DESIGNS AND CONSIDERATIONS FOR GREENHOUSES IN THE U.S., NOW AND IN THE FUTURE

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SUMMARY

Greenhouses in the future will utilize energy saving materials and systems. Alternative heating energy sources, such as solar, will be practical and economical.

Buildings will be designed to provide for natural ventilation in warmer climates to reduce summer operating costs and demands for energy. Materials handling systems will be included and the structures will be designed to carry the imposed loads. It is difficult to extrapolate the curve describing the greenhouse industry development. We can be sure, however, that people will still enjoy the beauty of flowers in their homes and yards and the greenhouse industry will meet that need.

INTRODUCTION

Prediction is not normally the lot of the engineer. He is more accustomed to making ideas work. Men had been dreaming for a long time about walking upon our moon. Engineers and scientists worked together for all to see Neil Armstrong take that one giant step for mankind on the moon. In retrospect, the last 25 years have brought spectacular advancement in transportation (the jet age), in information retrieval and assimilation (the computer), and the entire space program. The advancements in medicine and agriculture have been felt worldwide, although there is yet much to be done to distribute the benefits of medical and agricultural technology.

We can reasonably expect magnificent scientific development to continue. Yet as we look into the future, a dark cloud is emerging. The scintillating pictures of the earth from outer space have given us a dynamic visual presentation of the finiteness of the earth. This picture put us all in the ball game together. Not only is the earth finite but its resources are finite. Energy has become a household word and occupies the minds of world leaders including our President, who has indicated to us that a lifestyle change of some sort is in store for all Americans.

The total U.S. energy demand is projected to increase from an estimated 38 million barrels of oil per day in 1976 to 56 million barrels of oil equivalent in 1990.[1]

Flowers bring into our homes, filled with the stress of 'modern' living, design which we cannot duplicate, elegance which we cannot emulate, color which we cannot create, and serenity which we cannot stimulate. Vegetable production on a controlled year round basis in large population centers brings the delights of nutrition and taste to the home as well. Greenhouses are the means for allowing flowers and vegetables to enrich our lives. Production in greenhouses, however, is energy intensive and as such, is threatened by the growing crisis.

LOOKING AHEAD

New greenhouse design, in my opinion, will incorporate energy saving materials and energy saving operation and management. Double glazing techniques will be mandatory. Hollow walled translucent materials, more durable multi film layers or dual flat laminated plate construction will be incorporated into new designs to reduce heating loads.

The use of high strength cable and exotic designs can reduce traditional greenhouse shading problems. A design of this type shown in Figure 1 was developed simultaneously at the Agricultural Engineering Department at Rutgers University[7] and the National Institute of Agricultural Engineering at Silsoe, England, by Bowman. Its design was based upon earlier work at Rutgers[5] in 1965 in which air was forced between two layers of plastic film. This development gave the film integrity, increased its life and greatly enhanced the acceptability of film greenhouses. A greenhouse of this type has been further demonstrated on a large scale at Superior Farms in Tucson, Arizona.

Cooling loads for greenhouses in warm or tropical climates will be reduced by monitor type designs already used in some areas of the world. Some degree of control will be sacrificed by the use of natural ventilation but energy intensive mechanical systems will no longer be needed. A design developed at Rutgers[8] in 1974 utilized air inflated tubes to provide convenient and inexpensive ventilation, Figure 2.

Another design, proposed by Jensen and the authors, combines some of the features of low cost construction, polyethylene film covering and natural ventilation. The design would be utilized in low rainfall climates with moderate night temperatures. The basic design, Figure 3, would use cables attached to poles on a 6 x 3.25 meter spacing. Cables will run in each direction lacing the poles together. There will be no gutter and rain will be channeled at the soil level into an underground drainage network. The design will allow the roof sections to open at the gutter line. Warm air rising along the under surface of the plastic will be naturally vented at the gutter line. The cable linkage will be operated by a power controlled winch through a relay and percentage time clock actuated by a thermostat. This feature would allow the window to open and close slowly and compensate for the change in shape and air volume in the plastic roof envelope. This type of greenhouse would be used for a sand culture type of agricultural production. A small inflated tube would close the opening during the evening and on days when no ventilation is required.

New greenhouse designs of either glass, fiberglass or plastic film construction will have to use energy saving systems in addition to double glazing techniques mentioned earlier. These systems will resemble present day length control systems used for flower production.[6] Other systems will utilize schemes for introducing insulation materials between the double glazing during the night heating period. The Environmental Research Laboratory has reported on foaming techniques.[2] The Ohio Agricultural Research Station at Wooster has demonstrated theuse of polystyrene beads for a similar purpose.[10]

The use of insulation systems reduces the amount of energy required and prompts the attempt to use alternate energy sources. Roberts, et al. reported on a system which utilizes solar energy for the main fuel source.[9] Mears[3] has reported the success of this design shown in Figure 4. Sand culture growing of tomatoes could be readily adopted to the system in Figure 4 by substituting sand for the gravel and using a deeper bed of sand. Drainage ports would be built into the system at the 25 cm level, below the surface, to keep the root zone in the optimum condition. Warm water could be utilized for irrigation water and heated by the solar collector.

This system is suitable for heating a greenhouse with low temperature water from any source including industrial or power plant warm water discharge. In closed loop nuclear stations, an enclosed floor storage would be substituted for the present open system and drainage from the greenhouse floor would not mix with the closed loop water supply.

Under study at Rutgers is an idea illustrated in Figure 5. A solar collector boils a working fluid,such as Freon, which drives a turbine connected directly to a ventilation fan. An attractive feature of this system is that power to the fan is greater with increasing insolation. The spent vapor is condensed in a heat exchanger embedded in the gravel/water underfloor storage system similar to the one used in the Rutgers Solar heating system. A pump is used to send the condensed liquid to the collector to repeat the cycle.

This unit is most effective in the spring and fall when ventilation is needed during the day and heating at night. The waste heat from the mechanical cycle is stored in the floor system for use at night. During severe weather, a bypass valve at the motor sends the heat directly to storage. During extreme warm weather, additional fans, thermostatically controlled, provide extra needed ventilation capacity.

Future greenhouse designs must consider new and improved materials handling and mechanization systems. For instance, the design must be able to support monorail systems where applicable. Some glass ranges in Holland have nearly a completely automated system for raising mums and tomato transplants. Aluminum movable benches approximately 1.5 x 6 meters with polystyrene bottoms travel throughout the greenhouse on powered rollers or overhead monorail. Benches move down the greenhouse bays on 5 cm heating pipe which forms a track as well as providing heat exchange surface. In some instances, the pipe is attached to the interior posts and in this case, the design of the building must fit into the entire operational plan.

The floor heating system described briefly earlier in this paper and in detail by Mears[4] can offer some savings in bench layout, flexibility and construction. For those container crops which require hand operations, such as disbudding, simple bench frames which are elevated as needed can be used. The crop can stay in contact with the warm floor and elevated only when needed for root pruning and for hand operations. A prototype of this system is being tested by the Dutch.

Production of plants in growth chambers has been espoused by some. Controlled conditions of light, CO_2, temperature, humidity, and nutrition have created good crop response and productivity. Energy consumption for lighting, however, is very great. In an insulated structure, refrigeration is needed to control temperature if adequate light energy is provided. Our judgment is that growth chambers will be used only for the production of seedlings. Growth chambers will be operated in conjunction with greenhouses so that the refrigeration heat can be used effectively to assist in heating the greenhouse. The underfloor storage/heat exchange system could be an attractive method of utilizing this waste heat.

Environmental control of greenhouses will become more sophisticated. The Dutch are already leading the way in this area. Solar energy and outside climatic condition data together with information on plant requirements will be fed into a computer which controls the system automatically. Data on all crops will be kept on punch cards along with marketing information. The computer can receive this information and automatically control temperature, CO_2 addition, irrigation and fertilization, shading and, perhaps, harvest. A large research greenhouse has been erected near Monster, Holland, to test the feasibility of such an idea.

Agricultural engineers, although unable to see clearly into the crystal ball will be needed to innovate, experiment and put into practice those concepts which are developed. We will commit ourselves, to the best of our ability, to intelligent choices and meaningful compromises in maintaining an industry which provides beauty, serenity, and peace of mind.

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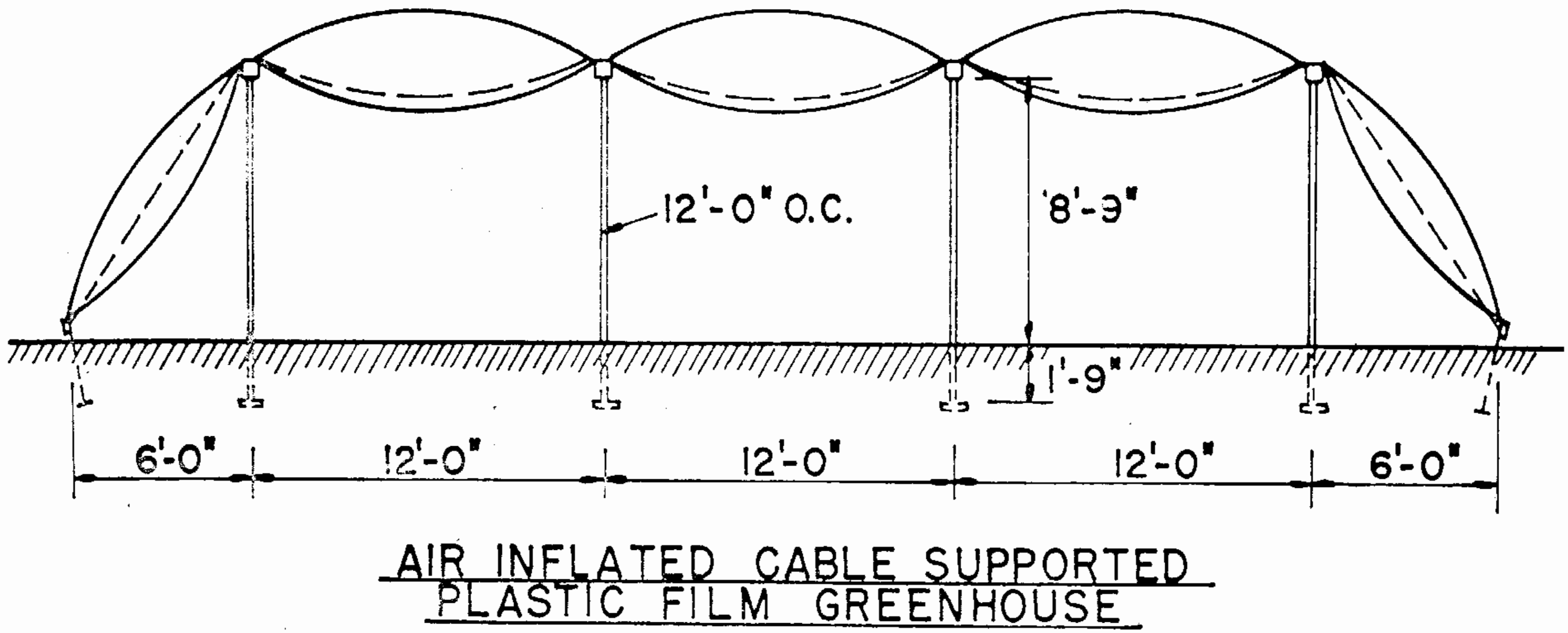


Figure-1 Cross section of 48' x 48' experimental greenhouse.

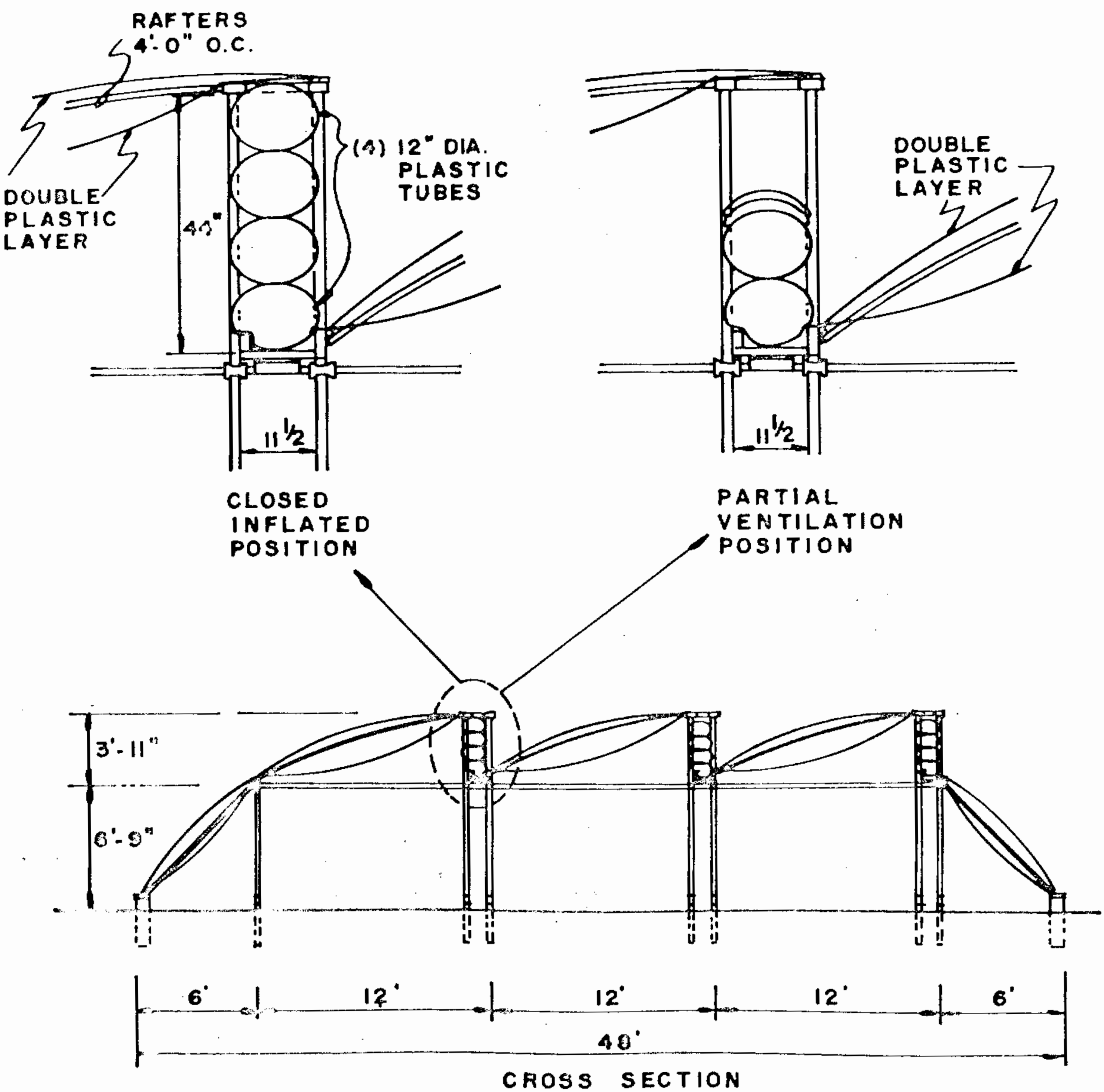
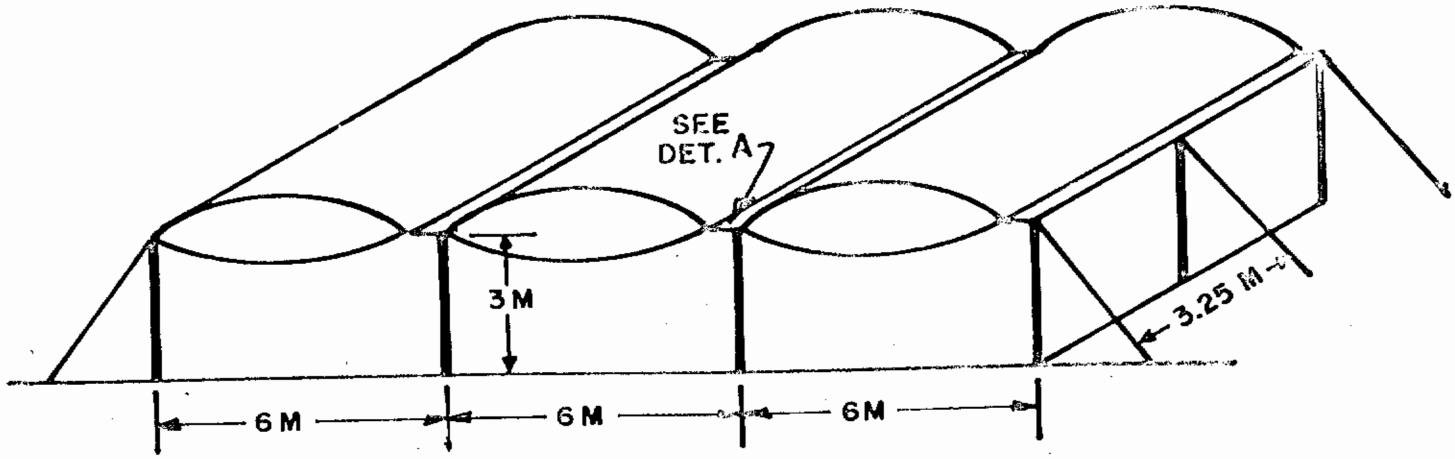
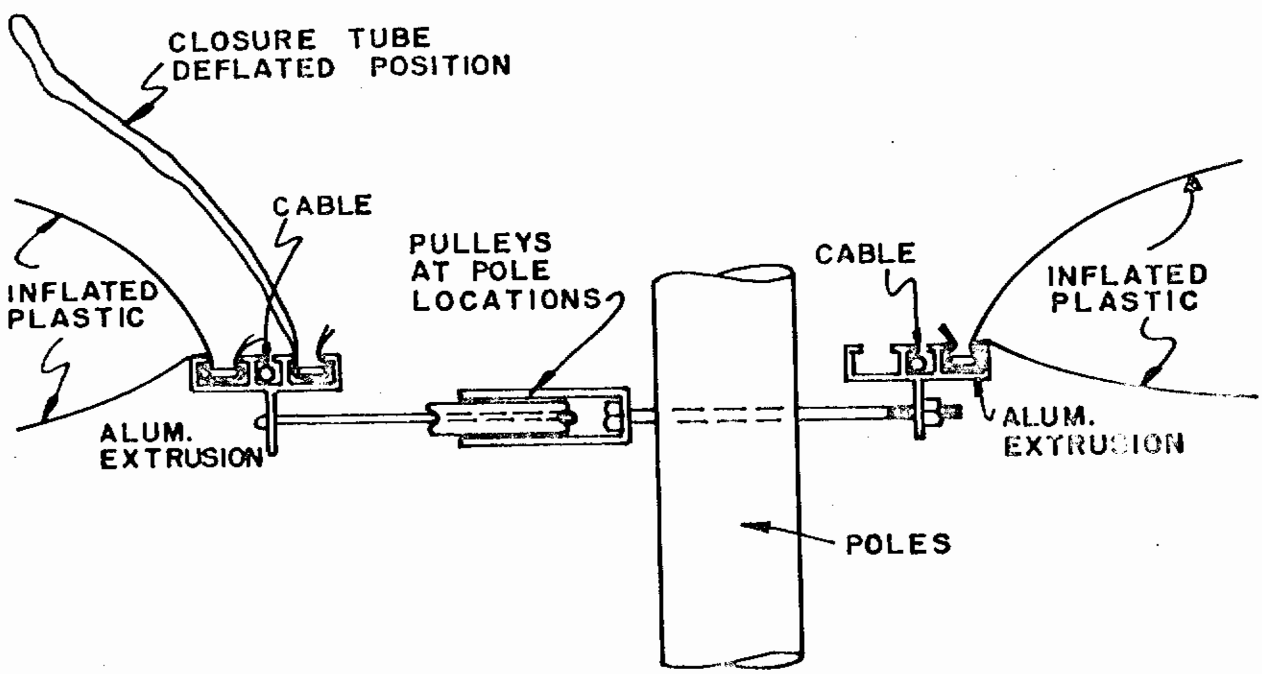


FIG. 2 MONITOR ROOF GREENHOUSE



ELEVATION



DETAIL - A

FIGURE - 3

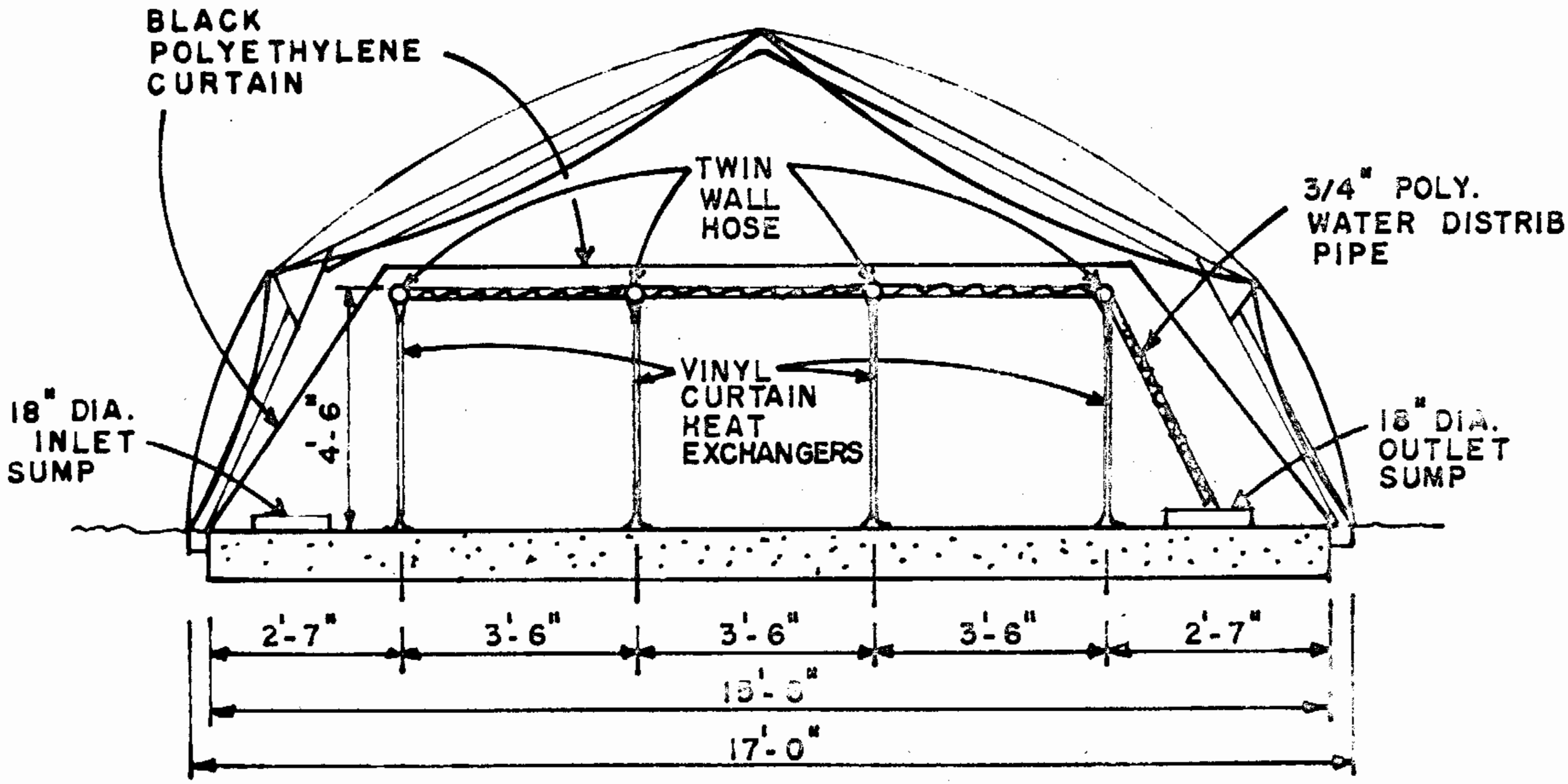
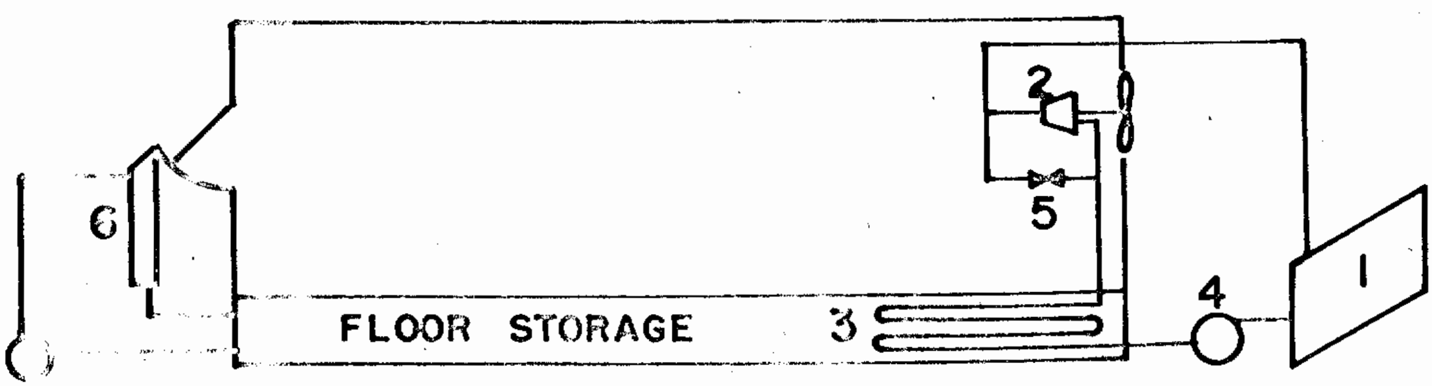


FIG. 4 DOUBLE-LAYER AIR-INFLATED 17' x 24' POLYETHYLENE GREENHOUSE WITH POROUS CONCRETE FLOOR, BLACK POLYETHYLENE CURTAIN AND VINYL CURTAIN HEAT EXCHANGERS

1. SOLAR COLLECTOR - BOILS WORKING FLUID
2. VAPOR MOTOR DRIVES VENTILATION FAN
3. VAPOR CONDENSER IN FLOOR STORAGE
4. CONDENSATE PUMP
5. BYPASS VALVE CUTS OUT FAN
6. EVAPORATIVE COOLING SYSTEM



SOLAR POWERED VENTILATION SYSTEM WITH HEAT RECOVERY FOR GREENHOUSES

FIGURE - 5