CFD Modelling of Combustion and Particle Behaviour in a Rotary Dryer

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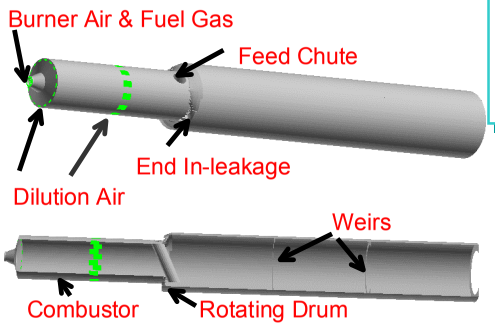
Industrial Problem: Oil shale particles were being over heated and produced odorous organic compounds.
Identify design changes that could reduce the maximum temperature that the particles are exposed to.
CFD modelling reduced odour release while increasing throughput by nearly 25%.

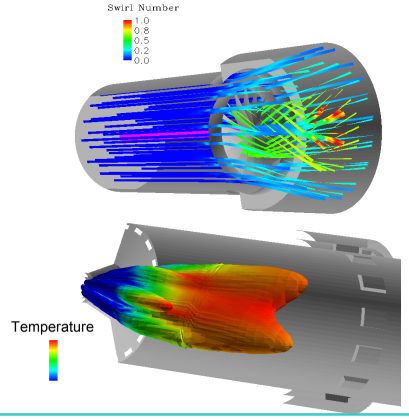
Model Description

Dryer information:
- Diameter: 4.5 m,
- Drum Length: 23.5 m,
- Fuel: Process gas similar to Natural Gas,
- Particles: Crushed oil shale,
- Size: Large size range from µm to mm.

Modelling Summary:
- CFX4 commercial software used,
- Reynolds stress turbulence model,
- Mixed-is-burnt combustion model,
- Discrete transfer radiation model,
- van-Leer higher order differencing,
- Coupled Lagrangian particle tracking,
- Modified spray-dryer model for particle drying,
- Particle reaction model for odour release based on drop tube furnace measurements,
- Multi-stage solution approach.

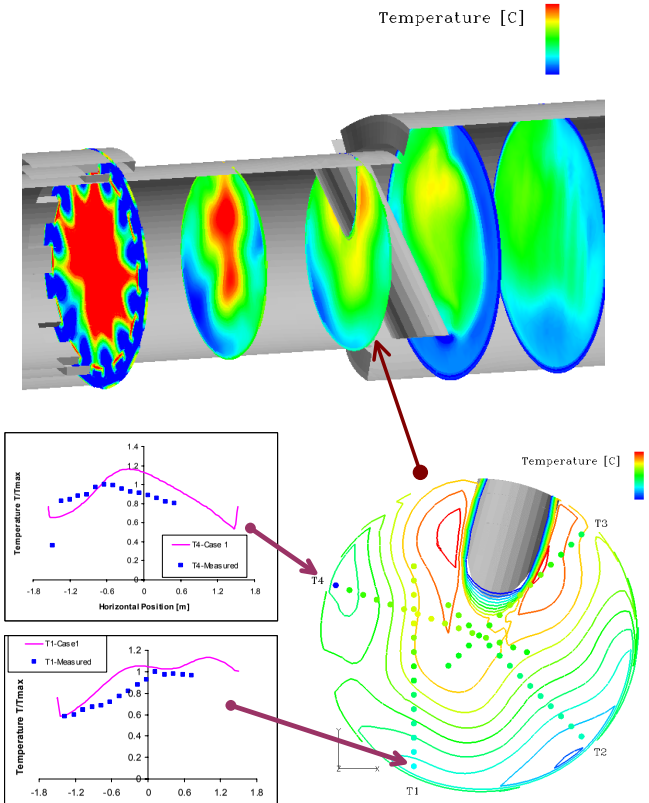


Gas Fired Combustor



An aerodynamic model of the combustor swirl blades was used to predict inflow velocity and turbulence conditions. Gas combustor flame shape and temperature prediction obtained using a mixed-is-burnt combustion model.

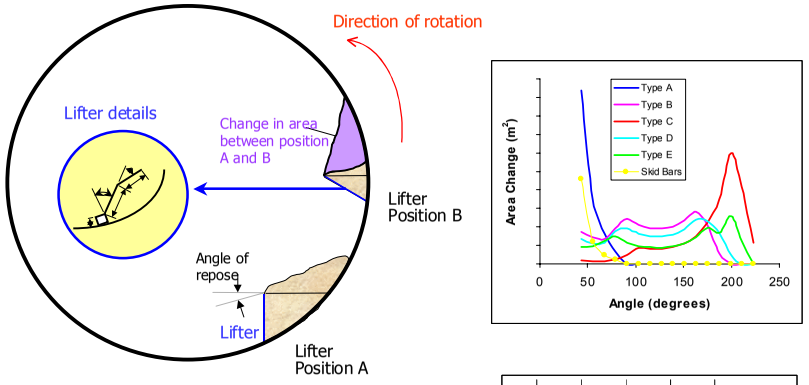
Temperature distribution at dryer entry



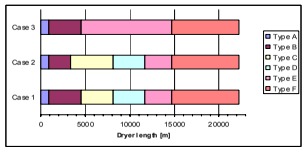
Oil shale particles when exposed to even moderate temperatures start to breakdown releasing unpleasant odours. Dilution ports add post-combustion air to cool the gas stream before it contacts the particles. Good mixing between the dilution and combustion streams is critical to avoid localised high temperature regions that will contact the particles.

To check the CFD model predictions a series of temperature traverses were performed near the exit of the combustor. Good agreement between the measured and predicted values was observed. A modified design of the dilution slots was developed using the CFD model to improve mixing and reduce the peak temperature at the combustor exit.

Lifter Model

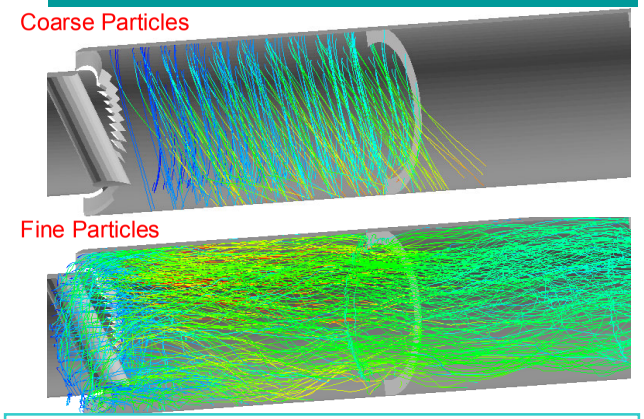


Lifters of various shapes and sizes are used to raise particles into the gas space. From the angle of repose and the change in area with rotation the mass of particles falling from the lifters at various rotational positions was determined and used as the initial boundary conditions for the Largrangian particle tracking model.



Axial location of different lifter designs evaluated.

Particle trajectories and temperatures



High particle loadings in the drum strongly effect the gas flow and temperature in the drum. The large particle size distribution results in markedly different behaviour of the fine and coarse particle size groups. Small particles are heated very rapidly to almost the gas temperature and are entrained in the gas stream. Large particles only undergo a few degrees rise in temperature while falling through the gas space back to the bed.

Results used courtesy of Southern Pacific Petroleum.