Lecture 2
Heat transfer in cold stores (fins)

280.371 Process Engineering and Operations

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Learning Outcomes

- Knowledge of refrigerated facilities features and the areas of importance to ensure efficient operation.

To estimate:

- Heat load in cool stores → Lecture 1
- Heat transfer in cooling → Lecture 2
- Cooling times for food products → Lecture 3
- Freezing times for food products → Lecture 4

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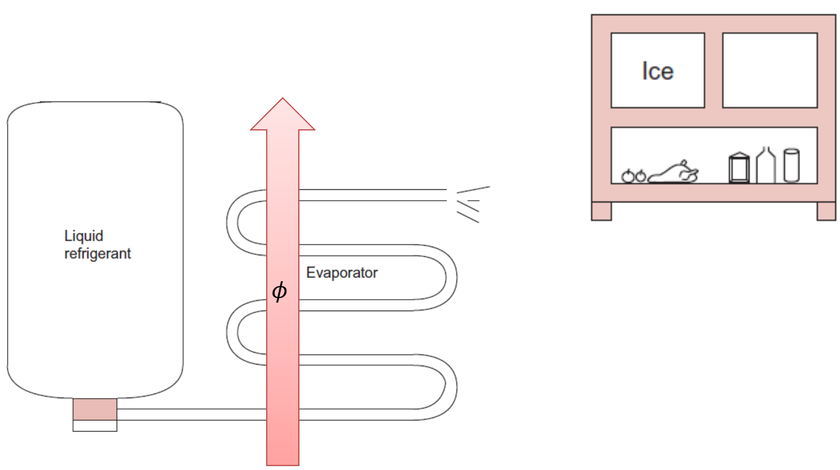
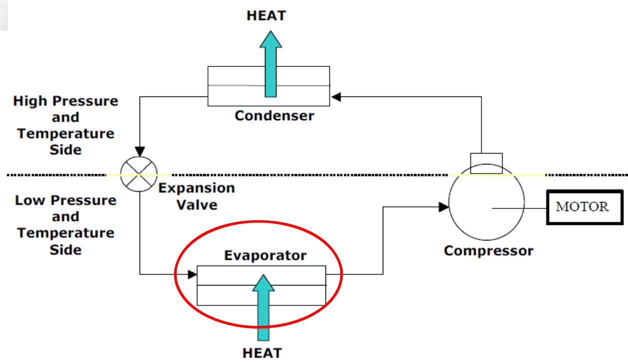
How is the C O L D produced?

Heat transfer for food cooling,
i.e. heat exchanger between food and boiling refrigerant



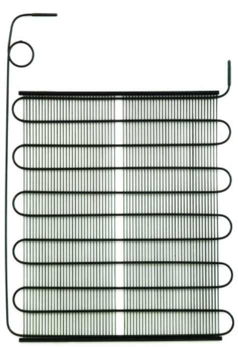
Recall - Refrigeration cycle

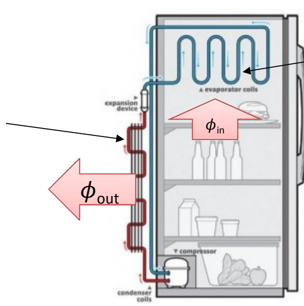


Heat load ϕ removed from food and facility

Refrigeration system: fins

The higher the surface area for the heat exchange, the better the cooling





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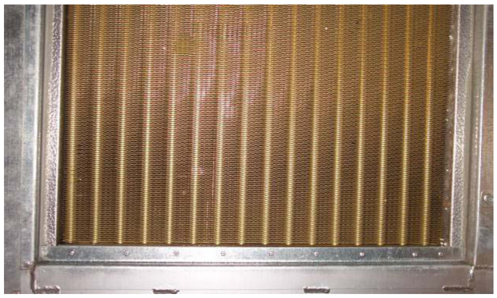
Why are the fins used? -example



- Evaporating liquid h_1 approx. 1000 W/m^{2}K.
- Flowing air h_2 are approx. 20 W/m^{2}K.
- A very low *U* value (high R) is caused by ……………… ……………….
- Need to increase …..

$$R \approx \frac{1}{h_1 A_1} + \frac{x}{kA_{12}} + \frac{1}{h_2 A_2} \approx \frac{1}{UA}$$

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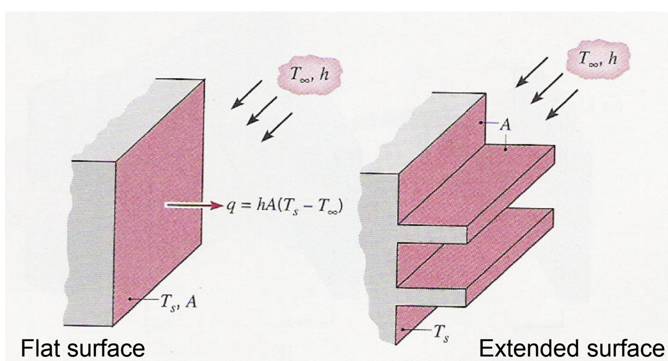
….more background: Heat flux from/to solid surface to/from air



If T_s (surface temp) is fixed, heat transfer from the surface can be increased by:

a) increase heat transfer coefficient ***h*** ↗ How ?

b) decrease the bulk temperature of fluid ***T_∞*** ↘ (Impractical/impossible?)

c) extent/increase surface area ***A*** ↗ – > employ **fins**

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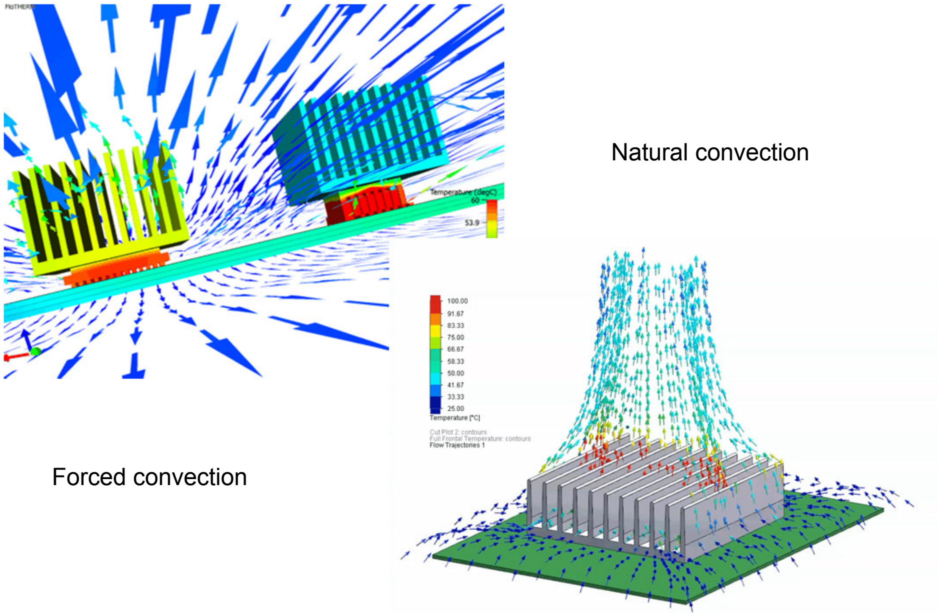
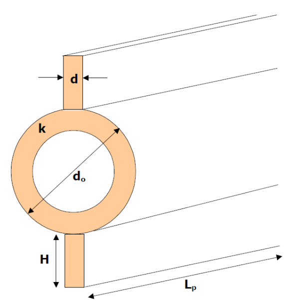
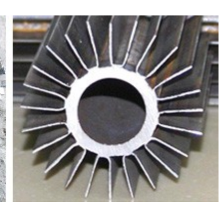
High surface area (for the heat exchange)



Longitudinal Fins

- Fins that are parallel with the refrigerant piping.
- Difficult to make (long weld length)





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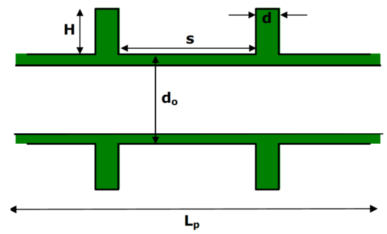
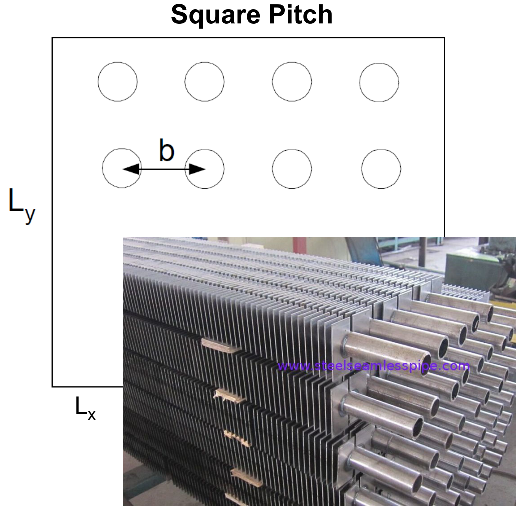
Collar Fins

- Fins that are perpendicular to the refrigerant pipe

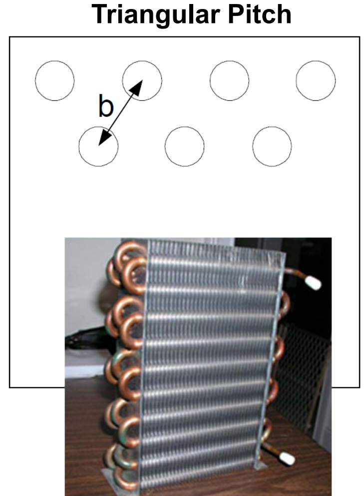


Fin Sheets – most popular

Square Pitch

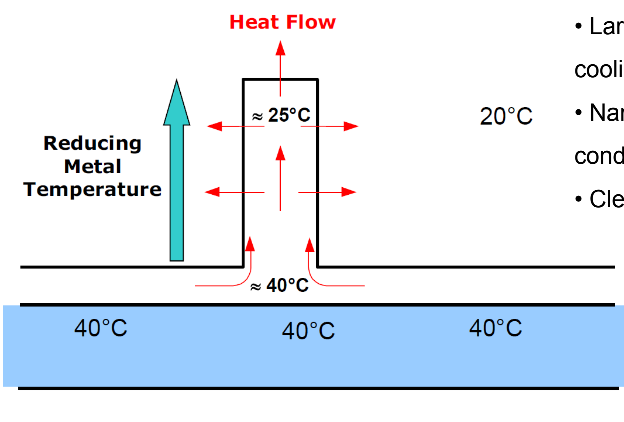


Triangular Pitch



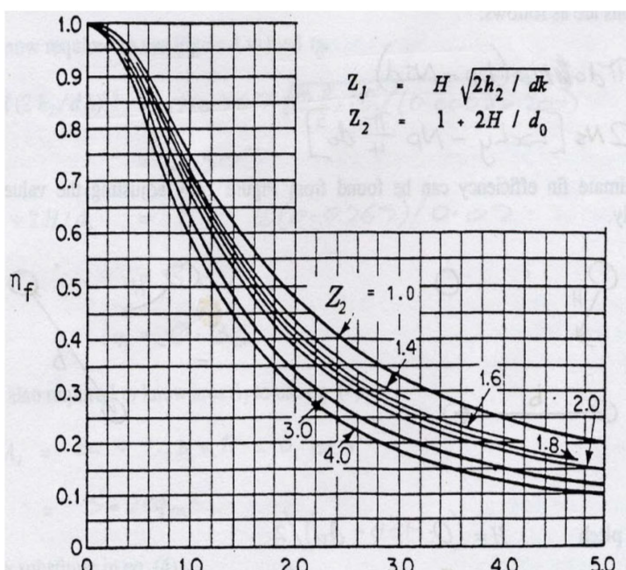
Heat transfer with fins added:

η_f = fin efficiency
(need to use table to find this out)



- The fin sheets can be 2-4mm or up to 12mm apart
- Larger spacing's are used in air cooling units where frost will form
- Narrower spacing's in condensers
- Cleaning can be a problem

Estimation of fin efficiency



Collar and sheet fins efficiency chart

η_f = fin efficiency
(need to use table to find this out)

Mathematical analysis

$$\phi = (UA)\Delta\theta$$

$$\frac{1}{UA} = \frac{1}{h_1 A_1} + \frac{x}{kA_{12}} + \frac{1}{h_2(A_p + \eta_f A_f)}$$

ϕ	=	heat flux (W)
(UA)	=	overall heat transfer coefficient (W/K)
$\Delta\theta$	=	temperature difference between air and fluid in pipe (K)
h_1	=	film heat transfer coefficient on the inside of the pipe (W/m^{2}K)
h_2	=	film heat transfer coefficient on the outside of the pipe (W/m^{2}K)
x	=	pipe thickness (m)
k	=	pipe thermal conductivity (W/mK)
A_1	=	area of the inside of the pipe (m^2)
A_2	=	area of the outside of the pipe (m^2)
A_{12}	=	mean heat transfer area within the pipe (m^2)
A_p	=	primary area (area of exposed pipe) (m^2)
A_f	=	secondary area (fin surface area) (m^2)
η_f	=	fin efficiency

Tutorial

- Air Fin Heat Exchanger tutorial problem

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