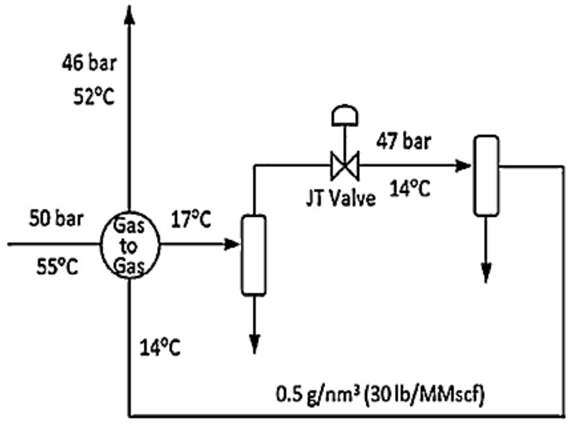
REFRIGERATION BASED DEHYDRATION

Refrigeration and condensation is a purification step in carbon capture processes aimed at removing water vapor from CO_2-rich gas streams to prevent water from freezing during the liquefaction phase. In this process, the CO_2 stream at high pressure is cooled by reducing its pressure using a Joule-Thomson valve and a gas-to-gas heat exchanger. A knock-out drum is used to remove the water that may have condensed. The CO_2 gas is then passed through a Joule-Thomson valve, where the temperature is further reduced by reducing the pressure. Another knock-out drum is used to remove the rest of the water. The cooled CO_2 stream is passed through the gas-to-gas heat exchanger to cool the incoming hot and pressurized CO_2 stream.



Open cycle refrigeration system for CO_2 dehydration

REMOVED COMPONENTS

- Water vapor (H_2O) is the primary target component.

FUNCTION IN CCU VALUE CHAIN

- **Purification** – this is crucial to prevent corrosion and hydrate formation, which can block pipelines or damage equipment.
- Ensuring **process efficiency** – high purity CO_2 is required for many CCUS applications.
- **Facilitating transport and storage** to prevent water from freezing during the compression or liquefaction of CO_2.

LIMITATIONS

- Energy requirements due to cooling and compression of the gas stream.
- High capital costs, especially for multi-stage (large-scale) refrigerant systems.

ENERGY

- Electricity is used to power refrigeration compressors and cooling systems.

CONSUMABLES

- Refrigerants in a closed-loop system may need some make-up.

Energy & consumables

Parameter	Value[1]
Electricity (MWh/tCO_2)	0.037
Cooling duty (MWh/tCO_2)	0.016

**All values estimated for both coal-based and NGCC-based power plants*[1]

COSTS

Dehydration costs depend on the water concentration in the CO_2 stream. Higher water levels require more energy for purification, increasing overall costs.
Total purification cost: 2.7 – 4.8 €/tCO_2[1]*

**includes both oxygen and water removal; lower range for coal-fired case and upper range for NGCC case; use CO_2 stream compositions from the table below to convert the values to per ton of water.*

[1]*Oxygen limit – 10 ppmv; water limit – 50 ppmv; palladium catalyst cost – 600,000 €/m^3; catalyst lifetime – 5 yrs; hydrogen – 23 €/kg; plant lifetime – 25 yrs; operating hours – 7446 hr/yr; discount factor 8%; CFR 0.0937; electricity price 38 €/MWh; cooling water price – 0.24 €/m^3; 2012 euros.*

Component	Coal base case	With purif.	NGCC base case	With purif.
CO_2 (mol%)	99.14	99.91	99.06	99.85
H_2O (mol%)	0.774	50.1	0.774	48
O_2 (ppmv)	67.6	11.4	317	10.3
N_2 (mol%)	0.0756	0.0762	0.134	0.135
Ar (ppmv)	11.3	11.4	22.5	23.4
CO_2 flow (t/h)	515	515	125	125

TECHNOLOGY PROVIDERS

- Joule-Thomson effect gas conditioning modules by **Flargent**, Argentina
- Joule-Thomson system by **GPR**, United States
- Joule-Thomson plant for natural gas by **CROFT**, United States
- Joule Thomson skid package for natural gas by **Rushton**, Canada

ALTERNATIVE TECHNOLOGIES

- **Absorption process**: Water vapor is absorbed into a liquid desiccant, such as triethylene glycol (TEG). The saturated desiccant is then regenerated by heating to remove water and the TEG to be recycled.[2,3]
- **Adsorption process**: This process uses solid adsorbents, such as zeolites, to adsorb water molecules. Regeneration is done by heat or pressure swing.[2,3]

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