Modelling & Optimization of a Distillation Train

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Table of contents

Goal

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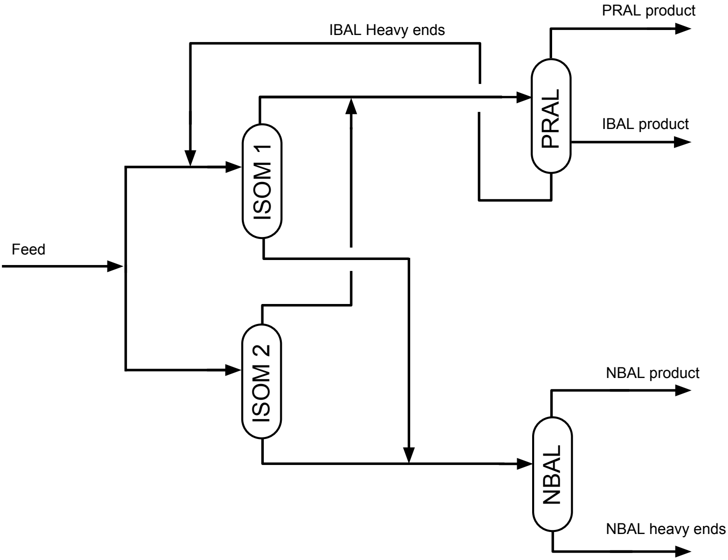
Find steam savings

The Process


PRAL product
IBAL Heavy ends
PRAL
IBAL product
ISOM 1
Feed
ISOM 2
NBAL product
NBAL
NBAL heavy ends

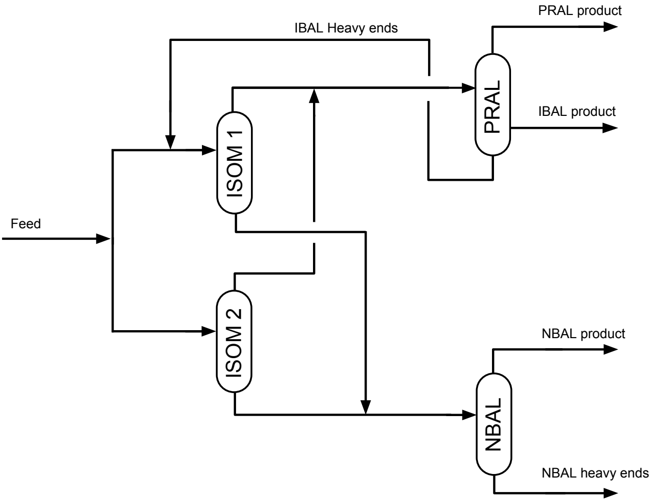
Over-purification

Assumption:

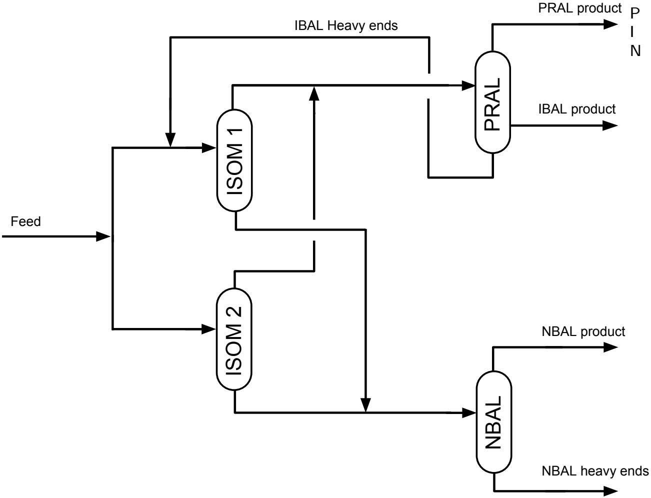
Excess steam usage gives over-purification of products

Over-purification

Spec **Base case**

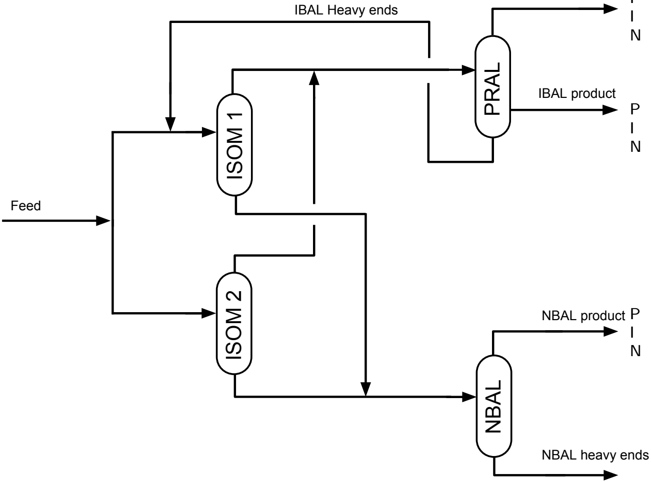


Over-purification



	Spec	Base case
P	0.996	0.9995
I	0.002	0.0002
N	0	0

Over-purification



Stream	Component	Spec	Base case
PRAL product	P	0.996	0.9995
	I	0.002	0.0002
	N	0	0
IBAL product	P	0.001	0.0002
	I	0.996	0.9983
	N	0.002	0.0006
NBAL product	P	0	0
	I	0.0012	0.0004
	N	0.996	0.9974

Over-purification

We do have over-purification!

The optimisation problem

$$\max_{M} Z = M_{PRAL} p_{PRAL} + M_{IBAL} p_{IBAL} + M_{NBAL} p_{NBAL} - E_{tot} H_{vap} p_{steam}$$

$$c_{\text{Ibal in PRAL}} \leq 0.002$$

$$c_{\text{Pral in IBAL}} \leq 0.001$$

$$c_{\text{Nbal in IBAL}} \leq 0.002$$

$$c_{\text{Ibal in NBAL}} \leq 0.0012$$

Results

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- Ibal price needs to be 7 times as large as other products
- Nbal price needs to be 8 times as large as other products
- For common price estimates, the optimal solution is always to minimise steam usage!

Steam distribution in Isomer columns

Assumption:
Uneven separation in Isomer columns gives steam losses

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Uneven separation in Isomer columns gives steam losses

- What is optimal steam distribution?
  - As much separation as possible in ISOM 1
  - As much separation as possible in ISOM 2
  - Equal separation in both columns

Steam distribution in Isomer columns

	Duty ISOM 1	Duty ISOM 2	Total duty	Savings
Units	*kJ/h*	*kJ/h*	*kJ/h*	*kr/h*
Base case	3,57E+07	3,17E+07	9,60E+07	
Same concentration	3,76E+07	2,86E+07	9,47E+07	
Difference	-1,91E+06	3,18E+06	1,27E+06	127

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- Product streams identical
- Yearly savings of $\approx$ 1 million
- Increased steam usage in ISOM 1
- Decreased steam usage in ISOM 2

Potential savings

We would like to reduce over-purification

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Where would it be most profitable to improve control?

Potential savings

Table: Changing concentrations from base case values to maximum allowable values

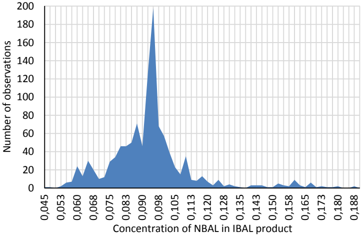
Ibal in PRAL	Pral in IBAL	Nbal in IBAL	Ibal in NBAL	Total duty	Savings
				kJ/h	*kr/h*
0,00028	0,00023	0,002	0,00042	9,03E+07	582
0,002	0,00023	0,00062	0,00042	9,42E+07	190
0,00028	0,001	0,00062	0,00042	9,53E+07	85
0,00028	0,00023	0,00062	0,0012	9,27E+07	347

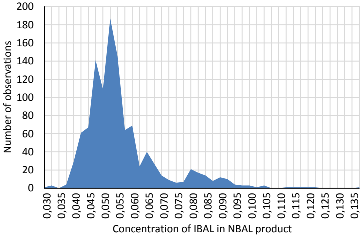
- The largest potential savings are from the Isomer columns

Realistic savings

- At the set point we will violate the constraint 50% of the time
- need back-off
- How much can we decrease back-off without violating the constraints?

Probability distributions





Savings with new set points

Table: Changing the concentrations out of the ISOM 2 column to meet new specified set points for the product streams

	Nbal in IBAL	Ibal in NBAL	Total duty	Steam savings
			kJ/h	*kr/h*
Measured data base case	0,062	0,042	9,60E+07	
Isomer set points 1% failure	0,091	0,058	9,18E+07	421,58
Isomer set points 2.27% (Norm distr.)	0,143	0,078	9,05E+07	543,29

Results

- For common price estimates, the optimal solution is always to minimise steam usage
- The largest potential savings are from the Isomer columns
- Identical separation in Isomer columns leads to steam savings without changing product streams
- To achieve this: Decrease steam usage in ISOM 2, increase steam usage in ISOM 1