# USE OF INFLATABLE ROOF GREENHOUSES AND OTHER POTENTIAL GREENHOUSE ALTERATIONS FOR ALBANIAN VEGETABLE GROWERS

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**Prepared for:**

**USAID - ALBANIA**
**Albanian Agriculture Competitiveness**

**And**

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## I EXECUTIVE SUMMARY:

One of AAC's challenges is to identify marketing opporutnties that will result in improved competitiveness, especially for greenhouse enterprises.

The primary reason for investigating building design was to allow growers to economically extend their growing season later into the fall/winter and earlier into the spring. In the highly competitive climate where first to the market receives a price premium just a few days earlier or later can make a big difference in profit

Achievements:
The STTA completed all tasks according to the SOW.

- STTA undertook rapid appraisal of existing greenhouse structure in order to design prototypes using industry accepted technology
- Two prototype greenhouse models were constructed by AAC clients under the guidance of the STTA
- Workshops and field days were provided to growers on how to construct the prototype greenhouses along with practical tips on how to improve growing conditions within existing greenhouses at no extra cost to the grower.

After the rapid assessment, two different inflated double polyethylene roof greenhouses were considered. The first one used the traditional mechanism for attaching the polyethylene to the building. The second which was newly constructed followed the typical U.S.A. pattern of rolling the polyethylene edges around a piece of lath and screwing them to the wood sides.

The traditional Albanian style house that covers several hundred hectares appeared to allow for this type of inflated construction even though many small air pressure leaks were encountered. It is believed that this problem was primarily due to having to apply the polyethylene in extremely windy conditions and good seals were not developed. Only an air-tight system will result in an almost totally "dead air space" which is needed for maximum insulation value. As air flow through the inflated area increases, the expected insulation value will decrease to near zero.

A second building covered using the common U.S. inflated double polyethylene method is holding pressure very nicely.

.
Although these test building were hastily erected and covered, due to length of the assignment, it is recommended that the "traditional" building be recovered using the same techniques but with slight modifications in polyethylene size and during a non-windy setting.

I fully expect that growers using the traditional greenhouse covering system (mechanical) will be able to use the air inflated system and save considerably on heating costs.

Importance of this assignment:
AAC has laid the foundation for real change in the greenhouse sector by presenting affordable options to commercial growers. An air inflated double polyethylene greenhouse has several advantages:
Heating fuel requirements may be expected to fall by as much as 28% for a well constructed house to as much as 50% for poorly constructed buildings. Other advantages include longer polyethylene life, greatly reduced effects of heavy winds and others.
The retrofits and new construction are nearly the same cost as the model currently in use.

Perhaps more important was the confidence building that occurred with the people encountered on this brief assignment. I observed genuine interest in change during my three workshops and in working directly with the two greenhouse operators. They realized that they can do these improvements themselves without purchasing expensive imported ready-made greenhouses at twice the price or more.
Suggestions:
1) Hold a workshop series on inflated greenhouse construction.
2) Conduct farmer field schools at the two sites so that growers can observe and assess challenges and opportunities.
3) Support field demonstrations that will test the advantages of the new system compared to the traditional greenhouse system.

## II. CURRENT SITUATION:

Greenhouse vegetable producers (tomato and cucumber primarily) have three major productivity-type problems that impact their marketing options. These are associated with 1/ heating their greenhouses in order to increase off-season production, 2/ cooling greenhouses during much of the remainder of the year, 3/ development of a soil nematode control system that if not done will surely put them out of business in the not to distant future.

The Albania costal climate is such that they have potentially a very long growing season. Using it effectively will allow them to expand current and open new markets in the future outside of Albania. Crop quality and yields appear very good with few nutritional problems as compared to many other areas of the world.

This project will speak primarily to the two issues of greenhouse heat conservation as it relates to carrying crops later into the fall and starting crops earlier in the spring and secondly, reducing temperatures in over-heated greenhouses which occurs during much of the remainder of the year.

Whereas plant respiration and general growth is controlled by temperature and continues even at very high temperatures (above 37C), photosynthesis optimum is 27- 30C and begins to slow by 32-33C and stops shortly thereafter. In short, plants in excessively hot greenhouses continue to grow but at the expense of previously trapped energy.

Maintaining cooler temperatures will allow plants to trap more sun energy through photosynthesis and mature in far less time thus increasing total yearly production.

Control of nematodes can be done using chemical soil drenches which are very costly and not allowed in many cases. Solarization (the heating of the soil using only sun energy and heat trapped in closed greenhouses) has only a very limited effect due to the limited depth of heating. Growers may have one or possibly two season before they will need to redo the solarization treatment. Much of the world is turning to various types of container culture in order to eliminate soil borne nematode problems.

## III. TRADITIONAL BUILDING DESIGN:

Hundreds of hectares of polyethylene covered buildings exist. Their general construction is nearly 98 percent identical. Nearly all buildings are of the "ridge and furrow" construction (all building connected to each other thus forming a single structure with many roof sections). Greenhouse posts are made of steel reinforced concrete approximately 15 x 15 cm by 3.2 meters long with about 0.3 meters buried in the soil. Roof bows are 16-17 mm reinforced concrete rod (referred to as "rebar" in the US). They are rough, oxidized steel rods. The rebar bows are welded to rebar that protrudes out of the tops of the concrete posts. All additional iron for either vertical or horizontal support is made of the same materials and all are welded in place.

The mechanism for holding the roof polyethylene in place consists of a 1 inch diameter pipe oriented horizontally in the gutter area between two adjacent roof sections. The polyethylene is clamped to the pipe using small PVC clamps and the entire pipe is then rotated to draw the plastic tight, much like a window blind. The mechanism makes covering the building relatively fast and effective. However, where two pipes are used in a single gutter, a great deal of air leakage (heat loss) can occur. Where a single pipe is used for two adjacent buildings (roof sections), no loss occurs. However, this latter type of construction allows no space to walk thus eliminating the possibility of roof repair. If one roof section needs replacement, two roof sections must be loosened to make the repair. Attachment of the polyethylene at building ends is similarly arranged.

### PROBLEM:

The general construction of the building allows the trellising for tomatoes and cucumbers to be hung directly from the roof supports. In the U.S., this is generally not done. A secondary weight carrying structure is set up totally separate from the building structure. One of the primary reasons for this is that U.S. buildings are usually engineered to carry tremendous snow and ice loads. Adding the load of a tomato crop would greatly affect the size and cost of the structures.

In most greenhouses, no roof ventilators exist thus trapping all heat inside.

Greenhouse sides are usually less than 2 meter high and are opened usually less than one meter.  Moreover, crops are grown well above this height.  The result is that little or no air flow can occur in that ventilation openings are small and the plant's height further block air movement.  Plant row orientation often runs parallel to the open sides thus shutting off all air flow and natural cooling of the building.

In short, nearly every aspect of building design prevents heat loss in cold months but conversely, the effects of excessive summer heating is exacerbated.

Much of the year, greenhouse crops are subjected to excessive heat each day. Optimum photosynthesis takes place from about 27 – 30C and then begins to slow as temperatures increase to 32C and above.  Although this differs with plant species, photosynthesis totally stops with temperatures above 35-37F.

Albanian vegetable greenhouses easily exceed these levels by 10:30 – 11:00 am during much of the year thus greatly restricting photosynthesis and fruit development.  Reduced temperatures will allow crops to trap more sun energy, grow and mature faster and at a higher quality.

**RECOMMENDATIONS:**

- Greenhouses are currently constructed with side walls less than 2 meters. Tomatoes and cucumbers are trellised to above this height thus cutting off much air movement.  Any new construction should be at lease 2.3 m at the eaves.
- Greenhouse end doors are often small.  They should be designed to take up nearly the entire ends of the buildings.  For larger buildings (10+ meters wide) additional ventilators should also be added above the traditional end doors.
- Buildings should be oriented so as to take full advantage of the normal wind direction.
- Planting of crops should also take advantage of normal air flow so that the wind can move into the building and down the rows, not across rows.
- Currently, greenhouse sides are left as wind barriers from the soil to about 80 cm or more in height.  In addition polyethylene is allowed to hang down from the eaves thus blocking potential air movement.  In both cases, the lower material needs to be totally removed and the material at the eaves needs to be totally rolled up and out of the way.  Currently, many houses with nearly 2 meter sides have effective openings of much less than one meter.
- In spring and fall, greenhouse temperatures must be monitored more closely so as to take advantage of optimum photosynthesis temperatures.
- Plant varieties differ widely in the amount of foliage produced.  When selecting new varieties, select not only for what "looks good" but for those varieties that produce high quality without huge amounts of foliage.

**IV. COMMERCIALLY CONSTRUCTED Inflated BUILDINGS:**

Only a few commercially made inflated buildings were found; one from Slovakia and another from Italy. The former uses an air inflation design similar to that used in the U.S. but overall costs must be tremendous due to the size and overall complexity of inflated areas and roof truss (bows) bracing. We were unable to run down the supplier at this writing.

U.S. constructed buildings come in two general models, i.e. inexpensive construction using few if any additional interior roof braces and a second highly engineered and heavily braced building of similar sizes. The highly engineered buildings are designed for heavy wind and snow loads.

The system proposed in this project is the use of an inexpensive building design coupled with an air inflated roof (and sides if desired).

**PROBLEMS:**

The principle problem appears to be initial costs of buildings. In this area where no snow loads are expected, lighter construction should be sufficient. In addition, highly engineered buildings will cost much more to ship, etc.

**RECOMMENDATIONS:**

- It is suggested that light weight buildings made from locally available galvanized pipe/tube can be constructed on site greatly reducing building cost.
- Air inflated, double polyethylene buildings for those desiring to carry crops later into the fall and winter or start earlier in the spring, would be preferred in that their costs would only be slightly higher but would result in considerable savings of fuel costs.

**V. AIR INFLATED DOUBLE-WALLED SYSTEM**: It is recommended that this inflated double-walled greenhouse design be used only where a serious effort is going to be made to lengthen the growing season into very early spring and/or late fall and winter.

**PROBLEM 1:** Lack of heat retention during winter months and buildings susceptible to damage from heavy wind loads.

**RECOMMENDATION:** The use of a double-walled, air inflated structure has several advantages:

- Buildings heat up and cool down more slowly each day than single polyethylene structures. The slower heating allows crops to carry out effective photosynthesis for a longer period each day. Where many tomatoes require 60 days from fruit set to maturity, fruit developing in houses that are excessively over-heated each day may require 70 days to mature. In short, more total production can be expected through out a season if temperatures can be maintained in the optimum photosynthetic region.

- Inflated structures reduce heating often by as much as 28%. For old, poorly maintained structure, this heat saving can be as much at 50%.
- Excessive wind destroys plastic through its constant movement. Inflated building move only slight even in winds of 70 kph thus greatly reducing potential damage and crop loss.
- With ridge and furrow buildings, gutters sufficiently wide enough to walk in are normally used. This allows for damaged sections to be repaired easily without releasing other roof sections as in traditionally used buildings.
- It is estimated that recovering time of the two types of structures will be somewhat similar.
- Double polyethylene causes an added measure of light diffusion as it enters the building. This diffusion can promote higher light intensities on foliage otherwise hidden in shade thus again increasing total photosynthesis.
- Greater light diffusion reduces heating of bow and other structural parts.

**PROBLEM 2:**

The small inflation fans run 24 hours a day. Where electricity outages are common, another approach is useful.

**RECOMMENDATION 2:**

Obtain a "blower" type fan from a 12 volt truck heater. Attach a small "trickle charger" (battery charger) to the electric system, then to a 12 volt car or truck battery and then attach the battery to the blower. While electricity is ON, the system remains running and charging. When electricity is OFF, the blower will run off the battery power. Hopefully, the system will be restored in a few hours and nothing will shut down in the interim. In extreme cases, soft ropes can be looped over the greenhouse roof in several places to help tie down the polyethylene during windy conditions.

## VI. CAUSES OF POLYETHYLENE FAILURE:

Several environmental factors cause premature polyethylene failure.

- Greenhouse polyethylene contains an ultra violet inhibitor that allows products to often last 4 years or more.
- As mentioned above, the destructive effects of wind are almost totally eliminated when the inflated design is used.
- A third and often unrecognized factor in polyethylene failure is heat! Excessive heating of long lived polyethylene can cause it to fail in a single season. Painting all structural members receiving direct exposure to the sun with "white latex paint" greatly reduces heating. This is accomplished by reflecting the light away from the painted objects as opposed to allowing these light rays to change to infra

red heat energy. Painting should only be done using a water base white latex paint, never use oil base paint!

- Use of double polyethylene, as mentioned above causes more light diffusion and thus heating of structural members is reduced.

## VII. COLD PERIMETER SOILS IN WINTER:

### PROBLEM:

Growers complain that perimeter greenhouse soils become excessively cold in winter thus greatly slowing crop development. This is a common problem all over the world when attempting to grow soil produced crops in winter. As temperatures lower in winter, cold rapidly enters the greenhouse via wet soils and greatly slows crops growing adjacent to the perimeter.

Various methods of insulating the soil have been used but all are quite expensive and require a great deal of labor to install. For example, Closed Cell Styrofoam has been buried along outer greenhouse walls….labor intensive and costly.

A number of variables are at work, i.e., temperature differential between inside vs. outside soil, soil type, degree of moisture normally in the soil, sensitivity of the crop to cold temperatures, etc.

### RECOMMENDATION:

Since Albania has a great deal of open weather during the winter months, the following is suggested:

**Minimal Effort:**

- Run 2-3, 27 mm (3/4 inch) black polyethylene pipes parallel to the perimeter side walls and in the space overhead of the crops.
- Attach wires overhead and tie the black polyethylene pipes to the wires.
- If the water volume through individual pipes is kept slow, 10-12 liters per minute, friction loss (pressure) will be very small.
- This area of the greenhouse is the warmest at any one time and often has excess heat (temperatures over 30C).
- Run similarly sized polyethylene pipes near the root system of the crops adjacent to these outer walls. Pipes buried in the soil a few cm will be much more effective than those left on the soil surface.
- The warm water collected from the upper areas above the crops can be circulated by small pumps and the heat will be lost into the soil.
- Because of the multiple factors involved, this is offered as a suggestion without a recommendation as to the number of pipes needed to collect sufficient heat. It is

offered, however, that if water speed is as above suggested, only one polyethylene line will be required to maintain the root system at or above the temperature of other crops in the building.

**Extended Effort:**

- In this case, it is recommended to use the system as above but also run one additional line per row of crop.
- Run this line directly overhead of the crop and attach it to a wire attached at both ends of the greenhouse.
- As above, keeping the water flow to 10-12 liters per minute will keep the friction loss to around one pound per square inch or very low.
- Next, bury the lower length of pipe directly under immediately adjacent to each row of crop.
- Caution: Take care not to overheat roots. Most crops do not want root temperatures in excess of the leaf temperature. On the other hand, equal temperatures can be tolerated by many crops.
- Caution: Only the perimeter heating line should be left ON on cloudy days. Rapid growth should not be forced to occur when insufficient sunlight is available. This will only weaken the crop and in crops such as cucumbers will cause abortion of many flowers.

## VIII. DAILY ACTIVITIES AND ACCOMPLISHMENTS:

Two inflation fans, mounting brackets and polyethylene tape were brought from the U.S. so as to insure having these items immediately on hand. They can be purchased from any number of western European greenhouse suppliers.

**A. Grower Meetings**: Three growers meeting were held in order to discuss and demonstrate current construction techniques, the double polyethylene inflated system and other construction and production related items i.e. photosynthesis, overheating, building design and ventilation, root knot nematodes, and several other items.

Individuals attending:
Meeting 1. 18 men, 1 woman, 4 DAI men
Meeting 2 18 men, 2 men USAID, 1 woman USAID, 4 men DAI
Meeting 3 10 men (local), 5 men from northern Albania, 2 men DAI

**B. Area and Facility Evaluation**: Many locally made greenhouses were visited and their traditional structure and building techniques considered. Essentially, almost no growers use single, free standing buildings. All are multiple units joined together and referred to as “ridge and furrow” construction.

**C. New Contract Construction Requirements**: Nearly every greenhouse is a minimum 1000m2 unit consisting of 4 to 10+ greenhouse units joined together. Much time was spent finding materials needed for construction and covering of two demonstration buildings. In as much as we were not capable of constructing a large unit, my DAI Regional Manager and translator, Pirro Raspushi did a great job in convincing a local school to allow us to cover their greenhouse. In addition, he persuaded a company in the Berat region to "immediately" build a new structure and cover it using our recommendations. Both of these activities required a great deal of time, tact, persuasion and energy.

**D. Commercial greenhouses:** One greenhouse from Italy and a second from Slovakia were visited. The Slovak greenhouse was double walled air inflated and quite expensive, about 27,000 euros per 1000 m2. The Italian house was quoted at about 22,000 euros per 1000 m2.

**E. Traditional Greenhouse**: A non-covered greenhouse frame was located at a school just outside of Fier in which horticulture is taught. This building uses the traditional method of attaching polyethylene i.e. horizontal rollers (see later). The double wall inflated system was attached using their traditional mechanisms.

Since the polyethylene was applied in the midst of an approximately 25 kph wind, the finished product was not as "clean looking" as if it had been applied when no wind was occurring. The inflation mechanism is working but at a reduce level and this is due to many small air pressure leaks. I have no doubt that this problem can be overcome if the polyethylene is reapplied under quiet wind conditions. Time constrains made application at this time and under these conditions requisite. Again, reapplication, due to current time constraints was not immediately possible.

## IX. CONSTRUCTION EXPENSES:

**A. Expenses: School Greenhouse**:

When covering the existing building (5 x 20 m) at the school, the only differences in costs as compared to their traditional houses would be the fan, mounting bracket and the added sheet of polyethylene. Under proper (wind) conditions, the labor requirements should be nearly identical.

| | |
|---|---|
| Fan and mounting bracket: | 4,578 lek |
| Polyethylene: | 19,219 |
| Poly tube (manometer) | 50 |
| White latex paint | 450 |
| Paint roller, handle, brush | 475 |
| Rope | 500 |
| Total Cost: | 25,272 /100 m2 or |

The above is what was actually spent but the only expenses not incurred by any other type of house are those related to the second layer of polyethylene, manometer and fan (blower).

| | | |
|---|---|---|
| Second layer of polyethylene: | 19,219 / 2 = | 9,610 lek |
| Blower (fan) and bracket: | $82.25 x 76.30 = | 6,276 lek |
| | Total = | 15,886 lek |

Of the above costs, the polyethylene is the additional layer and the blower and mounting will last very likely for 7-8 years or more.

Comparing amortized costs, the equivalent would be more like the following:

| | |
|---|---|
| Fan and bracket 6,276 / 8 years = | 785 |
| Polyethylene: one added sheet = | 9,510 |
| Total added cost over a single sheet of plastic…………….. | 10,295 |

Per 100 m2 or 102,950 lek for 1000 m2 or $1,350 per 1000m2 a value much less than what would be saved in fuel costs.

**B. Air Inflated Double Polyethylene Greenhouse**: A greenhouse vegetable producing family, Zeka and Zenun Astrit located in the Berat region agreed to erect a 5 x 30 meter (150 m2) pipe frame building similar to those used in the U.S. The building was covered using the inflated double polyethylene system and as recommended (see later), 2+ meter sides have been used. Again, due to time constraints and weather, the building was not totally completed but the inflated roof section is in place and functioning as advertised.

Expenses: Astrit Air Inflated Greenhouse:

All tube galvanized with exception of last item.

| | | | | |
|---|---|---|---|---|
| Fan and mounting bracket | $82.25 x 76.3 = | | 6,276 | |
| Tube 1.5" | 19 | 3000 | 57,000 | |
| Tube 1.25 | 1 | 2600 | 2,600 | |
| Tube 1 | 15 | 1000 | 15,000 | |
| Tube 0.5 | 12 | 1800 | 21,600 | |
| Tube 1 (black) | 3 | 1250 | 3,750 | (black was purchased due to shortage of galvanized pipe) |

| | | |
|---|---|---|
| Polyethylene | 182 kg at 320 lek/kg (2/3 used) 58,240 x .67 = | 39,021 |
| Polyethylene | 2 meters | 6,000 |

| | | |
|---|---|---|
| Wood frame | | 13,100 |
| Wood strips (poly mounting) | | 2,600 |
| Bolts, nuts, washers | | 1,600 |
| Poly tube (manometer) | 0.5 meter | 50 |
| White latex paint | | 450 |
| Paint roller, handle, brush | | 475 |
| Rope | | 500 |
| | | |
| Total Cost: | | 170,022 lek/150m2 |

Here again, many of the costs are similar to all buildings. The only major differences would be the added layer of polyethylene for the roof sections and probably the need for additional blowers.

If this was figured as the cost of 10 buildings (1000m2), each 5 x 20m, (not 30m as above) all costs would be greatly reduced. For example, a single free standing building as above uses 2 sets of side posts whereas a ridge and furrow unit of 10 buildings will only use a total of 11 sets instead of 24 as would be needed for 10 single building. Plastic would also be greatly reduced as well as other items. In short, it is difficult to compare the cost of a single 100m2 building with a 1000m2 ridge and furrow unit.

If the above polyethylene is considered to be 10 m wide and 68 m long or 680 m2 at 39,021 lek = 57.4 lek per m2

A 1000m2 building would use approximately 6 x 48 meters per each of the 10 units or 2,880m2 x 57.4 lek = 165,312 lek for the 1000m2 building + the cost of 5 blowers/brackets = 165,312 + (6,276 x 5 blowers) or 165,312 + 31,380 = 196,692 lek per 1000m2

196,692 / 122,3 /Euros = 1,608 Euros per 1000m2 for added polyethylene and blowers. And to further complicate matters, the blowers will likely last for at least 8 years and the polyethylene for 4 years.

Using 122.3 lek per Euro and 76.3 lek per dollar 1,608 Euros per 1000m2 seems like a very small price to pay for the heat savings as well as the many other advantages of the air inflated system.

**C. Solar Collector:** A small solar collector was made (1 x 2 meters) in order to demonstrate that growers could construct a similar but larger unit where hot water could be used under plants such as for seed germination and propagation of cuttings.

Expenses: Solar Collector:

| | | |
|---|---|---|
| Polyethylene | 2 meters | 600 |

| | |
|---|---|
| Black poly (used materials = free) | 00 |
| Wood frame 8 meters of 3 x 3 cm) | 500 |
| Screws and drill head | 500 |
| 300 mm black tubing (20 meters) | 300 |
| Valves (2) | 200 |
| Total cost: | 2,100 lek |

## X. FOLLOW-UP ACTIVITIES AND OTHER ISSUES:

### A. Existing Greenhouses:

- During this summer, periodically check if growers are doing anything to open their structures to promote greater air flow.
- Are any growers actually measuring temperatures in their greenhouses?
- Try to estimate the number of visits to the air inflated buildings. Post sign-up sheet of those viewing and possibly contemplating this type of structure.
- At monthly meetings, survey if anyone is going to try to take their crops later into the fall or earlier into the spring.

### B. Other New Challenges:

**1.** When visiting the JORDIL irrigation company in Fier, we were asked if there is some way to have someone trained in irrigation engineering for homes and yards. They are looking at the potential of large sales of home irrigation equipment in the future.

USAID might be interested in supporting such training. Ohio State University has a program in which students from various places in the world are placed with businesses for training. Visa's of course are required and OSU assists in selecting businesses, health insurance and various logistical requirements.

The student and host pay an initial fee, health insurance for one year and student and host companies take care of finding housing facilities, set up wages, etc. For more information contact:

Michael Chrisman
Assistant Director, International Programs in Agriculture
Director, The Ohio Program
Suite 360, 700 Ackerman Rd.
Columbus, OH 43202-1559
614.292.7720 phone
614.688.8611 fax

**2.** Bumble bees are excellent pollinators in tomato crops. A potential project would be to bring someone in to show how to raise and market these bees.

**3.** A related project to the above would be to bring in an individual to teach the raising or *Encarsia.* This is a small wasp that parasitizes the insect, White Fly!

## XI. APPENDICES:

I. Attached Picture File

II. Use of Polyethylene Greenhouse Coverings

## Appendix II: USE OF POLYETHYLENE GREENHOUSE COVERINGS

In the late 1950's greenhouse growers began using two layers of polyethylene film as a replacement for glass. The following information is some general comments concerning the use of double layered, air-inflated buildings.

- One of the principal problems with plastic films is that they tend to tear and break up in the wind. Air inflated, two layer houses don't move even in high winds because they are essentially balloons.
- The dead air space between the two sheets often results in as much as 30% savings on heating cost.
- Today's coverings often contain several additives. These additives can result in longer life; reduced surface condensation of water; inhibition of infrared radiation and other characteristics. Some additives may even affect plant growth.
- Most of the current polyethylene films will last 4 years and sometimes longer in full sun.
- These films come in a wide array of lengths and widths. Widths up to 12 m, or 40 ft. and larger.
- Several thicknesses' are available: 0.004 (4 mil) = 0.010 mm, 0.006 mil (6 mil) = 0.015 mm approximately.
- Growers normally use a small squirrel cage (blower type) fan to force air in between the two sheets. The fans use as little as 60 watts of power and run continuously.
- The pressurized area is maintained at a pressure of about 0.25 - 0.33 inches of water. This is about 8 - 10 mm of water. This can be easily measured by constructing a small manometer or air pressure gage. See later.
- Inflation fans are equipped with a small door that can be used to adjust the amount of air entering the dead air space. Once proper pressure is developed, the door is slowly closed to the point where the fan maintains the proper pressure. A pressurized plastic roof will have the feel of a firm pillow.
- Depending on the size of buildings, often only a single fan is used. Large building…may have 2 fans installed.
- The plastic sheets are usually attached only at the edges of the building, i.e. ridge (for very large buildings), eave, ends of the gable or Quonset roof.

- The attachment is made by placing the two layers of plastic in a small "C" shaped channel. Then a spring loaded wire is place on top to hold the plastic in the channel. (See drawings later).
- The locking devise must be made so as to make a fairly tight "air seal" around the total perimeter of the sheet of plastic. No holes are made at the opposite end of the house to cause an air circulation. A totally dead air space is most effective for insulation purposes.
- Plastic can also be attached to the building by rolling a small strip of wood in the plastic edge and then screw or nail the wood strip to the building structure. The wood strips are often 3 cm wide by 1 cm thick and up to 2 meter long. See later.
- Air inflated buildings usually remain intact even in 70 mile per hour (mph) = 112 km/hr winds. If anything breaks, it is usually the greenhouse structure that goes first.

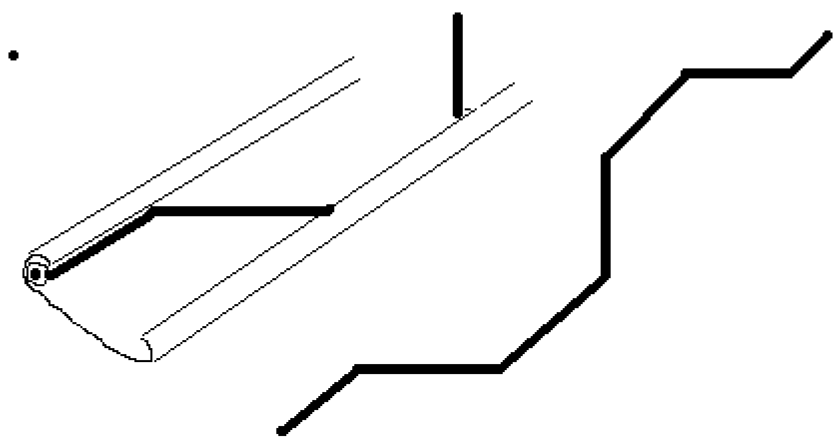
The following suggestions are listed if one is to refurbish a steel frame glass or fiberglass covered building.

- Remove all glass, fiberglass or other covering material.
- Remove every other roof bar (rafter that hold glass). In areas of heavy snow load, leave all roof bars in place.
- Determine size of plastic needed and determine availability.
- One must use greenhouse grade plastics. Cheap construction grade plastics may only last a few months.
- Place wood boards (4 x 10 cm) along edges and frame in the ends of building in order to anchor plastic locking strips. See drawings.
- Excessive heat also damages plastic. For this reason paint all surfaces that touch the plastic with white LATEX paint. Never use oil base paint in as much as it will damage the plastic. Sunlight when hitting a dark object changes to infra red heat energy and this heat can cause plastic to fail in only a single season. White surfaces reflect the light away and greatly reduce any heating effects. See later.
- Anchor the polyethylene mounting strips to the side boards of the greenhouse. When using Aluminum locking strips, screws are used about every 20 cm or 10 inches.
- Choose a calm day - no wind! Most growers cover buildings early in the morning when air movement is minimal.
- Lay out the two sheets lengthwise of the building. For a 30 m building, tie ropes every 5-6 m to the plastic and throw the ropes over the building. Using the ropes, gradually pull the plastic up and over the building. Have someone stationed inside with a long handled broom. If the plastic appears to get caught, they can life it from the inside and help keep it moving.
- When it is pulled over, immediately anchor the bottom edge in a few spots. Final anchoring should start at the top of the end rafters or bows and then begin anchoring the sides beginning in the middle of the house and go both directions. If wind begins to increase, don't start another sheet until wind speed drops to near zero.
- Plastic can be pulled over the building as a single or double layer. When the building is wide, two layers can be quite heavy and difficult to pull. In this case, pull a single layer and then immediately pull up the second sheet.

- Install inflation fans immediately and inflate the roof.
- Install one manometer or air pressure gauge. Once proper pressure is attained, begin closing door over fan air intake until proper pressure is maintained. When the proper pressure is achieved, lock the small door with a piece of tape to prevent movement due to vibration. Once this pressure is developed, most people can "feel" of the roof and then use this technique to set the pressure on other roof sections.

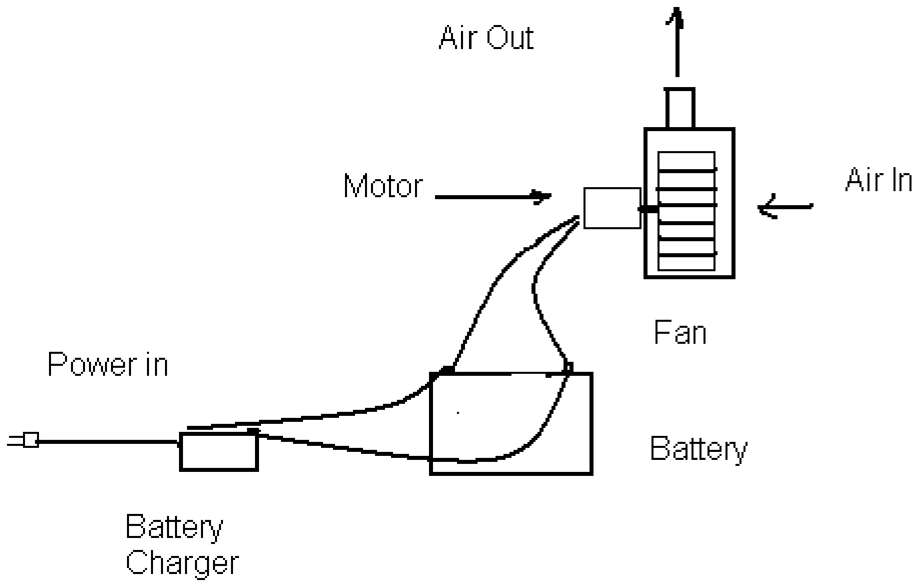
As indicated in the drawings, several different types of plastic anchor strips are available. Advantages and disadvantages between the types are small. The speed of application is very important especially when many hectares of roof need to be covered. Check speed of application as well as cost.

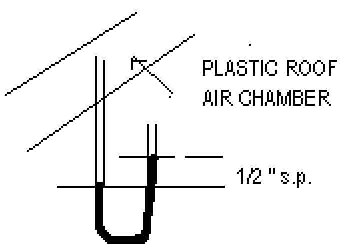
As mentioned above, ultra-violet inhibitors are added to all greenhouse plastics because sunlight and wind can destroy the plastics very quickly. Little is ever said about heat. Most plastics are injured by extreme heat. For this reason, painting of dark wood or any other dark material immediately under and touching the plastics is absolutely essential. For this reason, paint all exposed surfaces with white LATEX paint. Surfaces on south and west sides often receive the most direct sun and are therefore most critical.



WIRELOCK SYSTEM

Pressurized air located between the two plastic roof sheets pushes down on the water in the manometer. When 1/4 inch (8 - 10 mm) static pressure is reached, there is sufficient pressure to hold up the roof . In very windy areas a grower may increase the pressure to 10-12mm.




MANOMETER

TO FORM AIR LOCK, ROLL 2 LAYERS OF PLASTIC AROUND WOOD STRIP, USE 3-4 SCREWS PER METER