



Applications of process cooling

280.371 Process Engineering
Operations

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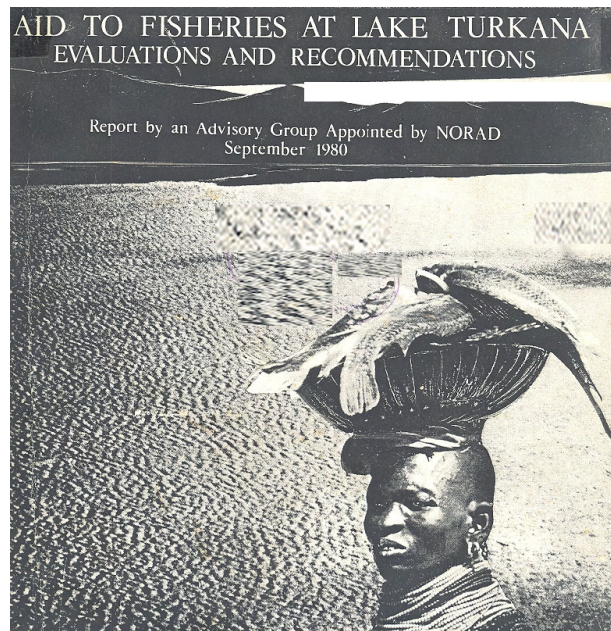
Why (efficient) cooling is important?

- In food (and drinks) industry refrigeration cost of overall site energy is up to **90%** in the case of some cold storage facilities.

Learning Outcomes:

- Knowledge of the features of refrigerated facilities and the regions of importance to ensure efficient operation:
 - Maintaining low temperatures for storage food
 - Reduce food temperature (freezing, chilling)
- Ability to use tools to estimate:
 - Heat load and operation costs for facilities

- **Project:** Lake Turkana fish processing plant, Kenya
- **Donor:** Norwegian government
Cost: \$22 million
- The project was designed in 1971 to provide jobs to the Turkana people through fishing and fish processing, storage & export.



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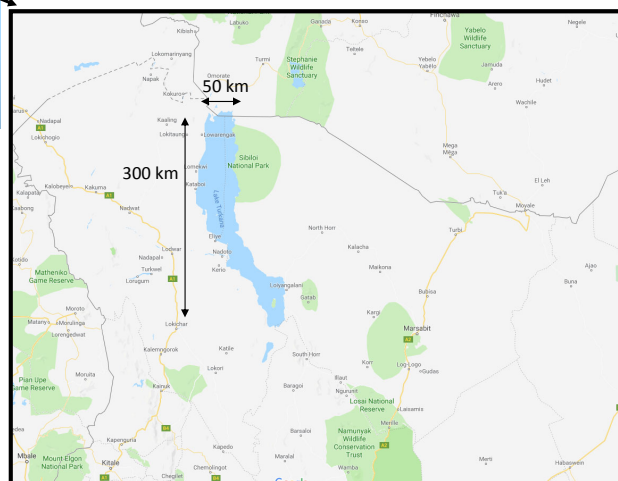
Lake Turkana:

- the world's largest permanent desert lake
- heavily fished: 50 fish species

New infrastructure will have:

- plant with freezing facilities
- processing unit
- storage facilities for frozen fish
- refrigeration machinery
- ice-making machinery
- generators and other facilities

It was shut after few days



Coldstores and cold-rooms are used to
maintain low temperature
e.g. Zespri in NZ - kiwifruit



Temperature control in the processing and
storage units



- How much heat has to be removed from cooling/freezing facility?
 - ✓ What are the sources of heat in the coldstore or cooling facility?



Heat Load

Heat load [ϕ] is defined as the amount of heat [$W=J/s$] that needs to be removed from a facility either to maintain product temperatures (in storage situations) or reduce product temperatures (in chillers or freezers).

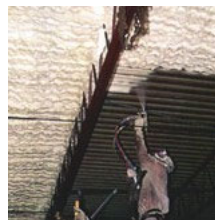
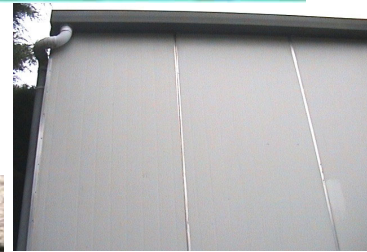
There are a variety of factors that contribute to the heat load:

- Product (in freezing and chilling)
- Fans, defrost and lights
- Other mechanical devices (e.g. forklifts, conveyors) and people
- Heat infiltration (through walls, ceiling, floor)
- Air interchange (through doors)
- Cooling of room structures, particularly concrete floors

Design considerations of the coldstore facility

Reducing heat load: Insulation Panels

- All refrigerated applications use thermal insulation around them to reduce heat load.
- Most modern facilities use expanded polystyrene sandwich panels.
- Polyurethane foam



Polyurethane foam 0.022 – 0.030 W/mK
 Polystyrene foam 0.028 – 0.035 W/mK

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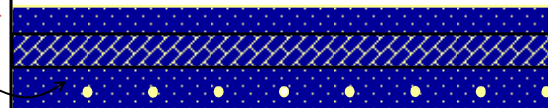
Heat load through floor

If the soil freezes under a store, the ice formed will physically lift the floor, causing frost mechanical damage.

In order to avoid this:

- Electrical heating tapes in the concrete floor under the floor insulation
- Air channels through the concrete relying on wind movement.
- Heated water or oil through pipes (usually heated with waste heat from the refrigeration system)

vapour barrier



wearing slab

insulation

channels in base

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Heat flow through doors



Rapid Roll Door



Air curtain

Forklift traffic increases the interchange on doors with protection by 30% for plastic strips

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The Loading Dock



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Lights & machinery



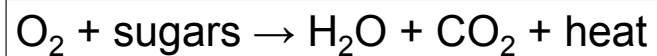
- The energy output of a light source is in two forms
- light and heat
- Energy used by lights must be paid for twice - both to put it in and to take it out via refrigeration
- Machineries engine produce heat



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Storage of Respiring Produce

- Respiring foods: fruit, vegetable (living systems)
- Hence they continue to respire:



- Good airflow required
- Controlled atmosphere uses high CO_2 and low O_2 to lower respiration rate.
 - Normal atmosphere of 21% O_2 : 79% N_2 is modified in a controlled or passive way
 - O_2 decrease and CO_2 increase reduces respiration which in turn reduces C_2H_4 and deterioration rate

Low temperature storage



- Most horticultural products are stored at low temperature (0-2°C) to reduce the rate of chemical reactions (respiration) and ethylene synthesis
- Some (eg tomatoes, bananas, avocado, pineapple, oranges, beans) are stored at 7-13°C to avoid chilling injury.

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Example of heat load estimation

- Calculate the cooling load present in a walk-in chamber, caused by the heat evolution of 2000 kg of cabbage stored at 5°C.

Answer:

From the table :28-63 W/Mg

Total heat evolution for 2000 kg of cabbage for the worst case:

$$(2000 \text{ kg})(63 \text{ W/Mg}) \times \left(\frac{1 \text{ Mg}}{1000 \text{ kg}} \right) = 126 \text{ W}$$

Table A.2.6 Approximate Heat Evolution Rates of Fresh Fruits and Vegetables When Stored at Temperatures Shown

Commodity	Watts per megagram (W/Mg) ^a			
	0°C	5°C	10°C	15°C
Apples	10–12	15–21	41–61	41–92
Apricots	15–17	19–27	33–56	63–101
Artichokes, Globe	67–133	94–177	161–291	229–429
Asparagus	81–237	161–403	269–902	471–970
Avocados	—	59–89	—	183–464
Bananas, ripening	—	—	65–116	87–164
Beans, green or snap	—	101–103	161–172	251–276
Beans, lima (unshelled)	31–89	58–106	—	296–369
Beets, red (roots)	16–21	27–28	35–40	50–69
Blackberries	46–68	85–135	154–280	208–431
Blueberries	7–31	27–36	69–104	101–183
Broccoli, sprouting	55–63	102–474	—	514–1000
Brussels sprouts	46–71	95–143	186–250	282–316
Cabbage	12–40	28–63	36–86	66–169

Estimation of the heat load

- Cooling load from a given space:

- Chilling product $\frac{m_p c_i (\theta_m - \theta_{in})}{t}$
- Freezing product $\frac{m_p [c_i (\theta_m - \theta_f) + \Delta h_f + c_s (\theta_f - \theta_{in})]}{t}$
- Heat due to vegies/fruits (at rate R(W/kg))
- Heat infiltration through walls, floor, and ceiling
- Heat gain through doors
- Heat given by lights, people, and fork lifts

A typical heat load breakdown is:

	Coldstore/Coolstore	Chiller/Freezer
Product	0-20%	50-75%
Fans	10-25%	10-40%
Heat Infiltration	20-50%	0-15%
Air Interchange	20-50%	0-15%

Total heat load is a sum of particular heat loads:

$$\phi_T = \phi_p + \phi_f + \phi_l + \phi_{md} + \phi_{pe} + \phi_i + \phi_a + \phi_s + \phi_d$$

