Hot Gas Clean-Up for Gasification Process

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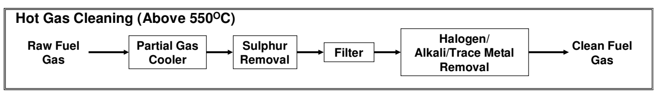
Introduction

- Gas cleaning systems for gasification-based power generation are needed to remove dust, S-species, N-species (e.g. ammonia, cyanides, etc), halides and trace metals from the gasifier fuel gases prior to their passage through the gas turbine and their subsequent release.
- Hot fuel gas cleaning generally refers to the removal of fuel gas impurities at temperatures above 250°C (Mitchell 1998) before the gas stream enters the gas turbine. The integration of hot gas clean-up (HGCU) technology to remove pollutants from coal-derived fuel gas offers the prospect of increasing thermal efficiency whilst simultaneously reducing the capital and operating cost of IGCC systems without compromising the environmental performance.
- Why Hot Gas Cleaning
  - Avoid the high capital cost, energy losses & complexity of totally cooling the hot raw syngas.
  - Avoids waste water & black/gray water slurry processing.
  - Increases IGCC efficiency & capacity by increasing the mass flow & sensible energy into the gas turbine.
- Objective: To investigate a novel hot flue clean-up system using molten tin as the scrubbing medium for the removal of solid particulates and H_2S.

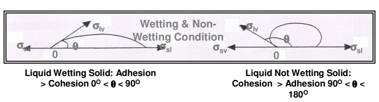
Hot Fuel Gas Cleaning

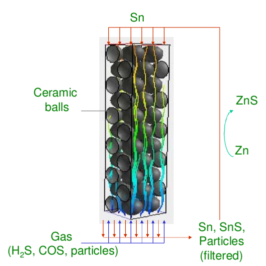
- **Hot Fuel Gas Cleaning (HGCU) vs Cold Fuel Gas Cleaning (CGCU)**
  - HGCU increases the overall energy efficiency (by 2-3%) by reducing heat loss as latent heat
- **Fuel Gas Cleaning versus Flue Gas Cleaning**
  - Better control system, low capital and operating costs
- **Gas Turbine Protection**
  - Particulate Matter: Fly Ash, trace components and metals
  - Particulates: 2 ppmw (< 10 mm)
  - Sulphur (H2S, COS, CS2): 20 ppmw



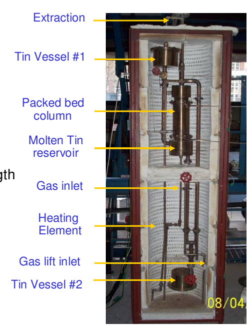
Hot Gas Scrubber – Using Molten Tin

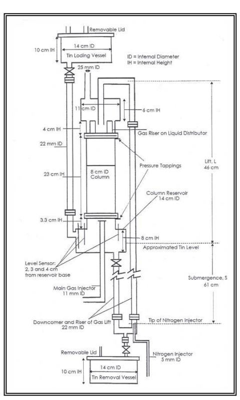
- **Tin (Sn) - Melting Point: 232°C**
  - Not pose a health impact
  - Low viscosity 1.41 cP at 400°C
  - Non wetting, easy dispersion into small droplets on the packing surface
  - Molten tin as the scrubbing medium for the removal of H_2S and solid particulates.



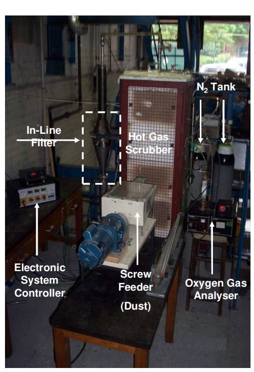


- **Desulphurisation by Molten Tin**
  - $H_2S + Sn \rightarrow SnS + H_2$
  - $COS + Sn \rightarrow SnS + CO$
  - Recovery of Tin: $Zn + SnS \rightarrow ZnS + Sn$
- **Particle Removal by Molten Tin**
  - Discrete molten tin droplets and rivulets on the packing surface act as solid particulate collectors.
- **Lab-scale Packed Bed Scrubber**
  - Size of packed bed: 8 cm - internal diameter and 23 cm - length
  - Ceramic balls: 9.53 mm high-purity ceramic alumina spheres
  - 316 Stainless Steel for resistance to corrosion.
  - Countercurrent flows of tin and gas.
  - Minimum operating temperature: 350°C
  - Glass powder as simulated particles





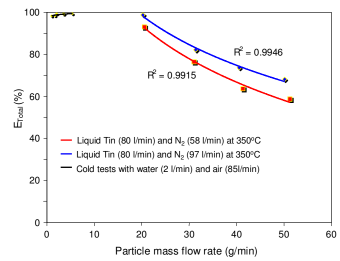
Schematic of packed bed scrubber



Setup for particle removal tests

Experiments: Particulate Removal & Desulphurisation

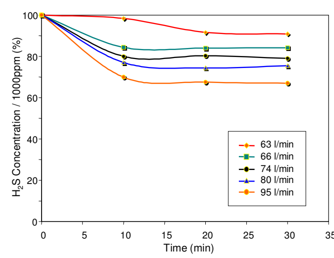
- **Key parameters: Dust loading, flow rates of H_2S, N_2 and tin, and bed temperature**
- **Particle removal tests**
  - The low capture of particles was due to the limitations of lab-scale scrubbers such as low temperature of particles at the inlet causing Si (glass powder)-Sn agglomeration.



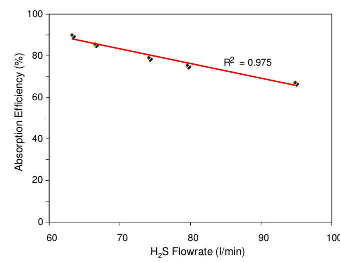
Total particle removal efficiency at 350°C

Accumulation of particles and tin

- **Desulphurisation Tests**
  - Absorption in the scrubbing solution (molten tin) was rapid as indicated by the high removal rate



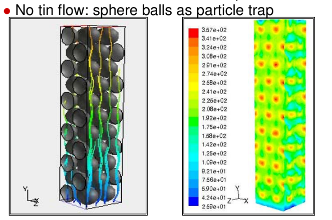
Absorption of H_2S with inlet concentration of 1000 ppm



Absorption efficiency of H_2S

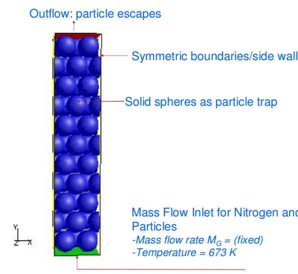
Computational Fluid Dynamics – Particle Removal

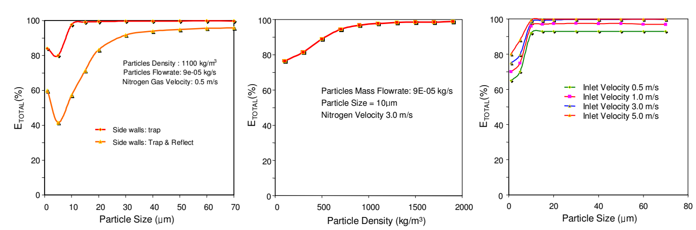
- FLUENT code used for simulation of particle removal
  - No tin flow: sphere balls as particle trap



Simulated Particle Trajectories

Velocity Magnitude (m/s), [M_G = 9 x 10^{-5} kg/s]





(a) Particle Size (b) Particle Density (c) Inlet Velocity

Total particle removal efficiency predicted for different particle sizes, particle density and inlet velocity

Conclusions and Future Work

- Total separation efficiencies were obtained, ranging from 60 to 95 % for particle removal.
- An increase in the H_2S gas flowrate will decrease the efficiency of the gas absorption.
- Desulphurisation efficiencies ranging from 67 – 95 % for H_2S cleaning
- Future Work
  - Investigation H_2S removal by molten tin.
  - Investigate the reactivity of the molten tin with others chemicals.
  - Further CFD modelling work incorporating chemical reactions of H_2S in the packed bed.
  - Validate the model using experimental data.

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More Information on SUWIC can be found at our websites: http://www.suwic.group.shef.ac.uk/

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