Greenhouse and Aquaculture Design considerations

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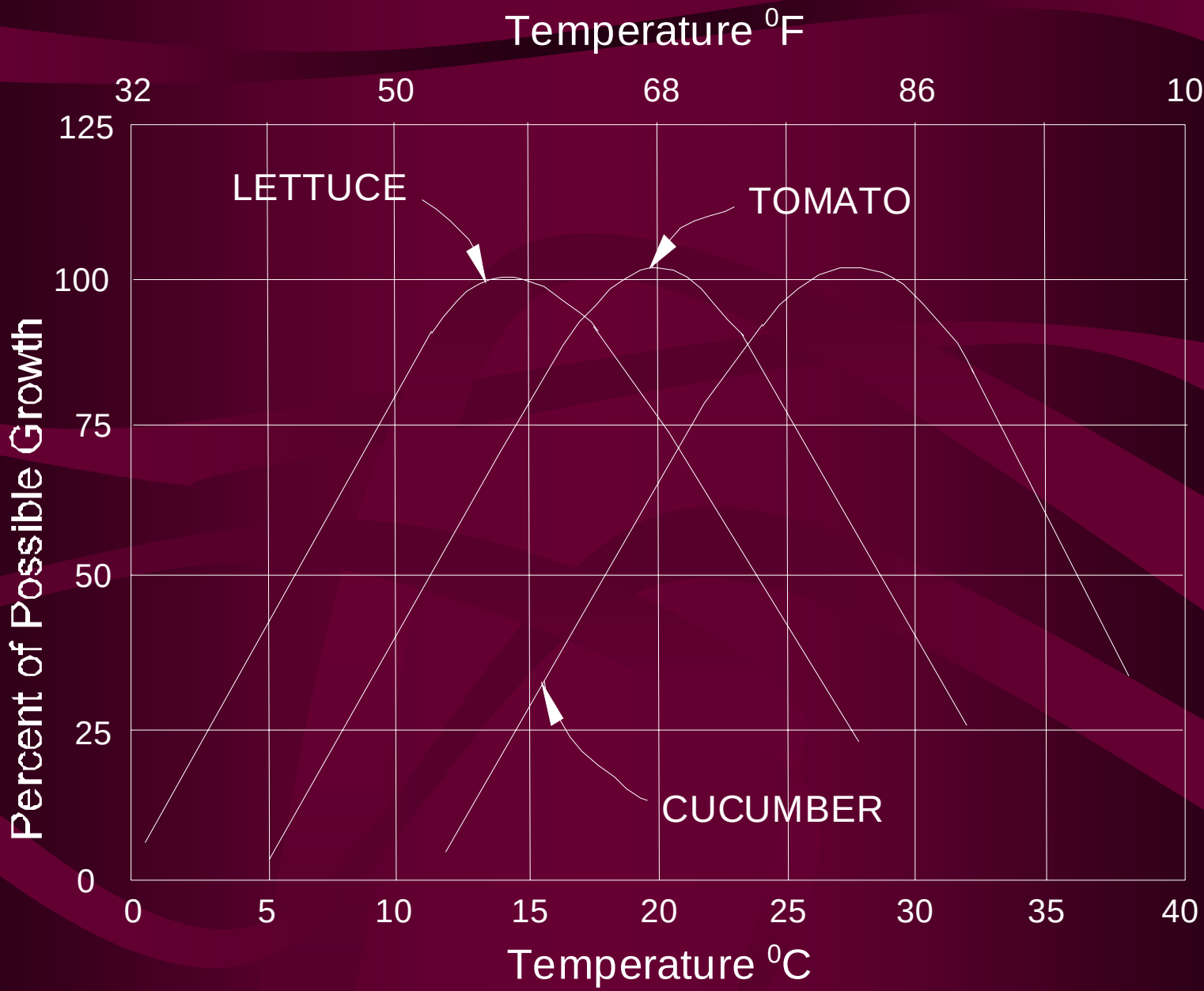
Geothermal Greenhouse Heating

IFA Greenhouses – Klamath Falls – 4 acres

Advantages of Geothermally Heated Greenhouses

- **Optimize growth by reducing time to maturity**
- **Reduce operating costs (up to 25%)**
- **Allows economic operation in cold climates**
- **Uses relatively low-grade heat (75 to 195°F)**
- **Better humidity control to prevent condensation and reduce problems with disease control**
- **Can be used in a cascaded situation**
- **Can be combined with fossil fuel system for peak heating to reduce costs and number of wells**


Temperature ^{0}F
32
50
68
86
104
125
100
75
50
25
0
Percent of Possible Growth
LETTUCE
TOMATO
CUCUMBER
0
5
10
15
20
25
30
35
40
Temperature ^{0}C

Greenhouse Construction

- **Most efficient consists of large, connected structures each covering 0.5 to 1.0 acre with several acres in the connected unit - up to 15 acres**
- **Typical size 120 x 300 ft. of fiberglass (0.80 acre)**
  (30 x 100 ft. or 150 ft. for plastic film type)
- **Heating by a combination of fan coil units with plastic tubing near the ceiling peak and horizontal pipes along the walls and under benches.**
- **May need storage tank to meet peak demand, thus reducing the number of wells and/or peak pumping rate.**
- **Approximately 100 gpm of 140 to 180°F water needed for peak heating (0.5 acre – 20,000 ft^2 – 100 $Btu/h/ft^2$)**
- **Capacity factor of 0.45**
- **Fortunately, most crops need lower nighttime than daytime temperature.**

Masson Greenhouse

New Mexico

16 acres

Potted flowers and tropical plants

Contruction Materials

- **glass**
- **plastic film**
- **fiberglass or similar rigid plastic**
- **combination of film and fiberglass**

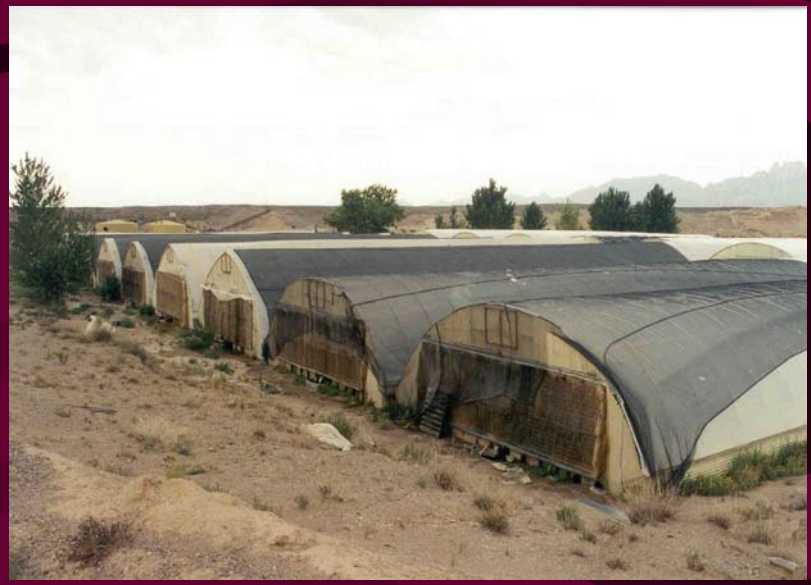
- **Steel or aluminum frame (wood in past)**
- **Glass most expensive to construct - used where superior light transmission is required - also, poorest energy efficiency - high infiltration rate**
- **Plastic film - arched design - replacement on 3-year interval or less - double poly more efficient.**
- **Fiberglass - peaked roof design - but requires less structural support than glass - heat loss about the same.**
- **Construction cost and outfitting with the heating system will run US$ 5 to 10 per ft^2 + the geothermal well and pipe supply system.**

Mt. Amiata

Italy, glass houses

Burgett's greenhouses, NM

High snow load design

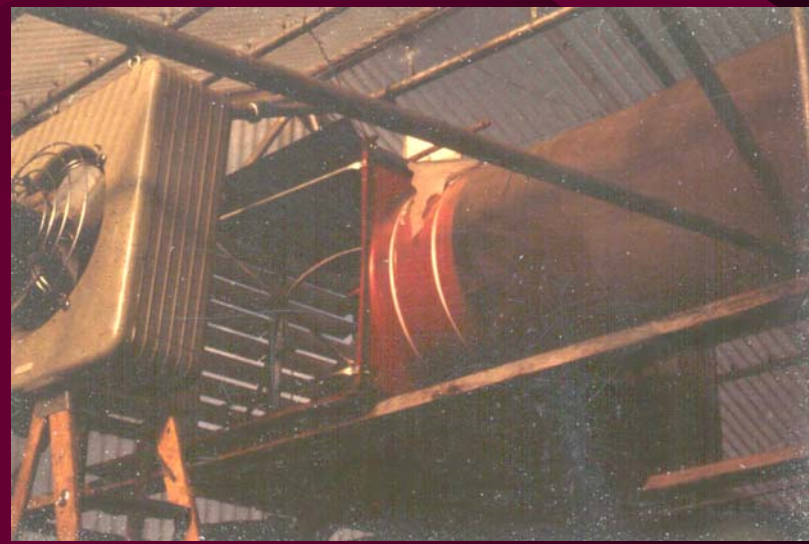


Heating Systems

Accomplished by:

- **Circulation of air over finned-coil heat exchangers carrying hot water**
- **Often used with perforated plastic tubes running the length of the greenhouse to maintain uniform heat distribution**
- **Hot-water circulating pipes or ducts located in (or on) the floor**
- **Finned tube units located along the walls and under benches, or**
- **Bare pipes running along the walls (Iceland: ROT - 2 m of pipe for 1 m^2 of floor area) = 0.5 ft per sq. ft.**
- **Combination of the above - typical**


MODINE



Heating Requirements

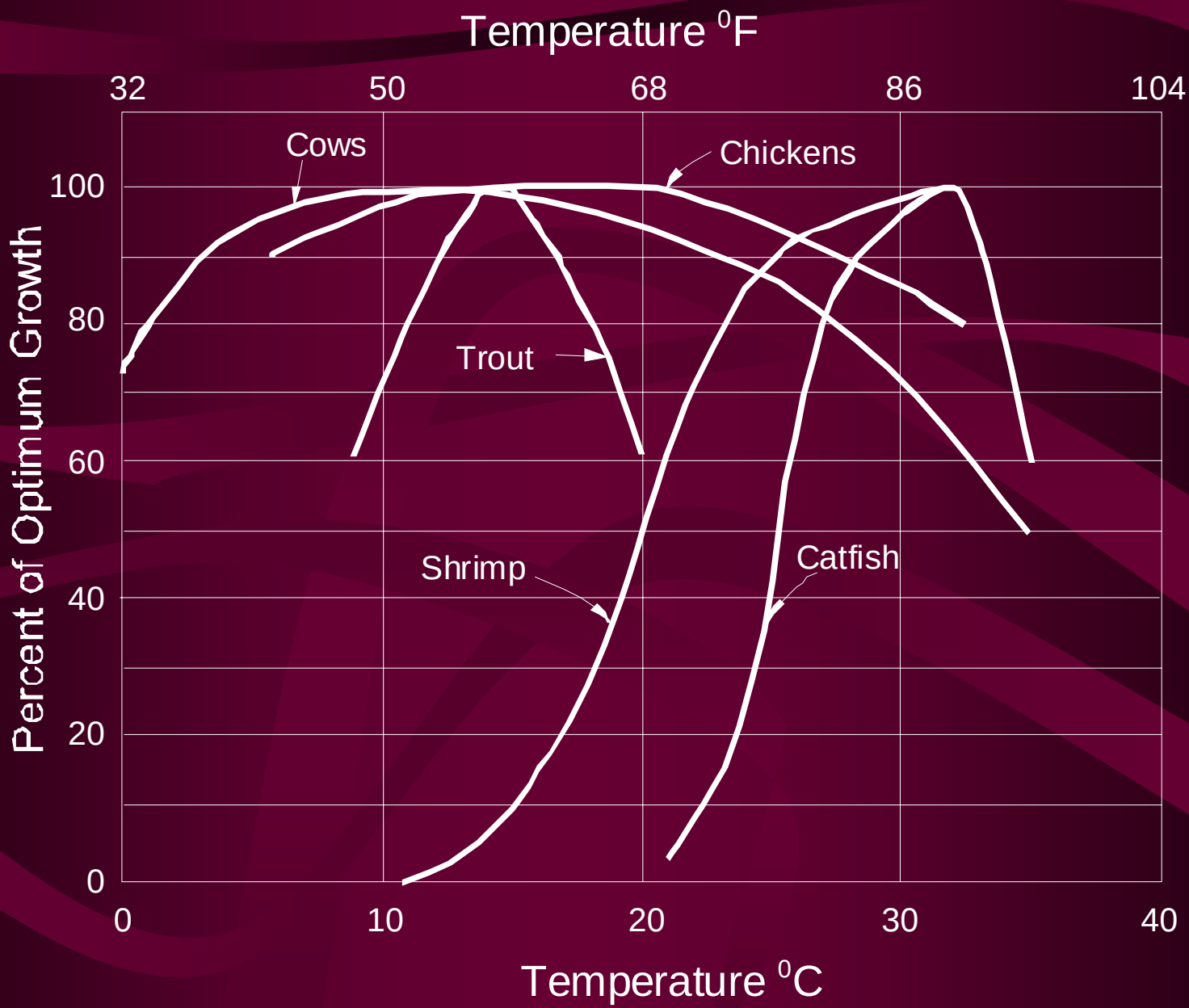
- Need to determine peak heating requirements for the structure
- The heat loss is composed of two components
  - Transmission loss through the walls and roof
  - Infiltration and ventilation losses due to heating of cold outside air – based on air changes per hour
- Annual heating load = CF = 0.45 worldwide

  x 8760 x peak heating loss

Geothermal Aquaculture Pond and Raceway Heating

Introduction

- Involved in raising of freshwater or marine organisms in a controlled environment to enhance production rates.
- Temperature control is generally more important for aquatic species than land animals. When the water temperature is below the optimum range, the fish lose their ability to feed because the basic body metabolium is affected.
- Geothermal energy can control the temperature much better than depending upon the sun for heating.


Temperature ^{0}F
32
50
68
86
104
Cows
Chickens
Trout
Shrimp
Catfish
Percent of Optimum Growth
100
80
60
40
20
0
0
10
20
30
40
Temperature ^{0}C

Design Considerations

- Ideal pond sizes from 0.25 to 0.50 acre with up to one acre used
- Many operations use circular tanks 30 to 120 ft. in diameter (plastic or metal)
- Minimum commercial operation require 7.5 to 10 acres (20 to 30 ponds or tanks)
- Typical water requirements: 100 to 150°F @ 80 to 160 gpm per 0.25 acre pond – cold climate and uncovered – (about 250 Btu/hr/ft^2)

Design Considerations 2

- Pond construction
  - Long axis perpendicular to wind to minimize wave action and temperature loss
  - Constructed of earth with clay or plastic liner
  - Some covered with plastic bubble or in a greenhouse
- Construction cost: $30,000 to $60,000/acre + geothermal system (wells, pipes, HE, pumps)
- Most important consideration: water quality and disease control (prevention) – may require HE

Design Procedure

- Uncovered ponds exposed to atmosphere lose heat by four mechanisms
- 1. Evaporation – 50 to 60 % of loss
- 2. Convection – 2nd largest loss
- 3. Radiation – 3rd largest loss
- 4. Conduction
- Sum is the total heat loss (peak): CF = 0.65
- Annual loss = 0.65 x 8760 x peak loss
- Covered pond – heat loss about 50% -
  - (About 100 Btu/hr/ft^2)

Slovakia

Eel farm

The final results!!

Thank You