CONTROL ELEMENT CONSTRUCTION AND INSTALLATION FOR AN AUTOMATED GREENHOUSE.

by

Jean Gastaldi

Report submitted in partial fulfillment

for the course 336-490 D

April 1984

DEPARTMENT OF AGRICULTURAL ENGINEERING

MACDONALD COLLEGE OF MCGILL UNIVERSITY

Saint-Anne-de-Bellevue

Quebec H9X 1C0

TABLE OF CONTENTS

ABSTRACT

This project dealt with a greenhouse operation. The term automation is given to any operation that is accomplished without human intervention, once functioning. This was achieved through the use of a computer. It works by receiving signals from three different sensors installed throughout the greenhouse. These signals help the computer make decisions during operation.

Control elements were not already present in the greenhouse, so they had to be constructed. These elements are two humidifiers, which are implemented to control relative humidity. As well, a frame had to be built and screwed into a concrete slab in order to hang each humidifier. After construction and installation had been performed, adjustments were made. The design of the humidifier was then modified so that it could perform at its optimum.

ACKNOWLEDGMENTS

The author is grateful to Dr. Robert Kok for his patience and weekly meetings throughout the project.

Special thanks also to Noreen Finnegan for her help in making up this report.

Finally a big "thank you" to Gaetan Desmarais for his help in taking photographs and devotion in giving me a hand when I needed it.

LIST OF FIGURES

I INTRODUCTION

This project was part of a master's degree research program on which Gaetan Desmarais was working. It consisted of automating a greenhouse. The first thing to do was to acquire a computer capable of handling operation control. Sensors for relative humidity and temperature had to be installed. This project involved building and installing control elements. These control elements were humidifiers which were used to control relative humidity. Initially, no such elements were in place, and relative humidity was varying according to both weather and season. Two steel frames had to be constructed, and on each one a heater and an evaporator were hung. To operate both humidifiers, a water supply for each was installed.

The way the greenhouse will eventually function is straightforward. The various sensors will continuously take readings of temperature and relative humidity. These will be fed into the computer as signals They will then be compared to the desired setting and from this comparison, the computer will send another signal back that will turn a control element on or off. This technique allows precise control. The atmosphere in the greenhouse will remain unchanged over the seasons, resulting in better growing conditions for the plants.

II LITERATURE REVIEW

Greenhouses are used to control or modify many of the environmental factors affecting plant growth. If the environment is controlled, crops can be produced for specific market dates and the quality can be enhanced by eliminating many of the variations and hazards associated with weather. Temperature can be regulated with a certain degree of precision. Damage from wind, rain and freezing are avoided. Injury from plant disease and insects is reduced, but not eliminated. The precision with which the environment is regulated depends on the ability of the grower to manage the greenhouse's equipment and control.

A greenhouse is a structure covered with transparent material that utilizes solar radiant energy to grow plants. Most greenhouses are heated, ventilated, and cooled for temperature control. Unheated greenhouses are more common in Europe and Japan than in the United States or Canada. Greenhouses may be covered with glass or glass substitutes. They are called plastic houses or plastic greenhouses when covered with film plastic, and fiberglass greenhouses when covered with glass fiber reinforced plastic panels. Unless otherwise specified, greenhouse is synonymous with glasshouse.

There are three basic types of greenhouses: (1) the lean-to type, (2) the detached or single-span greenhouse and (3) the ridge and furrow greenhouse. The roof of a lean-to greenhouse slopes in one direction only and is attached at the ridge to a building or another greenhouse. Relatively few lean-to greenhouses are used in commercial production of flower crops. The detached greenhouse stands independently from other greenhouses, but it may be connected to others by a corridor or attached at one end to a workroom building. It is an "even-span" greenhouse if the rafters are of equal length, and an uneven-span greenhouse if the rafters of one roof slope are longer than the rafters of the other slope. A "ridge and furrow" greenhouse consists of several greenhouses connected at the eaves. A special structural member known as gutter replaces the eave plates where two houses are joined. The terms "multispan house" and "gutter-connected house" are synonymous with "ridge and furrow" greenhouse. The interval walls beneath the gutters are generally omitted in contemporary ridge and furrow greenhouses. Only the posts that support the weight of the roof remain.

The 1970 U.S. Census of Horticultural Specialties (U.S. Bureau of the Census,1973) recorded 273,149,940 square feet or 6270 acres of commercial greenhouse space in the U.S.. In Canada, there are 40,138,766 square feet of commercial greenhouse. Ontario leads with 23,818,526 square feet, followed by British Colombia with 5,148,723 square feet. With its 4,835,120 square feet, Quebec is in the third position (1982 Statistics).

In the States, approximately 105.5 million square feet or 38.6 % were covered with glass substitutes, either film plastics or glass fiber reinforced plastic pannels. The census data shows that plastic fiberglass greenhouses were the only types constructed during the past decade. Apparently, glass covered greenhouses in urban areas were being torn down faster than they were replaced, and most of the new construction was covered with glass substitutes. The Netherlands leads the world in greenhouse area with 18,456 acres, Italy is second with 12,700 acres followed by the British Isles, West Germany, France and Belgium. The U.S. and the Britsh Isles have about the same area in greenhouses. Russia and Rumania have most of the greenhouse area in Eastern Europe. In the U.S., approximately 78% of the greenhouse area is used for the production of flower crops, 9% for vegetables and the balance in nursery and seed crops. In contrast, vegetable crops command 2/3 to 3/4 of the greenhouse space in most European countries. The exceptions are West Germany and the Scandinavian countries, which devote more than 1/2 of their greenhouse area to ornamental crops.

III OBJECTIVE

The overall objective of this project was to automate a greenhouse. The automation, consisted of controlling both temperature and relative humidity. To achieve this, control elements were constructed and installed, which allowed relative humidity to be adjusted.

IV INITIAL CONDITIONS

Before any modifications took place, the greenhouse was equipped with two propane gas heaters, one located at each end. These heaters were hanging from the frame of the structure and were a possible risk regarding structural weakness. In addition, there was no control over relative humidity.

Another element in place was a fan, which was present in order to ventilate the greenhouse (see fig. 1). When the project started, this fan was not in working order and the interior temperature on a warm, sunny day approached 35 C. The water in containers, used for lettuce experiments, was evaporating and therefore the relative humidity was high. Also, during the night, the temperature dropped. Our goal was to build and install control elements to control the atmosphere in the greenhouse with such precision that it would not vary with time or weather conditions.

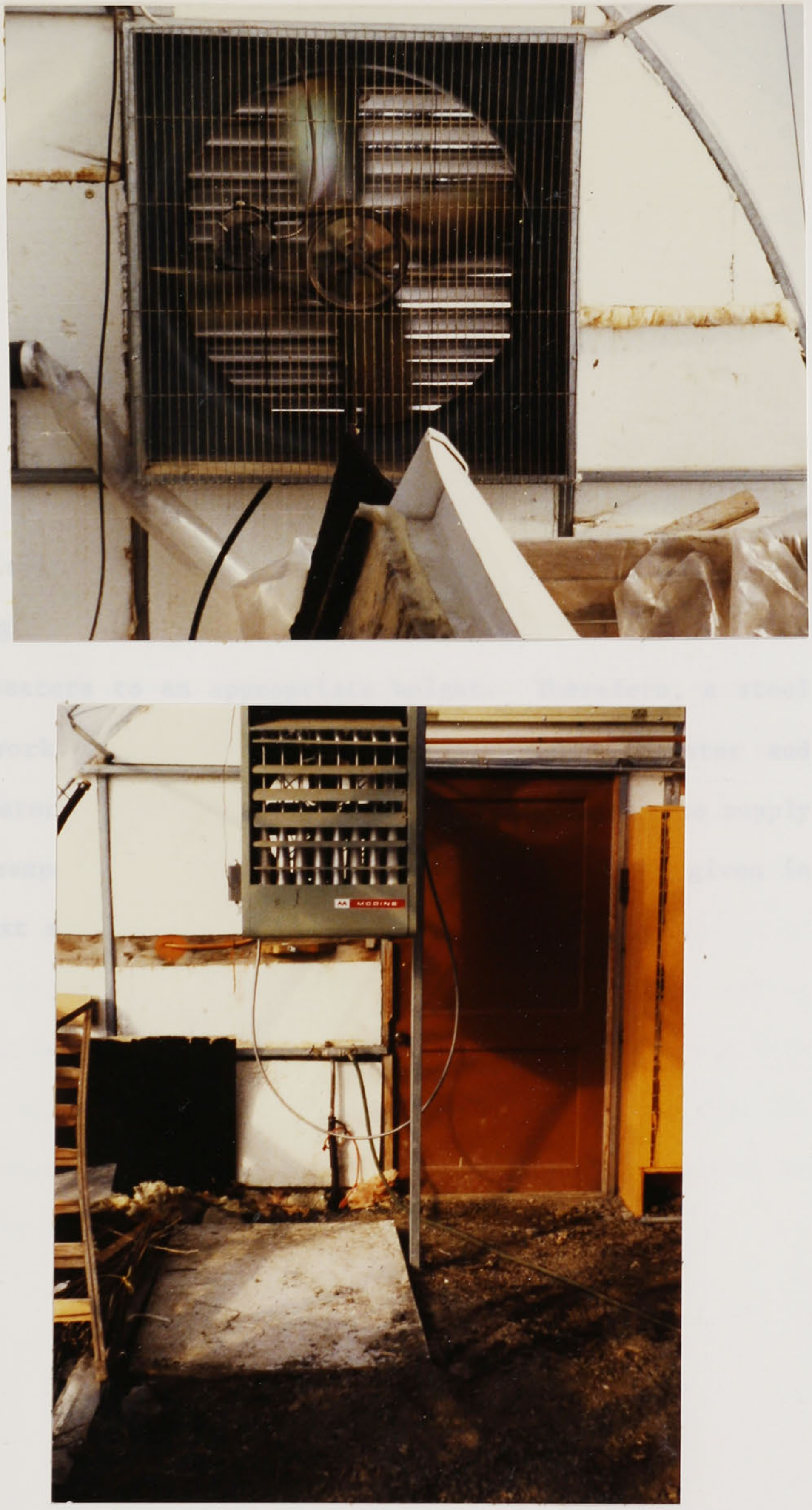

Fig. 1 Initial conditions of the greenhouse.

V MODIFICATIONS

The first modification that took place was the building of two humidifiers, each coupled to one heater hanging from a frame. The second modification was to lower both heaters to an appropriate height. Therefore, a steel framework was constructed to support both heater and evaporator. Later, a water line had to be installed to supply each evaporator. Details of the modifications are given in the next section.

VI DESIGN CRITERIA

i) Steel framework

The constructed frame had to be strong enough to support both heater and humidifier. Steel or wood were the two convenient materials to use. Steel was chosen over wood because of the strength it provides to the structure.

Another advantage is that steel can be arc welded. Since the frame is to operate in damp conditions, steel was subject to rust. So,to eliminate any rust problem, a rust paint coating was applied to the steel. The frame was made out of one inch square steel tubing, and painted bright yellow (see fig. 2). Two concrete slabs were poured and frames were fasten to these by means of screws.

Fig. 2 Pictures of the frame.

ii) Heater

Since the heaters were already in place, the work involved here was to lower them by 0.90 m (see fig. 3). The gas company was called in to do the proper modifications since a license was required to work on the associated propane pipe lines. As previously mentioned, the purpose of lowering the heaters was to allow the free operation of the night curtains.

Fig. 3 Pictures of the heater.

iii) Humidifier-evaporator

This control element was sized in such a way that it could operate at extreme conditions. The material chosen for the evaporator was galvanized sheet metal, since it is rust resistant. Because the humidifier will always be working in damp conditions, sheet metal, among many materials, was the most suitable one.

The existing fan blower, which was part of the heater, is used to blow either hot or warm air through the evaporator. Water is sprayed and then evaporated. When relative humidity alone is to be raised the blower will be turned on. If at the same time heat is to be added, both the blower and the heater will be switched on.

The evaporator consists of an open-end rectangular box. The spraying takes place in the first section, in order to prevent water from going out into the greenhouse. In addition, baffles were built, as shown in fig. 4 . They have been installed at an angle to ease air flow. The baffles play an important role: they collect the non-evaporated water and direct it back to the tank. By adding these baffles, the chance of workers being accidentally wetted is reduced. The second advantage is that the formation of muddy areas on the ground, directly under the end of the section, are avoided.

The excess water is carried back to the tank (see fig. 4). This later becomes the water supply for the high pressure pump. The best location of the pump is below the tank. This facilitates the priming of the pump.

The next component to be designed was the water tank. Water had to be enclosed to prevent its evaporation when only heat is required, so that hot air passing through the humidifier would not charge itself with humidity. A perforated floor was designed, as shown in fig. 4, to allow water to drain back into the tank and thus achieve maximum protection from evaporation.

To minimize costs, it was necessary to make the best use of the sheet metal. Sheet metal comes in 0.9m by 2.4m standard size, and any other size becomes more expensive, per square meter. Fig. 5 shows an efficient way of cutting the various pieces for the evaporator. After the cuts are made, there is at most 0.1 square meter left out of a 2.16 square meters sheet. The way the humidifier is mounted also helps keep costs down. One piece of sheet metal is folded to make the two sides and the bottom, thus avoiding soldering down the two edges. By folding the sheet metal, we avoid soldering those two edges, thus obtaining at the same time a waterproof joint. The two ends of the tank were then soldered and the top of the rest of the box was bind-riveted. Bind rivets were chosen since they are cheaper than solder. They also offer the advantage of being easier and faster to work with.

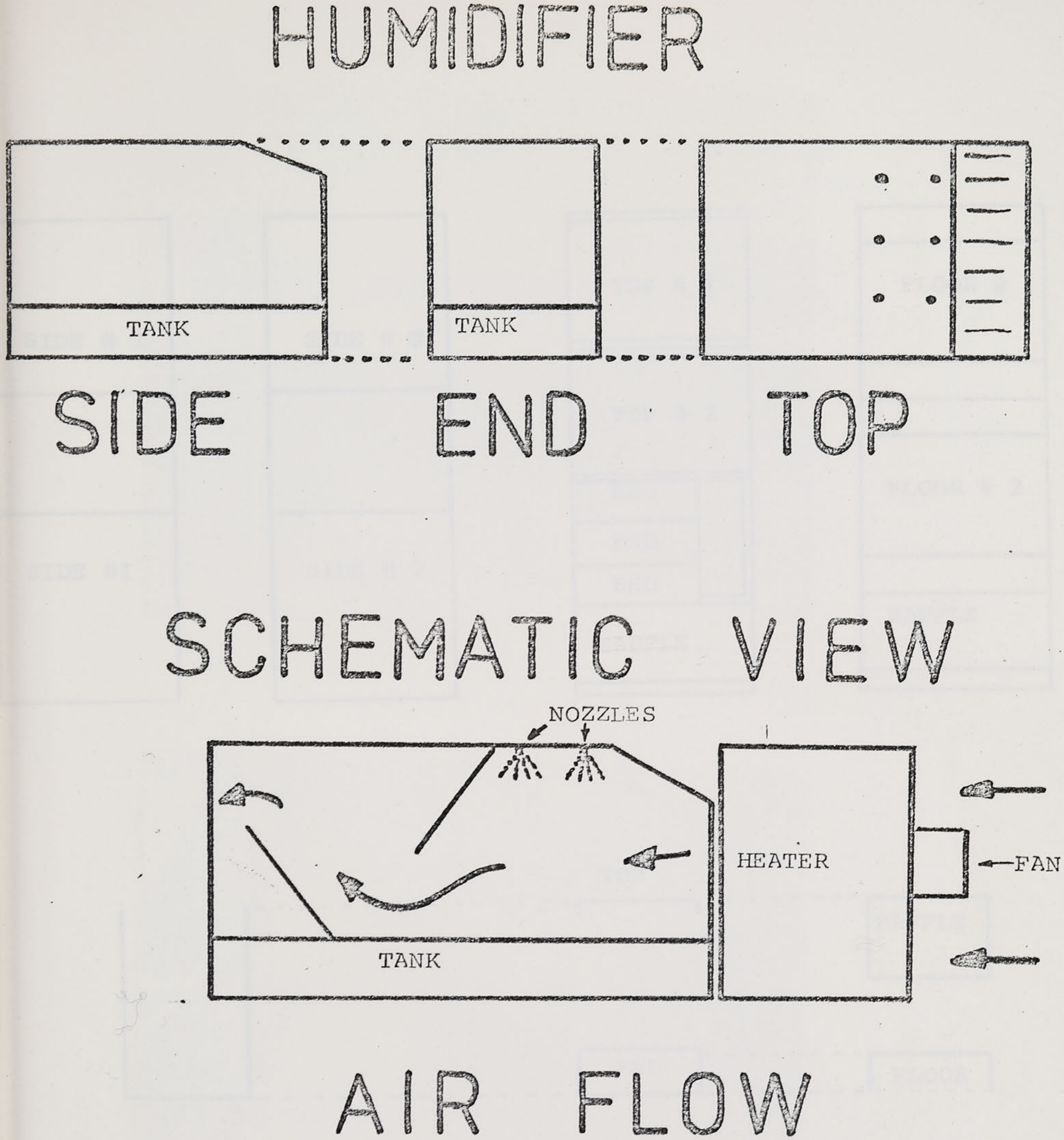

Fig. 4 Schematic view of the evaporator.

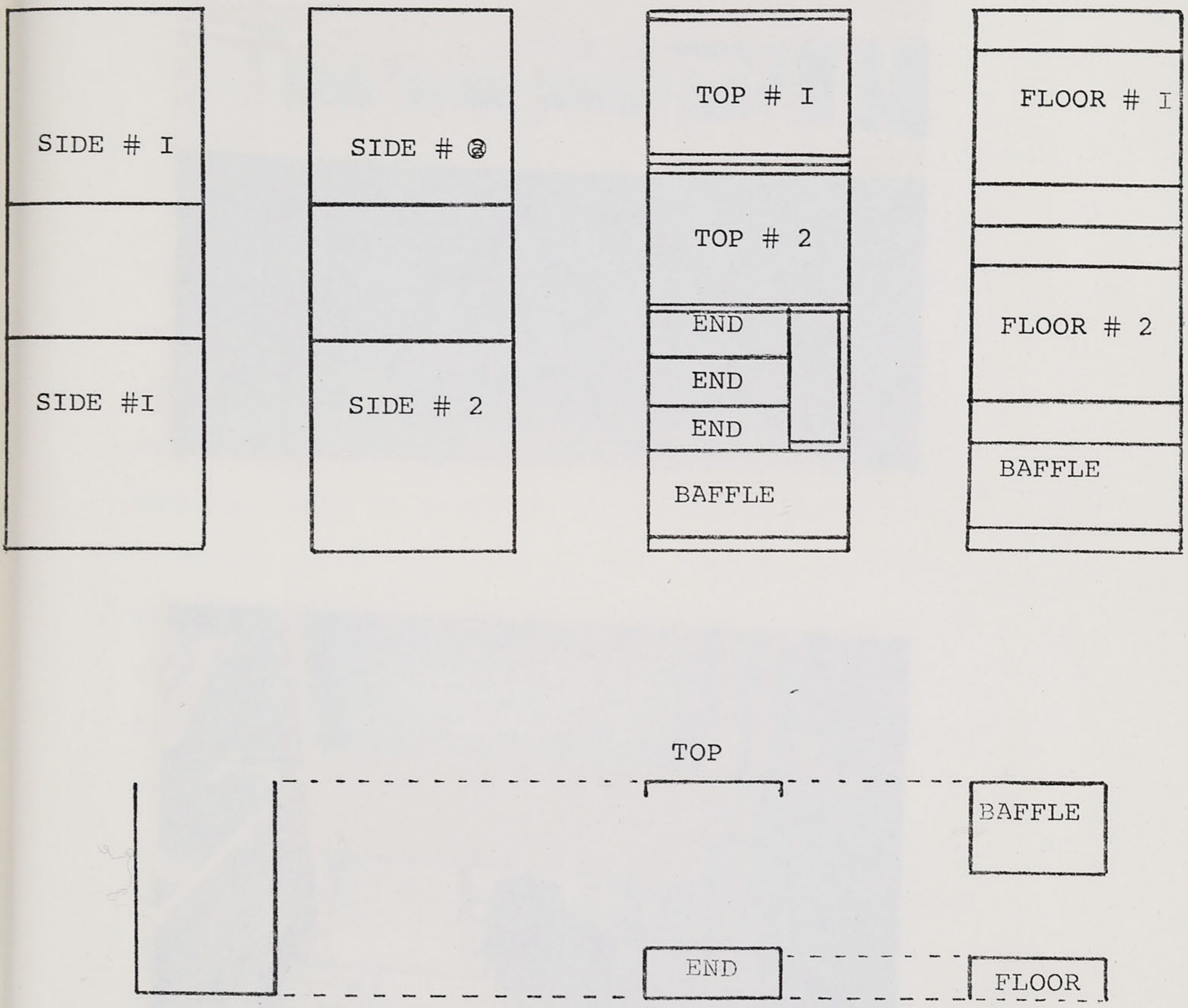

Fig. 5 Cutting the sheet metal.

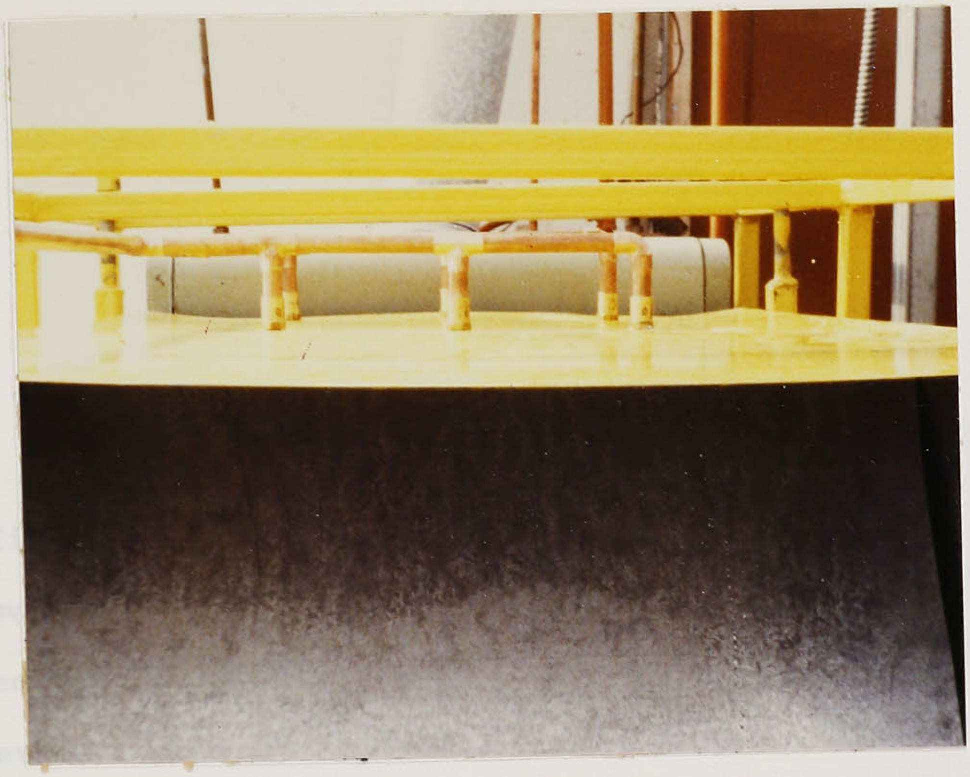

Fig. 6 Pictures of the evaporator.

iv) Water line

To supply water to each evaporator, the old line was first disconnected. A new one was then installed which made available more water outlets. The line was laid out from one end of the greenhouse to the other, and valves were installed every 10 feet. This allows for easy operation. Previously there were only two outlets at one end of the greenhouse.

Water can be shut off at any time and conveniently controlled by two valves. One of the two is an underground valve; the second is above ground and can be easily reached. Each of the 10 gate valves installed are coupled to a second valve. This design increases the convenience of the operation. This first valve lasts for a long period of time since its closure is achieved through metal-to-metal contact. The second one works on a metal-to-rubber system, which is less reliable. Eventually, the rubber in the valve will wear out and cause it to leak. It can then be replaced when the upstream valve is shut off. In this way, only one outlet is affected while the other nine are still in operation. Fig. 7 shows the water line and the various valves.

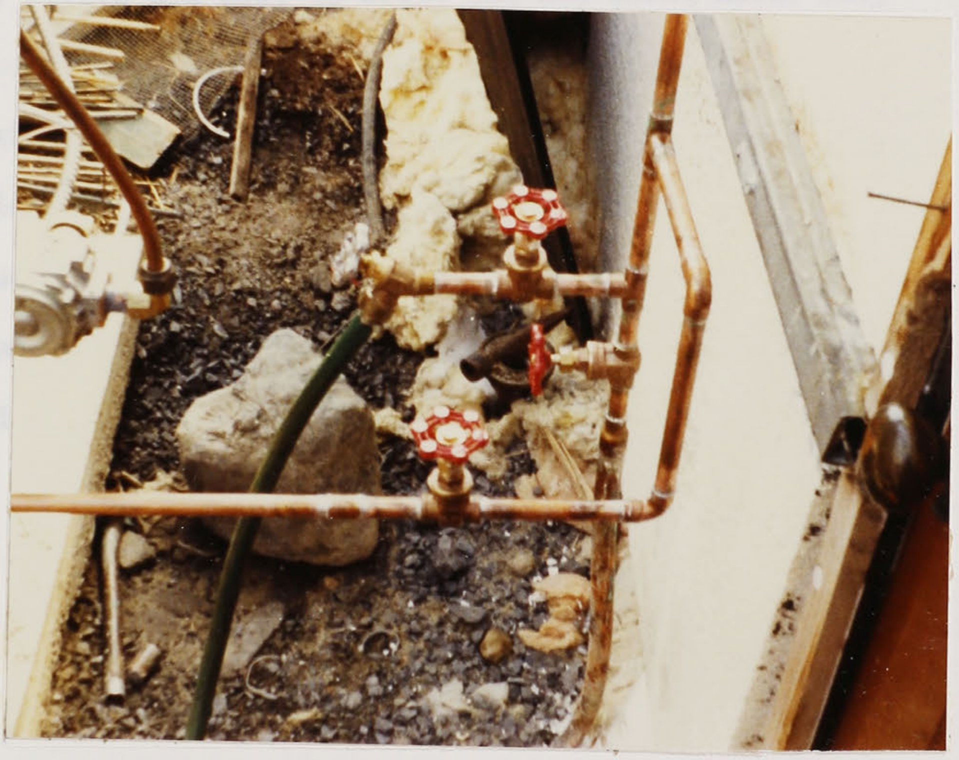

Fig. 7 Pictures of the water line.

VII CONCLUSIONS

Evaporators were hung on the frames. The hangers holding them were constructed so that the height could be adjusted.

An important conclusion of this project is that any apparatus built should be adjustable. Evaporators should be mounted in such a way that they could easily be modified. Also, pop rivets are easy to drill out and sheet metal easy to bend.

The equipment did not work as well as expected. Some minor modifications were required and later performed.

Construction and installation of the two control elements has been an enriching experience which has taught me how to design and to organize myself.

VIII APPENDIX

Calculations For The Evaporator

These calculations are necessary to design the evaporator. They reveal how much water must be evaporated for proper functioning.

1)-Greenhouse dimensions

Length : 30 m Width : 5 m

2)-Greenhouse volume :

300 cubic meters (cu.m)

3)-The number of air changes in a greenhouse is usually 1 per hour so the air flow rate at air out conditions is :

1/hr * 300 cu.m = 300 cu.m/hr

4)-Air in (design parameters)

at -10 C 60 % R.H.(Relative Humidity)

to +20 C 75 % R.H.

5)-Air in :

TEMPERATURE DB : - 10 C

R.H. : 60 %

H : - 8 kj/kg

H20 : 0.0008 kg of H20 / kg of dry air

6)-Air out :

TEMPERATURE DB : + 20 C

R.H. : 75 %

H : 47.5 kj/kg

H20 : 0.0108 kg of H20 / kg of dry air

1/p : 0.84 cu.m/kg

7) -Air Mass Flow Rate:

(300 cu.m / hr) * (1 / 0.84 kg da / cu.m) = 358 kg da / hr

8) -Total Water Flow Rate :

(358 kgda/hr)*((0.0108 - 0.0008)kg H20/kgda)= 3.58 kg H20/hr

9) -Evaporator Water Flow Rate

3.58 kg H20/hr for two evap. = 1.79 kg H20/hr /evaporator.

10) -Design capacity

5 kg H_2O / hr / evaporator

11) -Safety factor

5 / 1.79 = 2.79

The safety factor used here is high, because air conditions may vary. In addition, it does not matter if the capacity is too big since the computer regulates the amount of water being added. In this case, it is better to have an oversized apparatus than an undersized one.

IX REFERENCES

1. Higdon A., Ohlsen E.H., Stiles W.B., Weese J.A., Riley W.F., Mechanics of materials, 3rd edition, John Wiley & Sons Inc., New York, 1976.

2. Langhans R.W., Greenhouse management, Halcyon Press of Ithaca, Ithaca, New York, 1980.

3. Nelson P.V., Greenhouse operation and management, Reston Publishing Company Inc., Reston Virginia, 1978.

4. Potter C.H., Beneath greenhouse roof, Criterion Books Inc., New York, 1957.

5. Quarrell C.P., Ace G.W., Crops under glass, Macdonald & Co. Ltd., London, 1975.

6. Wahlfeldt B.G., All about greenhouses, Tab Books Inc., Blue Ridge Summit, PA., 1981.