FoulX: Fouling In Industrial Heat Exchangers

UNIVERSITY OF WATERLOO

Aliana Ricci Andres, Ricky Fan, Curtis Rhodes, Dorothy Wan
Supervisors: Dr. Lena Ahmadi, Dr. Ali Elkamel
Department of Chemical Engineering, University of Waterloo

PETRO-CANADA LUBRICANTS

Introduction

Problem Statement

Fouling within heat exchangers used in the oil and gas industry results in a decrease of thermal efficiency and affects chemical manufacturing processes globally. The goal of this project is to decrease the amount of fouling while maintaining performance efficiency.

Objective

FoulX is composed of an augmented design of a downstream steam trap [1] and predictive modelling of heat duties and correction factors [3] to determine an optimized heat exchanger cleaning schedule.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Solution Selection

Go-No Go Screening Method

Constraint	Coating Interior	Different heat exchanger configuration	Redesign steam trap	Optimize cleaning schedule/operating conditions	Heat exchanger network design
	Potential Solutions				
Cost Improvement	No Go	No Go	Go	Go	No Go
Long lasting	Go	Go	Go	Go	Go
Correction Factor	No Go	Go	Go	Go	No Go

Design and Solution Analysis

CONSTRAINTS

- Achieve a cost improvement of at least 11%
- A lifetime of within or exceeding 5 to 10 years [2]
- Correction factors are maintained above 0.8

CRITERIA

- Increase effective uptime of heat exchangers by 10%
- No negative economic or safety impacts
- Increase of 10% in thermal efficiency

Needs

- Reduce amount of fouling build up
- Applicable to multiple types of heat exchangers

Stakeholders

- Petro Canada in Ontario
- Heat exchanger manufacturers
- Process companies that use heat exchangers

Results and Discussion

Steam Trap Sizing and Design

The steam trap is designed based on pressure values of the outlet steam line downstream of the heat exchanger. Assumptions were made to calculate and determine the steam trap design. The steam trap type is to be a float and thermostatic from Spirax Sarco. The steam rating of the inlet stream is 175# therefore a pressure of 175 psi was assumed [1,4,5].

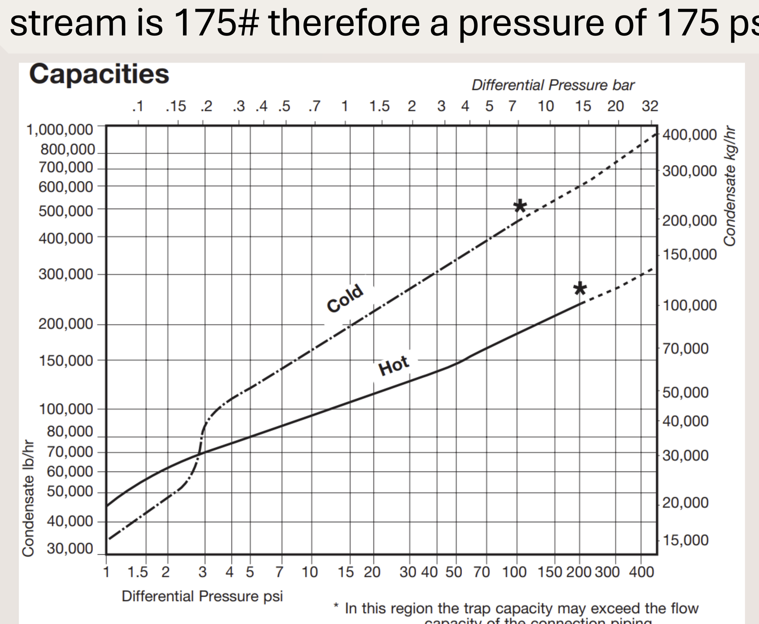


Figure 1: Spirax Sarco FT450 – Sizing Capacity Data [4]

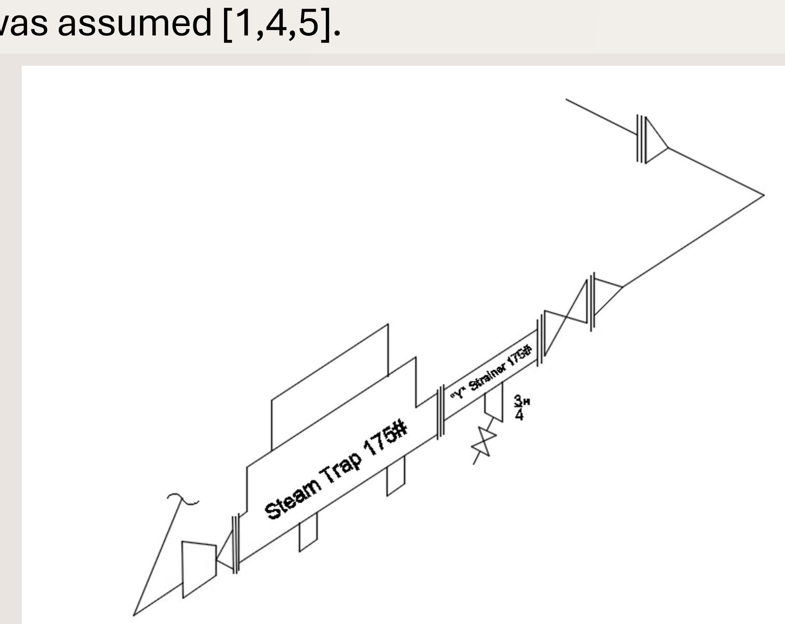
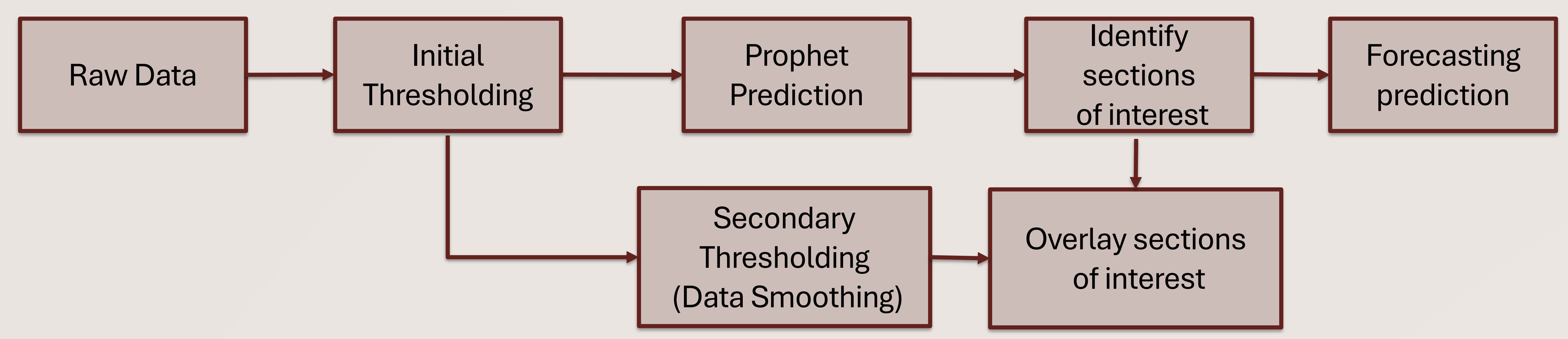


Figure 2: Isometric Drawing of Steam Trap Design

Results and Discussion

Optimized Cleaning Schedule

A function was designed to analyze variable data points to determine when the heat duty and friction factor reaches a set threshold to determine cleaning schedule.



The time series dataset was used to calculate the correction factor and heat duties of the heat exchanger to predict the future values.

This allowed an analysis to be made of when there were downward trends in the parameters, as shown by the highlighted sections of interest.

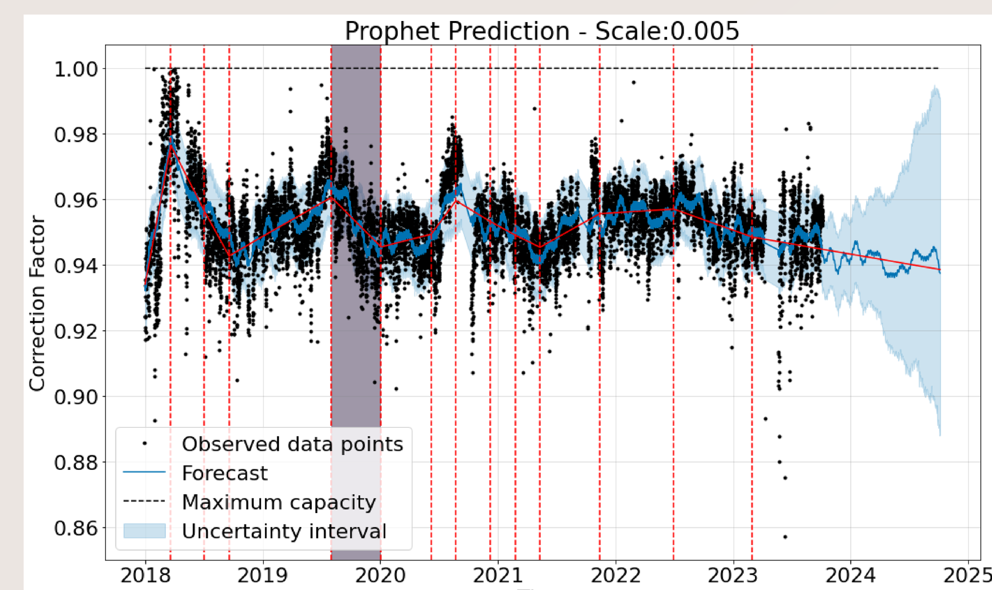


Figure 3: Meta Prophet Prediction

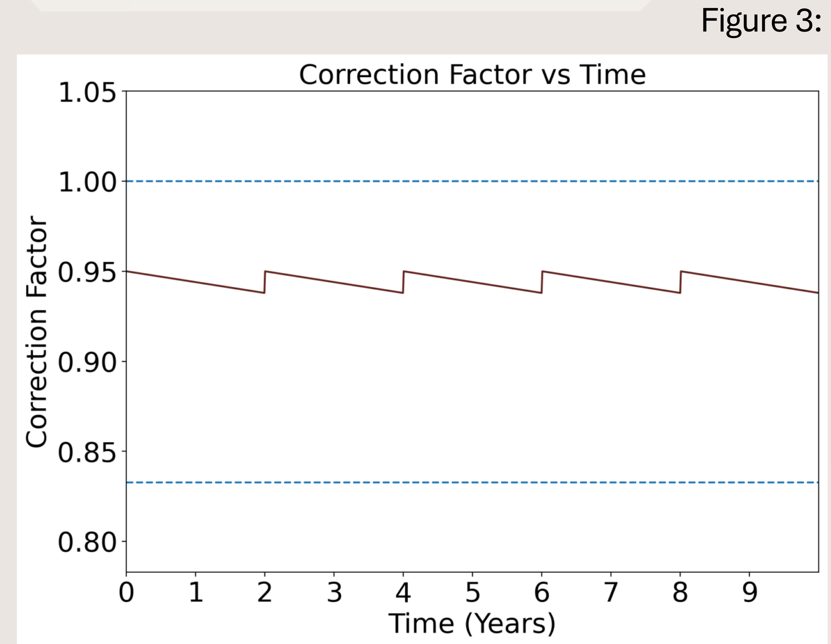


Figure 4: Correction Factor versus Time

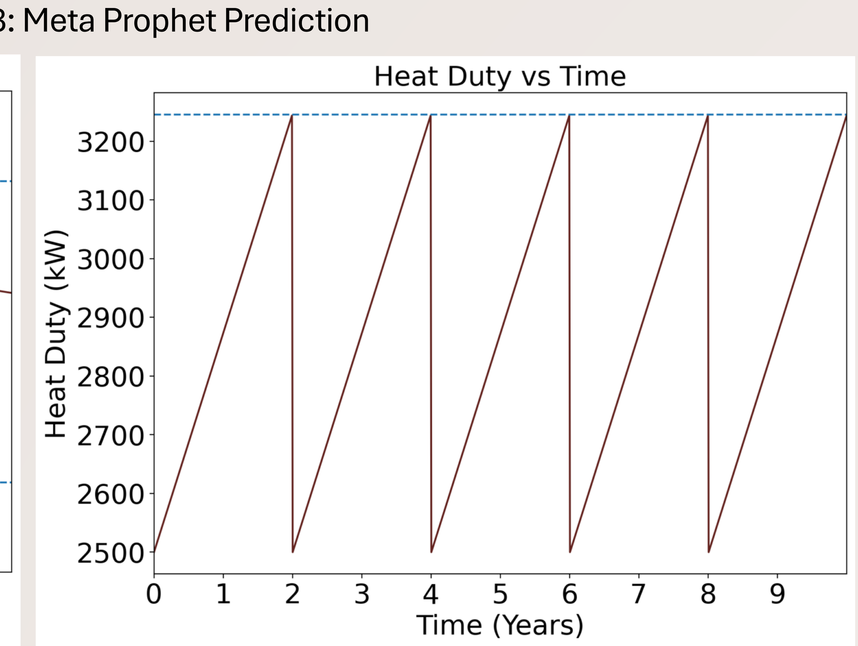


Figure 5: Heat Duty versus Time

Upper and lower thresholds are set for the correction factor and an upper bound on the heat duty values. The vertical sections of both graphs indicate when cleanings should be performed when the maximum heat duty threshold is reached, and downtime costs are reduced.

Impacts Analysis

Economical Impacts

FoulX would have a downtime of 20 days of cleanings every 10 years. The $6.5M reduction in downtime costs would positively affect the facility's bottom line and improve its overall financial performance.

Baseline Analysis [8] – Downtime (10 days):

Electricity Costs [7]: 18.2 ¢/kWh
Operation Costs: $19,000 per day
Average Daily Costs: $15,000 per day

Total Economic Impact:
Maintenance Costs: $150,000x2= $300,000
Total Impact: **$56,600,000**

Scenario Analysis – Optimized Downtime (20 days):

Operation Costs: $14,000 per day
Average Daily Costs: $12,000 per day

Total Economic Impact with Optimized Downtime:
Maintenance Costs: $150,000x4= $600,000
Total Impact: **$50,100,000**

Impacts Analysis

Safety Impacts – HAZOP Analysis

HIGH PRESSURE

Initiating Event
Due to valve malfunction

Scenario Description
Increased fouling rate, reducing heat transfer efficiency

Outcome
Increased pressure drop leading to equipment damage

Control
Install pressure control valves

HIGH TEMPERATURE

Initiating Event
Sudden increase in temperature - greater than 340 °C

Scenario Description
Quickens the fouling rate

Outcome
Increased electricity costs

Control
Install temperature transducer and controllers

HIGH COMPOSITION

Initiating Event
Presence of water exceeds 20% in the steam line

Scenario Description
Condensate remains in the steam system and causes sudden drop of pressure

Outcome
Increase overall plant's steam consumption and carbon footprint [5]

Control
Preventative maintenance – frequent testing

HIGH FLOW

Initiating Event
Excessive flow rate due to process demand

Scenario Description
Increases the chance of fouling formation

Outcome
Decreased production rate and heat transfer efficiency

Control
Install a flow control valve downstream of the heat exchanger

Summary

Conclusions

- The feasible inlet and outlet size of the downstream steam trap is 3" or 4"
- The optimized cleaning schedule is 4 cleaning sessions of 5 days of cleanings over 10 years, resulting in an overall cost of $50,100,000, an 11% reduction compared to the baseline.
- Through optimization, the minimum correction factor value achieved was 0.93

Future Direction

Future work would include:

- Explore effects of steam trap sizing and optimized cleaning schedule for further optimization
- Investigating applicability to different types of heat exchangers and processes

Acknowledgements and References

Acknowledgements

We would like to thank our capstone supervisors, Dr. Lena Ahmadi and Dr. Ali Elkamel, for their guidance throughout our project. Additionally, we appreciate the support and assistance provided by our advisors, Jamal Bajwa and Patrick Laflamme.

REFERENCES