# Intensification of Solvent Based Carbon Capture using Rotating Packed Beds

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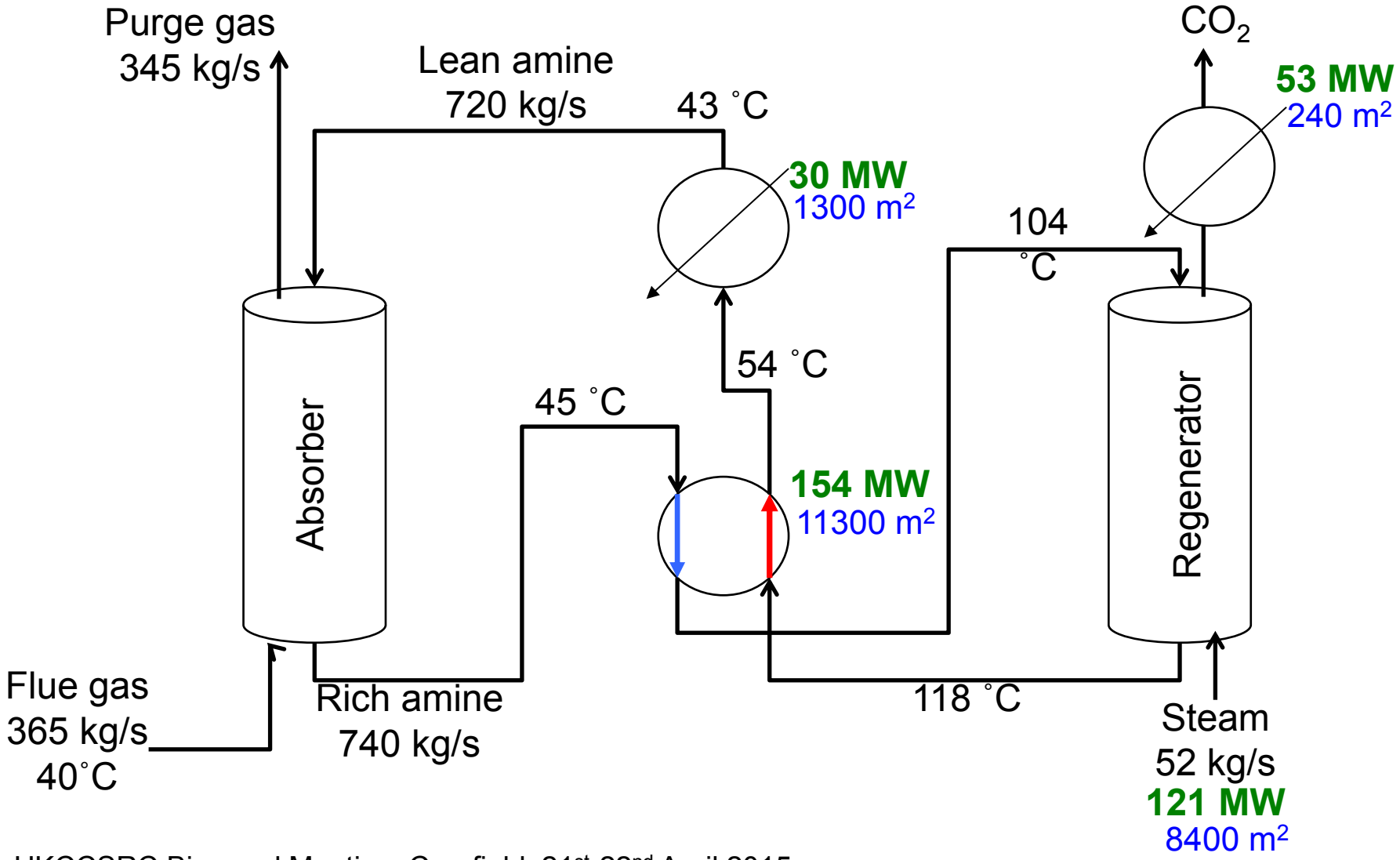
# Talk Outline

- The problem
- Process Intensification
- Proposed solution

# The Problem (250 MWe Gas Turbine)



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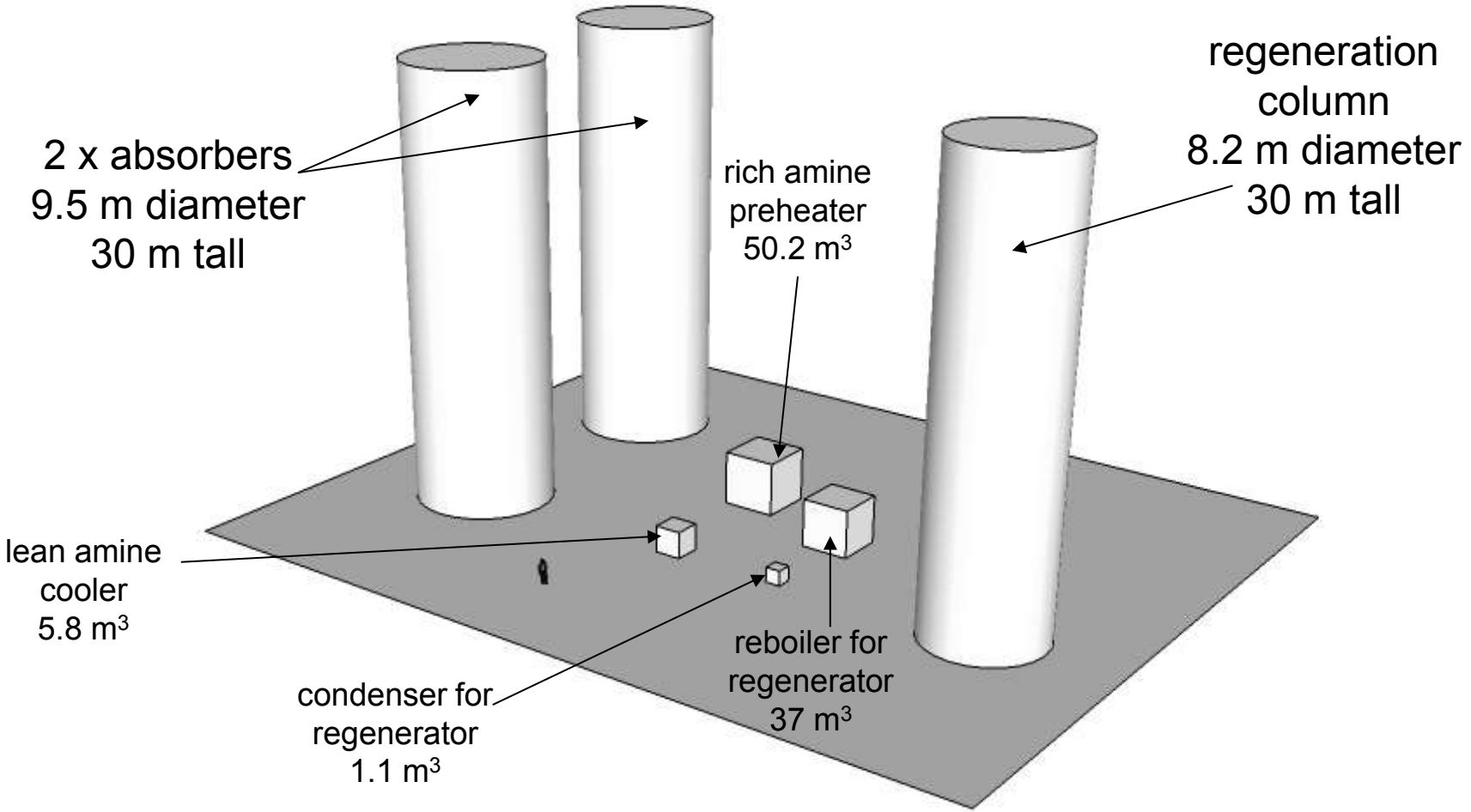


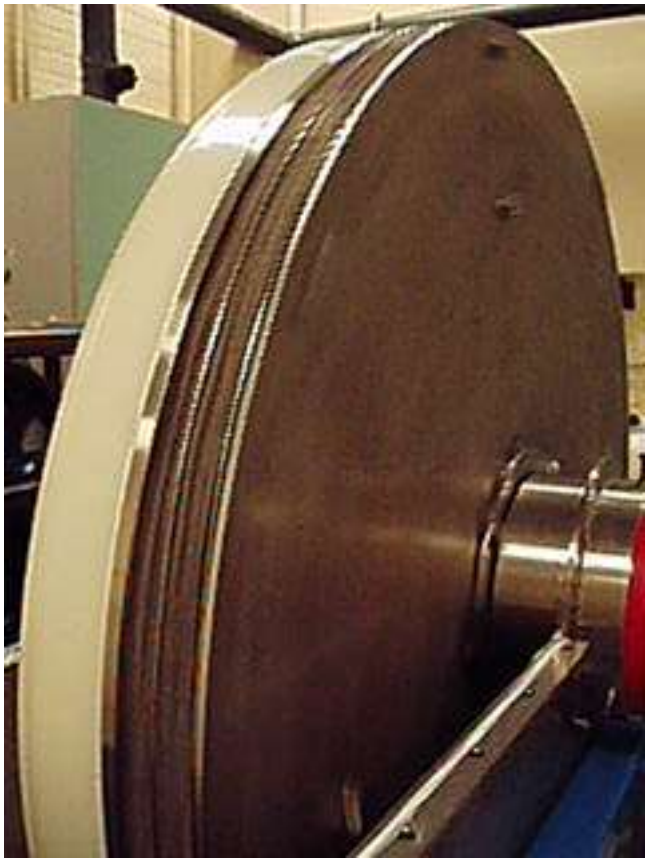

Heat exchanger volumes based on plate and frame area/unit volume of 225 $m^2\ m^{-3}$

# Process Intensification

1981 - propanol-ethanol separation. The first industrial demonstration of process intensification

40% reduction in capital costs

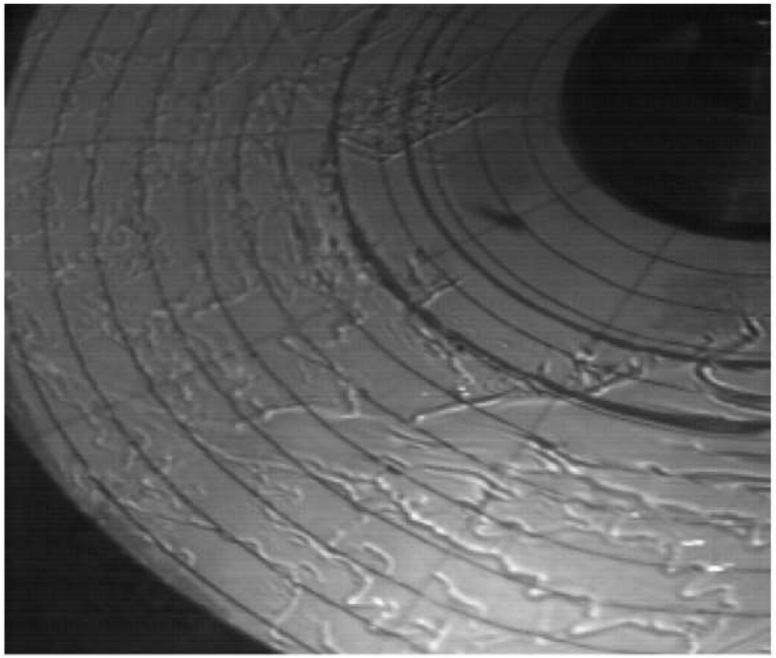
# Process Intensification



**Rotating Packed Bed (RPB)**

- High though put in a small volume.
- Diameters 0.2 – 4.0 m.
- 20 – 750 times gravitational acceleration.
- Rate of mass transfer $10^{-1}$ kmols $m^3$ $s^{-1}$ (HTU≈cm)
- Residence times of 1-10 s.
- Pressure gradient ≈ 500 Pa $m^{-1}$

# Process Intensification



**Spinning Disc**

- Extremely thin films (typically 50-500 μm thick)
- Excellent mixing characteristics due to high shear and surface waves.
- Rates of heat and mass transfer are very high.
- Convective heat transfer coefficient > 10 kW $m^{-2}$ $^{\circ}C^{-1}$
- Higher values for heat transfer during boiling/condensation.

# Process Intensification

Pictures from www.heatric.com

## Compact Heat Exchangers

- Heat exchange area/unit volume of up to 1300 $m^2\ m^{-3}$.
  - Shell and tube: 100 $m^2\ m^{-3}$.
  - Plate and frame: 400 $m^2\ m^{-3}$.
- Convective heat transfer coefficient for liquid duty 7-10 $kW\ m^{-2}\ ^{\circ}C^{-1}$

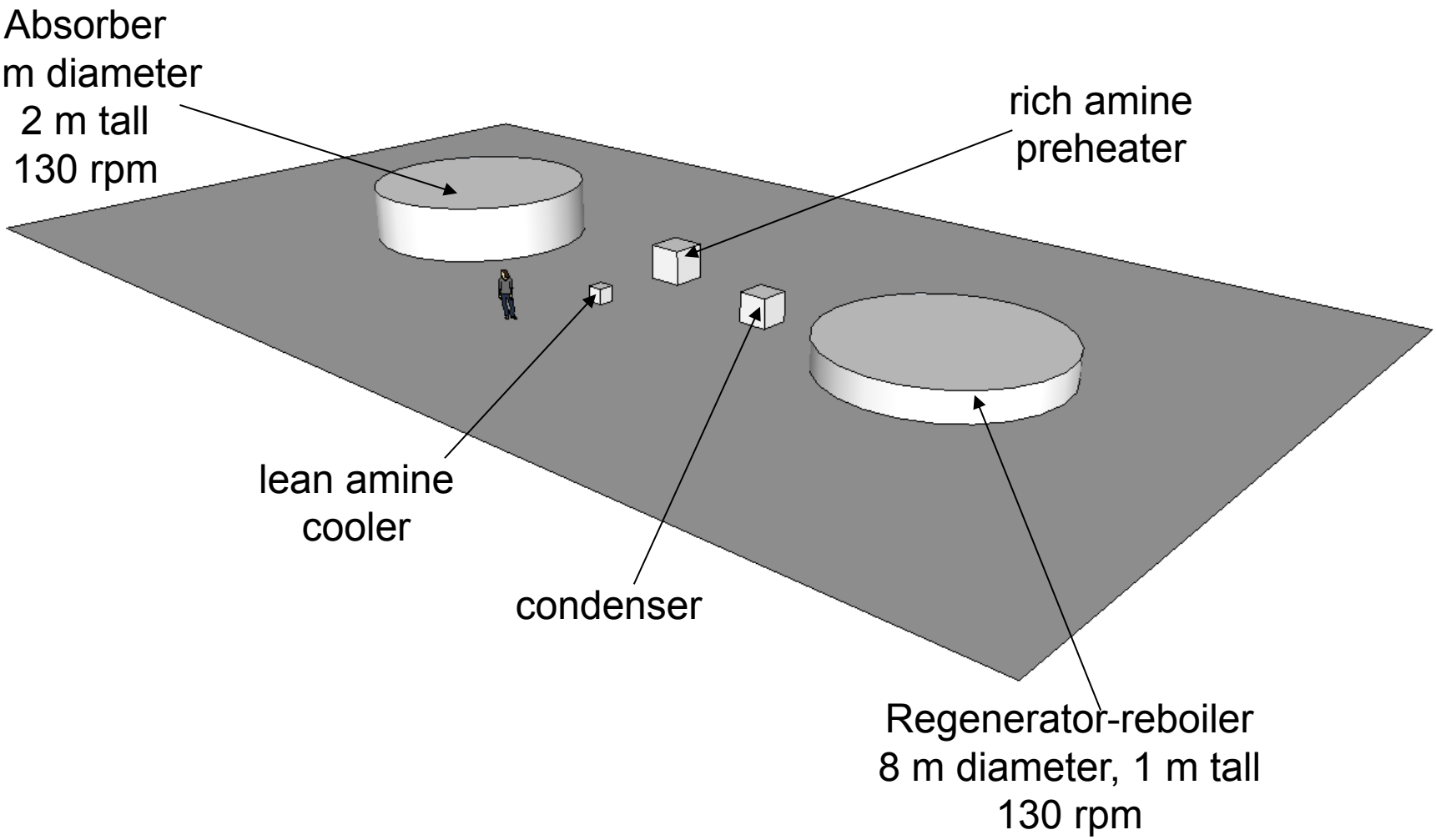
# Proposed Solution

- Consortium of Hull, Imperial, Leeds and Newcastle awarded funding for:

  Process Intensification for Post-combustion Carbon Capture using Rotating Packed Bed through Systems Engineering Techniques

- Use rotating packed beds to reduce the size of mass transfer elements.
- Use spinning discs for boiling heat transfer.
- Use compact heat exchangers for the rich amine preheater and lean amine cooler.

# Proposed Solution



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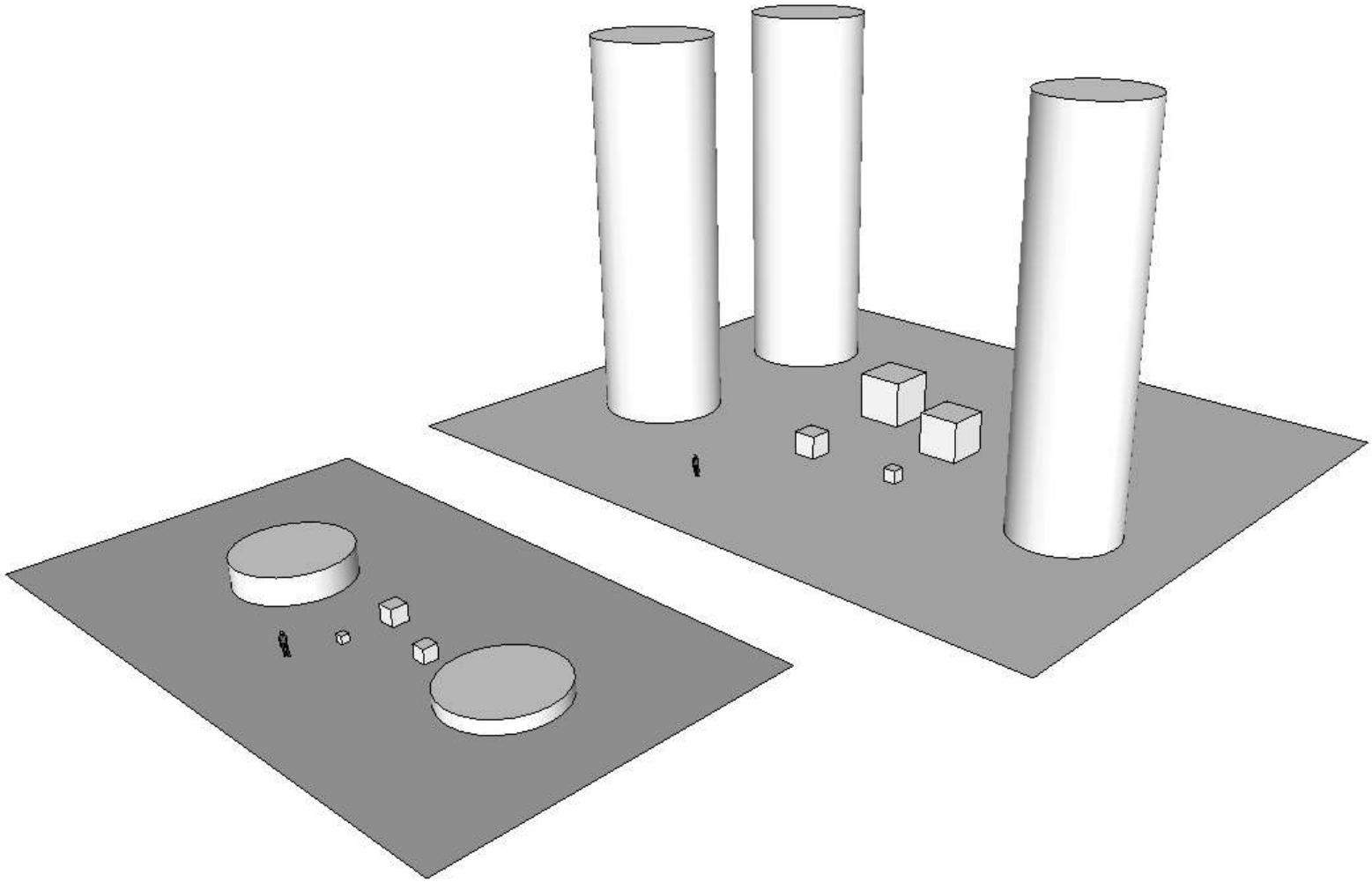

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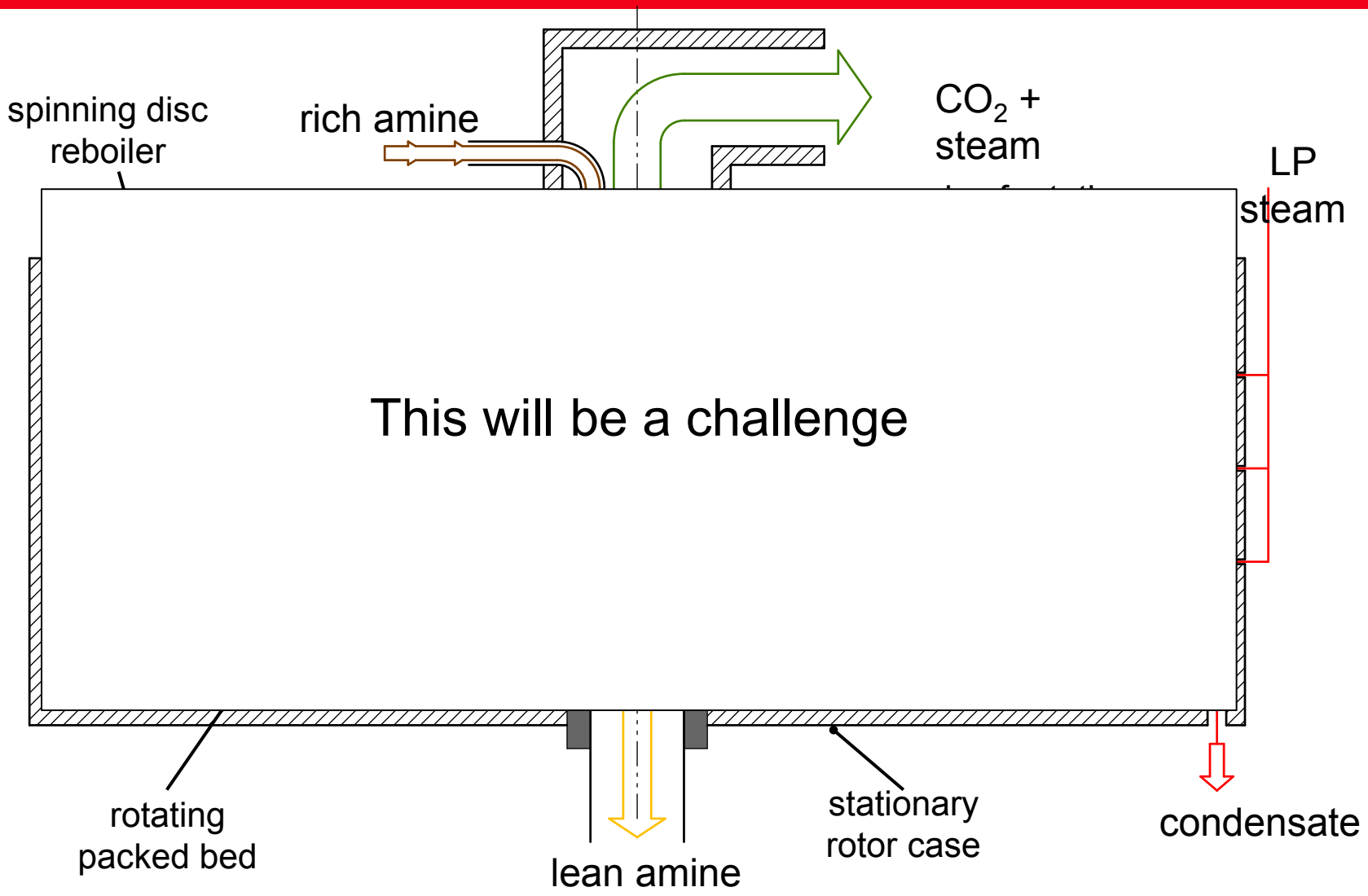

# Proposed Solution

## Increase MEA concentration from 30-80wt%

- Reduction in the liquid flows.
- Column diameters and heat exchanger sizes are reduced.
- Viscosity of the amine solution is increased.

$$\frac{(k_L a)_{\mu_2}}{(k_L a)_{\mu_1}} = 0.88\left(\frac{\mu_1}{\mu_2}\right)^{0.83}$$ packed column

$$\frac{(k_L a)_{\mu_2}}{(k_L a)_{\mu_1}} = 0.91\left(\frac{\mu_1}{\mu_2}\right)^{0.27}$$ RPB

Chen 2006

30wt% MEA $\mu_1$ = 3 mPa s  80wt% MEA $\mu_2$ = 16 mPa s

$$\frac{(k_L a)_{80wt\%}}{(k_L a)_{30wt\%}} = 0.22$$ packed column

$$\frac{(k_L a)_{80wt\%}}{(k_L a)_{30wt\%}} = 0.58$$ RPB

# Acknowledgements


- **Researchers, students and technicians at Newcastle**: Thea Coward, Brain Grover, Jonathan McDonough, Luke Krummins, Kejun Wu, and Dorata Plaza.
- **Prof. Meihong Wang** from University of Hull for data on 250 MWe plant.
- **Organizations who are supporting our RPB work**

ALSTOM

Carbon Clean Solutions CCS

ISPT

Department of Energy & Climate Change

EPSRC Engineering and Physical Sciences Research Council

- **Questions?**

# References

Chen Y, Fang-Yi L, Clifford Y T, Hwai-Shen L, 2006, “Packing Characteristics for Mass Transfer in a Rotating Packed Bed”, *Ind Eng Chem Res*, 45, 6846-6853

Canepa R, Wang M, Biliyok C, Satta A, 2012, “Thermodynamic analysis of combined cycle gas turbine power plant with post-combustion CO2 capture and exhaust gas recirculation”, *Proc IMechE Part E: J Process Mechanical Engineering*, 227, 89-105.