

"Wet-TSA" DAC: Explanation of the Original Technology

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◆ The Essence of the Heat Balance of the "Wet-TSA" Method, Significantly Different from the "Dry-TSA" Method

The idea is the exact opposite of the conventional TSA method: "Making water an ally, not an enemy."

The "Wet-TSA" method... uses the condensation heat of saturated vapor with a boiling point of nearly 100°C to desorb CO₂ gas, allowing for high-concentration recovery.

During desorption, condensed water from water vapor remains on the inner surface of the a laminated plate module with flow channels. In the processing zone, CO₂ is adsorbed while evaporatively cooling. This rapidly cools the rotor immediately after desorption, trading off the heat of CO₂ adsorption to suppress temperature rise and increase adsorption capacity.

Heat balance points:

◇ Desorption side:

- o Saturated steam condenses on the rotor surface → Condensation heat is used for CO₂ desorption
- o Condensed water remains as a thin film on the rotor surface
- o Since saturated steam is used and not superheated steam, there is less unnecessary sensible heat load.

◇ Adsorption side:

- o The rotor is in a "moist" state when in contact with the processing air
- o Water film evaporates → Latent heat of vaporization cools the rotor
- o CO₂ adsorption heat and evaporative cooling cancel each other out, suppressing temperature rise
- o As a result, adsorption capacity is dramatically improved compared to dry TSA.

◇ Behavior of condensed water:

- o The adsorbent material in the Wet-TSA rotor is not a granular layer, but rather a structure in which fine particle adsorbent material is fixed to a thin layer of a laminated plate module with flow channels.

Because it is a fixed sheet, condensed water due to capillary action does not block the flow channels, and particle clumping does not occur. While other CO₂ concentration technologies using solid absorbents struggle with "how to eliminate water," the crucial difference with Wet-TSA is that it is designed to "make water the main player in thermal management."

◆Wet-TSA DAC Unit Design Philosophy

50mm Depth Small Diameter Rotor ⇒ Why is a "Approximately 50% Recovery Rate" Sufficient?

1. Increasing the recovery rate → The rotor and the following disadvantages increase exponentially.

- Increased rotor depth: Approximately 8 times the required depth (400mm) is needed for 90% recovery.
- Increased desorption steam volume: More than double.
- Rotor pressure loss increases 8 times → Air conditioning fan power consumption increases approximately 8 times.
- Larger unit size: 200mmL ⇒ 600mmL → Becomes a large unit.
- Equipment cost: Cannot be manufactured with sheet metal units; cost more than 10 times higher?
- Increased equipment installation and maintenance space.
- Small units can be completely replaced with new units in a few hours of manual work.
- Replaced units are maintained at the factory in preparation for the next replacement.
- In urban buildings, "increased air conditioning load" is the most undesirable factor, so a CO₂ recovery rate of around 50% is the optimal point for both "acceptable range on the air conditioning side" and "amount of CO₂ recovered."

2. The Wet-TSA unit counteracts sorbation heat through "evaporative cooling of a wet rotor," allowing it to operate with almost no increase in air conditioning load if 50% recovery is achieved. When separating, concentrating, and recovering CO₂ from air, it is not necessary to increase the CO₂ recovery rate unnecessarily. This is because there is a large amount of air, and it is sufficient to adsorb and recover only the amount that can be easily separated. By reducing the rotor depth, even if the recovery rate is around 50%, the increase in blowing energy is small and the device is compact, so it can be introduced without increasing the burden on existing air conditioning equipment.

When the rotor depth is reduced from 400 mm to 50 mm (one-eighth of the original depth), the airflow energy is also reduced to one-eighth, but since the CO₂ adsorption efficiency is approximately 50%, if the CO₂ concentration in the passing air is 1000 ppm, the outlet CO₂ concentration can be estimated to be approximately 500 ppm. At this concentration, the CO₂

concentration is only slightly higher than the outside air concentration, so it can be reused as an air conditioning air supply source.

3. Heat recovery zone to improve heat recovery efficiency even in short depth rotors

On the other hand, to improve the energy efficiency of a CO₂ recovery system, it is desirable to increase the thermal efficiency on the desorption/recovery side. However, if the rotor depth is reduced, the thermal efficiency decreases as saturated vapor passes through in a short time.

Therefore, as shown in the figure, Wet-TSA DAC has one to multiple recovery zones, and by passing the gas through multiple recovery zones, even with a 50mm depth rotor, the thermal efficiency of the desorption/recovery gas can be increased to the same level as a 150mm depth rotor in the case of three stages. In other words, by preheating the rotor with the desorption/recovery gas, the thermal efficiency of the mixed gas passing through the multi-stage recovery zone is improved, and energy efficiency is improved. Conversely, since the recovered gas can be recovered with reduced temperature and humidity, the cooling and dehumidification load before compression and liquefaction in subsequent processes is reduced, and energy efficiency is improved.

We lent a test device with a multi-stage recovery zone to a certain research institution for experimentation, and they reported that "the recovery zone outlet temperature is the same from stage 1 to stage 3!" In a multi-stage recovery zone, the desorption outlet gas temperature increases, which in turn affects and increases the gas temperature in stages 1 to 3 through which the desorption outlet gas passes. Saturated steam has hundreds of times more energy than dry air at the same temperature, so even a 1°C difference makes a significant difference.

Therefore, it was necessary to explore how much the saturated steam supply could be reduced without compromising performance (energy efficiency).

This is an AI calculation result, so it's just for reference, but it states that "this is what will always happen in normal operation."

- Stage 1 (steam inlet side): Highest temperature (95-105°C)
- Stage 2: Temperature drops by a few degrees (90-100°C)
- Stage 3 (outlet side): Further decrease (80-95°C)

Even if there was an effect of leakage due to excess saturated steam, reducing the steam flow would have reduced the leakage, and data on energy-saving effects should have been obtained.

It seems the experiment was conducted without understanding the fundamental differences between conventional TSA and Wet-TSA.

It's unfortunate that the correct evaluation results for energy efficiency were not obtained.