Industrial Applications

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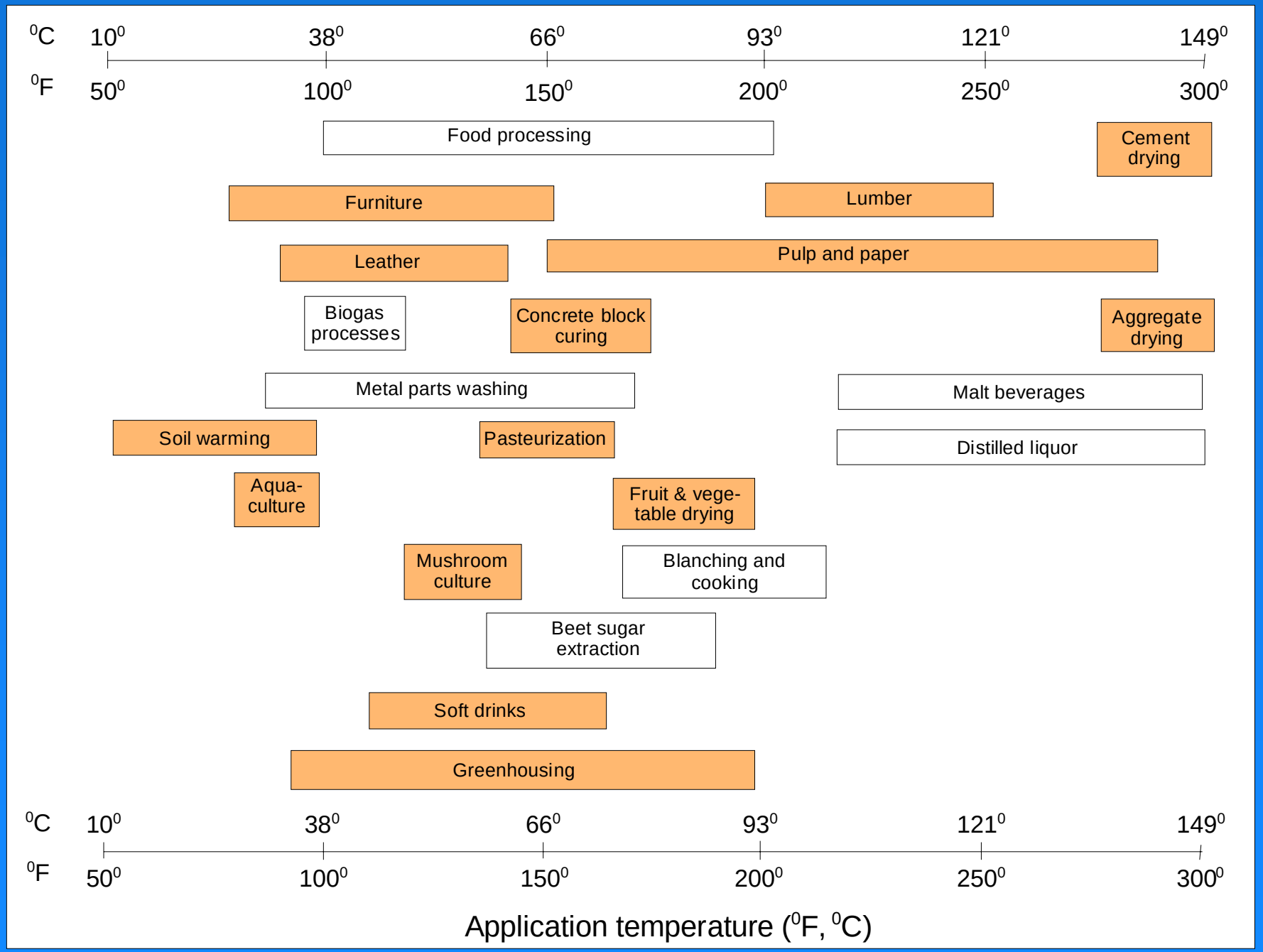
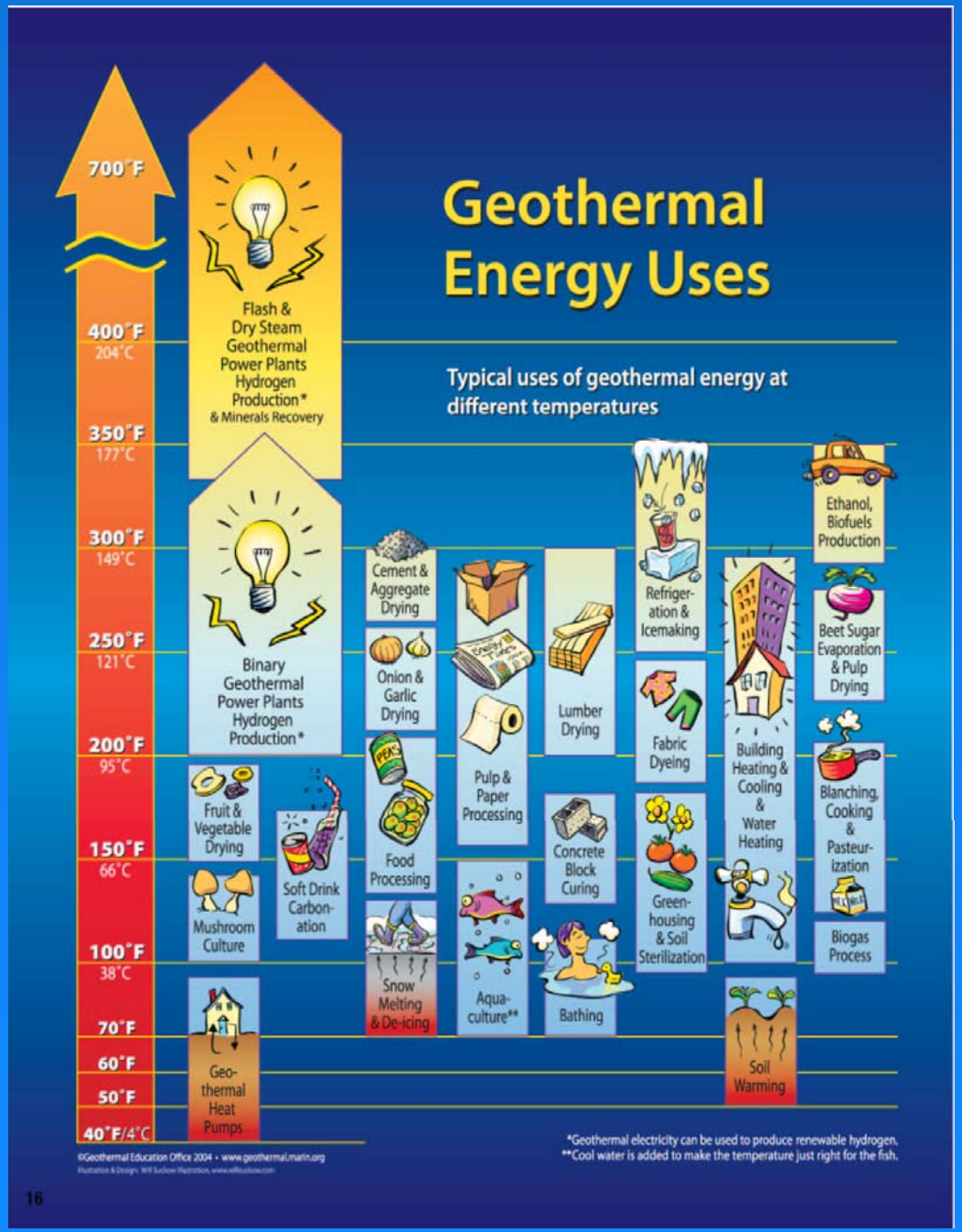
INTRODUCTION

- **Many applications over a wide range of temperatures – however, the use is normally associated with high temperature requirements: >212^{o}F, such as:**
  - **Evaporation**
  - **Drying (fish, grain, timber, fruit, vegetables)**
  - **Distillation**
  - **Refrigeration**
  - **Washing and sterilization**
  - **Chemical extraction (salt, boric acid, silica)**
  - **Pulp and paper manufacturing**


°C 10° 38° 66° 93° 121° 149°
°F 50° 100° 150° 200° 250° 300°
Food processing
Cement drying
Furniture
Lumber
Leather
Pulp and paper
Biogas processes
Concrete block curing
Aggregate drying
Metal parts washing
Malt beverages
Soil warming
Pasteurization
Distilled liquor
Aqua-culture
Fruit & vege-table drying
Mushroom culture
Blanching and cooking
Beet sugar extraction
Soft drinks
Greenhousing
°C 10° 38° 66° 93° 121° 149°
°F 50° 100° 150° 200° 250° 300°
Application temperature (°F, °C)


Geothermal Energy Uses
Typical uses of geothermal energy at different temperatures
700˚F
400˚F
204˚C
350˚F
177˚C
300˚F
149˚C
250˚F
121˚C
200˚F
95˚C
150˚F
66˚C
100˚F
38˚C
70˚F
60˚F
50˚F
40˚F/4˚C
Flash & Dry Steam Geothermal Power Plants Hydrogen Production* & Minerals Recovery
Binary Geothermal Power Plants Hydrogen Production*
Fruit & Vegetable Drying
Soft Drink Carbon-ation
Mushroom Culture
Geo-thermal Heat Pumps
Cement & Aggregate Drying
Onion & Garlic Drying
Food Processing
Snow Melting & De-icing
Pulp & Paper Processing
Aqua-culture**
Lumber Drying
Concrete Block Curing
Bathing
Refriger-ation & Icemaking
Fabric Dyeing
Green-housing & Soil Sterilization
Building Heating & Cooling & Water Heating
Soil Warming
Ethanol, Biofuels Production
Beet Sugar Evaporation & Pulp Drying
Blanching, Cooking & Pasteur-ization
Biogas Process
*Geothermal electricity can be used to produce renewable hydrogen.
**Cool water is added to make the temperature just right for the fish.
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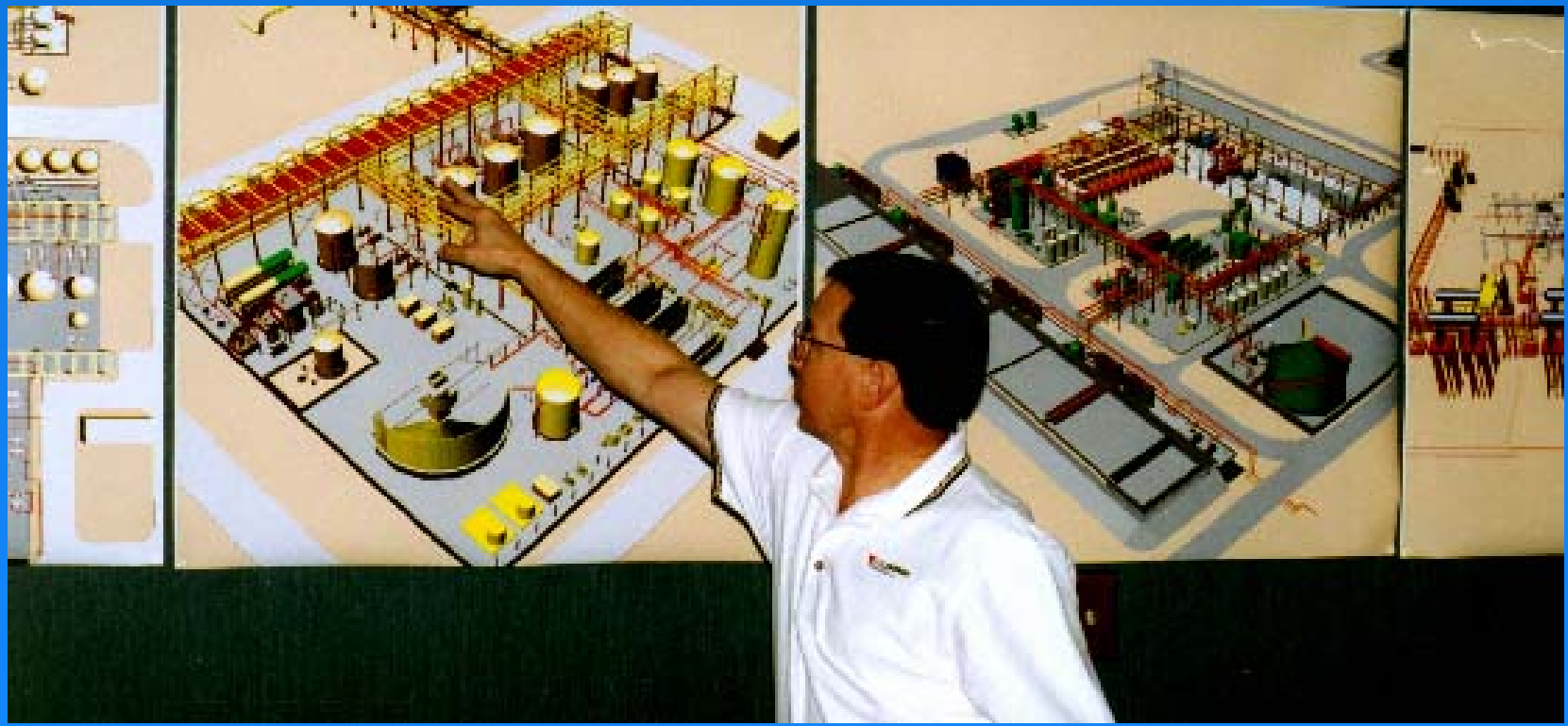
ZINC EXTRACTION

- CalEnergy Operating Corp. $200 million Mineral Recovery Project
- Located on the shore of the Salton Sea in southern California – Imperial Valley
- CalEnergy operates 10 geothermal power plants = 347 MWe
- 9,000 tons/hr brine at 600 ppm zinc
- Recover 33,000 tons/yr @ $/0.50/lb

  = $33 million/yr



HEAP LEACHING 1

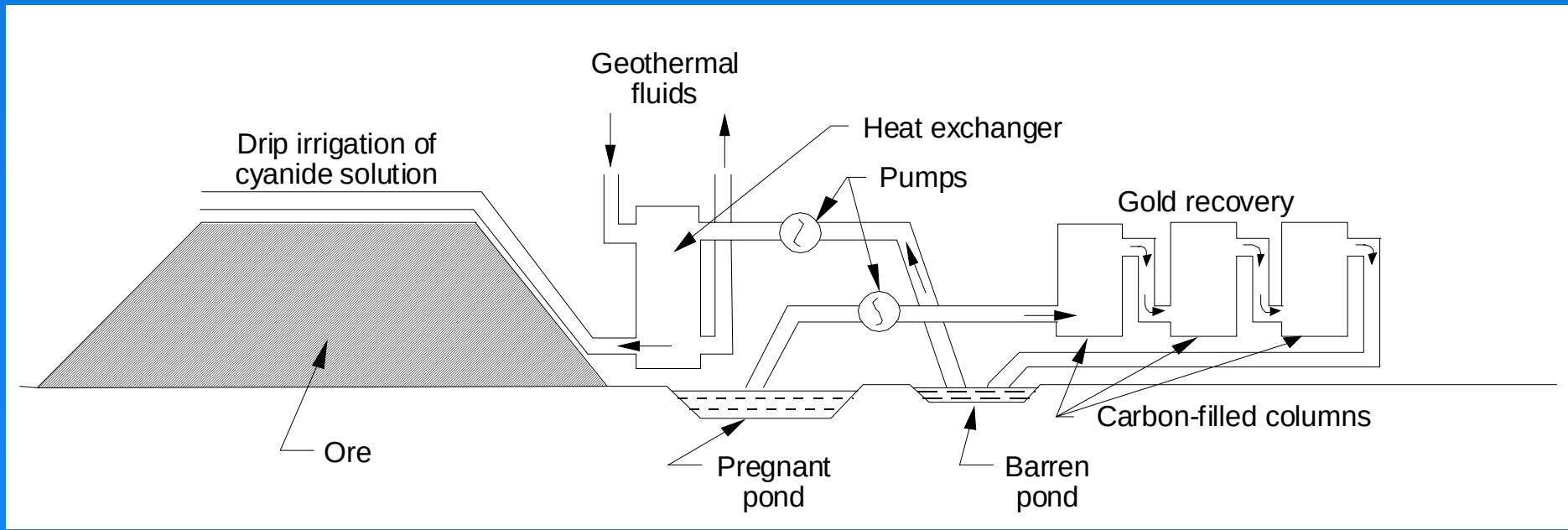
- Used in gold recovery from Nevada mines
- Process consists of dripping a dilute sodium cyanide solution over a crushed ore pile or heap
- The gold, in solution, drains from the heap and extracted by a charcoal process producing a bar of impure gold (doré).
- The cyanide solution is then recycled

HEAP LEACHING 2

- Operation can recover up to 95% of gold
- Also, used for silver extraction
- Under normal circumstances – in Nevada – operation takes place mid-March to late-October (min. production temp. = 40^{o}F)
- Using geothermal energy
  - Recovered enhanced by 5 to 17% by accelerating the chemical reaction
  - Year-around operation possible

HEAP LEACHING

Geothermal @ 180 to 210°F @ 350 to 1,000 gpm



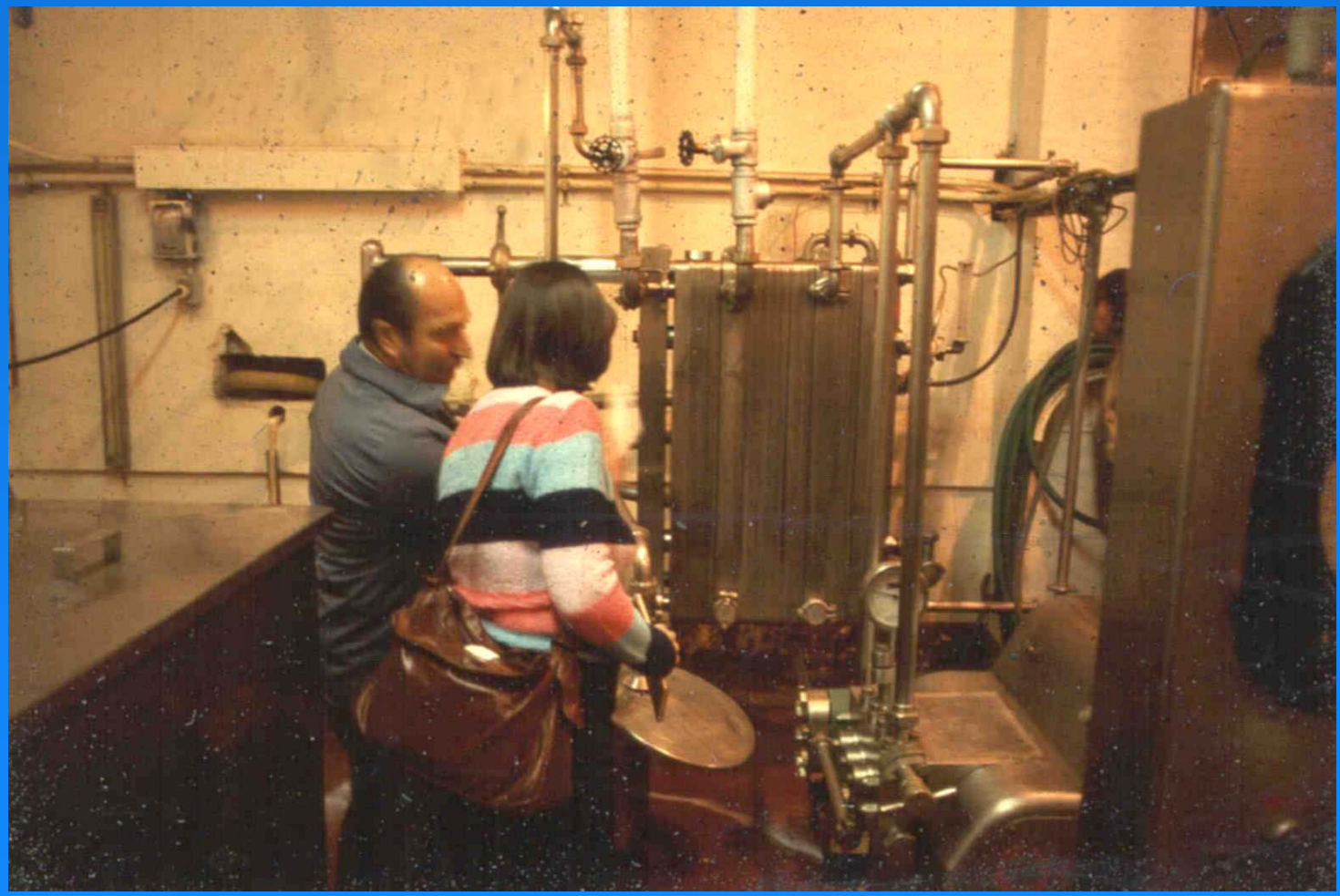
Round Mtn – 95,000 tons of ore/day @ 1g/ton

Florida Canyon – 13,000 tons/day @ 0.7g/ton

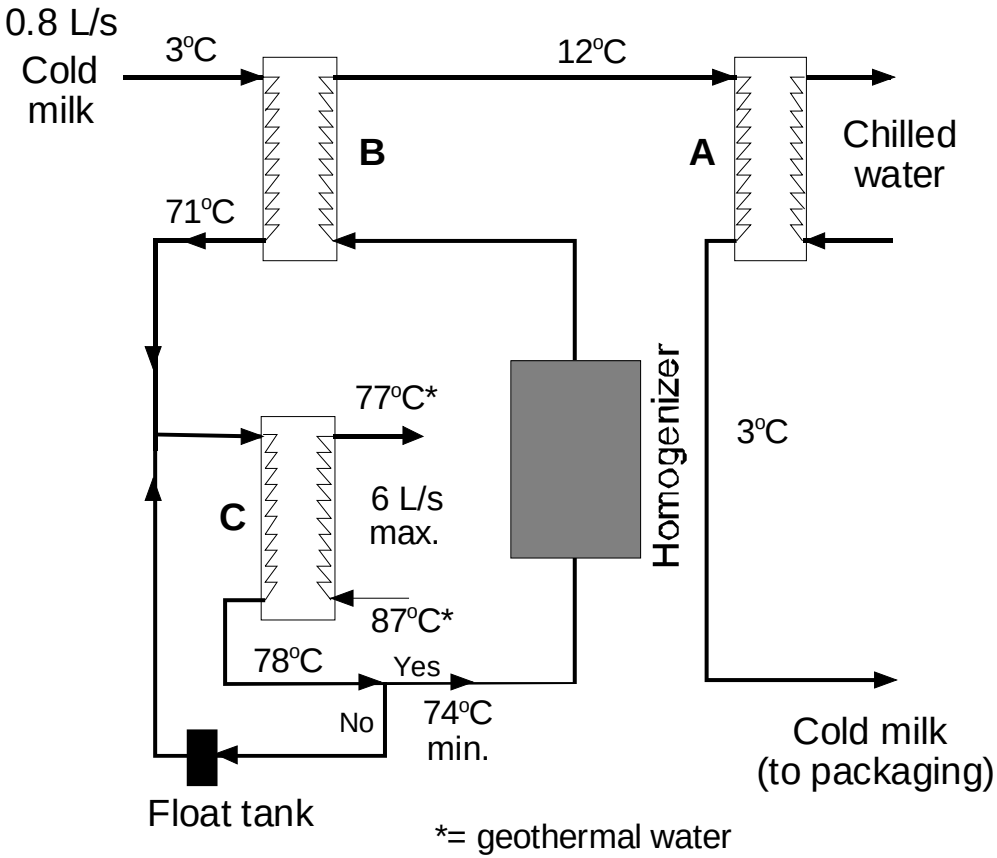
Round Mountain, Nevada

MILK PASTEURIZATION

- Plate heat exchanger's 3 sections:
- 1. Preheats incoming milk at 37^{o}F by outgoing (pasteurized) milk to 160^{o}F
- 2. Pasteurizes milk with geothermal water (in at 189^{o}F and out at 171^{o}F)
- 3. Finally, cools hot milk by preheating incoming cold milk and is then further cooled with chilled water back to 37^{o}F



Medo-Bel Creamery, Klamath Falls, Oregon



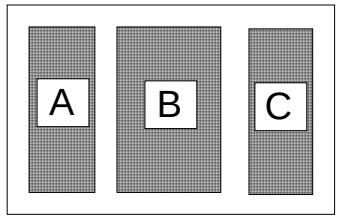
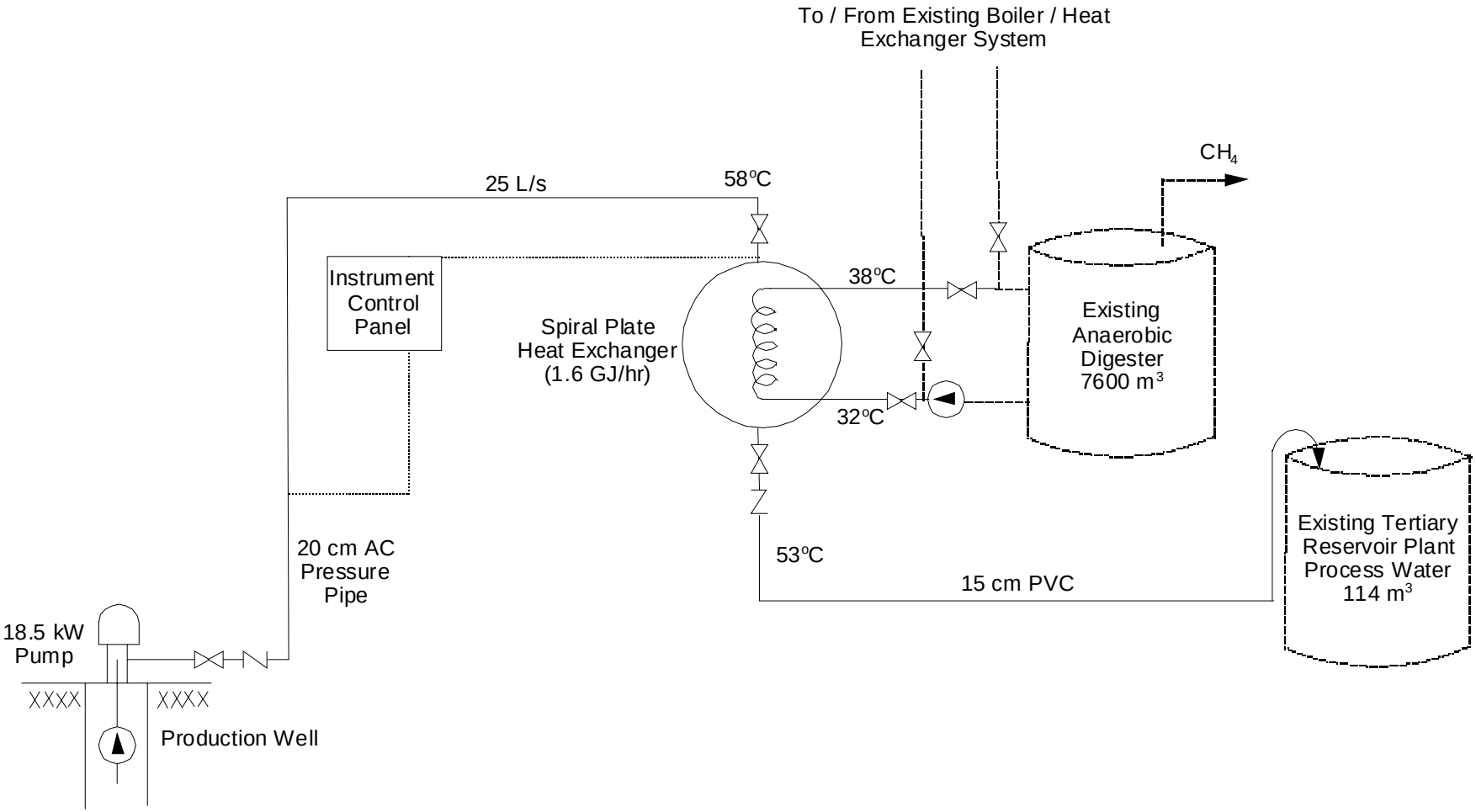


Plate heat exchangers (Cherry Burrell)
A: chilled water and hot milk
B: cold and hot milk
C: geothermal water and cold milk
(short term pasteurizer)

SLUDGE DIGESTION

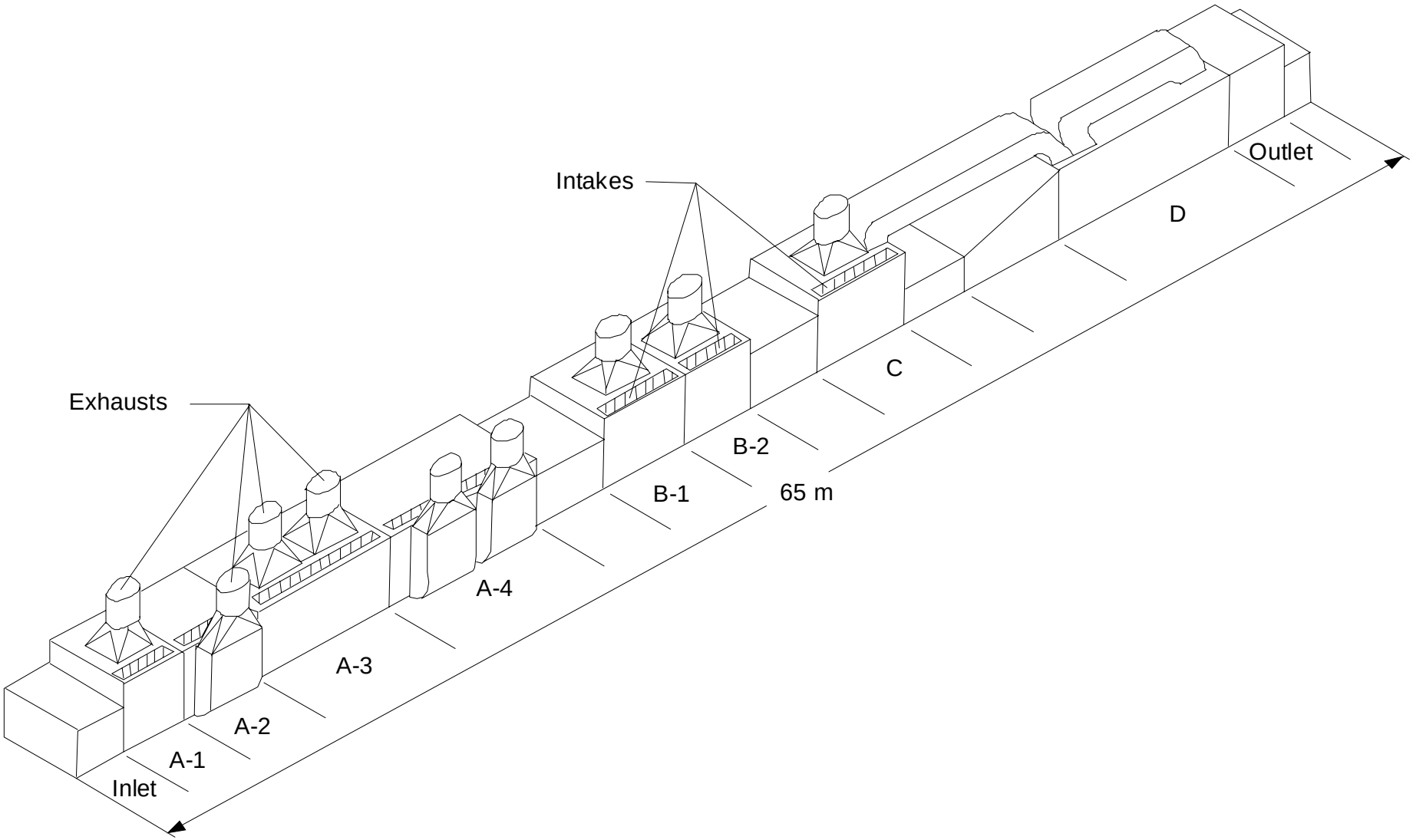
- City of San Bernardino has a geothermal district heating system serving 14 major buildings = 13 MWt
- The city installed a primary anaerobic sewerage digester in 1983
- Process uses 136^{o}F geothermal fluid which replaced methane fuel
- The digester, which uses living anaerobic micro-organisms to feed on the organics, uses geothermal to assist the process



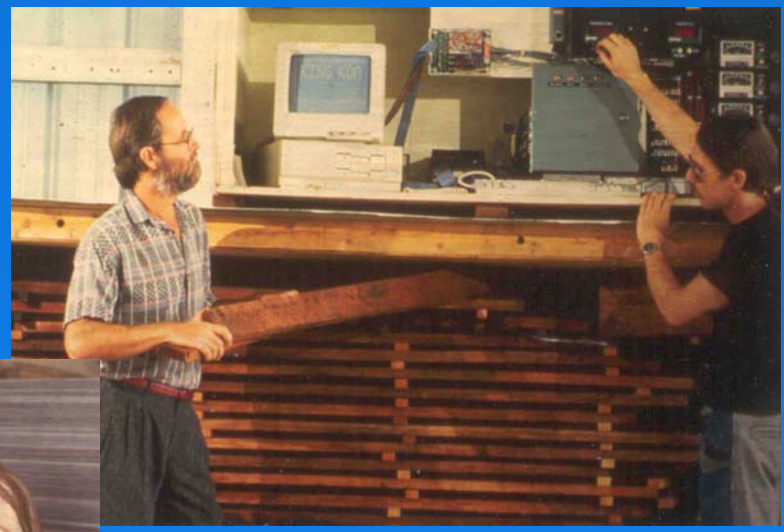
San Bernardino, California

AGRICULTURAL DRYING

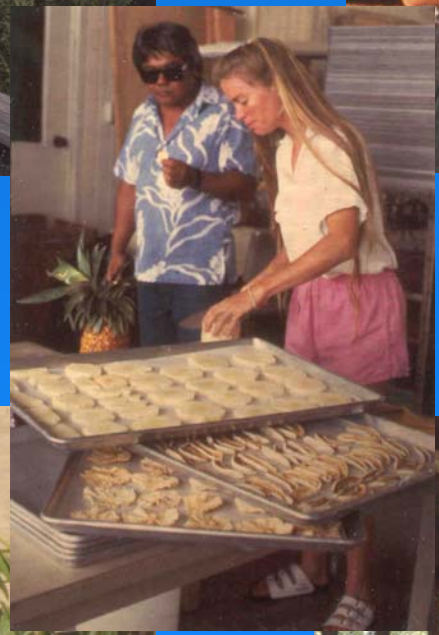
- Two large geothermal onion and garlic dehydrators are located in NW Nevada
- These units can process 10,000 to 15,000 lbs of wet onions/hr – drying them from 85% to 5% moisture (output = 2,000 lbs/hr)
- 15,000 Btu/dry lb used = 100 billion Btu/yr (150 days period) – 210 to 120°F air
- Product used in soups, baked goods, salt, & seasoning as powders to slices


Intakes
Outlet
D
C
B-2
B-1
65 m
Exhausts
A-4
A-3
A-2
A-1
Inlet


HOT



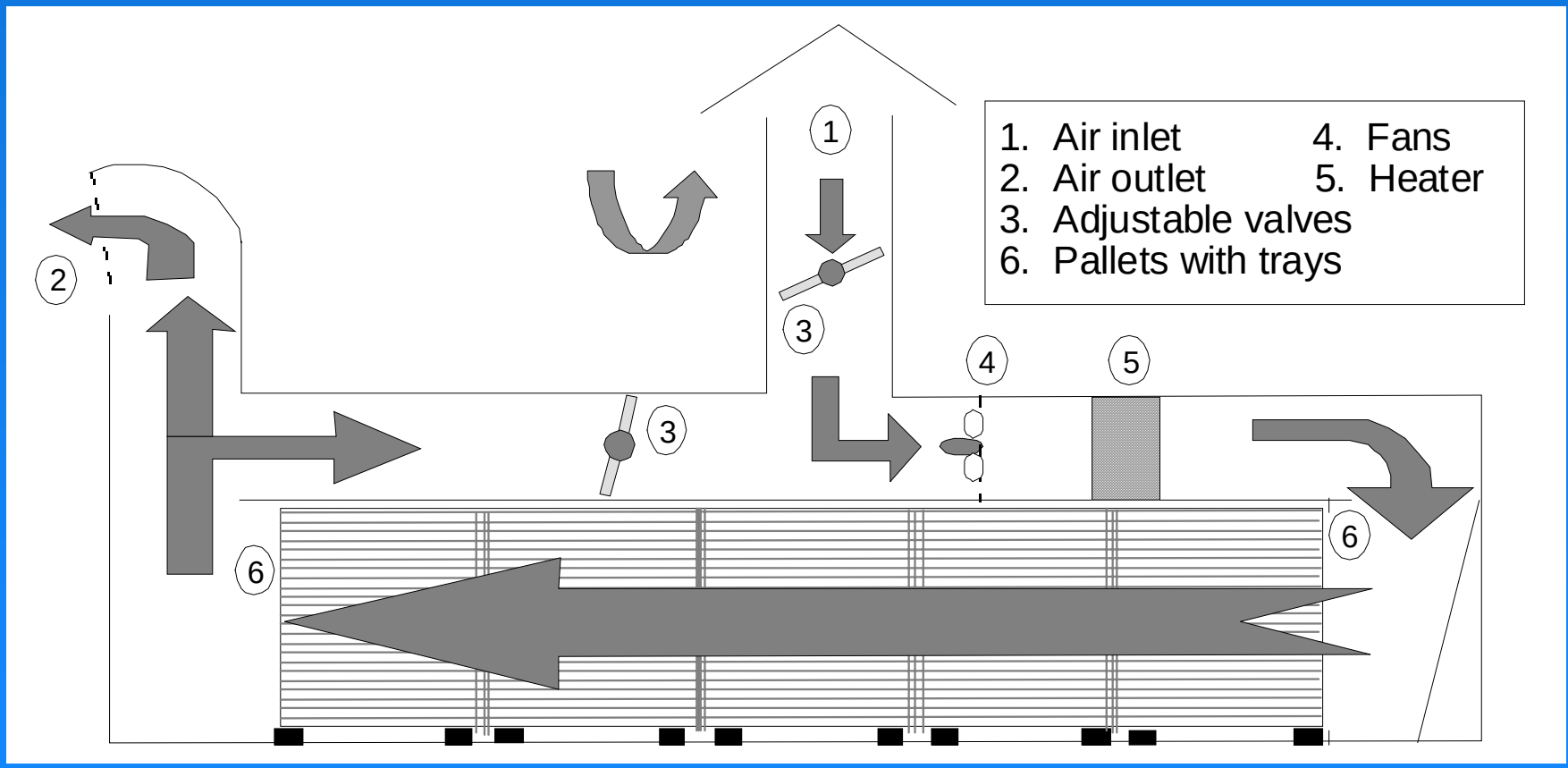
Noi'i O Puna
1985-89



Puna Geothermal
Research Center

FISH DRYING- ICELAND

- **Drying of cod heads – 12,000 tons/yr**
- **Primary drying – rack or conveyor-belt cabinet – 5 lbs/ft² @ 64 to 77ºF – 24-40hrs –moisture content reduced from 82 to 55%**
- **Secondary drying – in containers - 72 to 79ºF - 3 days – moisture content reduced from 55 to 15%**
- **Exported to Asia and Africa as a protein source**

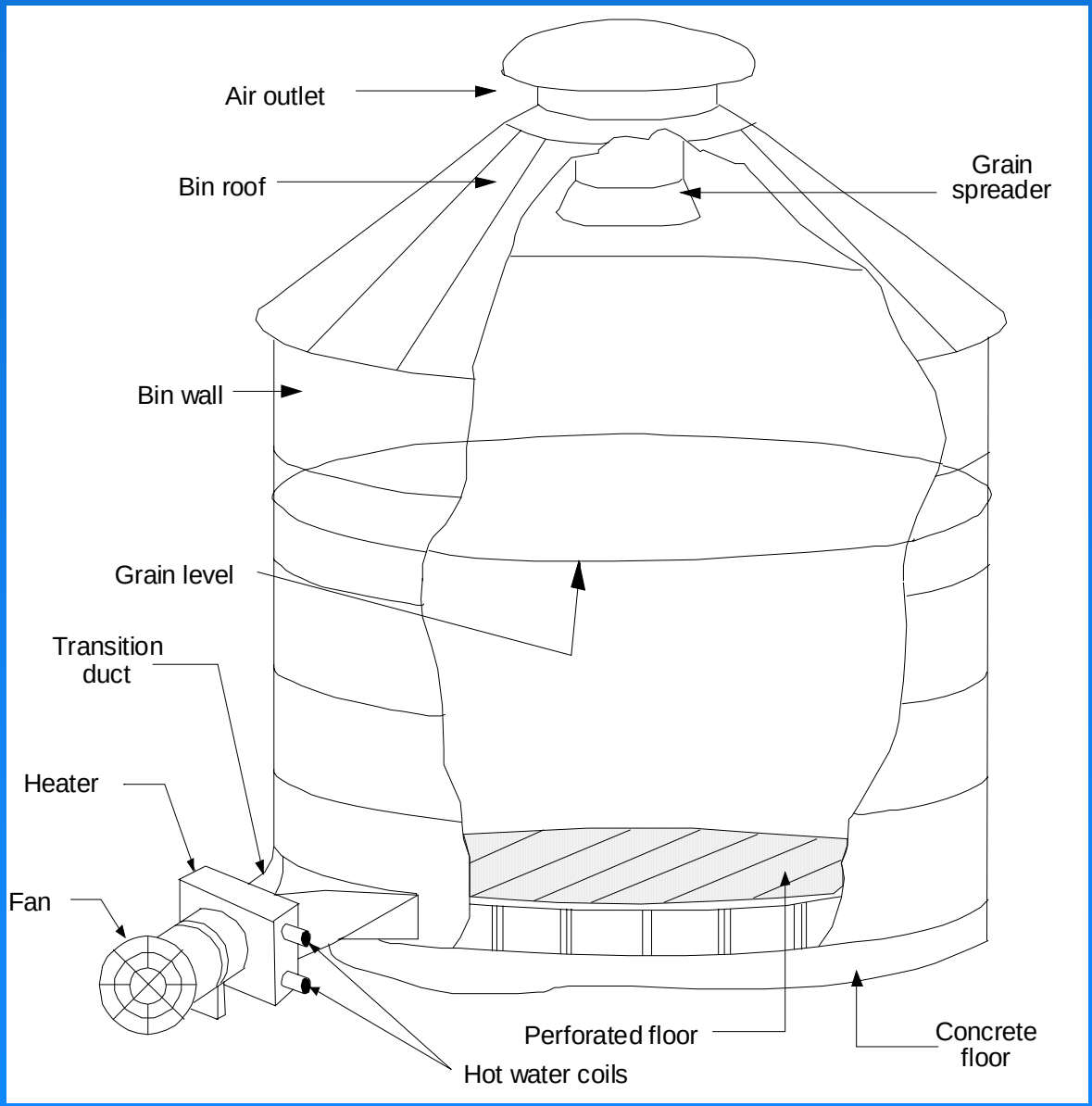


Rack drying cabinet for primary fish drying in Iceland

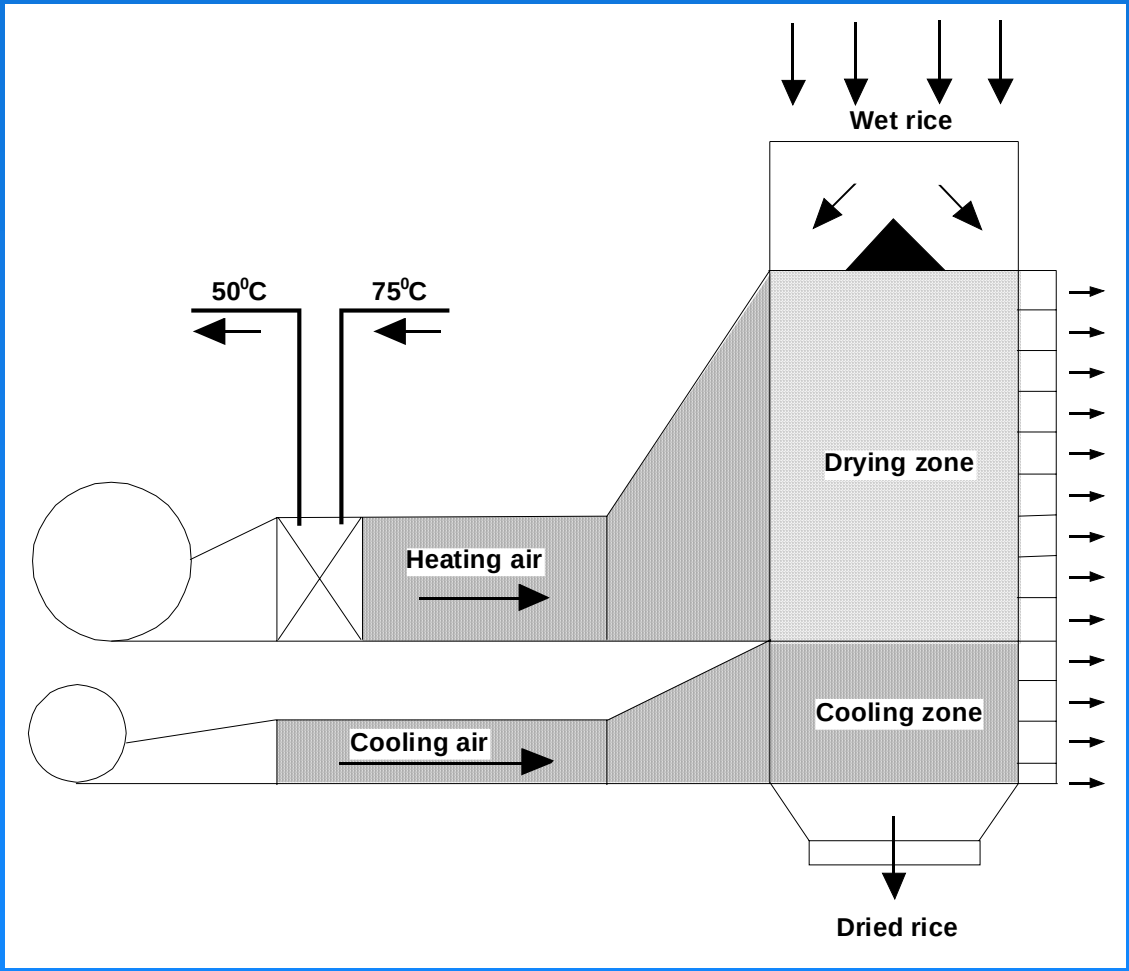
138ºF
geo.

6 lbs/h
4t/yr
dried

Tomato drying - Greece



Batch Grain Drying

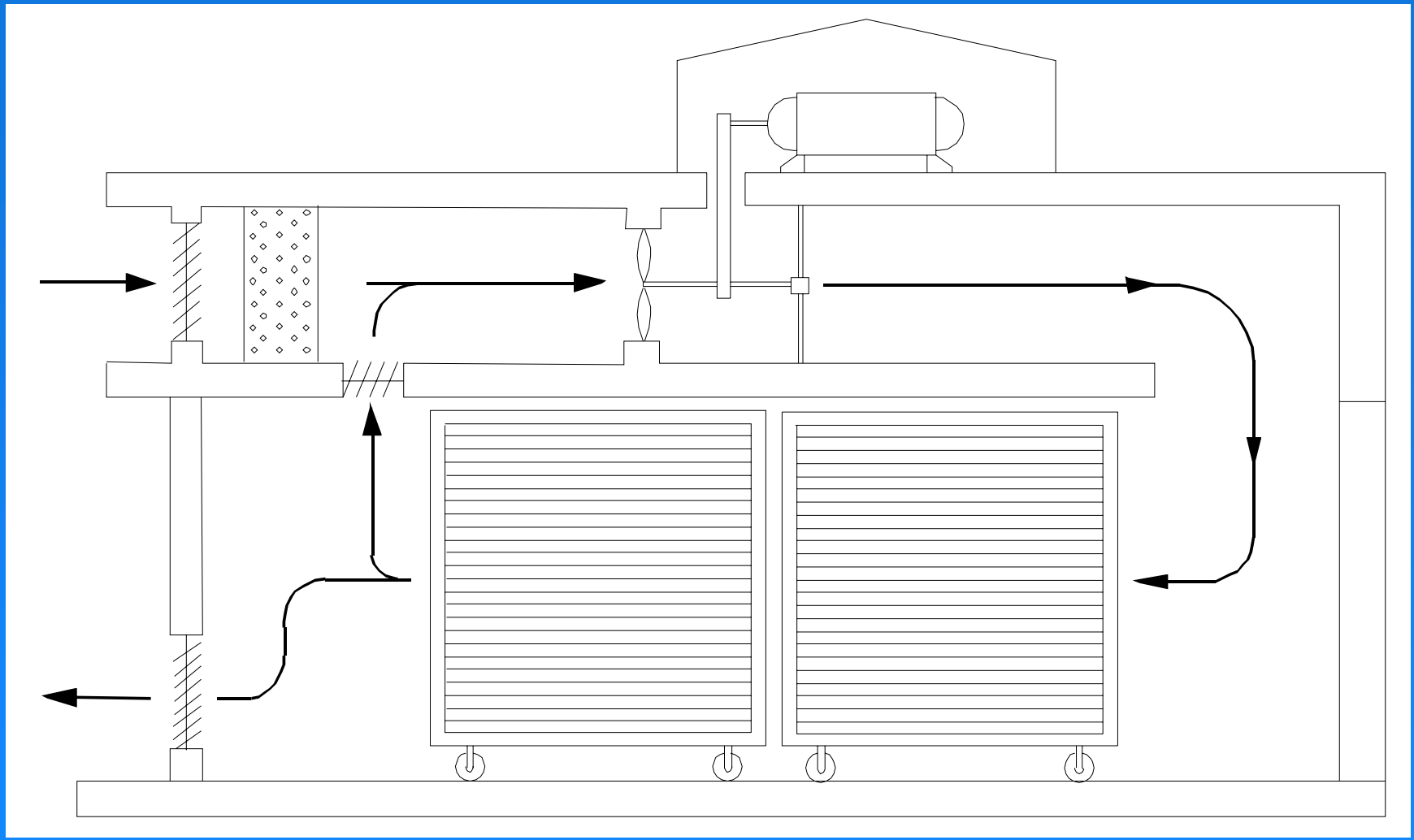


Rice dryer in Macedonia – 1360 kWt (4.6 mill. Btu/hr)

167ºF resource - 95ºF air – 10t/h – moisture 20% to 14%

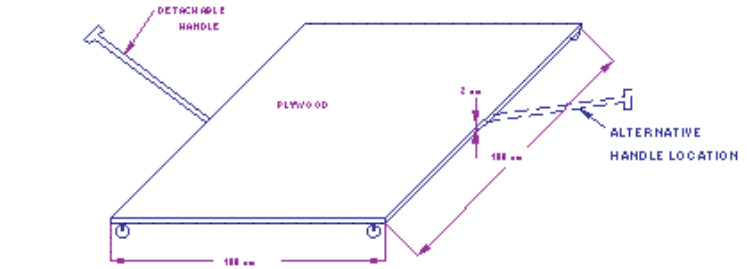
SMALL FRUIT DRIER

- **Designed for Los Azufres, Mexico**
- **Design (for pears, prunes, peaches):**
  - **Building 12 ft. x 4 ft. x 10 ft. high**
  - **Two trucks with 30 trays each**
  - **Each tray 3 ft. x 3 ft. x 2 in. high**
  - **Each tray will carry 33 lbs of wet fruit**
  - **Approx. one ton of fruit/cycle**
  - **Fruit dried from 80% to 20% moisture in 24 hr**

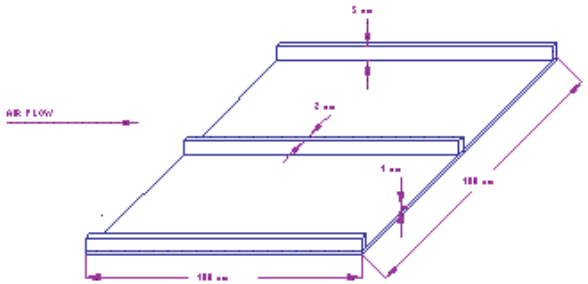


Fruit drier in Mexico

Details of the Los Azufres geothermal fruit dryer



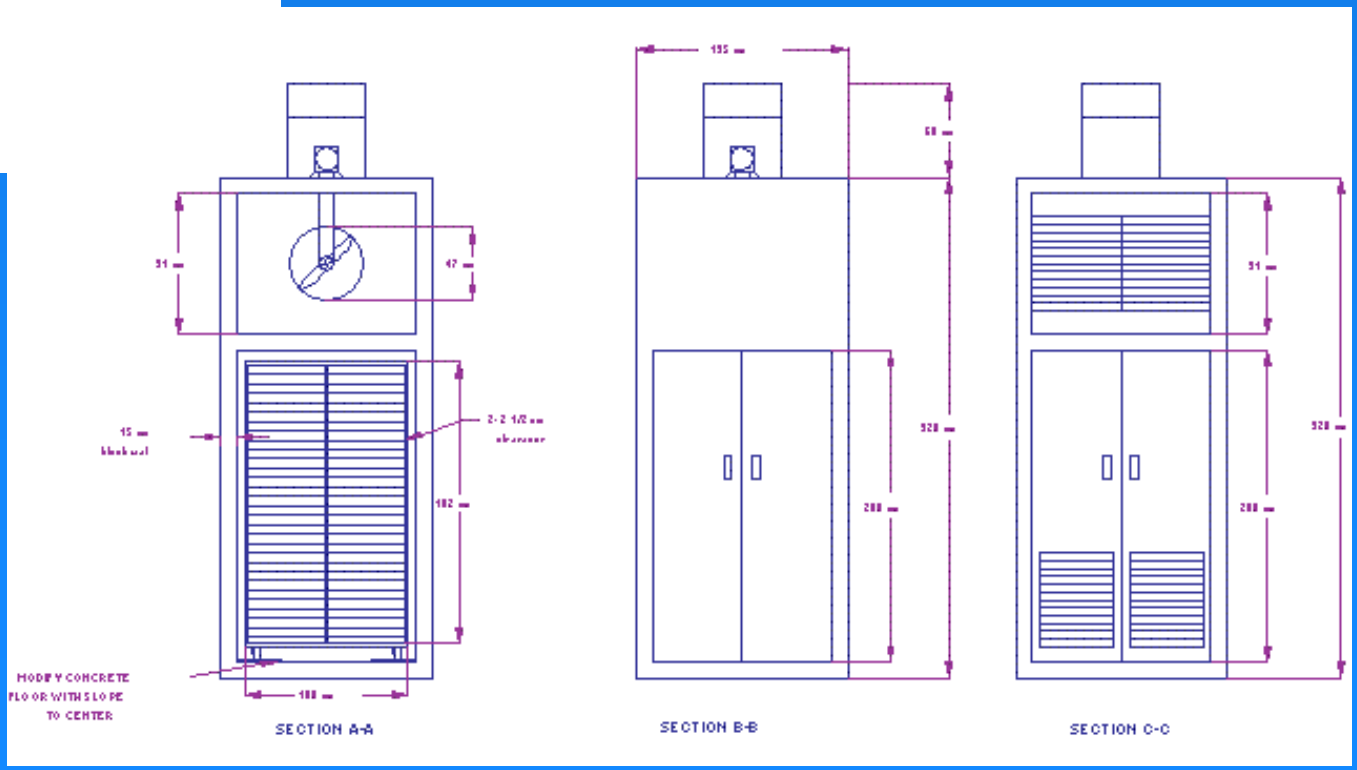
TRUCK BASE DESIGN

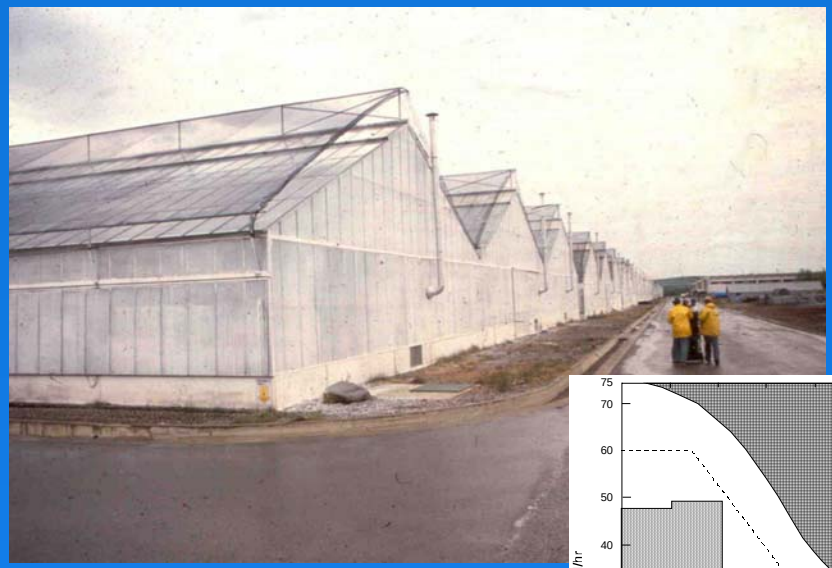


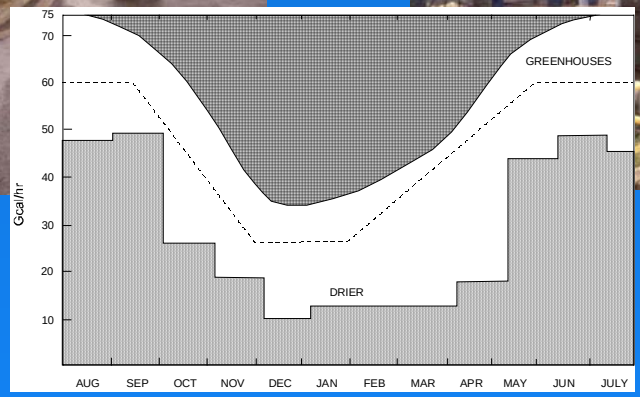
TRAY DESIGN
(30 per truck)

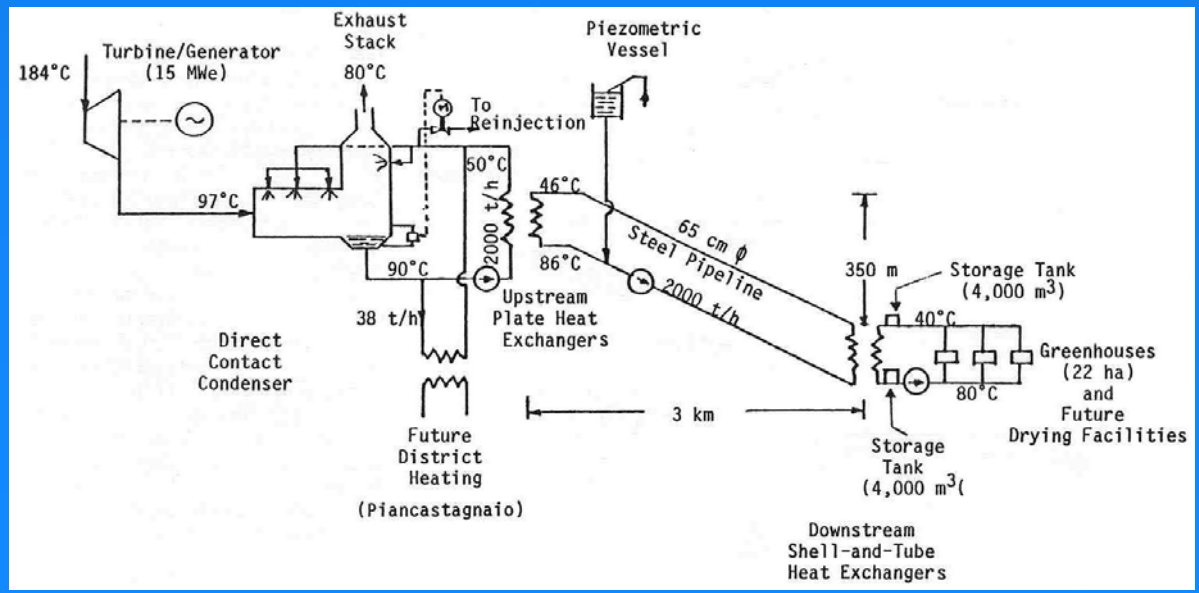
Trays

End view of cabinet







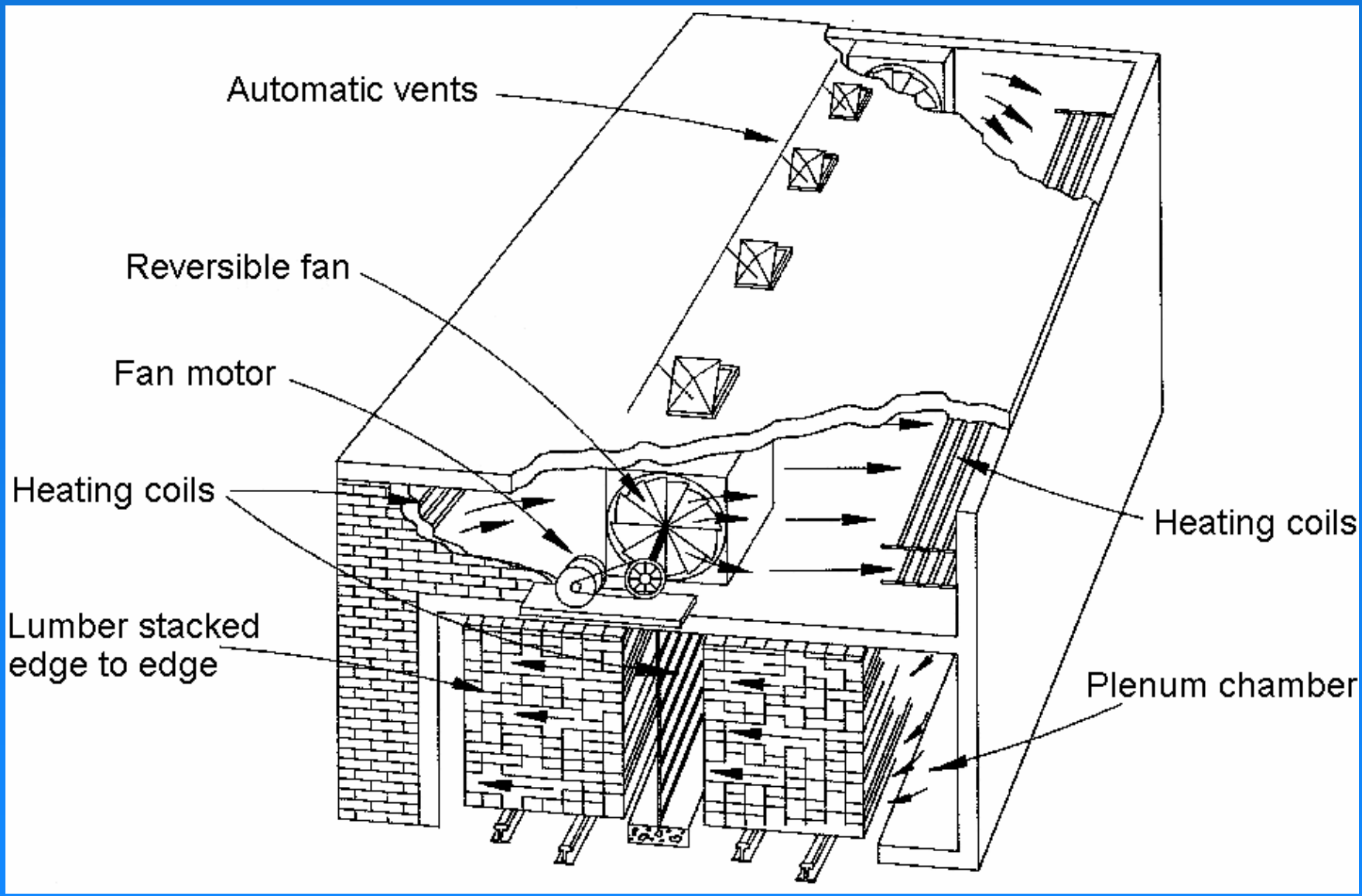


Mt. Amiata, Italy

- 15 MWe – 363°F
- 54 acres houses
- 186°F – 2000t/hr
- Flowers/plants
- Feed/vegetables
- 650 employees

KILN TIMBER DRYING

- Two basic purposes of drying timber
  - Set the sap
  - Prevent warping
- Sap sets at 135 to 140^{o}F
- Warping is prevented by establishing uniform moisture content throughout the thickness of the wood
- If left exposed to the sun (air drying)
  - Exterior loses moisture faster than the interior
  - Sets up stresses – causes warping



Long-shaft, double track, compartment kiln with fans

GEOTHERMAL KILN OPS.

- 1.5 to 3 x energy to evaporate moisture from wood as it does from pure water
- Entering water temperature (geothermal) must be 15 to 25ºF above temperature required in kiln
- Only 10 to 15% of heat used in geo. water
- Thus, discharge water can be cascaded for heating office buildings, greenhouses
- Since,175 to 195ºF geothermal supply water will be wasted at 160 to 175ºF.
- Using geothermal steam – non-condensable gas can be a problem when steam condenses at HEX surface

Fletcher Challenge Forest Operation – Kawerau, NZ

ORADEA, ROMANIA

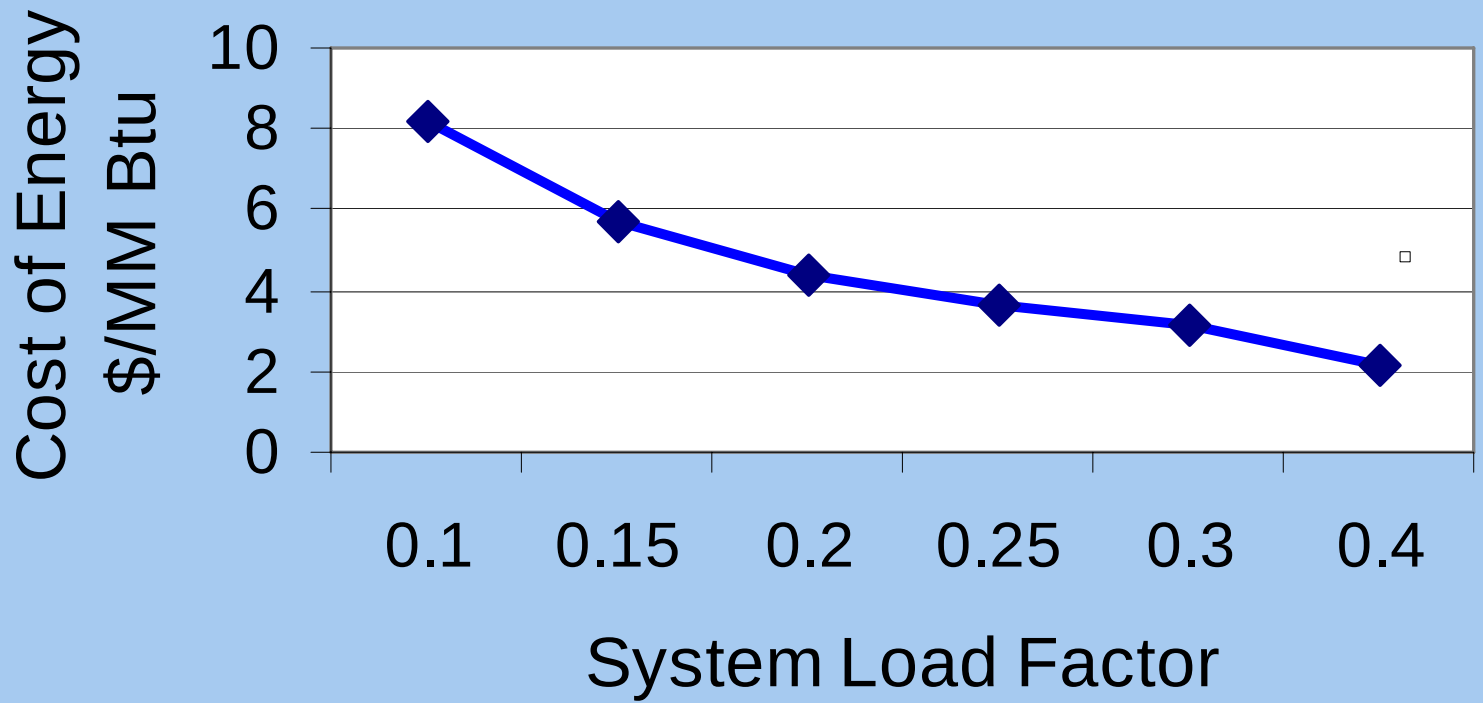
- **Furniture Manufacturing**
  - **175,000 ft^3/yr of oak**
  - **5,000 ft^3 in 3 bins**
  - **8 to 16 gpm of 212^oF water**
  - **122^oF drying temperature**
  - **2 weeks to 1 month per batch**
  - **Italian made dryer**

Lumber drying – Oradea, Romania

SUMMARY

- **Industrial use dominated by large facilities (onion dehydration, heap leaching, zinc processing)**
- **Small industrial uses include: laundries, mushroom growing, mineral water processing, grain drying, and an industrial park in Hawaii (experimental work)**
- **Higher temperature industrial applications include vegetable, fruit and timber drying/dehydration, refrigeration and enhanced oil recovery**

Cost of Energy

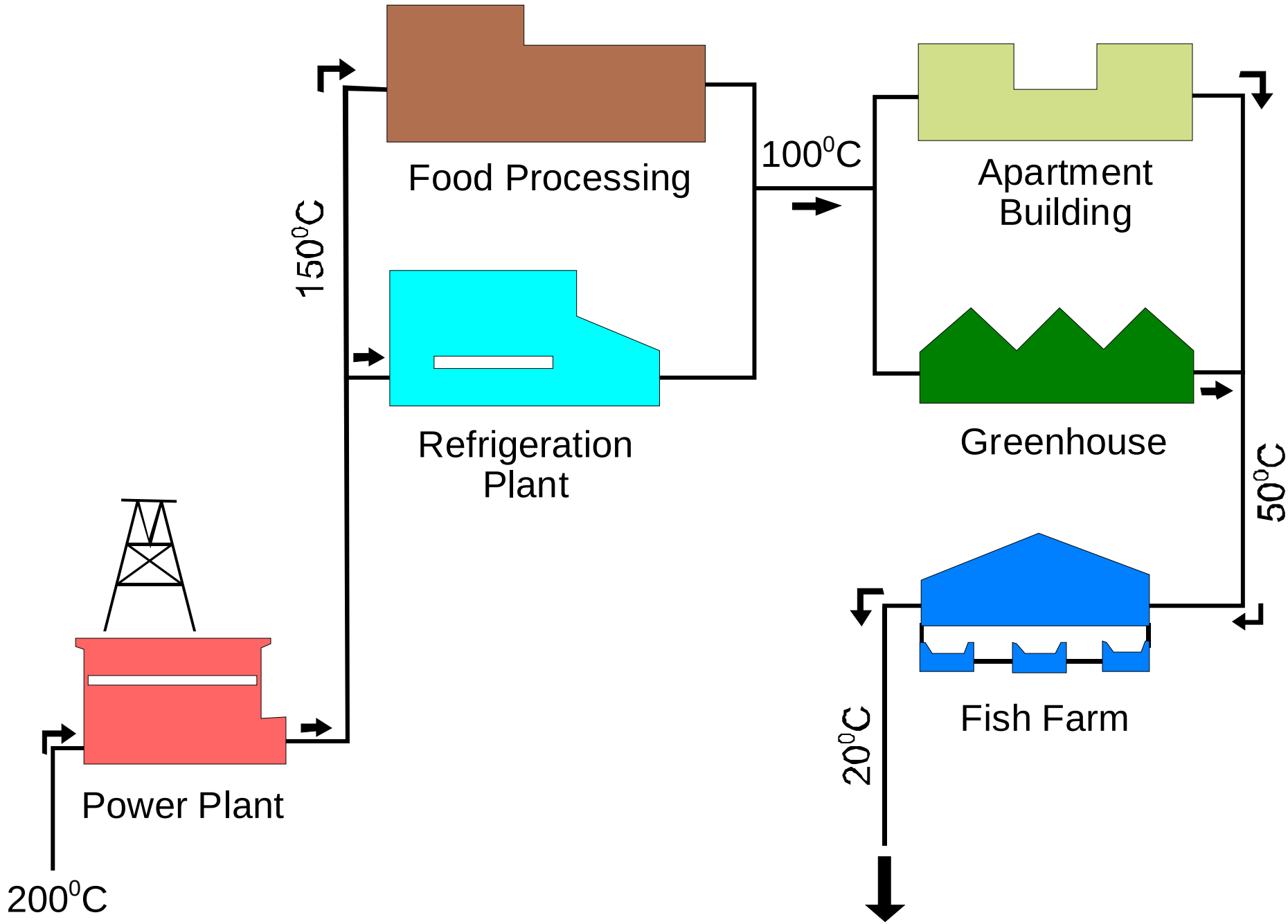


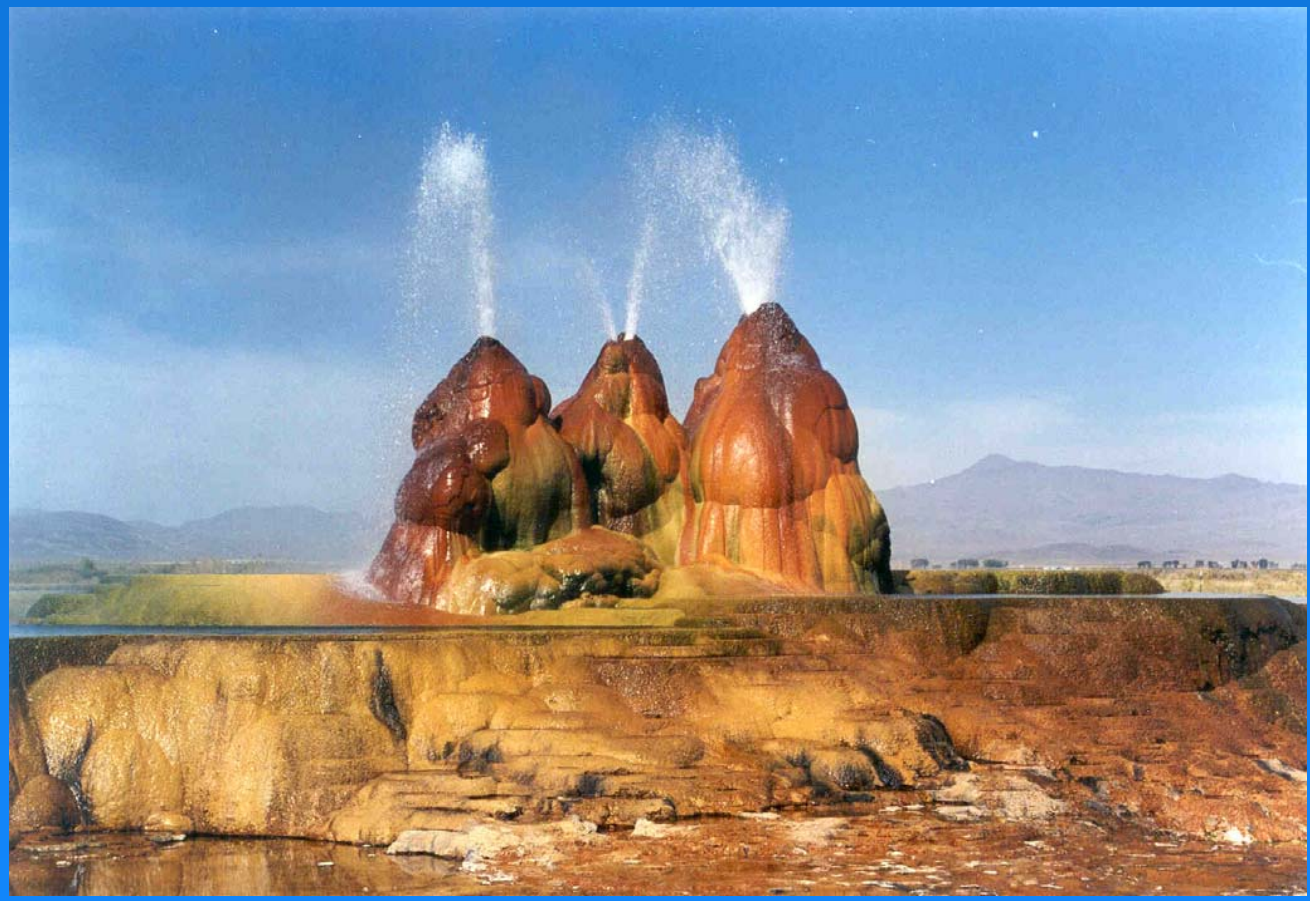
CONCLUSIONS 3

- Power plant vs dehydration plant

	Power plant	Dehydration plant
Capital Expenditure	$50 mill.	$15 mill.
Gross Revenue	$11 mill.	$18 mill.
Net Revenue	$ 9 mill.	$10 mill.
Resource require.	12,000 gpm	1,200 gpm
Employees	15	75

*source: D. Mendive, Geothermal Development Assoc., Reno, NV


Food Processing
100°C
Apartment Building
150°C
Refrigeration Plant
Greenhouse
50°C
Power Plant
Fish Farm
20°C
200°C



Thank you