Experience with the operation of dilute aqueous ammonia in a 20 kgCO_2/hr Post-Combustion Capture test facility

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Outline

- Australian Situation.
- Why aqueous ammonia?
  - Advantages.
  - Challenges.
- Experience at Delta-Munmorah Pilot Plant.
- PCC Test Facility.
- Experience with aqueous ammonia using the PCC Test Facility.

Australian Situation - Coal and PCC potential

Large reserves of black and brown coal.

World's (2nd) largest exporter of coal.

Coal contributes 15 to 20% of Australia's export income.

~ 75% of Australia's electricity is derived from coal.

Coal contributes 40% of net GHG emissions.

Australia has one of the highest emissions of GHG per capita in the world (~25 t/person.yr)

Why aqueous ammonia?

Advantages

(relative to amines)

- Lower cost.
- Robust .
- more environmentally benign.
- Higher CO_2 loading capacity.
- Lower regeneration energy.
- Removal of multiple components (SO_x, NO_x).
- Potential for value added products.

Challenges

(add cost)

- Loss of ammonia to gas stream -

Experience at Delta-Munmorah Pilot Plant

- AUD $7m pilot plant constructed by CSIRO and Delta Electricity (support from APPCDC)
- Capacity of 3,000 t CO_2/a. Aqueous ammonia (up to 6 wt%).
- Black coal. No FGD/$DeNO_x$
- Operational Feb 2009 - Dec 2010
- Pilot Plant relocated to Vales Pt Power Station (NSWCCF)

What we learnt:

- Technical feasibility of the process and some of the expected benefits confirmed .
  - CO_2 removal efficiency > 85%.
  - CO_2 product purity 99-100%.
  - > 95% of SO_2 in the flue gas is removed in the pre-treatment column.
- The system NH_3 loss and regeneration energy is relatively high.
- Absorption rate is lower than expected.
- Solids formation in top of the Stripper.

→ **further improvement required**.

Delta electricity

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Resolve Technical issues for PCC Test Facility

- Ammonia loss (slip):
  - Wash column water clean-up – Reverse Osmosis unit.

- Blockages by solid ammonium bicarbonate:
  - Hot water flush (condensate loop system).
  - Trace heating.

- Low rates of reaction:
  - Reflux feed to absorber.
  - Makeup NH_3 to absorber.

PCC Test Facility – 20kg/hr CO_2 – Newcastle, NSW

- Flexible modular facility.
- Small inventory (50kg)
- Synthetic feed gas (control composition).
- Separate absorber/desorber operation
  - Lean cooler + Rich heater
  - Tanks on weigh scales; closed loop
- Separate wash column
- Bunded, ventilated space
- Extensive datalogging, analysis

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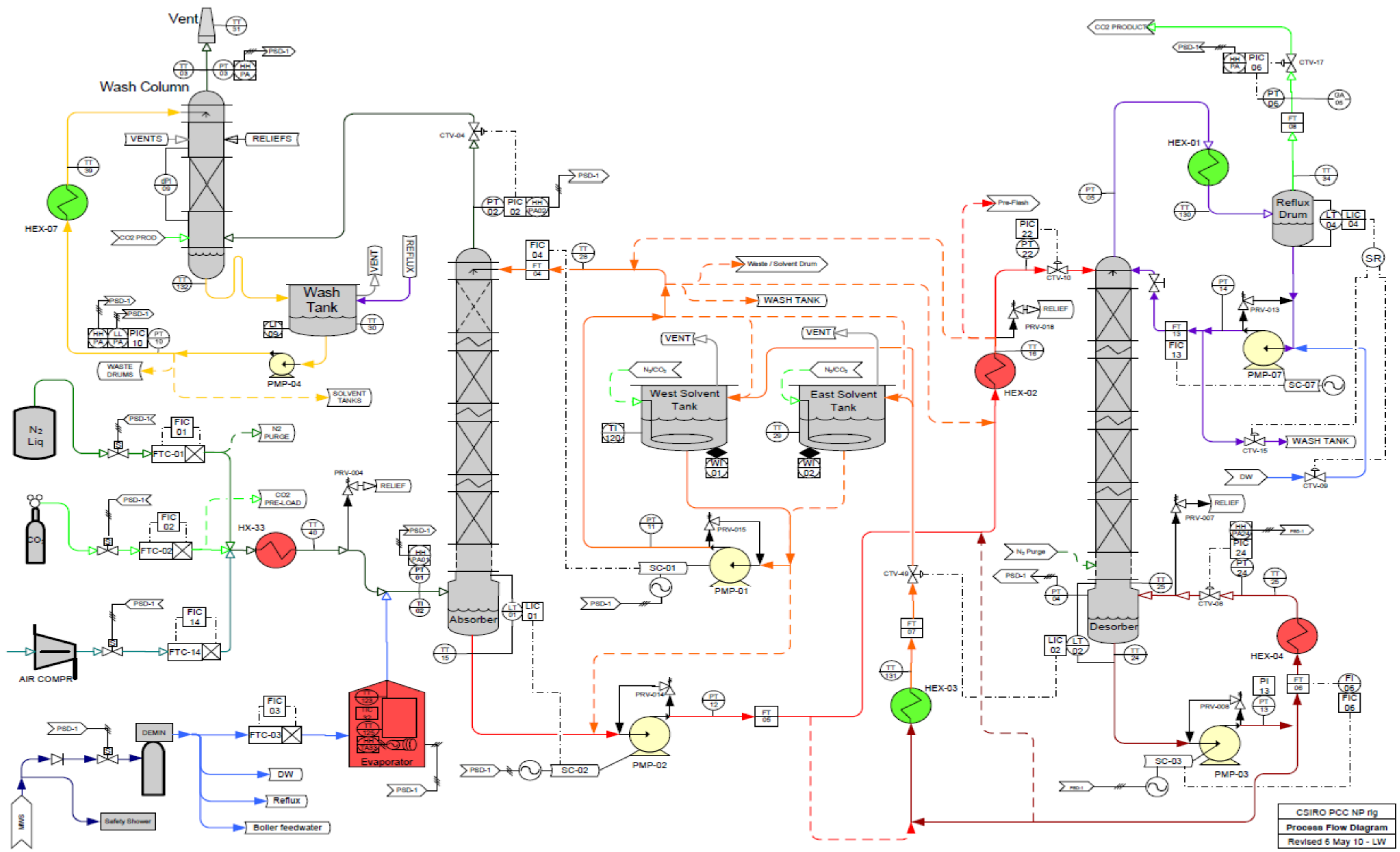
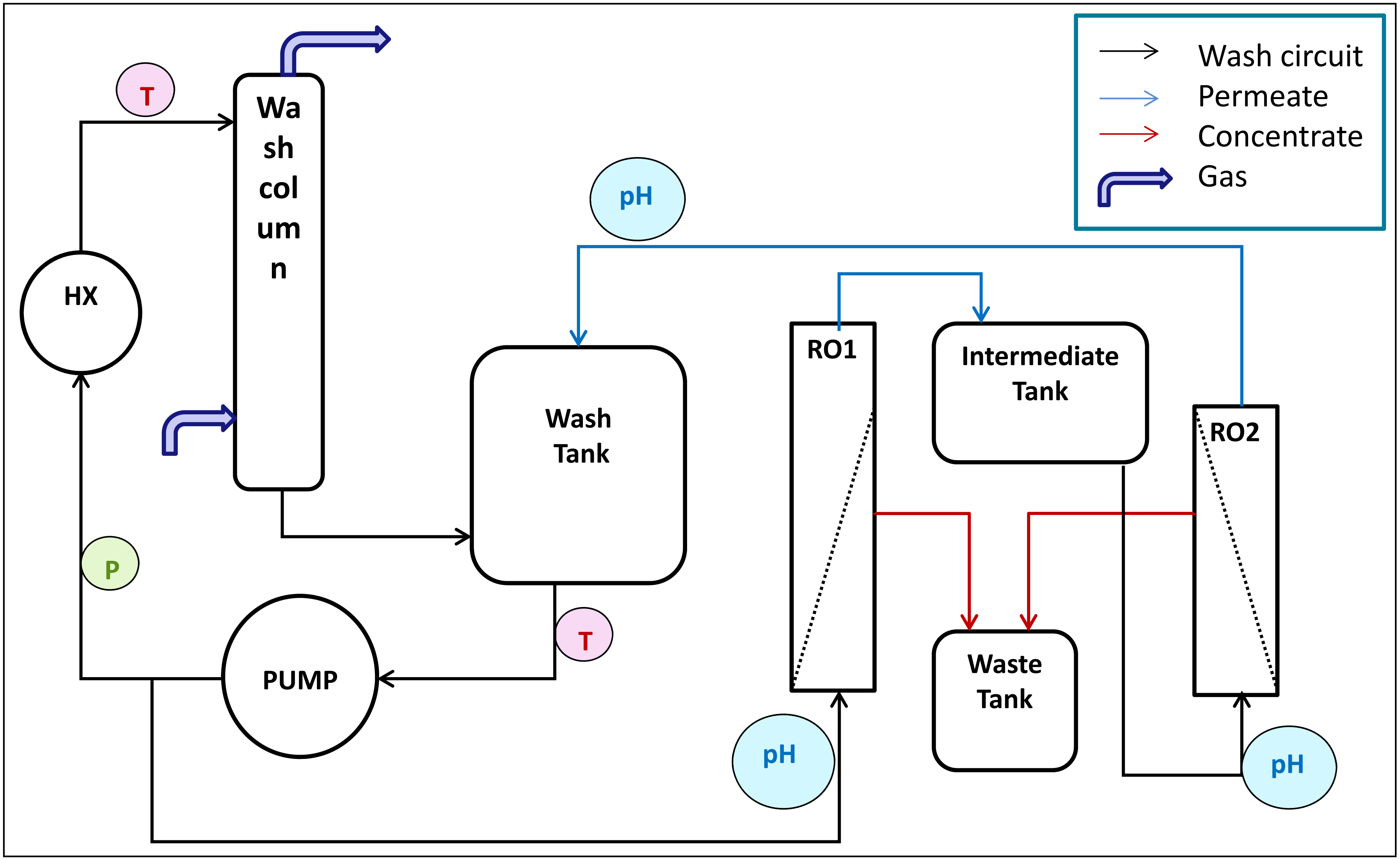
PCC Test Facility – implementation of aqueous ammonia



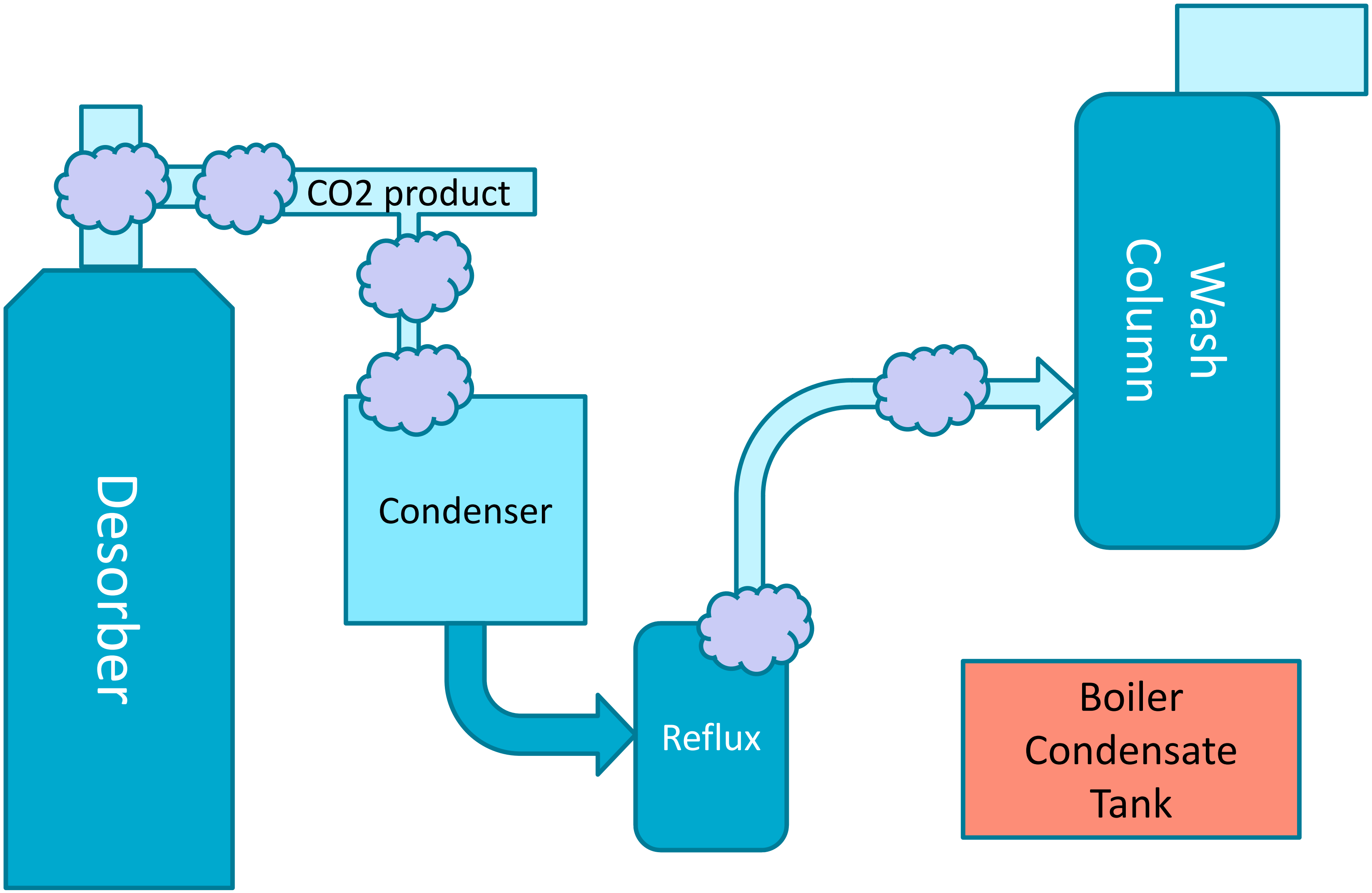
Wash water cleanup – Reverse Osmosis Unit

- Removal of carbonated ammonia species
- Off-shelf RO (brine) unit (Dowlex 4040)
- Two passes (4 units / 3 units)
- Series or parallel configuration
- Pressure: <1200 kPa
- Flows:
  - Concentrate: < 477 l/hr
  - Permeate: < 833 l/hr
- TDS meter monitor permeate flows.
- Concentration of waste water (batch opn)

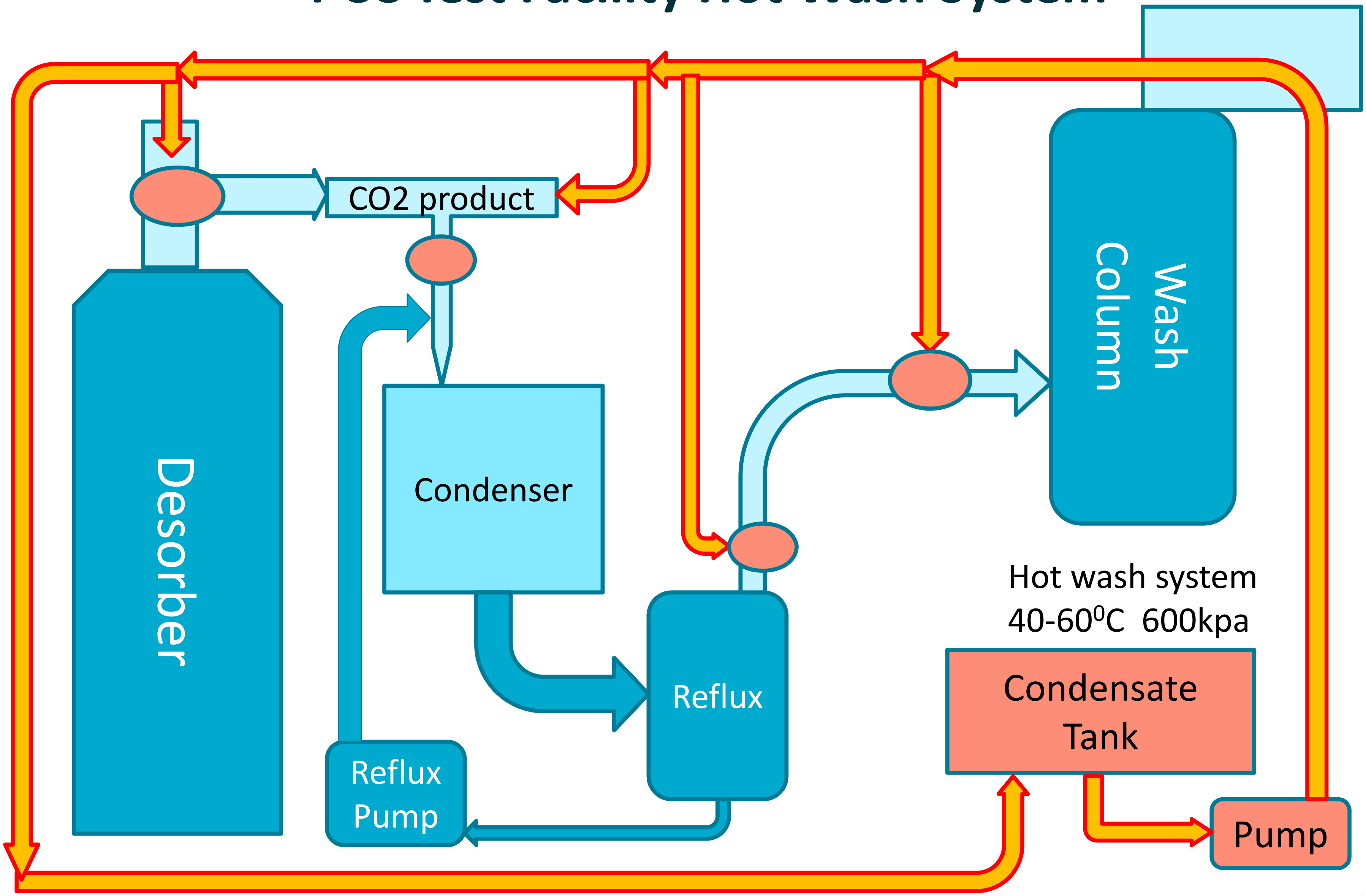
RO treatment of wash slip-stream



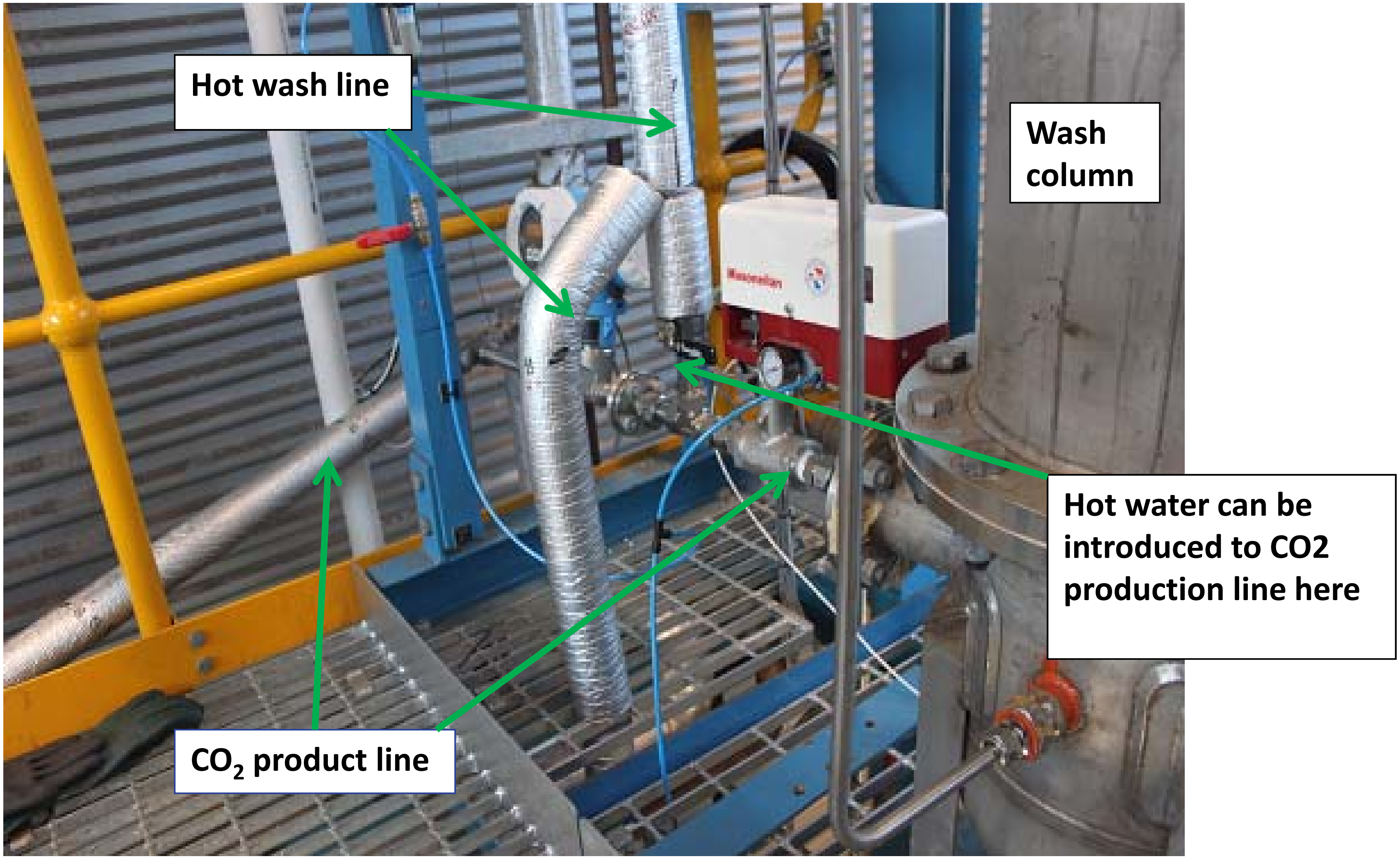
Solid bicarbonate formation in overhead lines



PCC Test Facility Hot Wash System



Hot wash injection point at end of CO_2 product line



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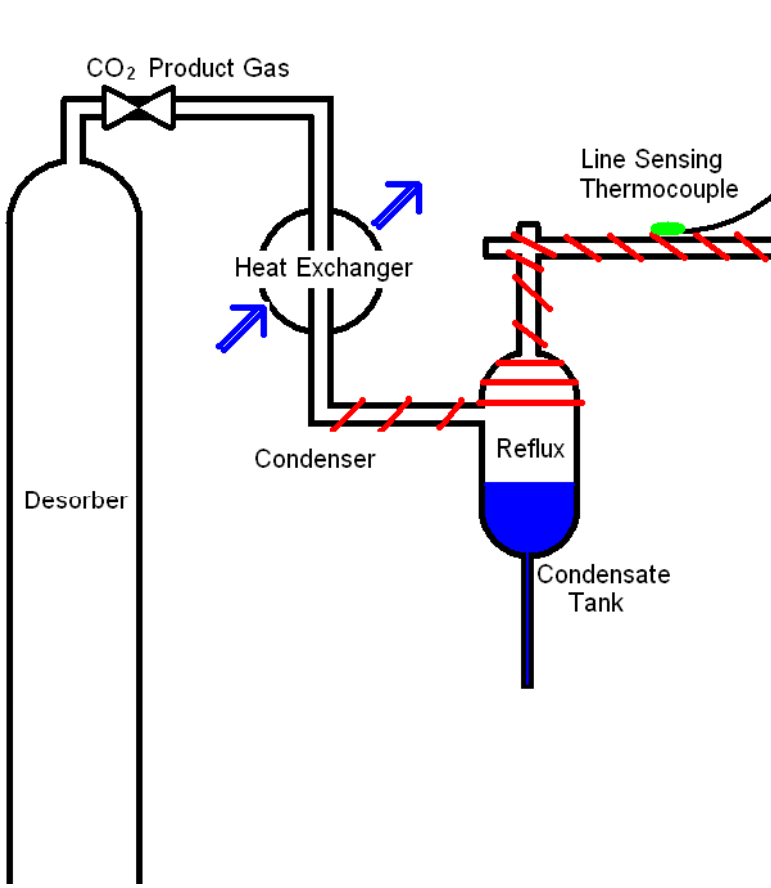
Trace Heat System

- Installed on pipe sections prone to blockages when running NH_3.
  - @ Temperature's > 40°C NH_3HCO_3 decomposes.
  - Cable is self regulating, safe and controllable (cannot exceed 110°C).
  - System worked well achieved prolonged operation.
  - Thermostat / Line sensing thermocouple.
  - Spreadsheet calculates heat loss from pipes.
  - HSE. Double insulated cable / system dedicated RCD.

Trace Heat System



Condensate into Absorber

- Non-volatile amines (MEA)
  - Condensate is mostly water
  - Returned to the top of the desorber (rectifier).
- Ammonia
  - Reflux is concentrated solvent
  - Further concentration with trace heating.
    - ➢ Return to the top of desorber is not ideal.
- Reflux fluid pumped into the absorber (tested 3 points).
- Very promising results:
  - Significant reduction in NH_3 losses.
  - Step change in CO_2 capture (5%).

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Ammonia make-up – Dosing into absorber

- Make-up (25% w/w NH_3) normally added to lean solvent return to Absorber – leads to higher losses.

- Directly pumped 25% w/w NH_3 into the absorber lower/ mid/ upper sections of Absorber (using metered dosing pump).
    - Improved capture rates (1-5% depending on position)
    - Higher injection points gave improved capture.
    - Prolonged steady state operation.
    - Blockages still became a problem at high dosing rates.

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Conclusions and Next Steps

- The advantages of aqueous ammonia as capture solvent make finding solutions to technical problems worth-while.
- Off-shelf RO membranes can adequately clean wash water
  - Evaluate alternate membrane types.
  - Scale-up issues.
  - Reduce problem of slip in other ways.
- Hot water pulse can clear blockages
  - Anticipate and automate this process.
- Trace Heating
  - Needs to be thorough and complete
- Ammonia rich streams back to absorber
  - Exploring process schemes

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Thank you

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