# IMPLICATIONS FOR ROBERT EVAPORATORS WITH CALANDRIAS OF DIFFERENT TUBE DIMENSIONS

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# What calandria dimensions are typically used in Robert evaporators?

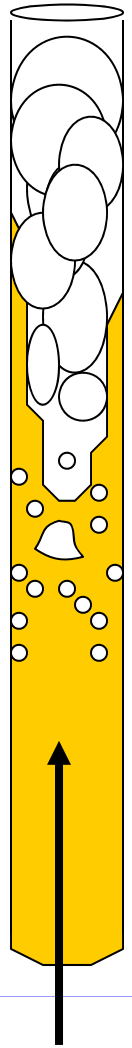
- Australia: typically tubes 44.45 mm OD and ~2 m length
- Brazil: tubes 38.1 mm OD is common; length ~3 m but may be longer for early vessels; perhaps shorter at final vessel
- Thailand: tubes 38.1 mm OD is common

What dimensions are best for heat transfer?

- Does the optimum tube dimension differ for different locations in the set?

**What are the implications of different calandria dimensions (costs, performance)?**

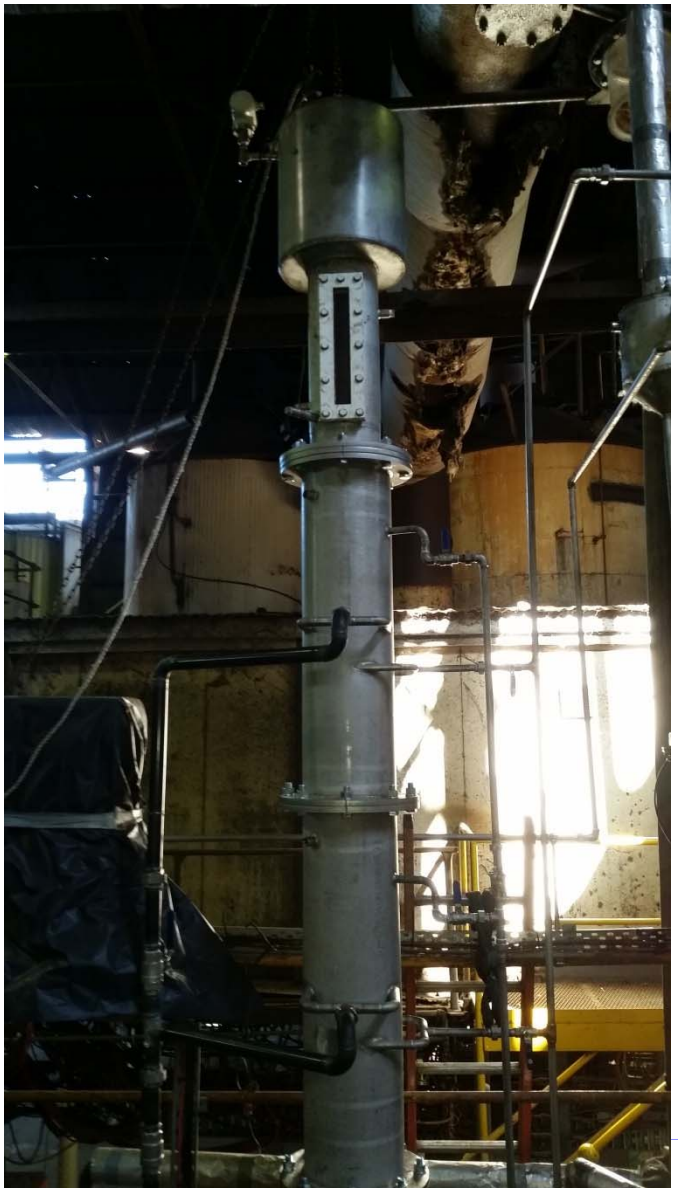
## Boiling mechanism in Robert evaporators



# Queensland University of Technology is undertaking a study to –

- Understand the boiling mechanism in rising film evaporation in tubes
- Investigate the heat transfer performance of tubes of **different length and diameter** for the full range of process conditions encountered in factory vessels

# Experimental rig



- 9 tubes
  - 38, 44 and 50 mm OD
  - 2, 3 and 4 m long
- Gutters on outside of heating tube to collect condensate → 4 segments
- Determine HTC for different segments of the tube.
- Installed at Rocky Point Mill

# Views of gutters and condensate collectors





# PhD study program

- Results from the experimental investigations –
  - Develop analytical model of heat transfer
  - Develop CFD model for an evaporator
  - Understand the flow behaviour in Robert evaporators
- Capital cost determined for Robert evaporators

  Evaporators of 2000, 3000, 4000 and 5000 $m^2$ for calandrias of different tube dimensions
- Combine HTC results and cost results

Determine optimum Robert evaporator at each effect position

# Design implications for calandrias of different dimensions

- Calculate the main design parameters for vessels of 2000, 3000, 4000 and 5000 $m^2$ with calandrias comprising three tube lengths and three diameters.

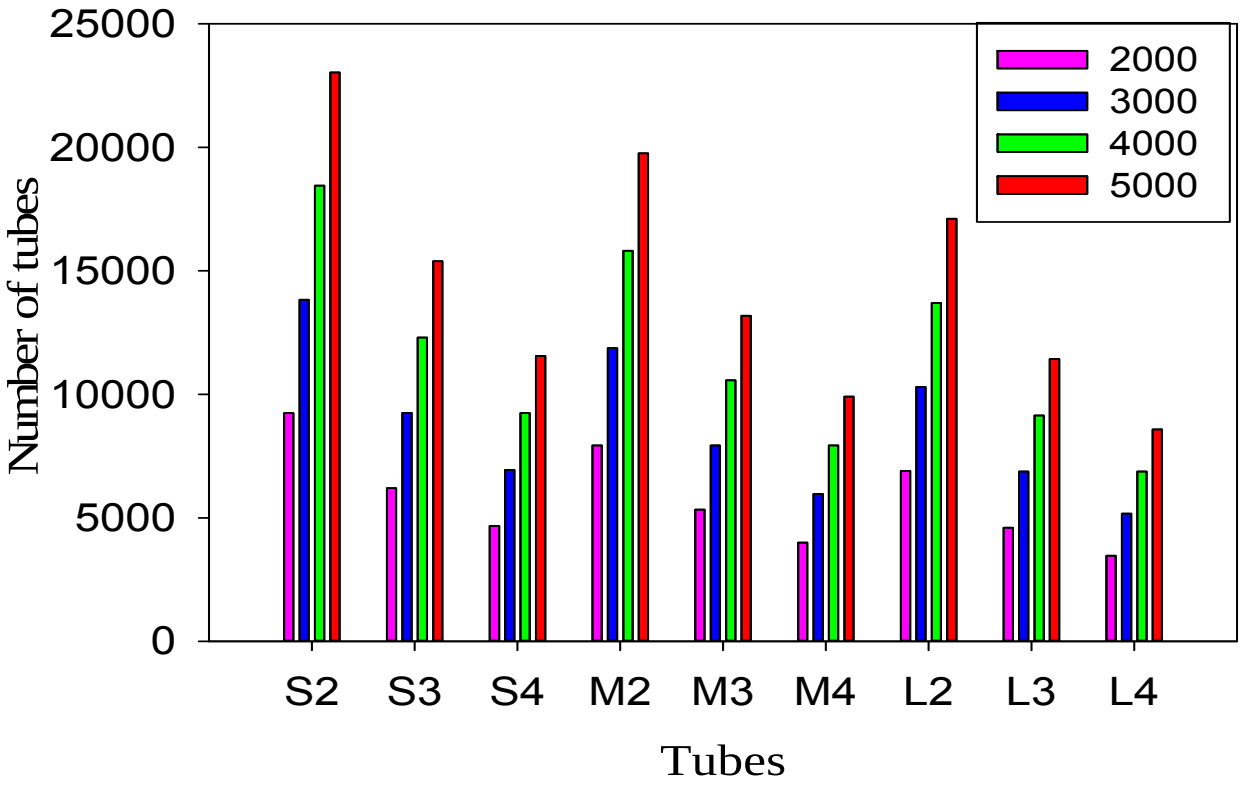
| Tube length (m) | Tube OD (mm) | Code |
|---|---|---|
| 2 | 38.10 | S2 |
| | 44.45 | M2 |
| | 50.80 | L2 |
| 3 | 38.10 | S3 |
| | 44.45 | M3 |
| | 50.80 | L3 |
| 4 | 38.10 | S4 |
| | 44.45 | M4 |
| | 50.80 | L4 |

# Evaporator Design

- All assessments based on SRI Robert evaporator design:
  - Multiple juice entry points through base of evaporator near outer wall
  - Central downtake for juice outflow (semi-sealed)
  - Mini–downtakes (150 mm)
  - Steam flows inwards from peripheral annulus
  - Central off-take of condensate and incondensible gases

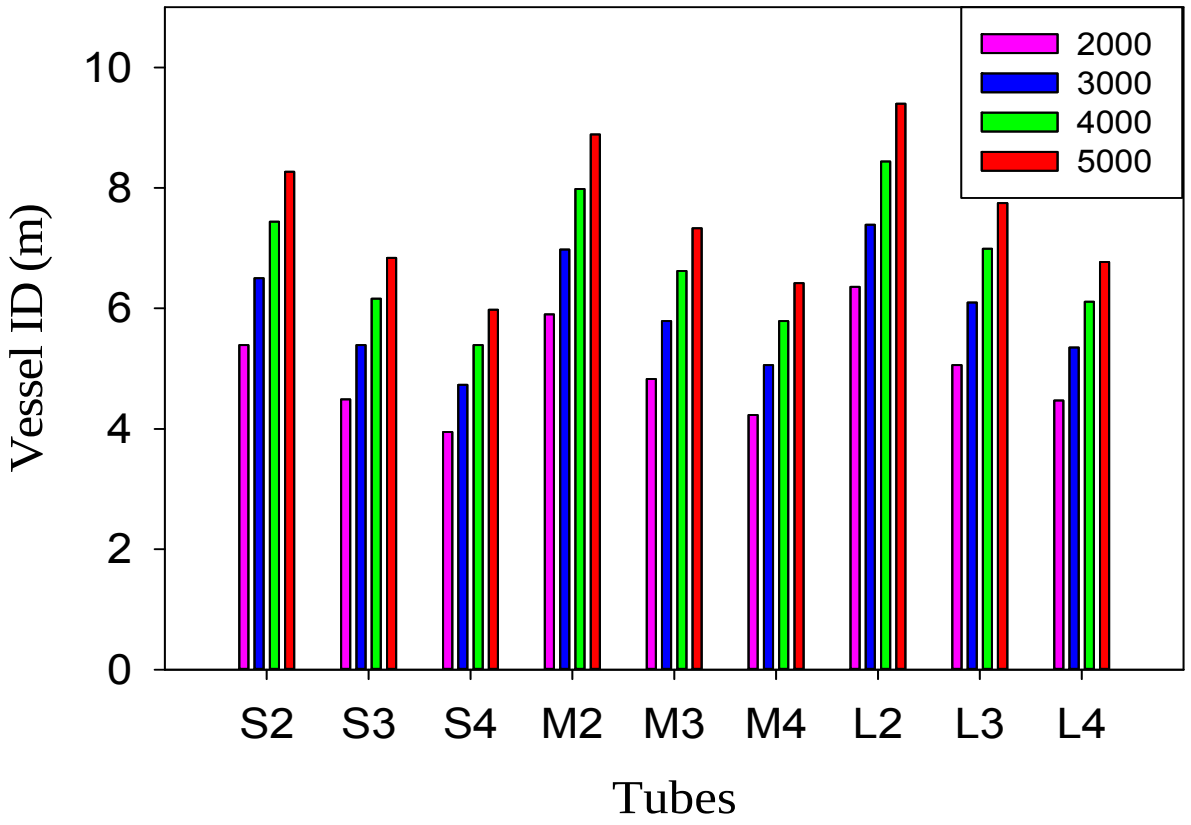
# Number of tubes

- L4 requires **56%** fewer tubes than M2 for same HSA.
- Calandria with L4 will provide **cost savings** in drilling and honing of tube plates, inserting and expanding tubes.



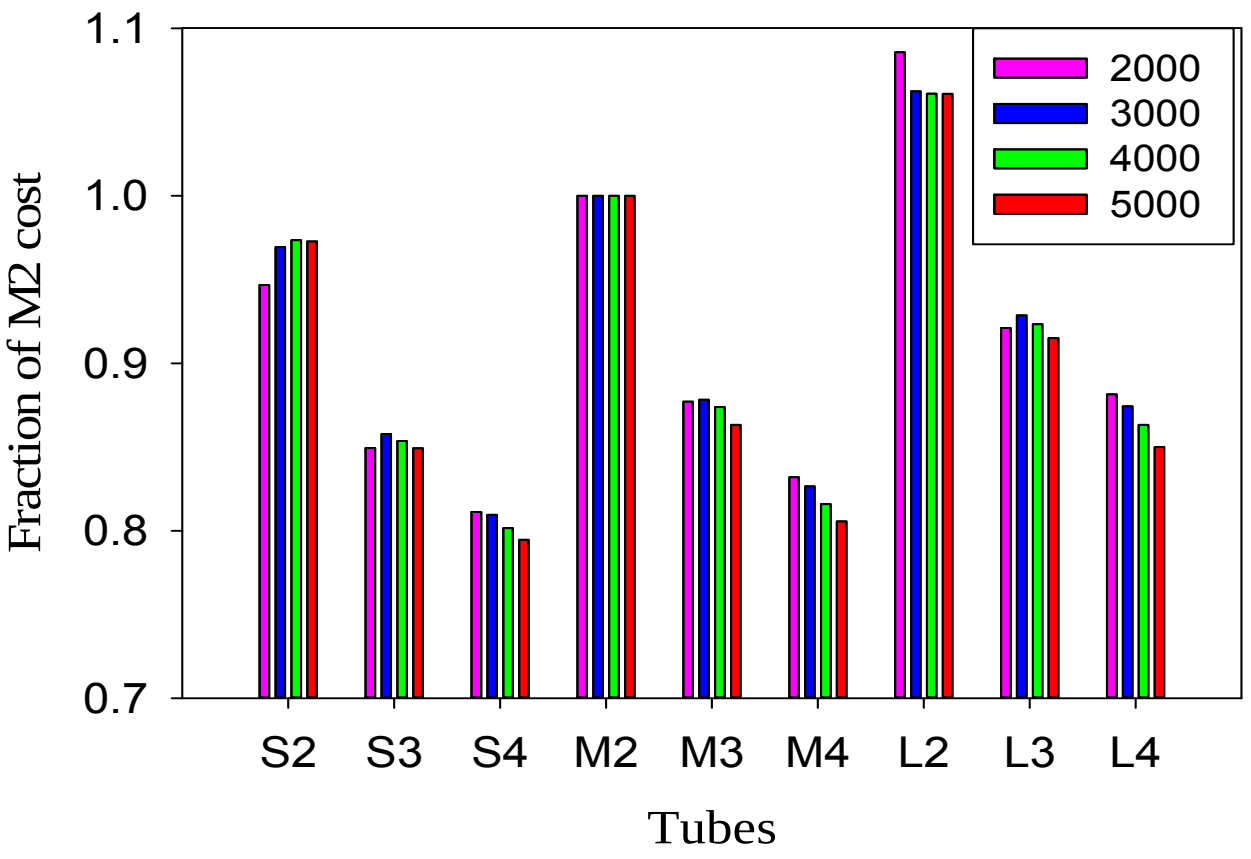
# Vessel diameter

- Vessel diameter determines the footprint of the vessel, mass of steel in the vessel, volume of juice held, total mass on the supporting structure and foundations.
- Diameter of vessel is reduced by **33%** when S4 tubes are used relative to M2 tubes.



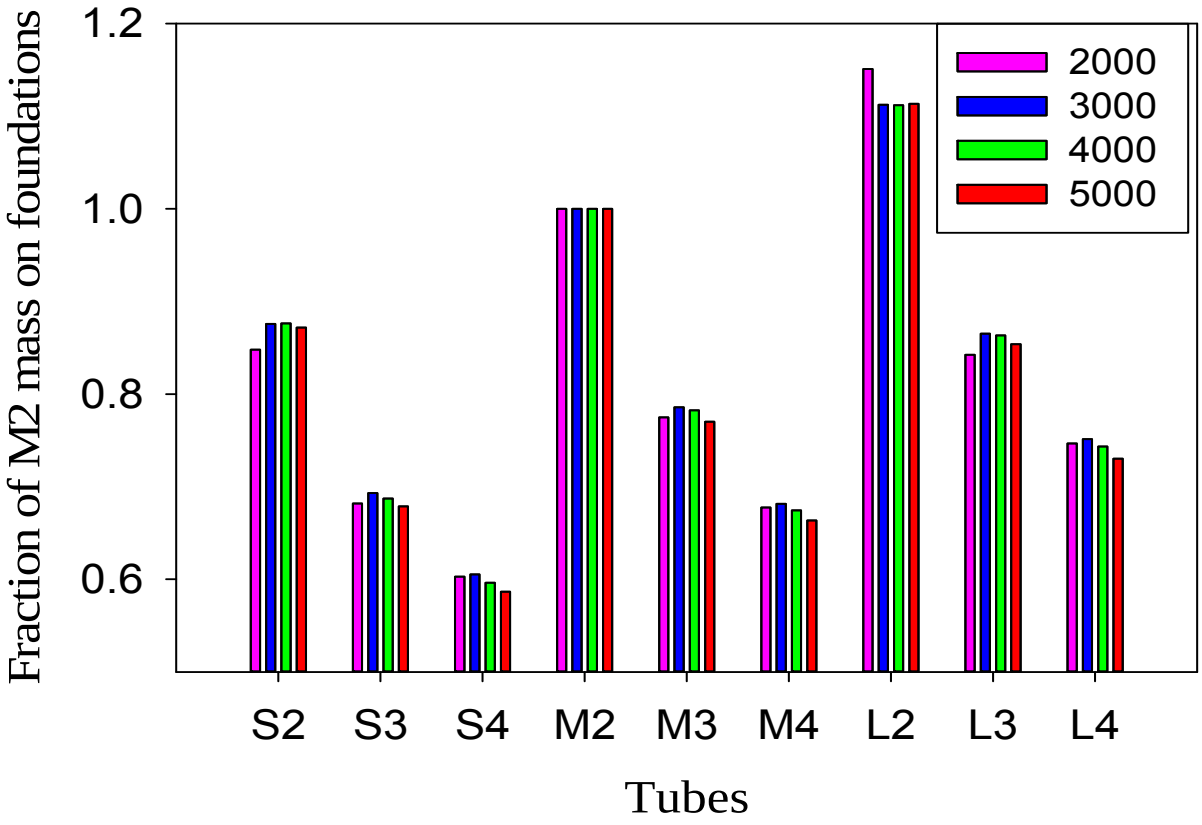
# Cost of supplied evaporator

- Data are expressed relative to the costs of vessels of the same HSA with calandrias of M2 tubes.
- M2 vessels are **more expensive** than all other arrangements except L2.



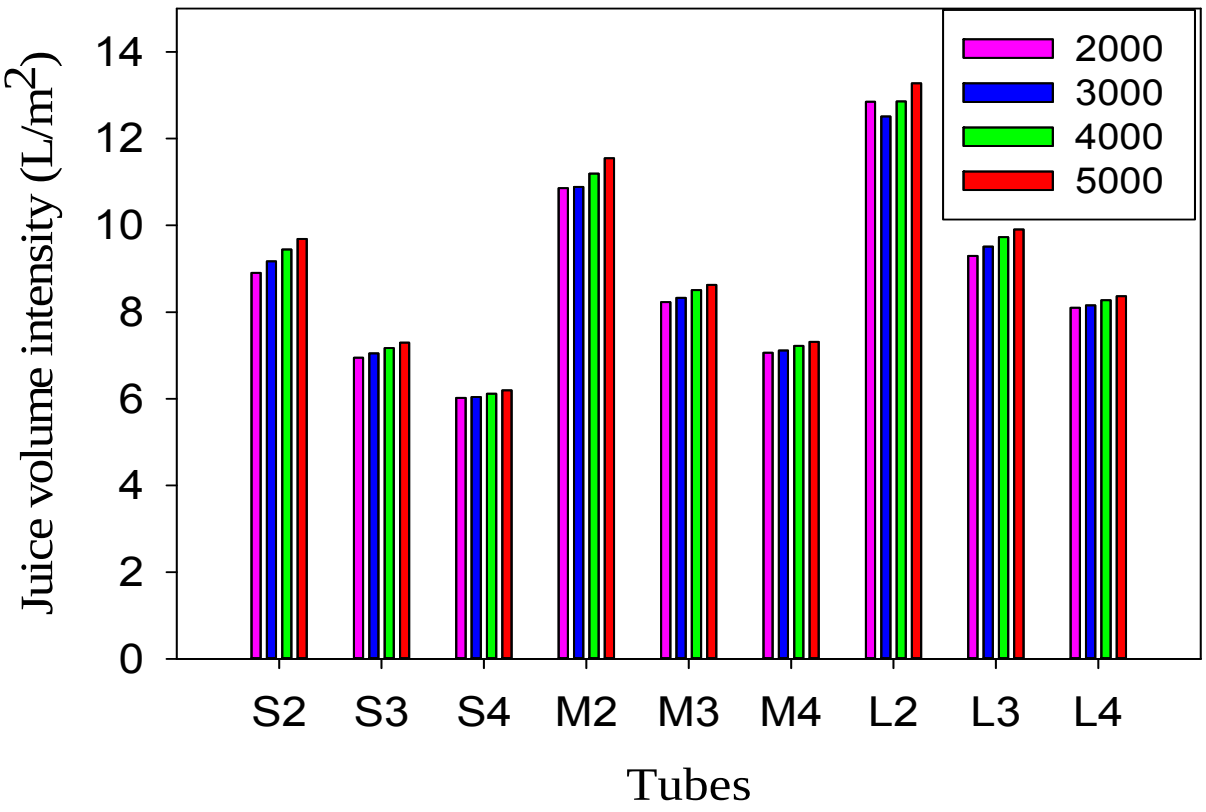
# Mass on foundations and structure

- Comparing S4 tube design with M2 tube design, a reduction of **40%** in the mass on foundations and structure is achieved.



# Juice volume intensity

- Juice volume/unit HSA is reduced with small OD and longer tube calandrias. Reduced residence time.
- Sucrose degradation is function of **juice conditions** and **residence time**.




Less sucrose degradation expected for vessels with smaller diameter and longer tubes. More important for evaporators early in the set (boiling at high temperature)

# De-entrainment of droplets

- Upflow vapour velocity in vessels with small diameter and long tubes is higher for same evaporation rate. Satisfactory for most circumstances, even for S4 at final effect.
- For almost all operating conditions, sufficient louvre area can be installed without increasing the diameter of headspace or installing external separator.

# Summary from design analysis

- Relative to the conventional evaporators (M2), savings in the ex works costs are:
  - **~12%** with 44.45 mm OD and 3 m length (M3)
  - **~15%** with 38.1 mm OD and 3 m length (S3)
  - **~20%** with 38.1 mm OD and 4 m length (S4)

- Vessels with smaller diameter, longer tubes have considerably less mass on the structure and foundations-
  - additional savings through **reduced** installation costs

# Summary from design analysis cont'd

- Vessels with smaller diameter, longer tubes have smaller juice volume per unit HSA.
  - ➢ Shorter residence time; less sucrose degradation?

- No difficulties are expected with droplet de-entrainment in Robert evaporators with smaller diameter, longer tubes (S4 tubes) in terms of upflow vapour velocity and installation of louvres.

Question: How does the heat transfer efficiency of small diameter, long tubes compare with say M2?

# Overview of project

- Incorporate results of experimental investigations

for HTC of different tubes at different processing conditions into CFD model of

- single tube
- representative wedge of Robert vessel

- Determine performance of Robert vessel under different processing conditions and define operational boundaries (constraints)
- Apply the results of the design analysis
  - ***optimum*** Robert design (for different boiling duties)

## Project Funding







Rocky Point Mill management and Staff

