Factsheet

26 feb. 2009

Cryogenic cooling

Cryogenic cooling uses phase change for cooling: sublimation of dry ice (solid CO_2) or evaporation of liquid CO_2 or N_2. The solid or fluid is produced in large-scale centralised plants, mostly as by-product of a chemical process (for instance ammonia production). The cold can be applied in de-central applications, including mobile applications. Especially the use of dry ice is technically quite simple, because no electrical driven cooling equipment is needed. Dependent on the situation safety measures may be needed.

Although CO_2 is considered a by-product of industrial processes, cyrogenic CO_2 is not available for free. Usually it comes available from regenerating gas washing fluids; the CO_2 will be available in (concentrated) gas form. This gas can be cooled and compressed for production of fluid CO_2. For production of solid CO_2 (dry ice), the fluid is adiabatically expanded (resulting in evaporation of about half of the CO_2 and solidification of the remainder).
Fluid N_2 is produced by compressing air.

Practical benefits

- silent (most relevant for mobile applications);
- very suitable for "refrigerated delivery": by adding some dry ice to a delivery, cooling is ensured for a certain period without need of power supply;
- high quality cold: low temperatures (far below the freezing point);
- buffer is very suitable for "peak shaving".

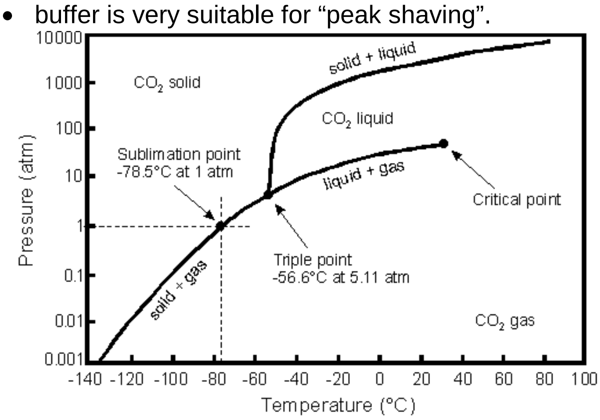

Figure 1. Pressure-Temperature phase diagram for CO_2.

Energetic considerations

Solid CO_2 at atmospheric pressure (sublimation point −78.5℃) has a latent evaporation heat of 571kJ/kg, whereas the specific heat (C_p) of CO_2 gas is 0.85kJ/(kg K). Thus, for cooling applications the evaporation of solid CO_2 will remove about 640kJ per kg CO_2.
When producing cryogen CO_2 a comparable amount of heat is removed from the gas, combined with compression; the exact amount of energy needed depends on the efficiency of the process. Since this is low-temperature cooling, generally this is less efficient than refrigeration cooling. Furthermore, it should be taken in account that losses in the supply chain will occur.
For cooling far below the freezing point, however, COP of mechanical cooling is low too; energetic performance of cryogenic cooling and mechanical cooling will be more comparable.
Energetic efficiency of using cryogenic (fluid) N_2 is slightly lower than for CO_2 because fluid N_2 is produced from air (which has other components that hinder the process efficiency) whereas fluid CO_2 is produced from nearly pure CO_2 gasses. However, fluid N_2 has some practical advantages: it can be kept fluid at atmospheric pressure.

Financial considerations

Costs of investments largely depend on the specific situation; no general indicative figures can be given.
Indicative prices of cyrogen CO_2 and costs of cooling:

- Fluid CO_2 (bulk amounts) €0.06 to €0.10 per kg (price 2006); cooling potential about 300 to 400 kJ/kg (dependent on temperature and pressure). Resulting variable costs for cooling €0.15 to €0.33 per MJ.
- Dry ice (small amounts): about €1 per kg; cooling potential 640 kJ/kg. Cooling costs about €1.60 per MJ.

For reference: energy costs for mechanical cooling are about €0.008 per MJ (with E-tariff €0.10/kWh and COP 3.5).

Conclusions

Generally, cryogenic cooling is energetically less efficient than mechanical cooling. Financial feasibility will depend on the specific situation.

Sources and further info

www.airliquide.com
Feron PHM and CA Hendriks (2005): CO_2 Capture Process Principles and Costs. *Oil & Gas Science and Technology* Vol. 60 (2005), No. 3.

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This renewable cooling research is executed with practical input by NVKL and financial support by the Dutch Ministry of Economic Affairs; program *Energie Onderzoek Subsidie: lange termijn (EOS-LT)*.