Heating and Cooling
Greenhouses (Greenhouse Environment)

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Environmental factors controlling plant growth

- Light
- Temperature
- Water and humidity
- Plant nutrition
Heating Greenhouses

- To heat a greenhouse you must add heat at the rate at which it is lost.

- There are three ways a greenhouse can lose heat.
  - Conduction
  - Air infiltration
  - Radiation
Types of heat loss

- **Conduction** = loss of heat through the covering materials of the greenhouse.

- **Air infiltration (Convection)** = leakage through the coverings, doors, etc.
  - Convective currents (wind) outside = more conductive heat loss

- **Radiation** = warm objects emit radiant energy, which passes through air to colder objects without warming the air.
How do we measure heat?

Units of heat quantity:

- **British thermal unit (Btu):** amount of heat energy required to raise the temperature of 1 pound of water 1 °F
  - 1 Btu = 253 cal.

- **Horsepower (hp):** another measure of energy; boiler heat output is reported as hp
  - 1 boiler hp = 33,475 Btu

- **Calorie (c or cal):** amount of heat required to raise 1 gram of water 1 °C
  - 1 Btu = 253 cal.
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**Heating Systems**

- Type of systems
  - Unit (forced air) heaters
  - Central heat (boiler and pipes)
  - Radiant heat
  - Solar heat
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*Unit Heater Systems*

- System
  - Multiple independent units place overhead
  - Fan-driven heat distribution systems
  - Least expensive heating system
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Unit Heater Systems

- Each has a self-contained fire box / combustion chamber
- Hot fumes rise inside heat exchanger, heating the tube walls
- Fan blows heated air from rear to front
- Exhaust fumes vented at top rear into a stack
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**Unit Heater Systems**

- Unit heaters
  - Fuels: No. 2 fuel oil, kerosene, LP gas, or natural gas
  - Supply 1 in\(^2\) of venting from outside for combustion for every 2,500 Btu output for oxygen
    - Some have forced air combustion vents (good)

- Use sufficient exhaust stack to assure good draw of fumes (80% efficiency = gasses)
  - Ethylene – injurious to plants; other hydrocarbons
  - Sulfur – may be a fuel contaminate
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*Unit Heater Systems*

- Heat distribution
  - Heater fan only – very small greenhouses
  - Convection tubes for distribution
  - Horizontal airflow (HAF) fan systems
Unit Heater Convection Tubes

- Polyethylene tube running length of greenhouse
- Round holes (2-3” diameter) in pairs on opposite sides every few feet
- Warm air exits holes, mixes with cool air
- Can keep tube inflated / blowing even when heater is not running
  - Air movement and temperature uniformity
  - Winter cooling
Heat distribution

Unit Heater Systems

- Horizontal Air Flow (HAF)
  - Small horizontal fans above crops circulate air
  - Offers better temperature uniformity than tube systems
Horizontal Air Flow Fans

- Set up circular patterns with fan positioning
- Use height of 3 feet above the crop and below the eaves
- Install first fan 10-15 feet from end wall
- Maximum of 50 feet between fans on the same side
Unit heaters

If utilizing natural gas as a heat source:

- Must monitor for:
  - Carbon monoxide
  - Ethylene gas
  - Oxygen consumption
  - Dirt and corrosion on heat manifold
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Central Heating Systems

- System
  - One or more boilers in a central location
  - Distribution of pipes moving steam or hot water into the greenhouse
    - Most new installations are hot water
  - More expensive to install than unit heaters, but can burn cheaper fuels and require less maintenance
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*Central Heating Systems*

- **Boilers**
  - Firebox, flue, and heat exchanger
    - Heat exchanger – tubes filled with water surrounded by flue gasses or tubes filled with flue gasses surrounded by water
  - Locate boilers in service building, not humid greenhouse
  - Locate stack so no shadows and no smoke covers greenhouses
Boilers

Water tube boiler

Fire tubes
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Central Heating Systems

- Heat distribution
  - Hot water or steam leaves the boiler
  - Heat exchanged in greenhouse via pipe coils, unit heaters, or both
  - 2-inch diameter pipe is used for hot water
  - 180 °F water is pumped through pipes
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Central Heating Systems

- Pipe placement
  - Wall pipe coils:

Overhead pipe coils:
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Central Heating Systems

- Pipe placement
  - In-bed pipe coils
    - Along edges of ground beds
    - Beneath benches
    - Within ground beds
    - Within concrete floor
    - Puts heat near plants
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Radiant Heater Systems = infrared radiant heaters (IR)

- System
  - 4” diameter steel pipes filled with burning gas suspended over plants full length of greenhouse
  - Over-line aluminum reflector bounces IR down to ground / plants
  - Little air absorption of heat; plants / ground / benches absorb most
  - Fuel efficient: burn natural gas or propane
IR-Radiant Heater Systems

- Heaters must be at least 5’ away from plants, 4’ from roof, and 10’ from walls to prevent damage
- Heaters placed 20-30’ apart
- Use only reduced velocity HAF for circulation
- Little snow melt protection
- Overhead
  - Shadows
Backup Electrical Power
Cooling the Greenhouse

On a bright sunny day

- 30 x 100 ft gh will gather about 32 Btu of heat = burning 320 therms of natural gas

- If full of plants
  - ½ of this heat is used for transpiration and evaporation

- If empty
  - Temps can exceed 150 F
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Types of Cooling Systems
- Summer cooling
- Winter cooling

Via
- Active cooling
  - Evaporative cooling
- Passive cooling
  - Venting
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Passive Cooling Systems

- Open ridge and side wall vents
  - Temperatures can still rise 20 °F above outdoors in old-style greenhouses
    - Ridge vent area is only about 10% of the total roof area

- Newer passive cooling greenhouses have ridge vent areas equal to 20-40% of the total roof area
  - Helps to maintain temperatures closer to outdoor temperatures
Passive Cooling Systems
Greenhouse Cooling

*Active Cooling Systems*

- Takes advantage of heat *absorption* from air during the evaporation of water
- Two major types of systems
  - Fan and pad
  - Fog
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Active Cooling Systems

- Accurately designed fan and pad system should be able to lower the temperature of incoming air by 80% of the difference between the dry bulb and wet bulb temperatures
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Active Cooling Systems

- Dry bulb temperature
  - Actual air temperature measured with an ordinary thermometer

- Wet bulb temperature
  - The air temperature if enough water were to be evaporated into it to saturate the air
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**Active Cooling Systems**

- Wet bulb temperature is what the air can be cooled to if the evaporative cooling system is operating at 100% efficiency
- Fan and pad systems
  - 80% efficiency
- Fog
  - 95% efficiency
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**Physics of Evaporative Cooling**

- The use of the heat in the air to evaporate water from leaves and other wetted surfaces. This will cool the gh to 10 – 20 degrees below outside temperature.
  - Humid air containing the heat that it picked up in the greenhouse is exhausted out through vents or fans.
  - Cooler, drier air is brought in.
Fan and Pad Systems

- Most common evaporative cooling systems
  - Contains
    - Cellulose or aspen pad
    - Overhead water supply pipe
    - Gutter to collect excess water
    - Sump tank
    - Pump
    - Piping and control
Fan selection and placement

Pads are normally installed continuously along the side or end of the wall opposite the fans.
Pad types and specifications

Aspen pad

- Fan and pad cooling adds moisture when air is drawn through a wet pad.
- The humid air picks up heat which is exhausted out through the vents or fans.

Kool Cel
Summer Cooling

_Fog Cooling_ -- Concept:

- High pressure system generates a fog opposite the fan end of the house.
- Droplets small enough to stay suspended until they evaporate.
- The smaller the droplet size, the quicker it absorbs heat and changes to vapor state.
- People and plants stay dry.
Fog Cooling
Greenhouse Cooling

Winter Cooling

Concept:

- Need to cool greenhouses on bright, sunny winter days
- Some type of mixing of cold air with warm air is required prior to the air reaching the plants
- A system that keeps the house closed but circulates outside cooler air with the air in the greenhouse
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Winter Cooling

System components:

- Exhaust fan turning on to remove hot air
- Louver or vent opening up to allow entrance of cooler outside air
- Cold air distribution system
  - Fan-jet with tube
  - HAF fans
Winter Cooling
Environmental control

- Manual controls
- Thermostats
  - Temperature response
    - On/off
- Step controllers
  - Signals received from more than one sensor
    - I.e. Temperature and relative humidity
- Dedicated microprocessors
  - Simple computers that receive 20 or more sensor signals
    - Temperature, light intensity, wind speed, etc.
- Computers
  - Handle complex, cutting-edge programs