GREENHOUSE DESIGN: THE CHOICE OF COMPONENTS 1/

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Abstract.--There are various type structures, many different kinds of coverings, and a wide range of heating, cooling, watering, lighting, controls and other related equipment available for the construction of greenhouses for seedling production. This paper covers the known range of available items and how the design engineer might go about selecting the components to put together a highly reliable system that will meet the long term requirements of the grower at the most economical level.

INTRODUCTION

The purpose of this paper is to explain how a design engineer might approach the problem of selecting components for the development of a complete greenhouse for the production of tree seedlings. The desired end results are to have a highly productive, economical system with minimum maintenance. Due to the value of the crop, a high degree of system reliability is needed with adequate safeguard emergency systems. Consideration must also be given in the initial design phases to deferred improvements of the system and future expansion of production. An item which could be overlooked by the designer is the size of the seedling containers in the greenhouse and how they will be handled since it affects door sizes, overhead clearance and structural design of floor grates to accommodate forklifts. Throughout the entire process of selecting components, the designer must be aware of the financial constraints as well as the limitations on temperatures, humidity, water, nutrients, carbon dioxide and lighting established by the nurseryman.

CODES AND STANDARDS

During the selection process particular attention must be paid to the applicable codes and standards. The following codes and standards should govern the equipment selected and its installation:

1. Heating, ventilating and air conditioning equipment -

a. Electrical appliances and equipment required shall be Underwriters' Laboratories, Inc. (UL), or Canadian Standards Association Testing Laboratories (CSA) approved and listed.

b. Motors shall be rated in accordance with the National Electrical Manufacturers' Association (NEMA) standards. The horsepower rating of all motors shall be such that the motor will carry continuously, the maximum load possible to be developed under all conditions specified, without exceeding the name-plate rating and without benefit of the service factor. The temperature rise shall be based on an ambient of 40° C. The temperature rise rating for the type motor enclosure shall not exceed the temperature rise listed in NEMA Standard MG1-10.36A.

c. Motors shall conform to the applicable standards of the Institute of Electrical and Electronics Engineers, Inc.

d. Gas-fired apparatus and devices forming a part of the equipment and required for the complete operation of the system, including gas piping and flue vents, shall conform to the latest applicable standards of the National Fire Protection Association (NFPA) of Gas Appliances and Gas Piping.

e. Gas-fired appliances shall be design certified that the appliance complies with the National Safety Requirements of the American Gas Association, Inc. (AGA).

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f. Water heaters shall be constructed in accordance with the requirements of the The American Society of Mechanical Engineers Boiler and Pressure Vessel Code.

g. The air delivery rating and construction of fans shall exceed or conform to the standards established by the Air Moving and Conditioning Association (AMCA).

h. Fired boilers and unfired pressure vessels shall meet the American Society of Mechanical Engineers (ASME) standards for the type vessel.

The installation of equipment and materials shall conform to the recommenations and instructions of the respective anufacturers of equipment and materials, to applicable National Electrical Contractors Association (NECA) code requirements, local codes and National Board of Fire Underwriters rules and regulations covering the respective installations.

2. Plumbing Systems - Plumbing installation shall be in accordance with local codes and regulations, the National Plumbing Code and the requirements of the grower.

3. Steam Piping - Steam piping systems shall be in accordance with either the Steam Heating Equipment Manufacturers Association (SHEMA) or the Standard Codes for pressure piping by USA Standards Institute (USAS).

STRUCTURES

The first phase in the selection process is to determine the overall, general type of structure. Many factors could be involved, but the deciding one is usually that of available financing if a permanent, continuous operation is desired. The choice could, however, be made from the following available types:

1. Wood truss frame
2. Hot dipped galvanized or aluminum 6063 T6 alloy bow
3. Hot dipped galvanized truss frame
4. Aluminum 6063 T6 alloy truss frame
5. Air supported structure

I personally feel that the most desirable permanent structure for development of a highly productive tree seedling greenhouse is the galvanized or aluminum truss frame. It has all the advantages of large end areas, high side wall clearance and available structural components for hanging heaters, water piping, lights and related equipment. The only disadvantage would be cost. However, annual maintenance, reliability and user convenience would offset the advantages of other cheaper structures in a continuous operation.

COVERINGS

Covering of the selected type structure is also influenced by the planned duration of the operation, possibility of hail, high winds and value of the crop. Selection could be made from:

1. Single vinyl
2. Double vinyl with air inflation between layers
3. Translucent fiberglass panels
4. Translucent fiberglass panels treated with clear Tedlar on the exterior side
5. Glass

Based on a continuous operating system, while considering the impact the loss of a crop might have upon the grower's operation, I feel the only practical covering is translucent fiberglass panels treated with clear Tedlar on the exterior side. This selection provides a reasonably maintenance free covering while providing protection from hail and high winds. It does not rely on air inflation, nor would there be concern about tears in the covering. Also, when required, selective replacement of panels can be made, rather than replacing an entire covering. Its disadvantages are high cost, condensation and fire hazard rating. However, crop insurance more than offsets these disadvantages.

FLOORS

Economics could well dictate the type of flooring in the greenhouse. Since humidity control is critical with seedlings, a floor which doesn't retain moisture is the logical choice. Selection can be made of:

1. Open soil with walk ways of gravel, wood, concrete or asphalt
2. Gravel throughout floor of greenhouse
3. Asphalt throughout floor of greenhouse
4. Concrete throughout floor of greenhouse

With a solid floor such as asphalt or concrete, floor slope and a system of drainage must be provided in the original design. The selection of floor covering can have a definite bearing on other problems within the greenhouse. To reduce the humidity control problem, aid in the movement of seedling containers and to make clean housekeeping possible, a full concrete floor with drainage is strongly recommended. As a minimum, I would recommend the floor be asphalt throughout.

COOLING

In the process of selecting the cooling system, the size and structural shape of the greenhouse becomes quite important. An arch type structure, unless it is raised on some type wall, does not have the same end area opening for pad cooling as a truss type structure. Some modification of the old standard vertical pad layout might be necessary. The pad systems in use today are:

1. Vertical
2. Horizontal
3. Angled
4. Zig-zag

The pad cooling system which I favor is the zigzag pattern, on a chain link fencing support and which incorporates automatic (interior) motorized vent louvers with bug screening. The system provides near maximum cooling with high reliability and full control, and within an economical level of finance.

The pad cooling system must incorporate a water spray, collection trough(s), collection tank, shutters and screening to eliminate bugs and birds. The pad cooling system should be designed such that pad thickness, density, texture and construction provide at least 80% evaporative efficiency when the entering air is around a face velocity of 150 FPM and yet not have a pressure loss exceeding approximately 0.05 inch water static pressure. This may have to be varied. However, in a truss member building with end entrance cooling it is not too difficult to achieve.

To eliminate maintenance headaches the collection tank should not be placed in a hole where it can't be serviced and where it collects debris from the floor. A galvanized stock tank works very well and is certainly cheaper than forming a pit in the floor.

The other prime portion of the cooling system is the exhaust fans. These are sized according to the dimensions of the greenhouse. Consideration of single and two-speed fans, manual or automatic exhaust shutters and location is given to the grower to select the system most desirable to him. However, all fans should be guarded to prevent accidents; and two-speed fans are a must for flexibility of operation.

All intake and exhaust openings must be above the seed bed height to prevent "burning" of the seedlings. A "tight" house is very important to prevent entrance of non-tempered air, insects and airborne weed seeds. It will also keep tempered air and CO_2 in the house where it's needed and/or can be controlled.

If money is no problem, or if the greenhouse is quite small, refrigeration type cooling could be considered. However, on large greenhouses such as we are discussing, the heat loads make this system almost prohibitive.

A system for cooling, dehumidification and circulation of air in a greenhouse, yet untried as far as I know, is a Rotaspray Weathermaker, as manufactured by the Carrier Air Conditioning Company. This system provides for a complete closed loop whereby outside air would be permitted into the house only on an emergency situation. I have a proposed layout of this type system available if anyone is interested.

HEATING

Methods for heating usually are a composite of various standard heating systems. The size operation planned would normally dictate the basic heating unit. A small greenhouse can be heated with an upright home furnace and blower. However, for example, a 130 ft. x 34 ft. greenhouse lends itself to unit heaters with blowers and turbulator tubes.

I definitely think the only practical way to heat a large greenhouse is by using steam heat. Steam permits a large quantity of heat to be transmitted from the boiler to the heating unit with very little temperature drop, thus having a very high heating efficiency. Steam also responds rapidly to fast pick up of heat demand and will cool down rapidly when circulation is stopped. A steam heating system is easy to control, distribute or expand as the complex gets bigger, without making major basic changes to the original designed system. Steam is also a flexible media and can be used effectively for humidity control and seed bed sterilization. A steam heating system, if properly maintained, will last the life of the complex.

Bare pipe or a combination of bare pipe with fin tube sections usually provides cheaper and more maintenance free hot water or steam perimeter heating system, when used in conjunction with the blower/turbulator tube overhead. In some cases turbulator type fans might be used with pipe chase heating in lieu of turbulator tubing and blowers. Do not use metal duct work in lieu of turbulator tubing, since its cost is excessive and it provides unwanted shade.

LIGHTING

Growth lighting can be accomplished by ordinary incandescent light bulbs, and I recommend their use. However, there are growth lights available which give a more concentrated direct light and have a longer service life at a somewhat higher initial cost. The main thing to consider in lighting is to meet the grower's foot-candle requirements and cycle time periods. Reflectors protect light bulbs from water spray and dripping condensation in addition to directing the light where it's needed. The reflector must be kept as small as possible to reduce shading to the absolute minimum.

Tungsten carbide, mercury vapor, quartz-iodine and other sophisticated lights are being used quite effectively for flood lighting of certain crops and might work with tree seedlings too.

As a matter of safety, all wiring should be moisture resistant. Fixtures, including switches, must be suitable for use in moist locations without corroding.

WATERING

Watering can be accomplished automatically or manually, however, its cycle is usually based on observation rather than moisture sensors. Known systems range from individual pot tricklers to overhead traveling boom systems. In the mid price range are spray stakes and overhead fixed spray bar systems. Mist, droplet and large volume heads are available. A system which will accomplish the job with the least maintenance cost is usually the fixed spray bar, and I would recommend it over other systems now in use.

There are many good corrosion-resistant nutrient feeders available on the market. The injector pump must be capable of accurately proportioning liquid nutrients to water ratio of 1:200 minimum. Ratios should be adjustable, however, and at any set ratio the proportion must remain the same regardless of changes occurring in the water pressure. The main thing to be concerned with in relation to the nutrient feeder is that a wash down "rinse" cycle of clear water be incorporated in the watering cycle to remove nutrients from the foliage and greenhouse covering.

CO2

Oxygen is generated within the plants' micro-organisms. Carbon dioxide is required, and this must be supplemented by a CO2 generator because of the closed greenhouse system. Carbon dioxide can be introduced into the system by burners located outside the structure (thus reducing some of the heating load which must be controlled), or by the placement of overhead units within the structure itself.

The CO2 levels desired will determine the size required, and the grower will usually determine the type/location installed. Shading from large interior-mounted units must be avoided.

Availability of fuels and/or cost will determine the type fuel being fired. CO2 generators burn:

1. Propane/Butane
2. Kerosene
3. Natural Gas

Natural gas is preferred, if available, due to safety and ease of handling.

Dry ice could be used for CO_2 introduction into the greenhouse, but its cost is prohibitive.

Controls for shutting off the burners during time the ventilation system is open and/or when CO2 is not required, should be provided to reduce waste of gaseous fuels.

SHUTTERS

Shutters should be provided on all openings in the system except door. The pad cooling and exhaust fan shutters could be manual or of the automatic and motorized type. The tempering air shutters used in conjunction with turbulator tube and blower are usually motorized. Motorized shutters cost more, however, they are definitely required in a fully automatic controlled greenhouse.

CONTROLS

The greenhouse operation can range from full manual to full automatic with manual override. Automatic control of light bank sequence, watering, rinsing, heating, cooling, ventilating, humidity and CO2 are all possible. Timing of light duration, water amount, partial or full heat and cooling are also able to be controlled. The basic control items are:

1. Timer clocks
2. Thermostats
3. Humidistats
4. Solid state sensors for indoor/outdoor temperature sensing
5. Staged electronic sequencers for cooling, ventilation and heat
6. Photo conductive cell
7. Emergency alarm inside/outside buzzer

MISCELLANEOUS

Other items to be considered in the selection of components are requirements for standby power and a telephone receiver connection in the alarm system to specified phones.

Don't overlook the high hazard of plastic poly-fiberglass coverings and the need for adequate fire protection.

Shade cloth, hail screen and spray-on shade materials were not covered in this paper since they come into use after construction and are based on location and/or at the nurseryman's desires.

Screening on all fresh air openings is a must to prevent blown weed seeds, leaves, bugs, etc. from entering the greenhouse.

If the lack of smooth air flow throughout the house becomes a problem, it may be necessary to install baffles, however, turbulator tubing usually eliminates the need for baffles.

SUMMARY

In the process of selecting components to meet the nurseryman's requirements, the design engineer must stay within the financial constraints but yet assure a highly reliable total system. At the same time, alternatives or trade-offs should be considered so that the user can select those components of the system most desirable to him in the total design package.

Question: Why do you say air-supported structures are not practical?

Newland: There have been some spectacular and astronomically costly failures. Even though air-supported structures do have some possibilities, we are not sure they are reliable enough yet.

Question: Do asphalt floors have an advantage over concrete floors in maintaining greenhouse humidity?

Newland: I don't know, but I would expect asphalt and concrete would affect humidity about the same.