Plant Propagation PLS 3221/5222

Guest Web Lecture

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CEAC
Controlled Environment Agriculture Center

The University of Arizona Controlled Environment Agriculture Program

College of Agriculture and Life Sciences

Department of Agricultural & Biosystems Engineering

With programs in

- **Education**
- **Extension - Outreach**
- **Research**
- **Design Analysis**
- **Business Development**

Ventilation and Cooling

Procedures to modify the greenhouse effect

ventilation

- for air exchange
- natural, forced air, screened

evaporative cooling

- for reducing air temperature

shading

- prevent solar radiation

Expectations

Temperature Reduction

Moisture Reduction

(or increase)

Prevent Carbon Dioxide Depletion

Air Movement for Oxygen & Carbon Dioxide Exchange

Improved Labor Climate

Begin Cooling Difficulties Immediately!!

Ventilation and Cooling

Procedures to modify the greenhouse effect

- forced air ventilation

Benefits

Positive Displacement of Air

Immediate Response to Controller

Fan Staging

- Small Air Exchange in Winter
- Reduce over-Cooling
- Save Electrical Energy

Combine With Other Systems

- Evaporative Cooling
- De-Humidification

Active Ventilation and Cooling

Capacity

- Cubic feet per minute (CFM)

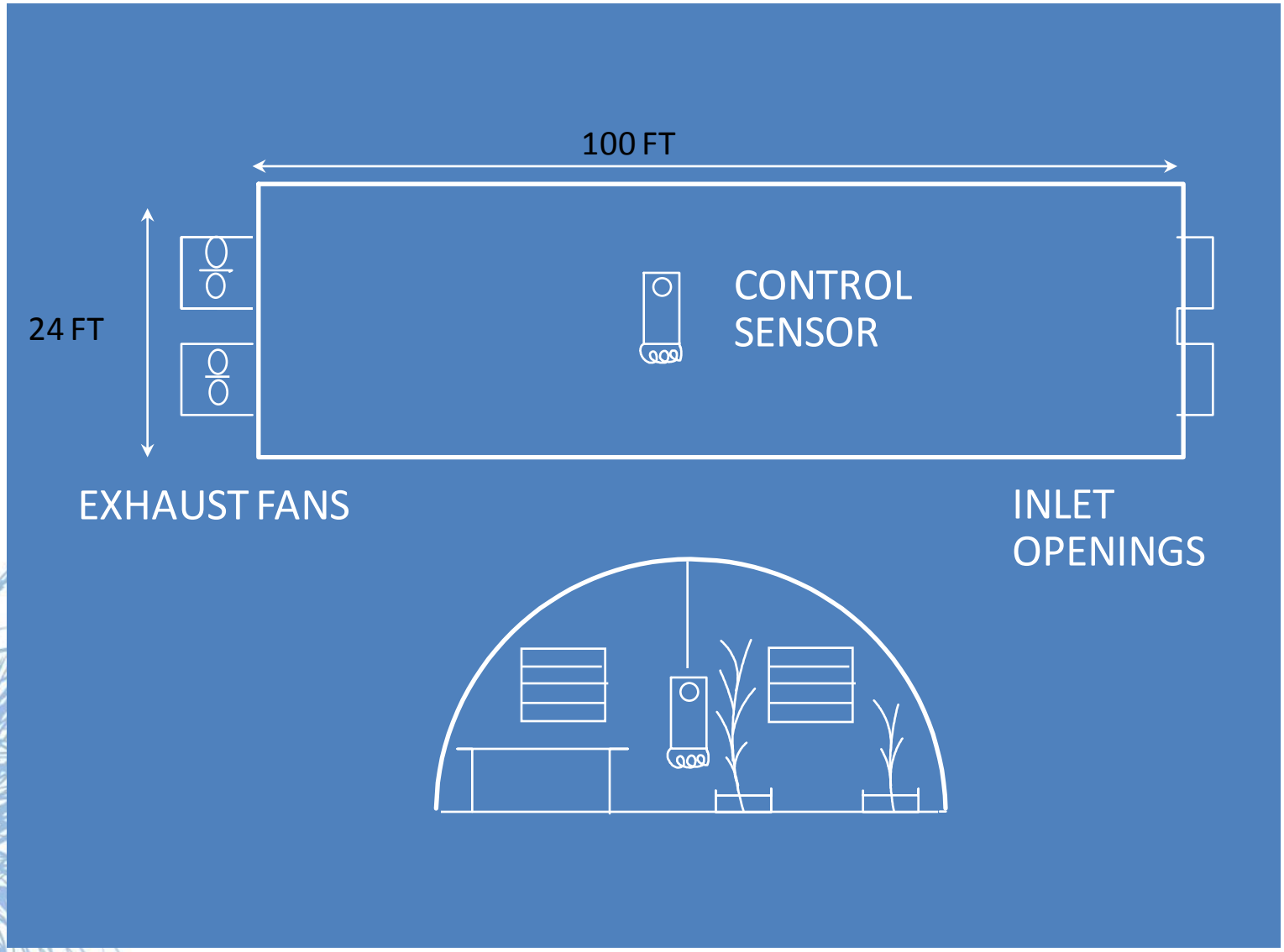
Static Pressure

- Air Flow Resistance (inches water)

Power Requirement

- Motor Horsepower

Floor Plan of 24' x 100' Greenhouse



Vent Inlet Openings

Louver Shutters	Continuous Windows	Sidewall Opening
• Square shape • “Point” Source	• Motorized Window • Continuous Inlet • "Line" Source	• Roll-up Sidewalls

Locating Fans and Inlets

Location of Inlet More Critical Than Location of Fan

- Suction by Fan on Greenhouse

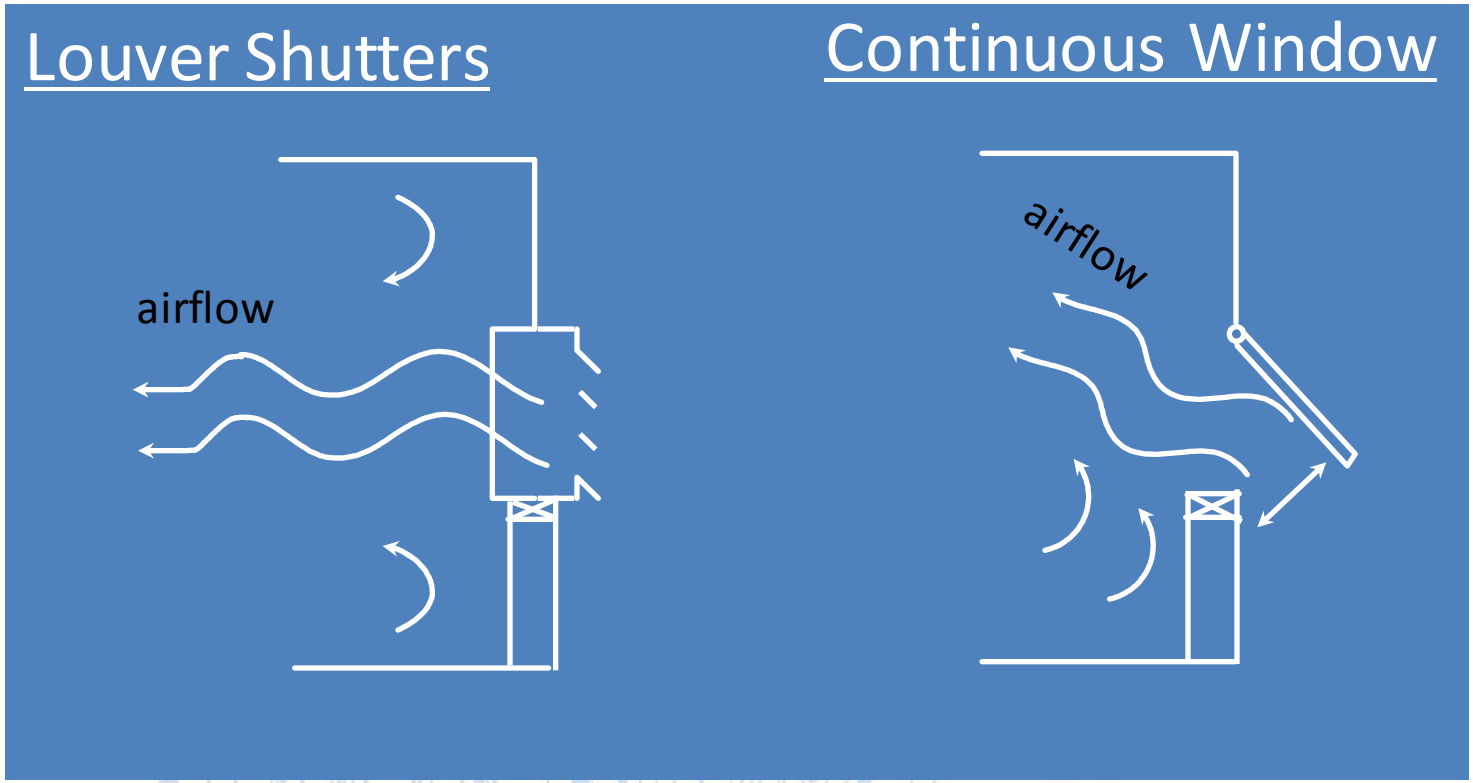
Distance From Inlet to Fan

- Freestanding - 100 Ft
- Multi-span - 200 Ft
- Long distance increases air temperature rise from inlet to fan

Put Inlets at Plant Height

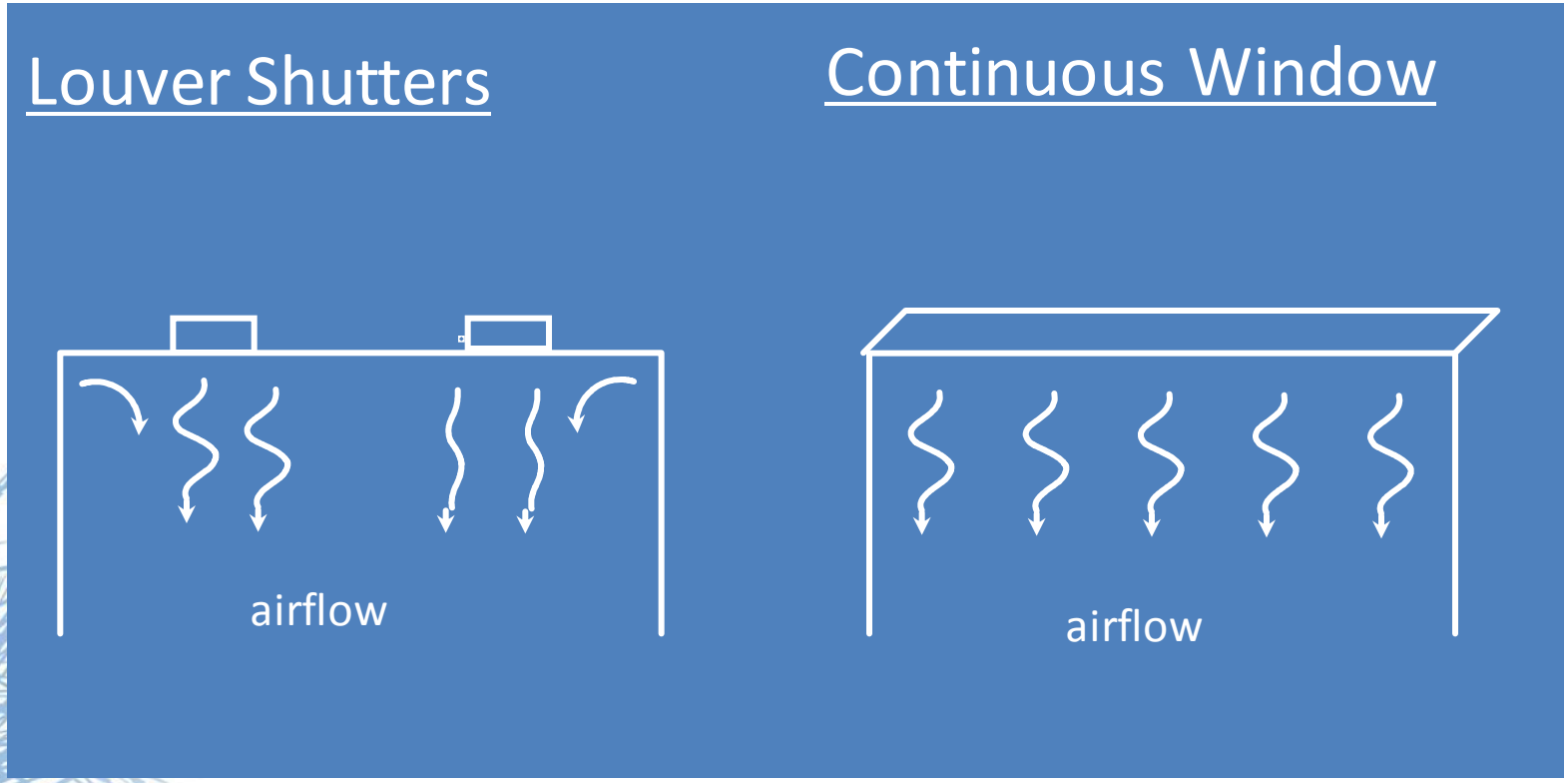
Locating Fans and Inlets

Inlet Opening (endwall side view)



Locating Fans and Inlets

Inlet Opening (endwall top view)



Ventilation and Cooling

Procedures to modify the greenhouse effect

- Natural or passive ventilation

Natural Ventilation

Traditional for Glasshouses

Cooling Dependent Upon

- Air Temperature Difference
- Winds

Least cooling in summer when most needed

Natural Ventilation

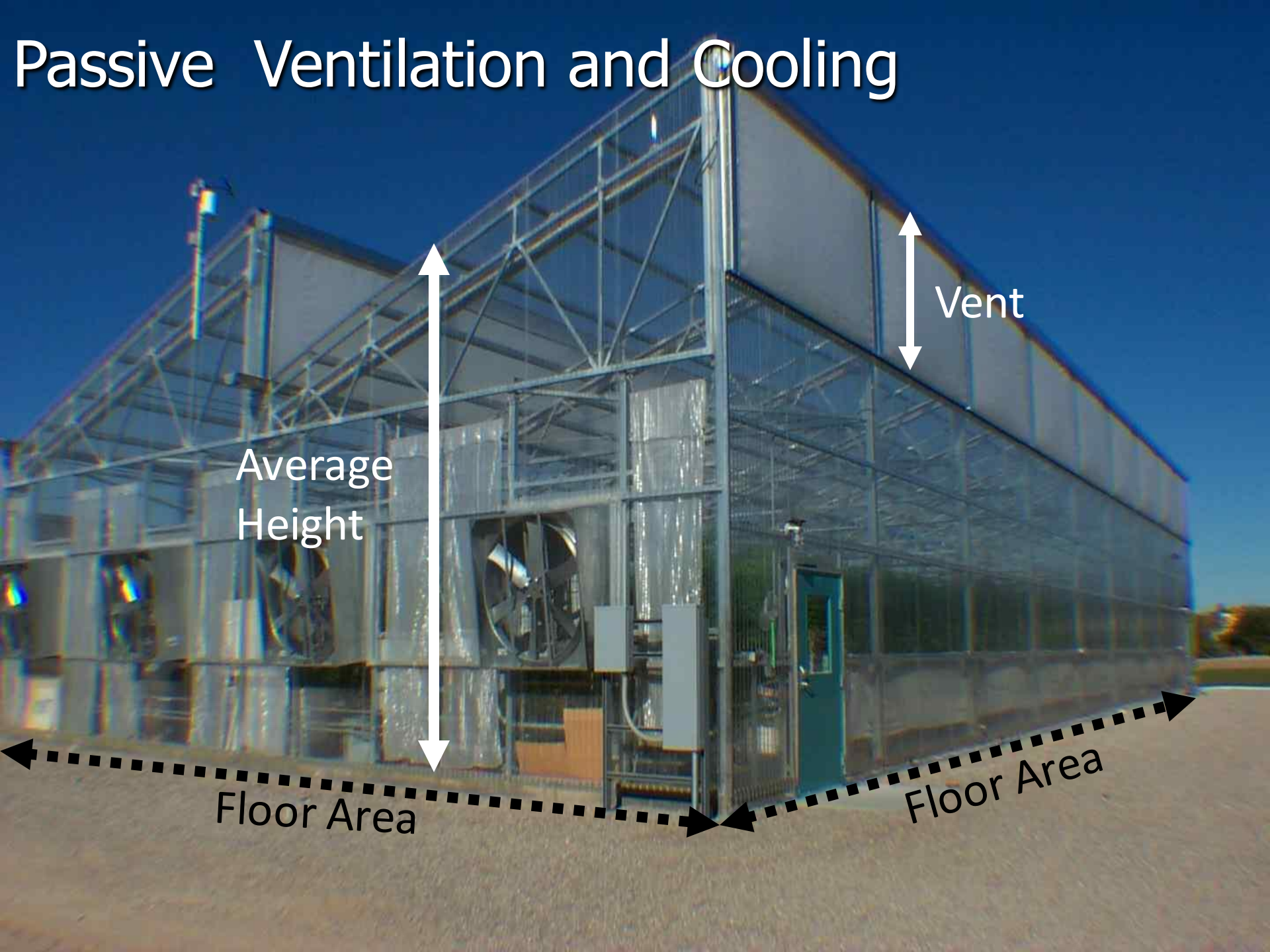
Ridge or Peak Openings

Sidewall Openings

Unglazed Roof Bays

Screen Greenhouses

Passive Ventilation and Cooling



Roof Vent in Partial Open Position

Traditional Dutch Venlo style glass greenhouse with ridge ventilation

Opening Roof Greenhouse

VanWingerden GH Co.

Early design (1989 'MX')

Hinge at gutter

One side open per bay

Roll-up Sidewalls and Opening Screened Roof

Hines Nursery, Houston, TX

Ventilation and Cooling

Procedures to modify the greenhouse effect

- Ventilation and Cooling

OBJECTIVE OF EVAPORATIVE COOLING

Cool Below Outside Air Temperature

Humidify Inside Air

Modify Leaf Temperature

Propagation

THEORY OF EVAPORATIVE COOLING

- Water Evaporates
- Energy is Consumed and Air is Cooled and Humidified
- Evaporation Rate Depends on "Dryness" (Humidity) of Air, and Temperature of the Air
- Continued Evaporation Requires Exchange of Humid Air with Dry Air

TYPES OF EVAPORATIVE COOLING SYSTEMS

Pad and Fan

Misting

Fogging

Pad and Fan

Components

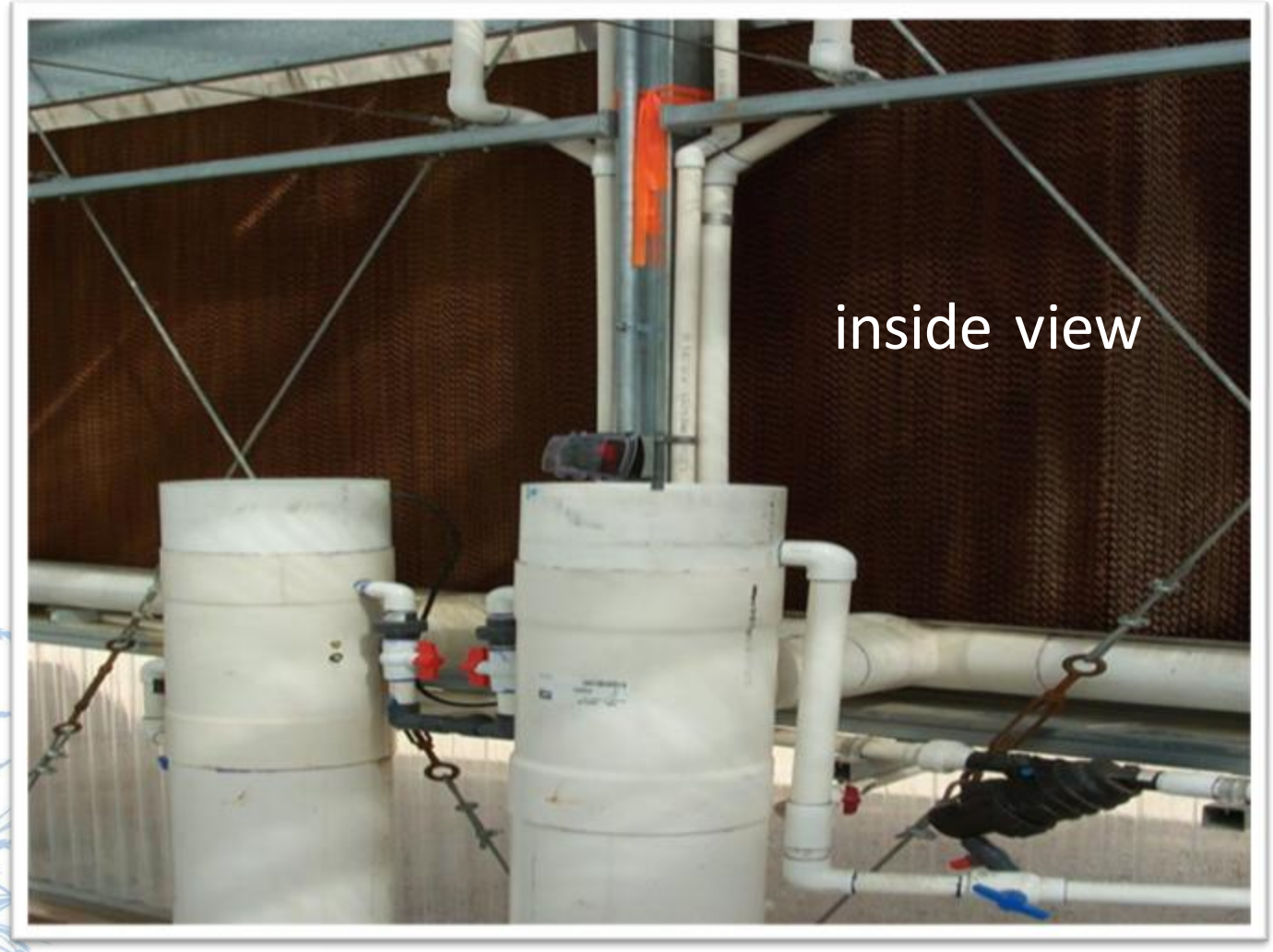
- Pad at Ventilation Inlet
- Ventilation Fans

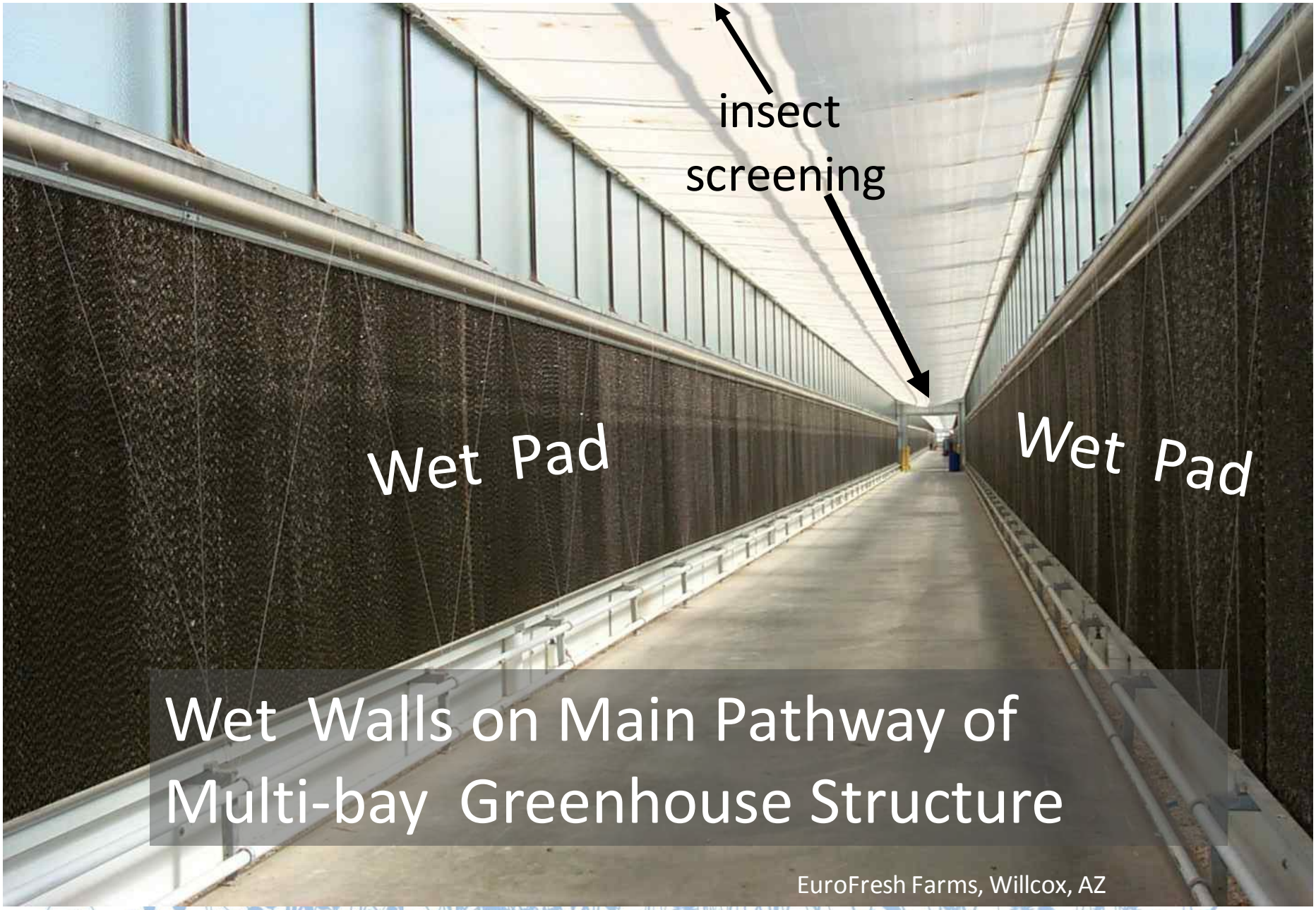
Operation

- Recirculate Water Through Wetted Matrix
- Force Outside Air Through Matrix
- Want ‘Tight’ Greenhouse (few leaks)

Wet Wall Pad at Inlet Window

Wet Wall Pad at Inlet Window





Wet Walls on Main Pathway of Multi-bay Greenhouse Structure

EuroFresh Farms, Willcox, AZ

Inlet Vent above Main Pathway of Multi-bay Greenhouse Structure

EuroFresh Farms, Willcox, AZ

Misting Components

Mist Nozzles

- Low Pressure (40 - 60 psi)
- High Volume (4 GPH)
- One Nozzle per 25 - 50 FT

Overhead Pipe Network

Pump and Controls

Fan Ventilation

Misting Operation

"Large" Water Droplets

Surface Wetting Occurs

Contact Evaporation

Intermittent Spraying

Good Cooling Uniformity

Fog Cooling Components

Fog Nozzles

High Pressure (1000+ psi)

- Low Volume (1.2 GPH)
- One Nozzle per 50 - 100 Ft
- Overhead Pipe Network

Pump, Filters and Controls

Water Quality

Fan Ventilation

Fog Cooling Operations

"Tiny" Water Droplets

Instant Evaporation

No Wetting

- 3 to 12 F Cooling (humid climate)
- 10 to 35 F Cooling (arid climate)

Excellent Cooling Uniformity

1 GPM per 2000 Ft Greenhouse

Fog Nozzle for Cooling

Fog for Cooling

Ventilation and Cooling

Procedures to modify the greenhouse effect

- Shading Systems
  - prevent solar radiation from entering greenhouse

Shading

Reduces

- Greenhouse Cooling Load
- Leaf Temperature
- PPF (PAR Needed for Growth)
- Plant Stress

Shading Systems

- Paint Glazing
- Attached Exterior Netting
- Movable, Exterior Netting
- Movable, interior Shade Material

Attached Exterior Shade Netting

Movable, Exterior Shade Netting

Hines Nursery, Houston, TX

Movable, Interior Shade Material

Retracted, Stowed

Deployed

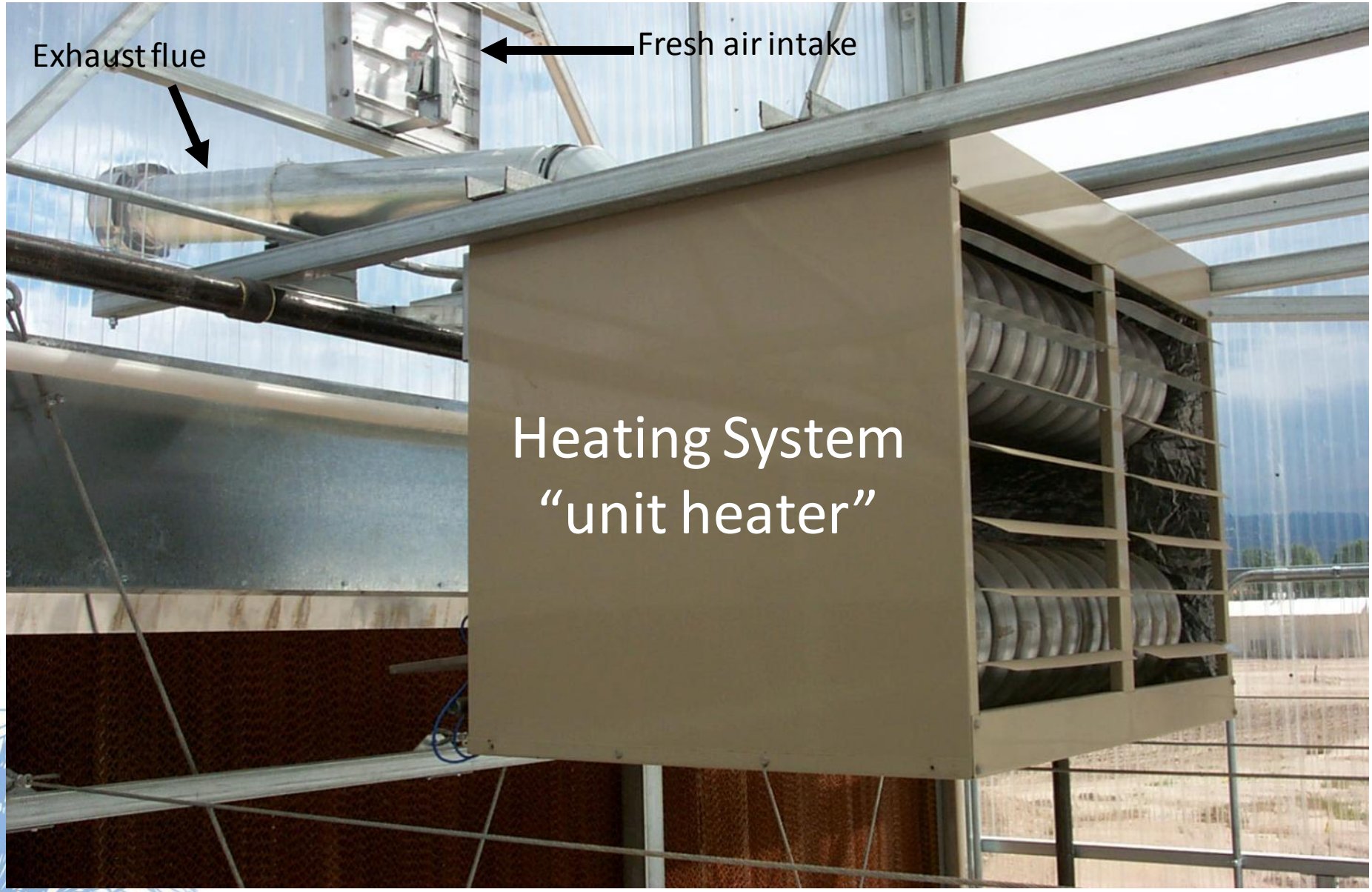
Knox Nursery Inc.

Florida

Heating

Procedures to modify the greenhouse effect

- air heating
  - by hot air
  - by hot water
- root zone heating
  - bench heating
  - floor heating



Hot air Gas-fired Intake/exhaust Vents

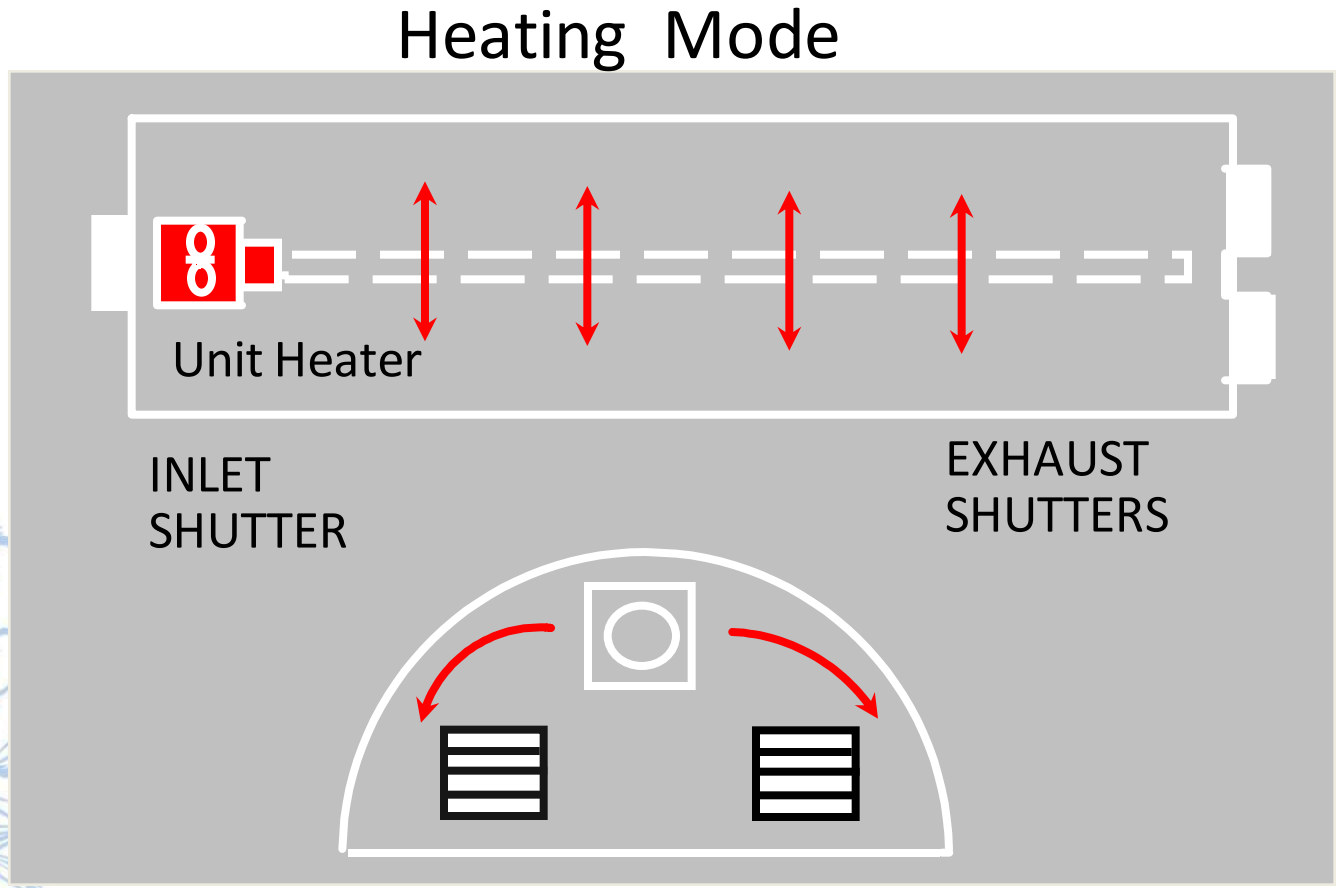
Natural Gas for Heating Fuel

Location of the Unit Heater Relative to the Crop

Ventilation Fan and Plastic Tube Air Distribution Duct

Ventilation Fan and Plastic Tube Air Distribution Duct

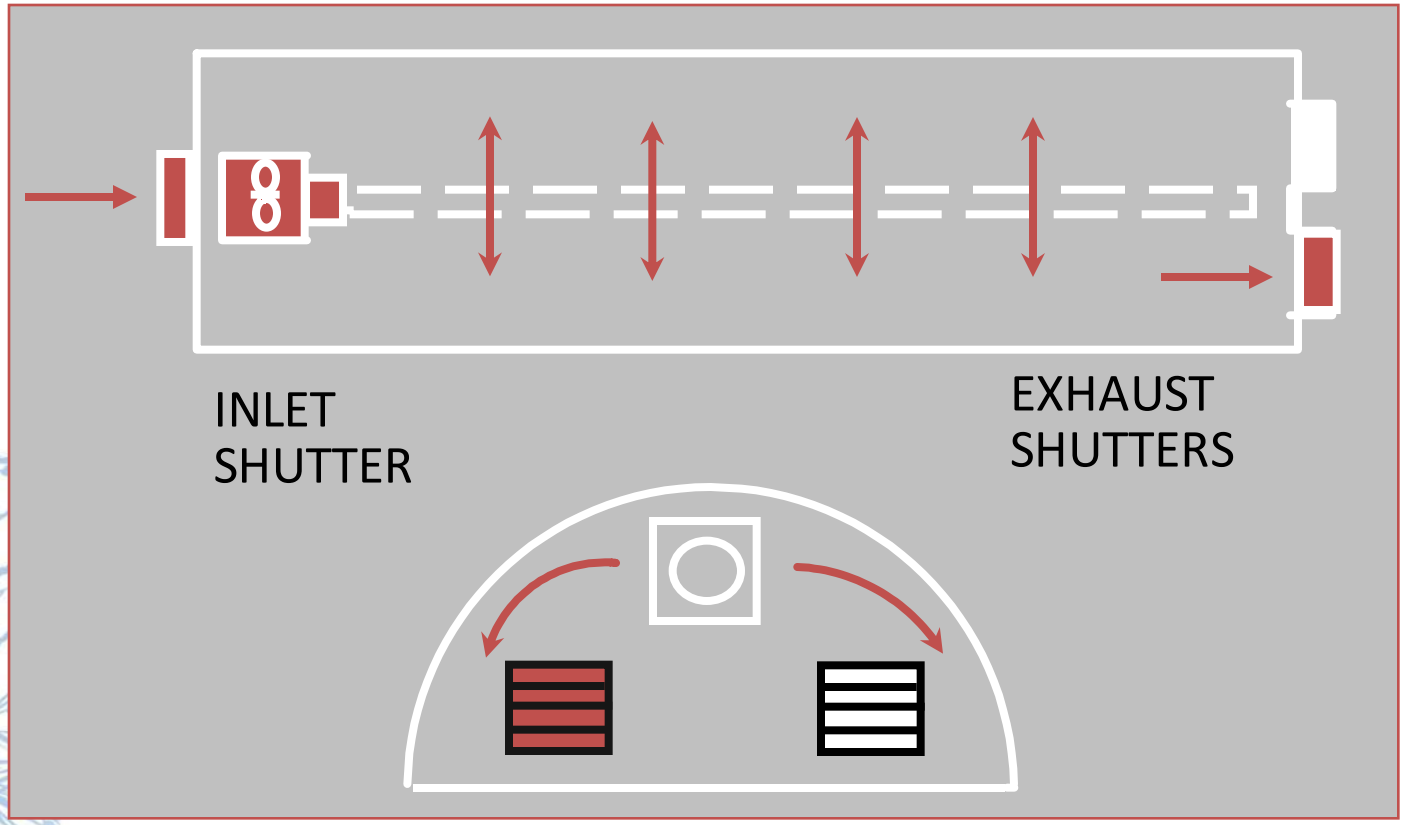
FORCED HOT AIR HEATING



Heater ‘On’ / Inlet & Exhaust Shutters ‘Closed’

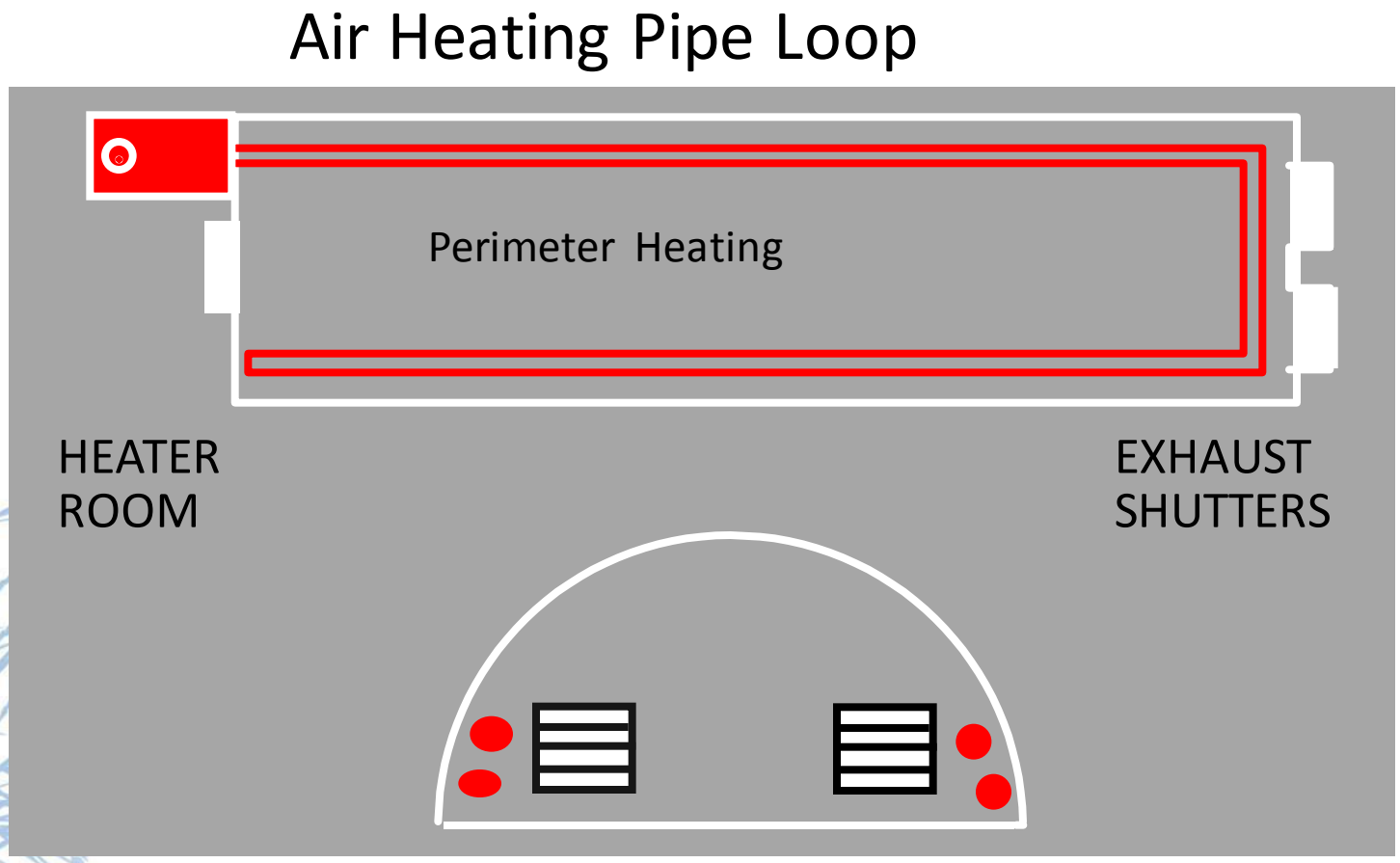
FORCED HOT AIR HEATING

Ventilation Mode



Heater ‘Off’ / Inlet & Exhaust Shutters ‘Open’

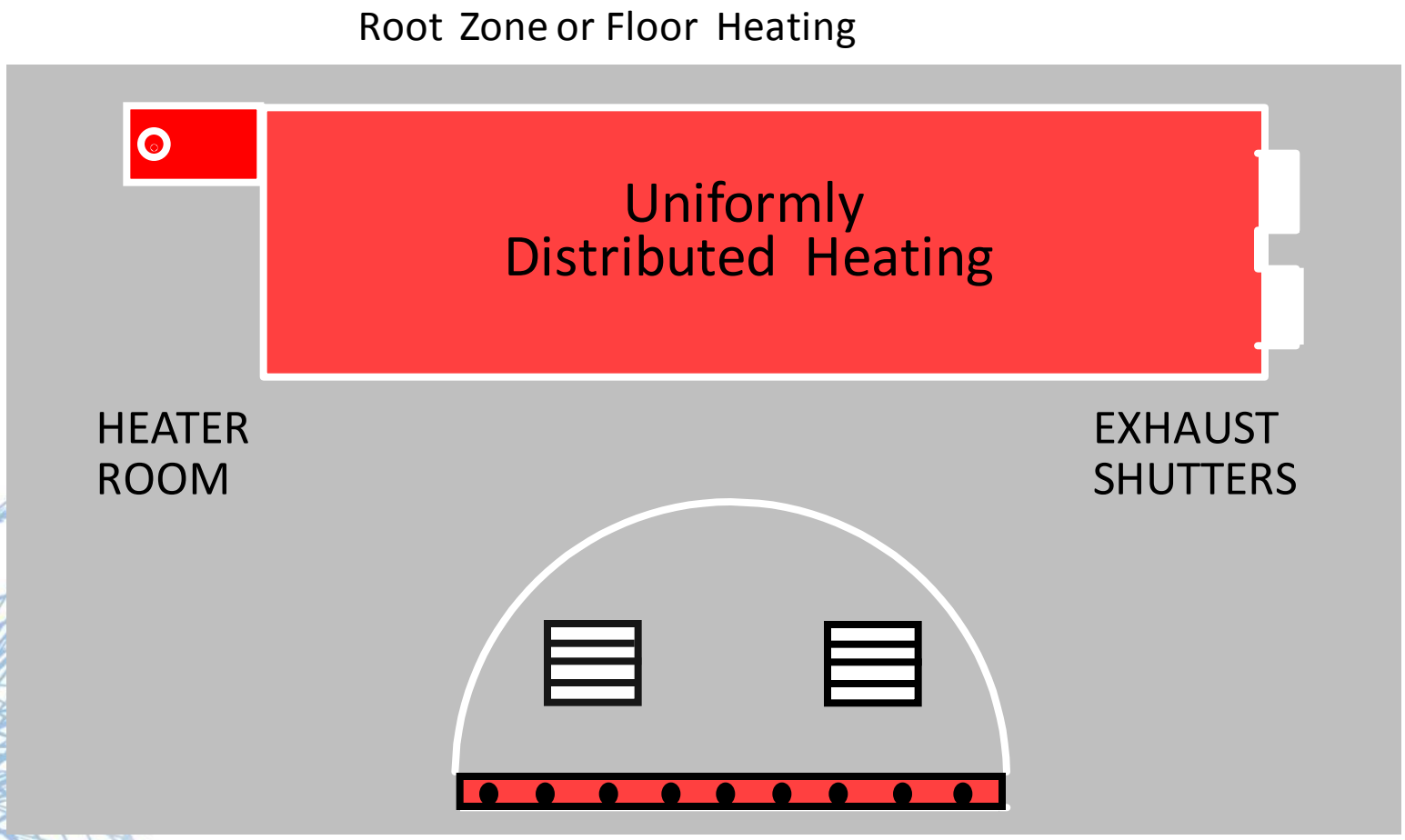
HOT WATER PIPE HEATING



Under Bench Air Heating
Hot Water Finned Tube

Pipe Rail Hot Water Heating and Transport System

HOT WATER PIPE HEATING



Concrete Floor Heating System

H.A.F. Fans - Horizontal Air Flow

Environmental Monitoring and Control

Procedures to modify the greenhouse effect

- Thermostats to Computers
- Energy Conservation Techniques

Environmental Control System

GOALS

- Enhance Plant Growth
- Assure Timing of Maturity
- Maintain Quality

PROCEDURE

- Provide Spatial Uniformity
- Provide Control Strategy
- Minimize Energy Consumption

HEATING/COOLING CONTROL SENSOR

- Locate Near Plant Canopy
- Representative Greenhouse Location
- Shade From Direct Sun
- Protect From Moisture
- Aspirate With Fan

Environmental Control and Plant Culture

Monitor Plant Parameters with Sensors

- Air Temperature
- Root Zone Temperature
- Humidity
- Light Intensity
- Nutrients (pH & E.C. & CO_2)
- Time

Basic Air Temperature Monitoring

Inexpensive

Accurate

Manual

Remote Sensor

Digital Temperature Monitor

Infrared Surface

Temperature Sensors

Thermistor

RADIATION MEASUREMENT

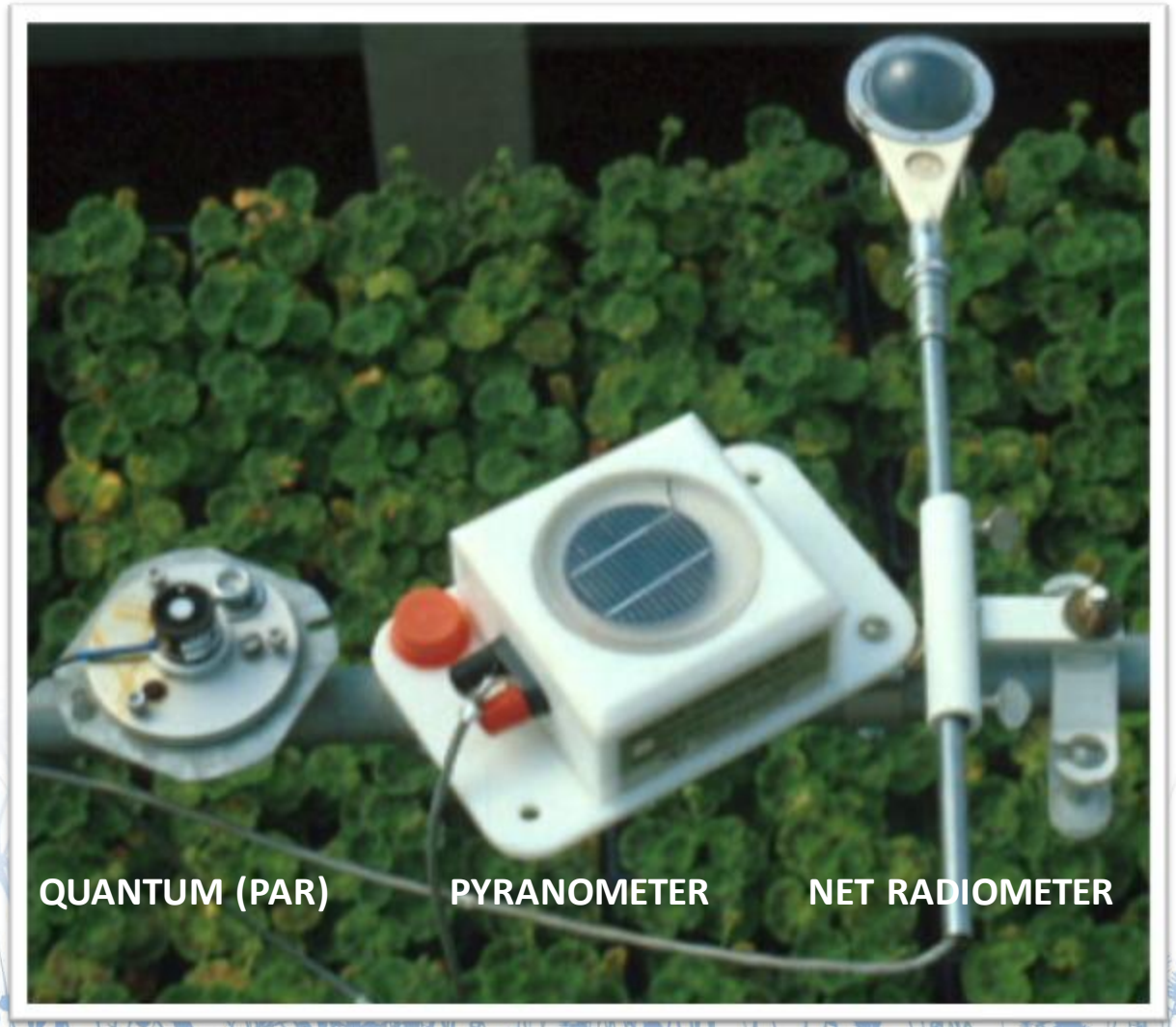
Radiometric (Total)

- Irradiance (Watt per square meter)
- Pyranometer (250 – 2300 nm)

Photosynthetic (PAR)

- PPF (micromole per square meter per second)
- Quantum Sensor (400 – 700 nm)

Radiation Measurement Sensors



HUMIDITY MEASUREMENT

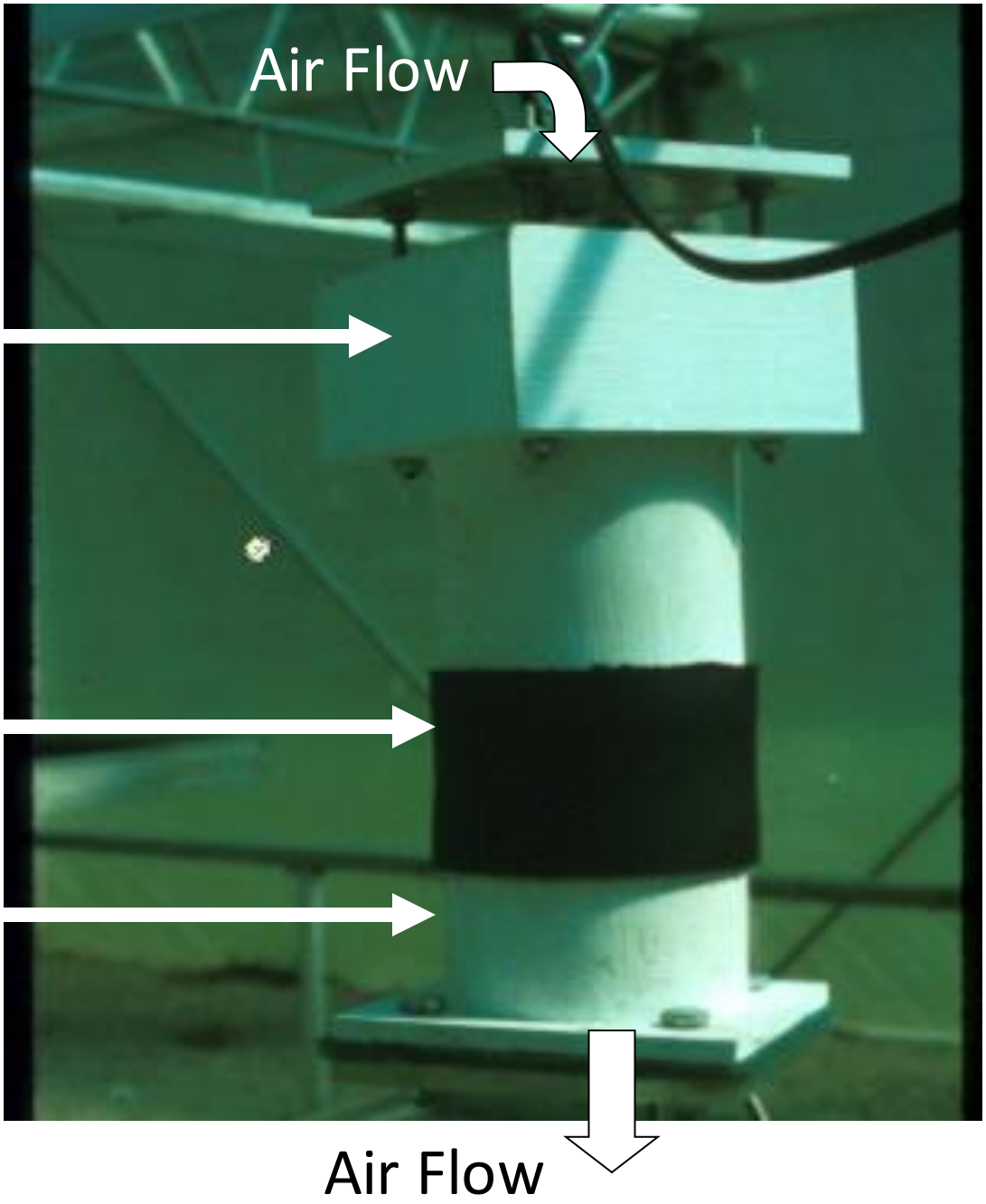
Psychrometer

- Dry Bulb and Wet Bulb Air Temperature

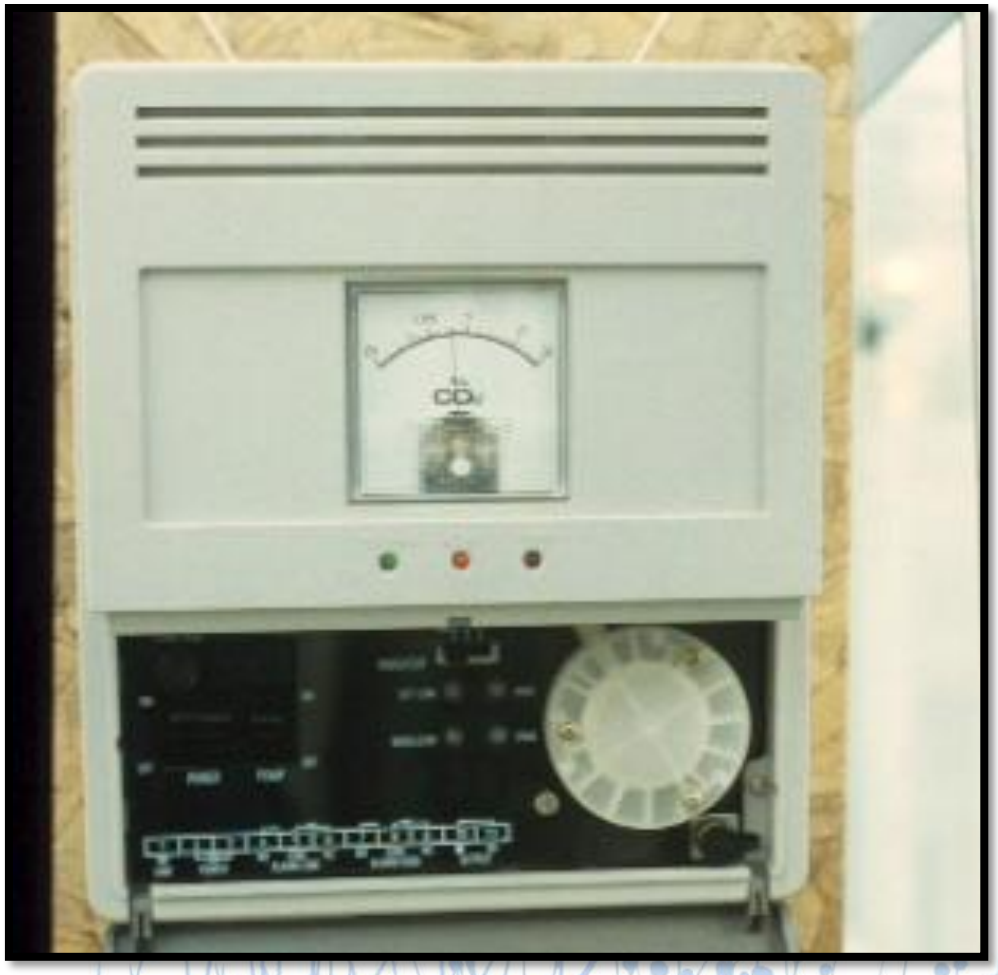
Solid State Device

- Capacitance or Inductance

Aspirated Psychrometer

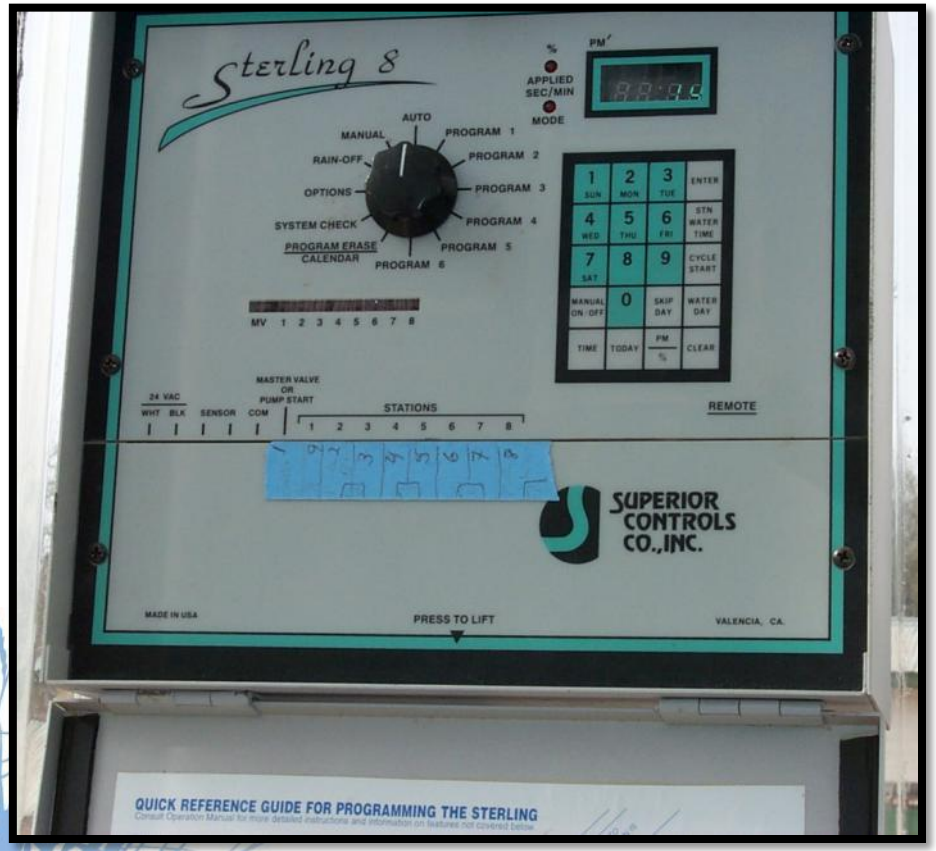


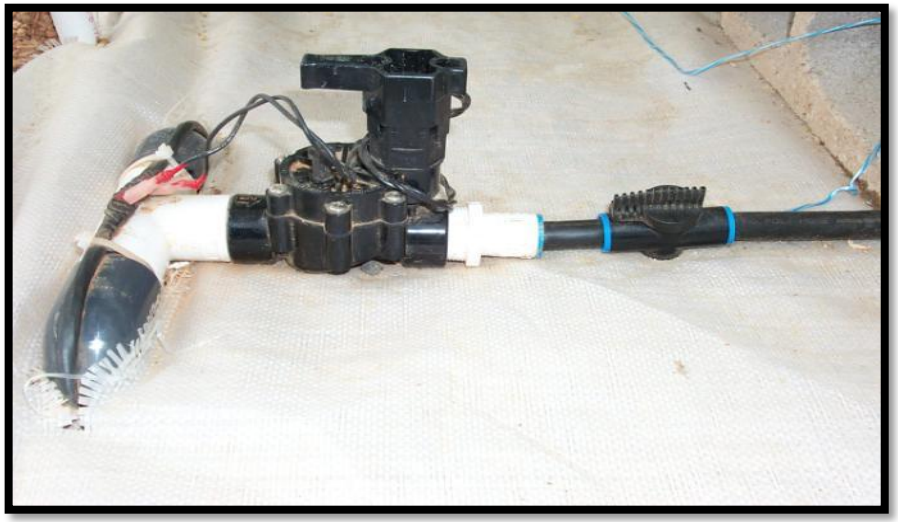
CARBON DIOXIDE MEASUREMENT



Infrared Absorption concentration (ppm)

Multi-Zone Irrigation Timer





Irrigation Zone
Solenoid Control Valve

Environmental Zone Step-Controller

Computer-based Controller

Multiple Zones

Multiple Sensors, Multiple Types

View, Process and Store Data

Control Software

Highly Flexible

Plastic Greenhouse Energy Conservation

- Double-layered P.E. Covering
- Multi-bay, Gutter-connected Greenhouses
- Internal insulation curtain
- Concrete Floor Heating
- Solar & Reject Heat Utilization

Mears, 1977

Horticultural Engineering Research Programs Impact on Industry

90% reduction

- of greenhouse [GH] energy-use over past 30 years

60% of all US GH's

- are covered with double-layer, air-inflated polyethylene film

Internal GH energy blanket system

- ubiquitous in industry
- evolution into shading, cooling and insect screening

100% of field transplant crops

- grown in economical GH's

Horticultural Engineering Research Programs Impact on Industry

Floor heating technology applications

- necessary for ebb & flood irrigation system

Transportable bench system US industry standard

- for highly mechanized potted plant growing systems

GH Controlled Environment Agriculture technology

- applied to plant growth chambers,
- plant micro-propagation facilities,
- plant biotechnology systems,
- NASA bioregenerative life-support in space,
- phytoremediation, plants are the processors.

Integrated Crop Production System

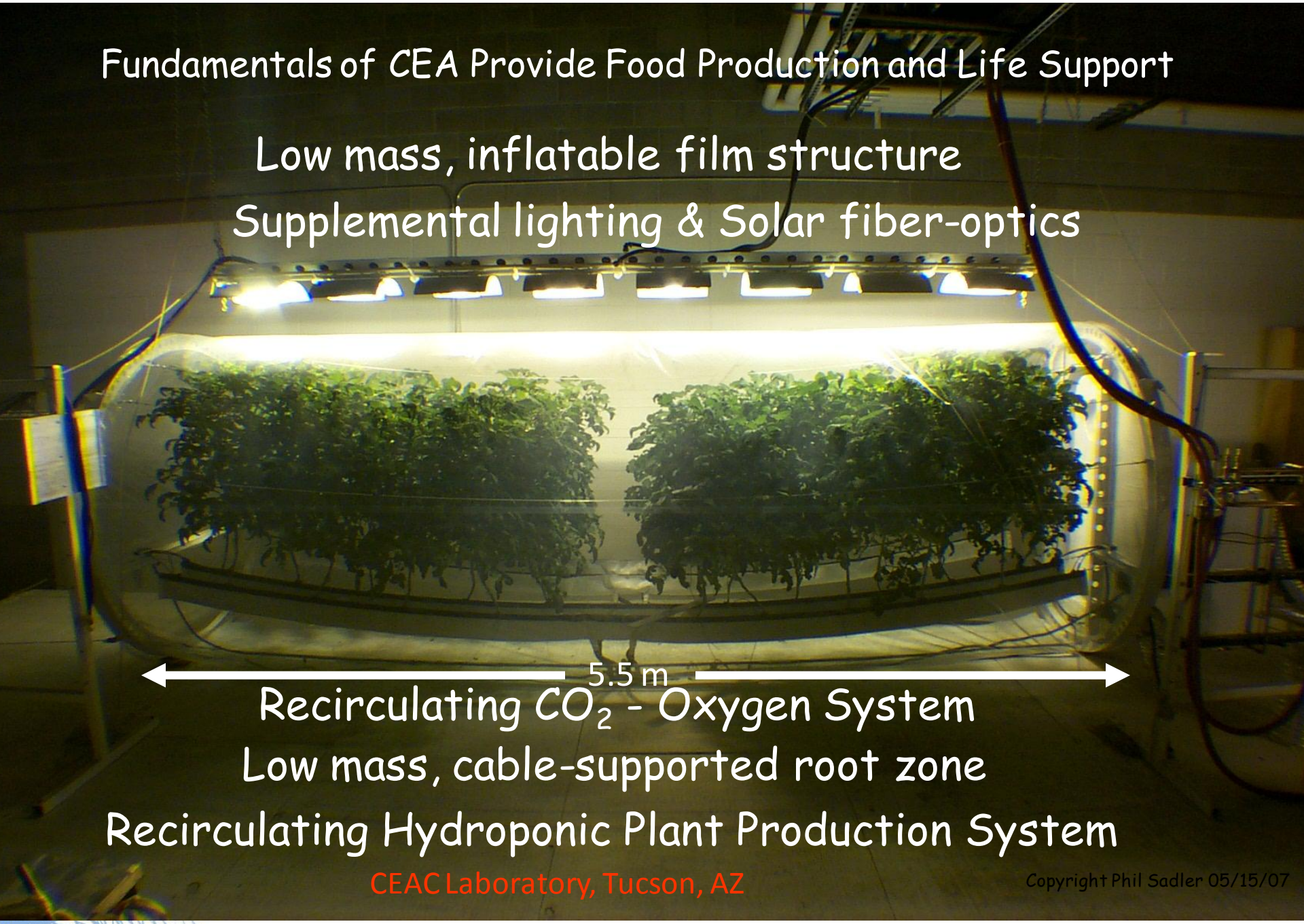
Integrated Crop Production System

It is Important to improve environmental control and uniform distribution of environmental parameters

such that:

- [1] the effect on the plant's microenvironment [mass temperature, PPF, and vapor pressure], and
- [2] the subsequent effect on plant processes such as metabolism, photosynthesis & gaseous transfer

are similar for all plants within the controlled environment system.


Fundamentals of CEA Provide Food Production and Life Support
Low mass, inflatable film structure
Supplemental lighting & Solar fiber-optics
5.5 m
Recirculating CO_2 - Oxygen System
Low mass, cable-supported root zone
Recirculating Hydroponic Plant Production System
CEAC Laboratory, Tucson, AZ
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