Permanent foundations shall be provided for glass and heavy plastic materials.

7.1.3 Greenhouses to be covered in polyethylene usually do not require an extensive foundation, but the support posts shall be set in concrete footings.

7.2 Walls

7.2.1 Height of side posts and columns should be 0.30 m - 3 m.

7.2.2 For greenhouses with wooden structural members, a 0.4 m high reinforced concrete wall at the bottom shall be provided for support. Sidewalls shall be provided with vents for cooling.

7.3 Roof

7.3.1 Frames

7.3.1.1 Framing shall adequately support the covering and any equipment and/or hanging baskets suspended from the framing. It shall be able to carry trellising loads up to 25 kg/m².

7.3.1.2 Framing shall be able to withstand maximum wind gusts of 250 km/hr.

7.3.2 Framing materials

7.3.2.1 Steel

7.3.2.1.1 Commonly used but shall be painted or galvanized to resist high moisture condition, needs more maintenance than aluminum and is heavier, requiring additional support.

7.3.2.1.2 If galvanizing is done, it shall preferably be done after all cutting and welding has been performed. Those areas where bare metal is exposed by cutting or welding shall be painted.

7.3.2.2 Wood

7.3.2.2.1 Common framing material but it deteriorates over time. Pressure treated lumber should be purchased and then treated with commercially available coatings.

7.3.2.2.2 Rafters should be placed 0.6 m – 1.2 m from center to center, depending on the strength requirements. Depending on the width of the structure, truss or curved arch type rafters are used. Greenhouses over 15.25 m wide shall require a reinforced truss construction.

7.3.2.2.3 Purlins should be connected by a cross tie. One to 2.5 m spacing should be used depending on the size of the greenhouse.

7.3.2.3 Aluminum

Most economical material for constructing the greenhouse frames, it can be shaped to form various structural components and needs no maintenance after installation. Aluminum has the longest life span and allows for light reflectance.

7.3.3 Coverings

7.3.3.1 The coverings shall be clear enough to provide optimum light transmission.

7.3.3.2 The covering should be able to absorb the small amount of ultraviolet radiation in the spectrum and cause some of it to fluoresce into visible light useful to plants.

7.3.3.3 Covering should be able to reflect or absorb infrared radiation, which plants cannot use and which cause greenhouse interiors to overheat.

7.3.3.4 Covering should be available locally and in unlimited sizes.

7.3.3.5 It should be durable as well as economical and should withstand heavy loads like wind gusts of 150kph.

7.3.3.6 It should be easy to install and covering should fit snugly.

7.3.3.7 Combustibility, durability, insulation, life span, maintenance and guarantee should be check in choosing covering materials.

7.3.3.8 The type of frame used should be compatible with the covering desired.

7.3.4 Covering materials

7.3.4.1 Glass

Glass can best transmit light.

7.3.4.2 Plastic

7.3.4.2.1 Polyethylene

Polyethylene sheet roofing provides good protection from rain and has low investment and need less structural components. It shall have a minimum thickness of 130 μm .

7.3.4.2.2 Fiberglass

It is very durable, rigid and available in various light transmission levels.

7.3.4.2.3 Corrugated plastic sheets

Provide good protection from rain and provide better light transmission. They have high material, installation labor and maintenance costs.

7.3.4.3 Screen

Usually used for shading purposes and protection from falling branches and the like but they do not provide protection from the rain. Low material, installation labor and maintenance costs. This includes fishnets and mesh wire.

7.3.5 Roof pitch

7.3.5.1 Roof pitch for a glass greenhouse should be 51% to prevent inside condensation from dripping on plants.

7.3.5.2 Plastic covered greenhouses require a steeper pitch of 58% - 70% to prevent drip.

7.3.6 Fasteners

Bolted fasteners, galvanized iron and weatherproof wood fasteners shall be used.

7.3.7 Gutter

For gutter connected greenhouses a 2% slope shall be provided for drainage.

7.4 Access

7.4.1 Large doors in the end of the greenhouse should be provided. If walking tractors are to be used, 1.2 m wide standard doors shall be provided. A minimum of 0.8 m wide side doors shall be used.

7.4.2 The doors of the greenhouse should close with a slight tension on the covering. Doors should not be sealed up tight or stale air will develop.

7.4.3 An anteroom should be provided for insect protection. A fan should be installed to prevent entry of insects when the door is opened.

7.4.4 Weather stripping around the door and vents should be used.

7.4.5 For sanitation a footbath should be provided.

7.5 Floor and walkways

7.5.1 Floor shall be able to resist heavy loads such as weight of heavy equipment used.

7.5.2 Permanent flooring should not be recommended because it may stay wet and slippery from soil mix media.

7.5.3 A concrete, gravel or stone walkway 0.60 m – 0.9 m wide should be built for easy access to the plants. The rest of the floor should be covered by several inches of gravel for drainage of excess water.

7.5.4 The used of regular concrete should be avoided for aisles in growing areas between since it will not drain properly.

7.5.5 If the floor will be used as benches, the cement should be laid exactly level in order to achieve an even distribution of water when flooding floors.

7.6 Facilities

7.6.1 Benches

7.6.1.1 Bench size

7.6.1.1.1 Benches should be of height and width suitable to an averaged size worker, benches shall not exceed 0.90 m high when against a wall.

7.6.1.1.2 If tall flowering plants are grown, lower bench beds should be used. For temporary benches for growing and bedding plants, benches as wide as 1.50 m - 1.80 m and only 0.45 m - 0.60 m high should be used. When shade plants are to grow under the benches, bench heights as high as 1.20 m should be used.

7.6.1.1.3 Allow air circulation for plants by having an open bench floor. Benches shall offer enough rigidity to prevent sagging and toppling pots.

7.6.1.2 Bench arrangement

7.6.1.2.1 The arrangement of benches within the greenhouse should depend on dimensions of the house, walkway location, heating and air circulation patterns, and material handling into and out of the greenhouse.

7.6.1.2.2 In commercial houses the standard arrangement is to run benches the length of the house to permit long continuous runs of watering lines, heating pipes and/or plant support techniques.

7.6.1.2.3 The peninsular type bench arrangement gives the greatest amount of bench area per unit of aisle space and permits convenient access to all areas.

7.6.1.3 Bench design

The commercial and peninsular bench arrangements should be either flat or stepped. With stepped and flat benches, either a solid or open bottom should be provided. Open benches should have sides to keep plants from being brushed off the benches. If solid-bottom benches will be used it should be strongly constructed in order to carry the weight of the sand and gravel placed on it.

7.6.2 Artificial lighting

Artificial lighting should be provided for the production of photo-period sensitive plants and for the workers, 200 lux should be provided. High-pressure sodium lamps are usually used to artificially light greenhouses. Incandescent lamps should not be used because the red light emitted from these lamps causes the plants to stretch. Fluorescent lamps should be used in growth chambers, these lamps are rich in blue light.

7.6.3 Irrigation and drainage

7.6.3.1 Irrigation systems shall meet the specific crop requirements and be suited to soil or other media.

7.6.3.2 Irrigation systems should operate accurately at low pressures and capacities.

7.6.3.3 Water should be applied by means of an overhead sprinkler, a drip or trickle irrigation system, by hand using a hose or similar device, or some combination of these delivery systems.

7.6.3.4 Drip or tickle systems are the most efficient and provide greater control over the amount of water applied. There is a reduced potential for diseases and injury since the foliage does not become wet.

7.6.3.5 Irrigation systems should include central pump, pipes and drip irrigation extensions. Irrigation drips should be spaced depending on the planting distance or density.

7.6.3.6 If overhead sprinklers and hand watering will be used, too much wetting of the foliage should be avoided.

7.6.3.7 In areas where soluble salts are high, use of subirrigation or capillary mats should be avoided since mats do not provide for leaching.

7.6.3.8 A general rule of thumb to follow in irrigating greenhouse crops is to apply 10%-15% more water than the container will hold to facilitate leaching at each irrigation and reduce the potential for the accumulation of soluble salts.

7.6.3.9 Water quality should be tested on a regular basis.

7.6.3.10 The recommended drainage rate is 30% - 50% of the water dose given to the plant. The drained water should be contained in a storage tank.

7.6.3.11 The growing media should be well drained to avoid root diseases.

7.6.3.12 Soil beds and benches are leveled with a slight slope of 0.8% - 1.0 % to drain the water dripping from the media containers.

7.6.3.13 If water will be plumbed from the home supply line, a backflow prevention valve in the water supply line should be installed to prevent the possibility of contaminating the water in the home.

7.6.4 Work and storage areas

A work area for potting and maintaining plants should be made, and should be located inside or outside the greenhouse. The north wall may be a good location for a work area inside the greenhouse. It may include a sink. Storage areas for soil and containers should be located outside the greenhouse but should be protected from the weather and not be an eyesore.

8 Ventilating and cooling greenhouses

8.1 Natural ventilating system

8.1.1 Ventilation should either be built-in in the design of the roof and wall configuration.

8.1.2 There should be vent openings on both sides and ridge of a greenhouse.

8.1.3 Large vent openings provide the most ventilation, the total vent area should be 15%-25% of the floor area.

8.1.4 For single unit greenhouses, the combined sidewall vent area should be the same as the combined roof vent area.

8.1.5 Ridge vents should be top hinged and should run continuously the full length of the greenhouse.

8.1.6 Top hinged ridge vents should form a 60° angle with roof when fully opened.

8.1.7 Automatic vent systems should be equipped with rain and high wind sensors to prevent crop and ventilator damage.

8.2 Mechanical ventilating systems

8.2.1 Relatively low-speed fans capable of moving a large volume of air slowly should be used. A maximum ventilation rate of $\frac{3}{4}$ -1 air change per minute is recommended for most greenhouses.

8.2.2 Ventilation fans should deliver the required ventilation capacity at 0.03 kPa static pressure when all guards and louvers are in place unless specific design requirements require air delivery at higher static pressures.

8.2.3 Fans should be spaced not more than 7.5 m apart for uniform ventilation.

8.2.4 Fans should be located on the downwind side or end of the greenhouse. If the fans must be located on the windward side, increase the design ventilation capacity at least 10%.

8.2.5 A clearance between the fan discharge and any obstruction of at least 1.5 times the fan diameter should be maintained. Fans may be mounted in the roof if obstructions interfere with other mountings.

8.2.6 Exhaust fans should have freely operating pressure louvers on their exhaust side to prevent unwanted air exchange when fans are not operating.

8.2.7 Air intake louvers or shutters should open outward. They should be motorized and wired into the fan control circuit to open during fan operation.

8.2.8 Intake louver area should be at least 1.25 times the area of the fans.

8.2.9 Fans should be provided with fan guards to prevent accidents. Manufactured guards should be used or install a woven wire mesh screen of at least 1.5 mm (gage 16) wire and 13 mm openings, for placement within 100 mm of moving parts. Guards more than 100 mm from moving parts may be made with woven wire mesh of 2.7 mm (gage 12) wire, and 50 mm openings.

8.2.10 All fans should be louvered so that unwanted air cannot gain entry when the fans are not operating.

8.2.11 Fans may be located at either the air inlet (pressure ventilation) or the air exhaust (exhaust ventilation).

8.3 Evaporative cooling

8.3.1 Pad and Fan Cooling

8.3.1.1 The pad to fan distance should be 30 m - 50 m. For very long houses, installing fans in the roof at the midpoint and pads at both ends will help to reduce air velocities across the plants.

8.3.1.2 The pad is normally run continuously along the side or end of the house opposite the ventilation fans. Vertical pad height should not exceed 2.5 m nor less than be 0.5 m for uniform water flow.

8.3.1.3 Vertical pads should be well secured to prevent sagging. Pads should be easy to install and replace.

8.3.1.4 Air inlet should be constructed so it may be readily covered without removing the pads.

8.3.1.5 Pads should be located on the prevailing wind side of the greenhouse. Pad location is not as important when the greenhouse is sheltered from prevailing winds by another building or greenhouse located within 7.5 m.

8.3.1.6 Keep fans from exhausting directly into pads on an adjacent greenhouse, unless they are separated by at least 15 m.

8.3.1.7 It is preferable to protect the pad assembly by installing it inside any air inlet openings. The air inlet opening need not be continuous but should be uniformly distributed.

8.3.1.8 If the pad assembly is located outside an inlet vent, the opening should be continuous, have no large obstructions and be centered in relation to the pad.

8.3.1.9 When the height of the pad exceeds that of the air inlet, set the pad back from the vent a minimum distance of half the amount of the height difference.

8.3.2 Misting and fogging system

A sprinkler may be provided to increase humidity and reduce internal temperatures. Caution should be observed not to soak the plants.

9 Shading

9.1 Overhangs should be sized to fit the particular design requirements of the space. The length of the overhang should be $\frac{1}{3}$ to $\frac{1}{2}$ of the glazing height, and the height of separation between window and overhang should be $\frac{1}{4}$ of the window height.

9.2 Exterior shades can be mounted as rigid panels or as roll-up mechanisms. They must withstand wind, rain and ultraviolet light. Plastic glazing should not contact exterior shades as they may be scratched through abrasion or should they get too hot they may fuse to the

shade. Hold the shading off any glazing in order to allow connective cooling around the shade.

9.3 Paint-on shading may be appropriate for some solar greenhouse applications.

10 Instrumentation and Controls

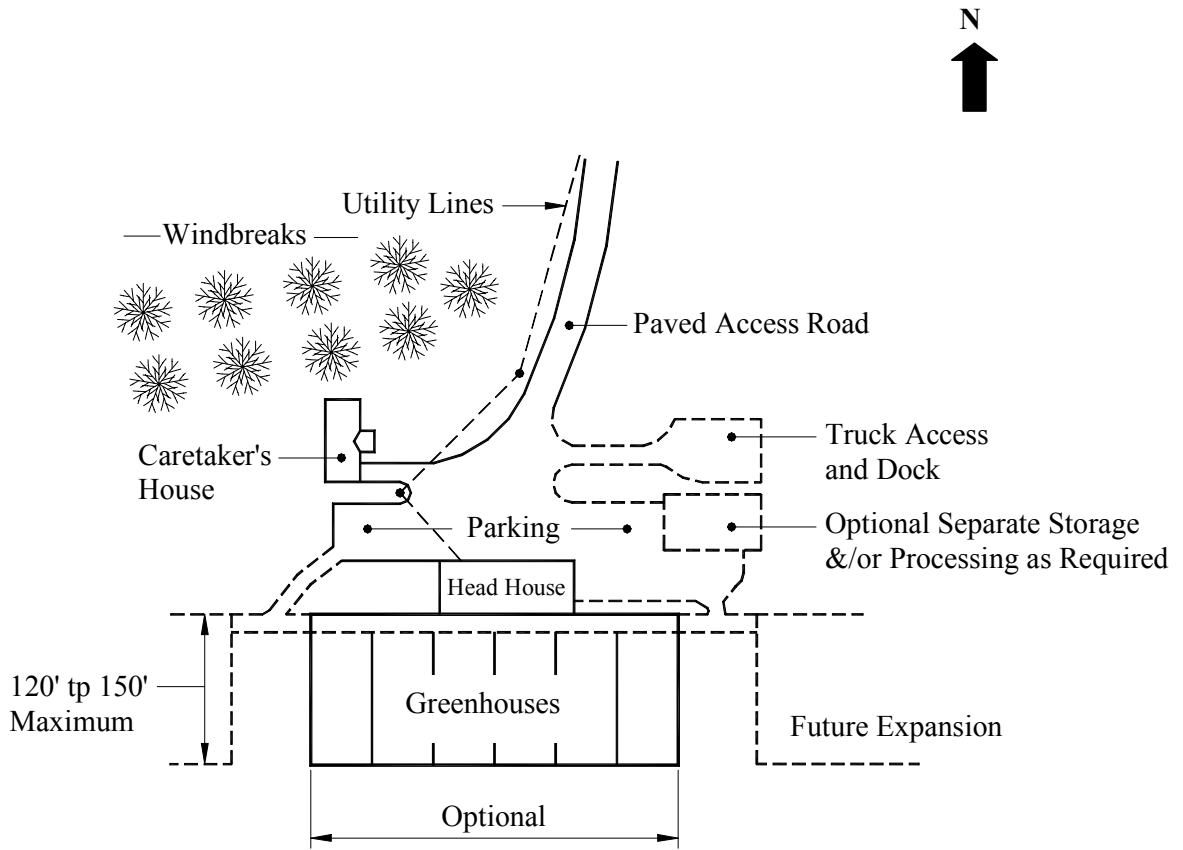
10.1 Thermostats should be used to control individual units, or a central controller with one temperature sensor can be used.

10.2 The control sensors should be fully shaded from direct solar radiation. The shade should be made of a material having a low thermal conductivity and high reflectivity such as white painted wood. Wood should have a minimum thickness of 13 mm.

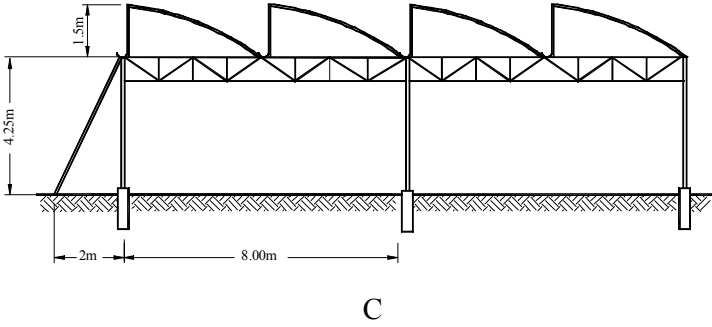
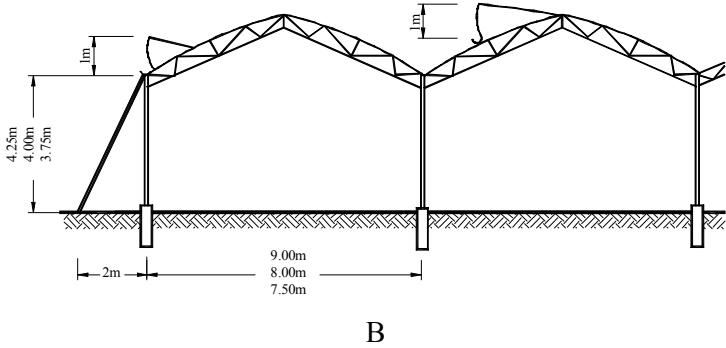
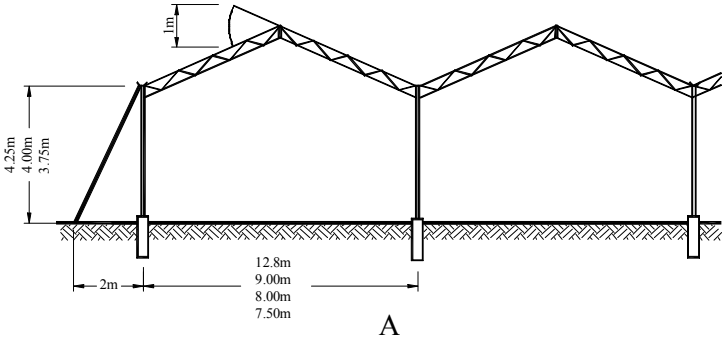
10.3 Controls and sensing devices should be located near the center of the greenhouse and near the plant growing area. The location should be representative of the plant requirements and should not be abnormally affected by heat ducts, ventilators or sidewalls.

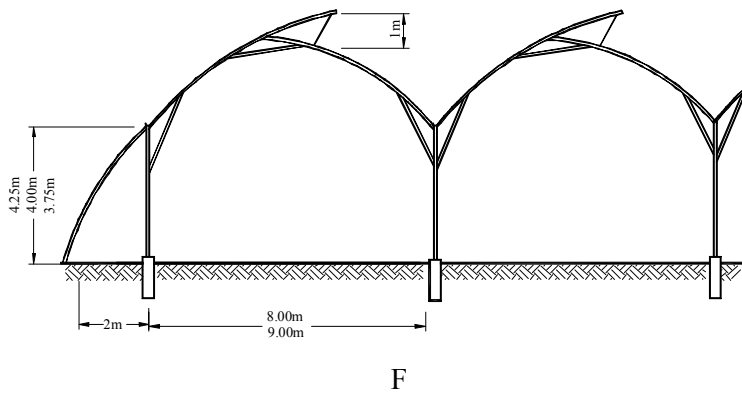
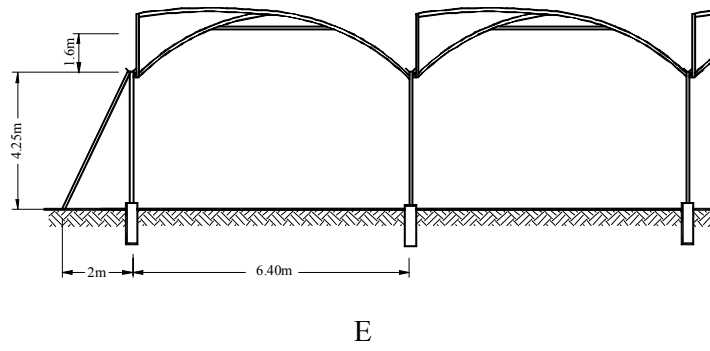
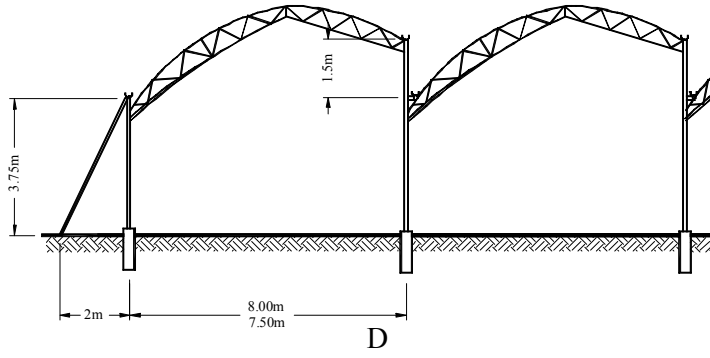
10.4 Water quality control should include water temperature, Electrical Conductivity, and pH.

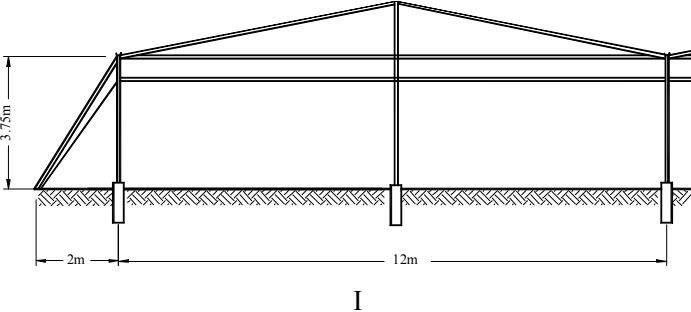
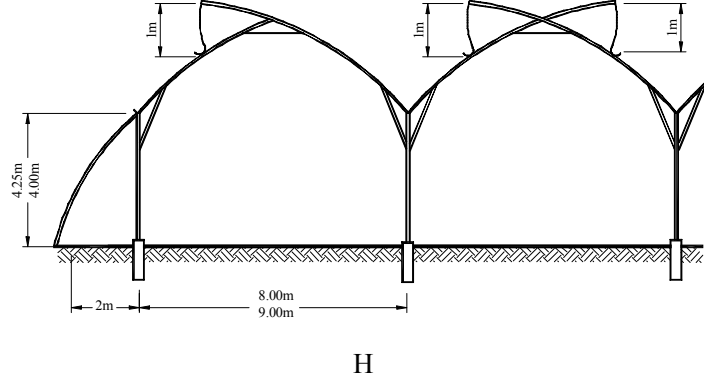
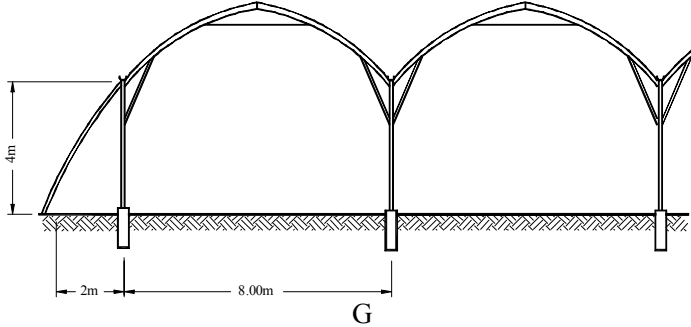
Annex A
(informative)
Typical layout of a greenhouse



Annex B
(informative)
Typical designs of greenhouses







Annex C
(informative)

Typical pipe-frame greenhouse

