Reducing Unplanned Repair Costs using Predictive Maintenance with MATLAB

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Presenter Biography

- Completed Mechanical Engineering Degree at John Moore's University in Liverpool
- Worked in various sectors including Rail, Water and Sewage Treatment, Construction/Building Services and Nuclear.
- Nuclear Industry for last 20 Years – at Capenhurst Site
- Regional Chair of IMechE committee (Merseyside and North Wales)
- Sit on the Industrial Advisory Board For John Moore's University.

- Primarily involved in Storage and Decommissioning including care and maintenance of Storage Containers and the buildings they sit in, with a view to eventual decommissioning.

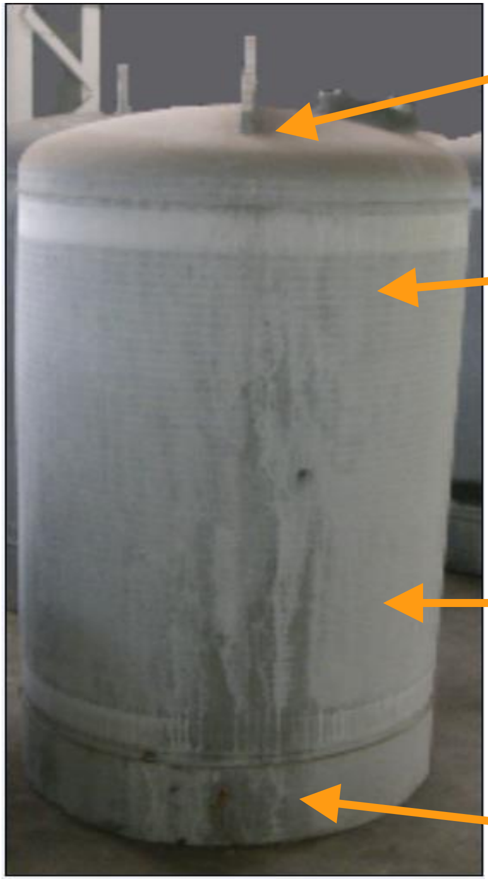
Brief History of Urenco

- The 1st centrifuge plant on the Capenhurst site, E21 was built in the late 1970's and had an output of 200 tSW/a. It took 3 years to decommission.
- URENCO (Capenhurst) Limited became a wholly owned subsidiary of URENCO Limited in 1993 following a restructuring of BNFL and in 2008 it changed it's registered name to URENCO UK Limited (UUK).
- UUK operates world leading centrifuge technology to enrich uranium to enable nuclear power stations around the world to generate electricity.
- The site operates three plants producing a total output of 4600 tSW/a.

Problem Statement

- Urenco needs to manage an aging inventory of waste containers.
- A scheduled maintenance plan would involve replacing the containers at fixed intervals, regardless of their condition.
- We want to minimise unnecessary worker exposure to a hazardous environment, replacement and inspection costs.
- Gathering data is hazardous, time-consuming, and expensive.
- Can we improve on a fixed maintenance schedule by modelling and simulating the container condition as a function of time, usage, and environmental conditions?

Storage Containers



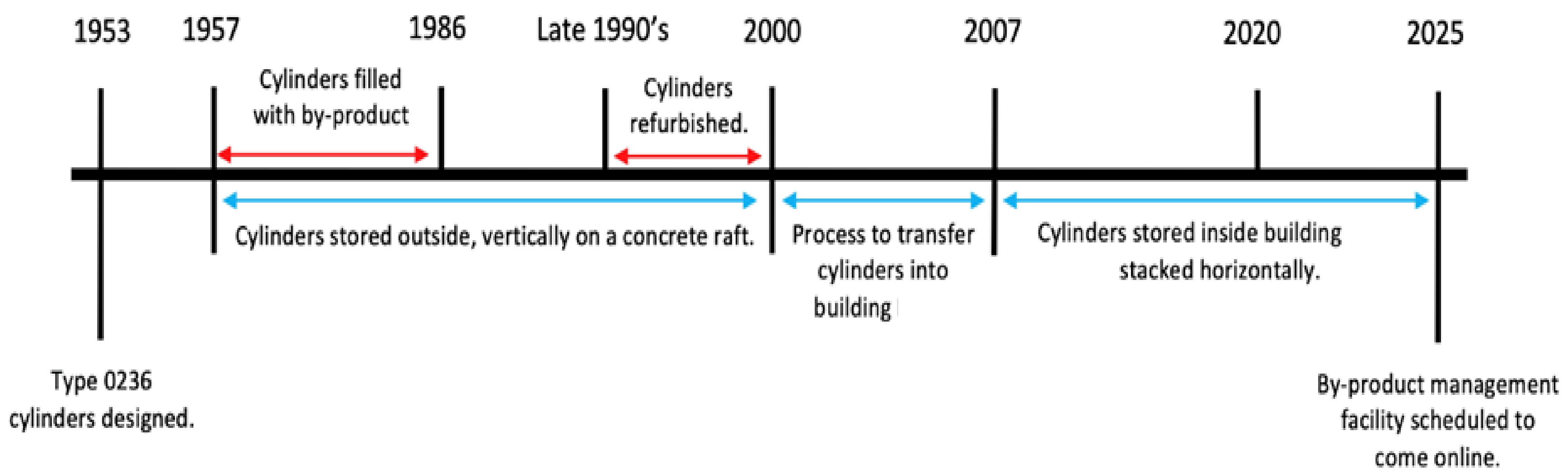
Position 1: Top Dome / Blank Dish

Position 2: Upper Body / Shell

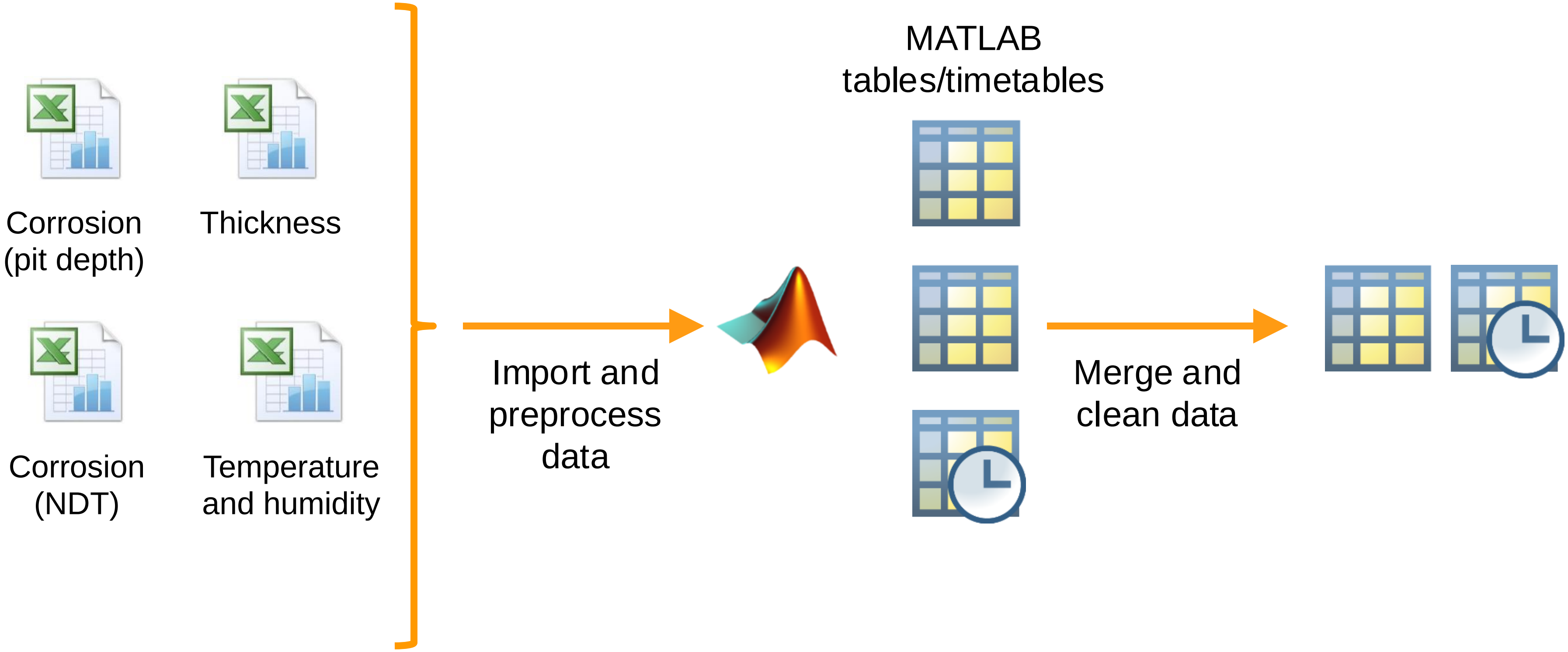
Position 3: Lower Body / Shell

Position 4: Bottom Dome / Skirt Dish

Time Line


1953
1957
1986
Late 1990's
2000
2007
2020
2025
Cylinders filled with by-product
Cylinders refurbished.
Cylinders stored outside, vertically on a concrete raft.
Process to transfer cylinders into building
Cylinders stored inside building stacked horizontally.
Type 0236 cylinders designed.
By-product management facility scheduled to come online.

Inputs



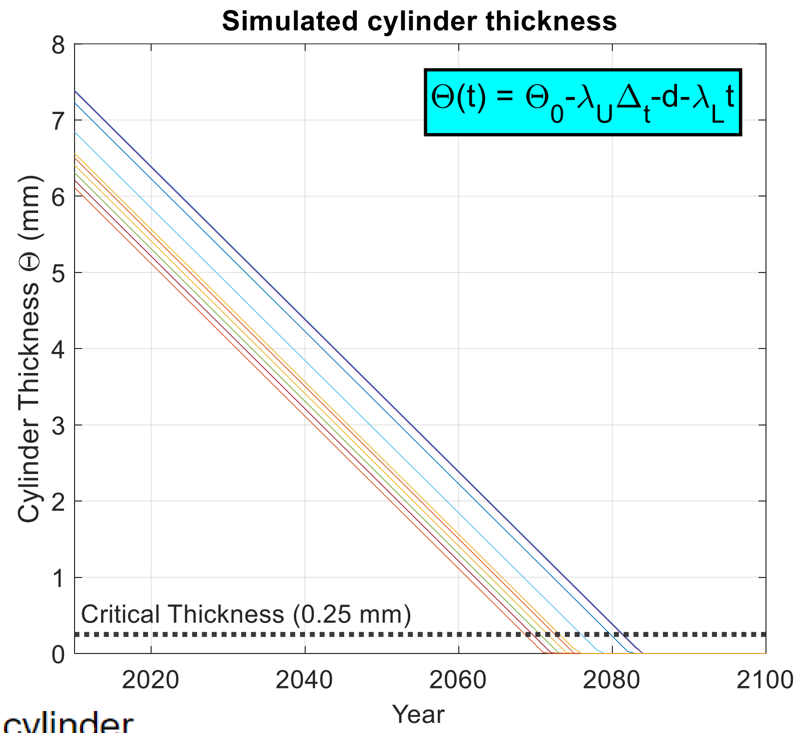
Corrosion (pit depth)
Thickness
Corrosion (NDT)
Temperature and humidity
Import and preprocess data
MATLAB tables/timetables
Merge and clean data

Model Equation

$$\Theta(t) = \Theta_0 - \lambda_U \Delta_t - d - \lambda_L t$$

where:

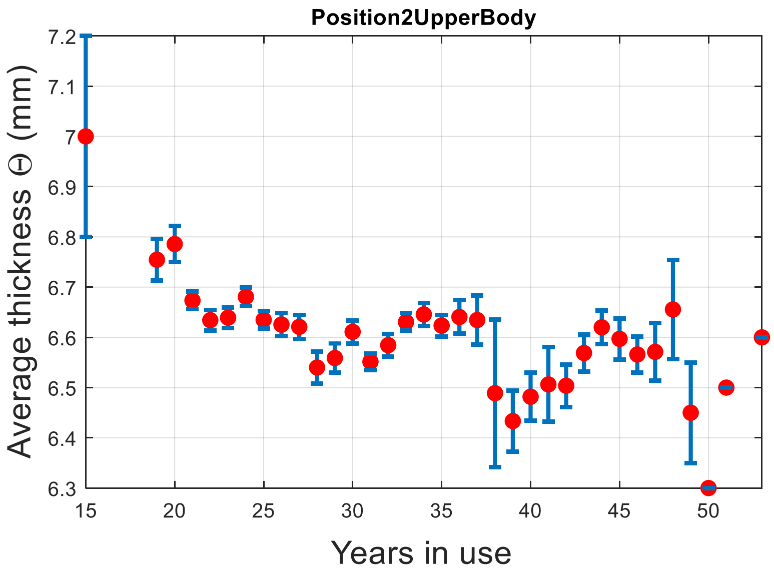
- $\Theta(t)$ is the cylinder thickness at time t (mm),
- Θ_0 is the current cylinder thickness (mm),
- d is the corrosion depth (mm),
- t is the time (years),
- $\lambda_L > 0$ is the local corrosion rate (mm/year),
- $\lambda_U > 0$ is the constant uniform corrosion rate of the cylinder (mm/year),
- Δ_t is the time difference (in years) between the measurement of the corrosion depth and the cylinder thickness.



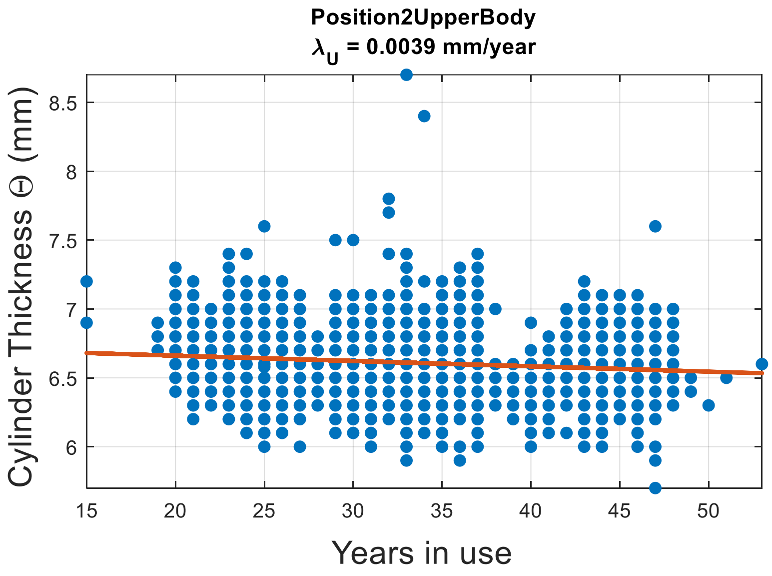
Parameter Estimation

The corrosion rate parameters λ_U, λ_L are estimated using the historical data and the environmental variables (temperature and humidity).

Average thickness over time



Linear fit of thickness over time



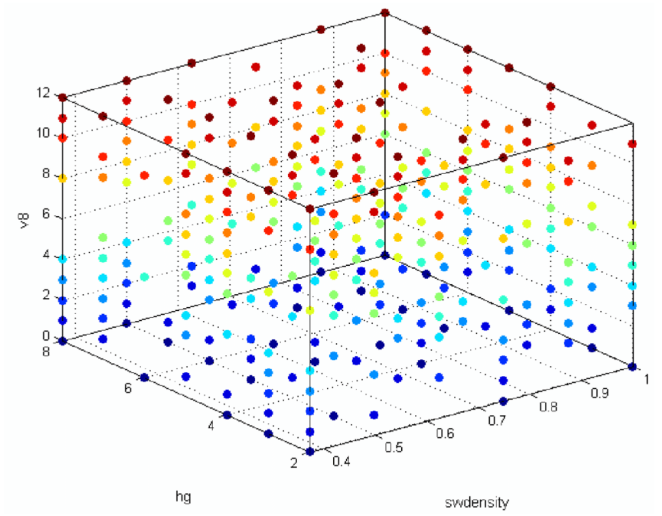
Monte Carlo Simulation

- Some model parameters have a higher level of uncertainty.

- We need to ensure that the model is robust across the parameter space.

- The marginal distribution of each parameter is modelled using an appropriate probability distribution.

- We then sample from these distributions to produce a range of possible failure times.

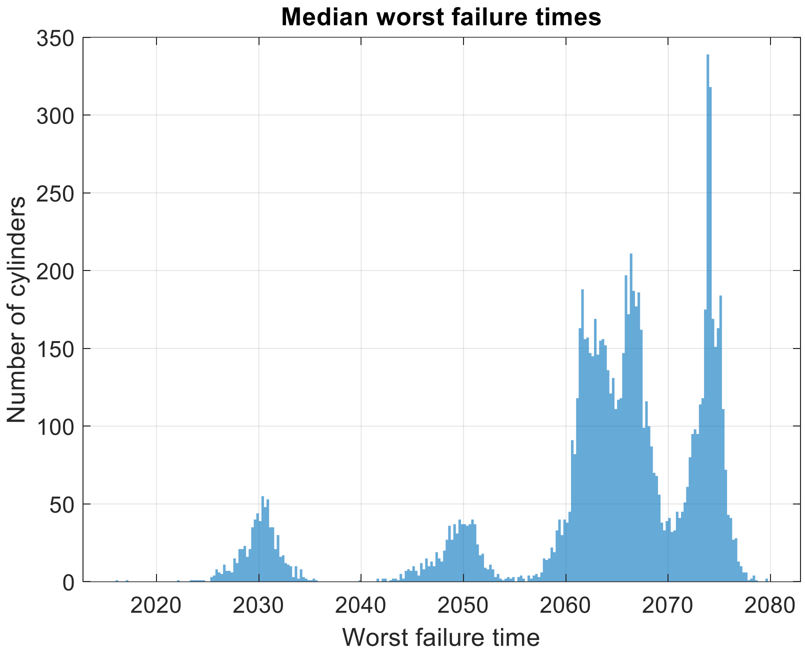


Simulation Process

- In the model equation, solve $\Theta(t) = \Theta_{crit}$, where Θ_{crit} is some critical thickness (e.g., 0.25mm). This gives an estimated failure time t.

- Repeat the simulation for each cylinder position.

- Take the minimum failure time over all the positions to obtain the overall cylinder failure time.



Output Details

- Detailed prediction of containers to be examined for possible failures in spreadsheet format to ensure data can be interpreted easily.
- The model is extensible when new data is available from regular inspections.
- Graphs of predictions and timescales to be aware of and act as benchmarks for future.
- Report format enabling clear information to regulators and senior staff.

Future updates

- Ability to build upon base model to add any future failure modes.
- Annual update to base information from ongoing inspections.
- Sharing the model with colleagues and regulators via a user interface.

Any Questions?