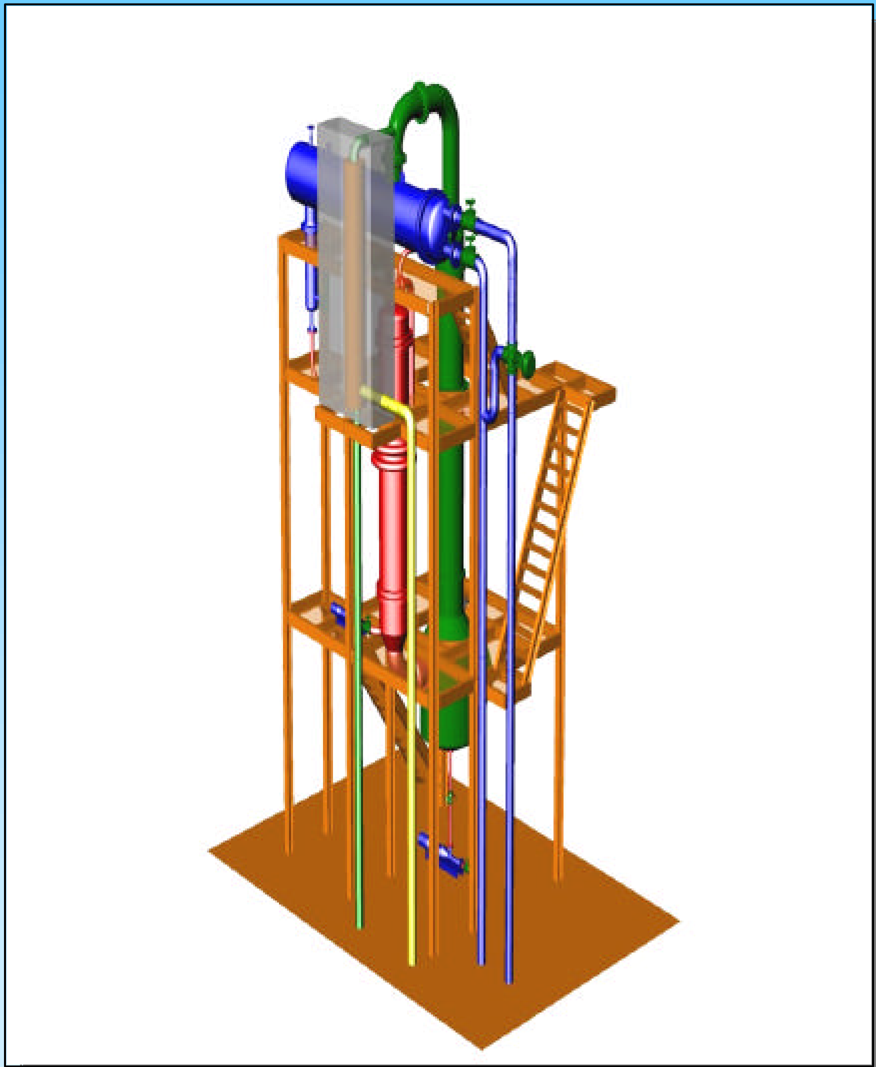


Life Cycle Simulation using Bayesian Calculation

by Ferdinand Heru Utomo

Project Description

Initiatiate the Life Cycle simulation using the Bayesian Calculation

- Building Bayesian network model for a chemical process
- Modeling a database for the process
- Implement the simulation application
- Building a user interface for the application
- Add knowledge-rules for the decision advices

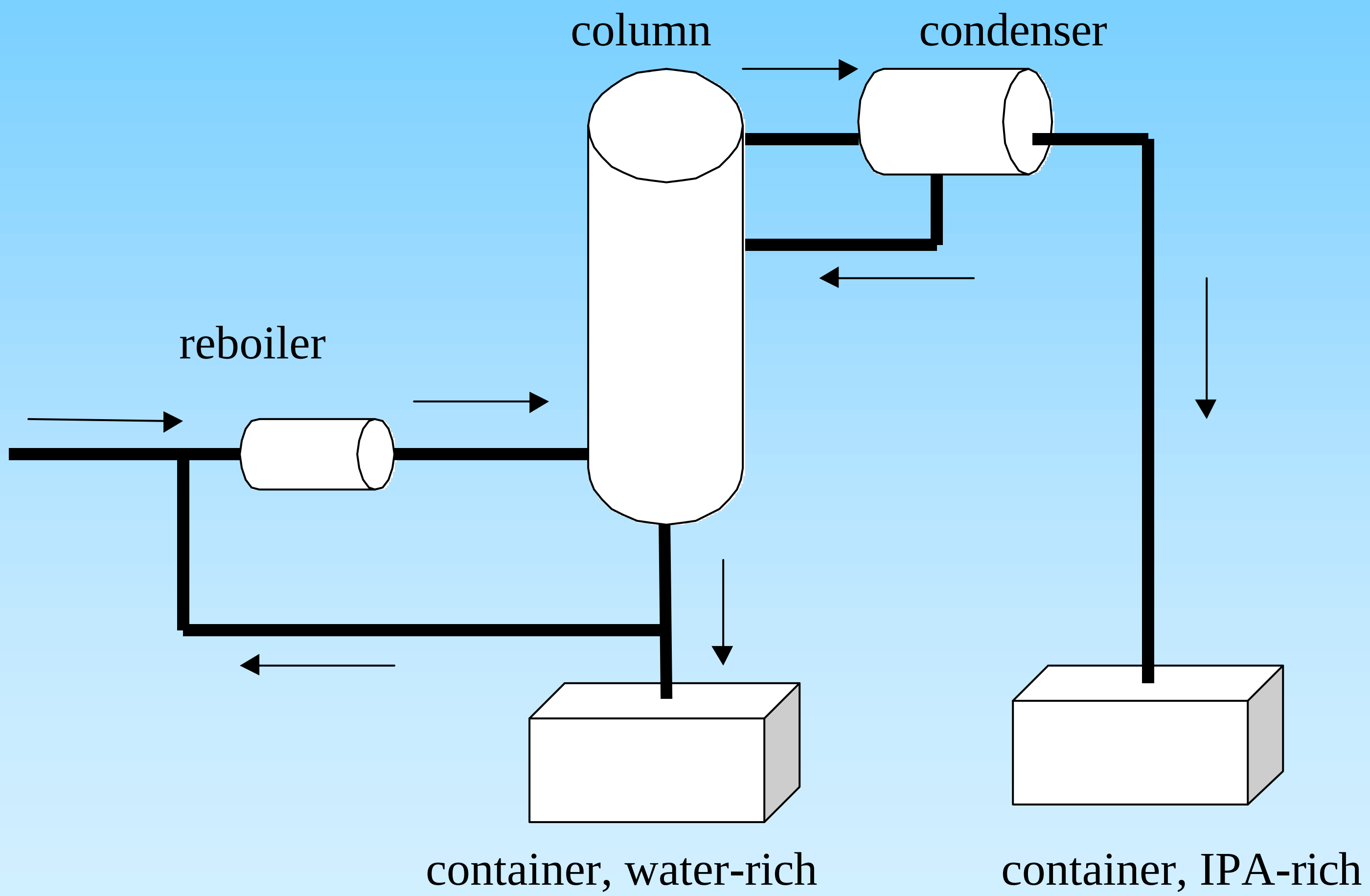
Area of Application

Hybrid Distillation and

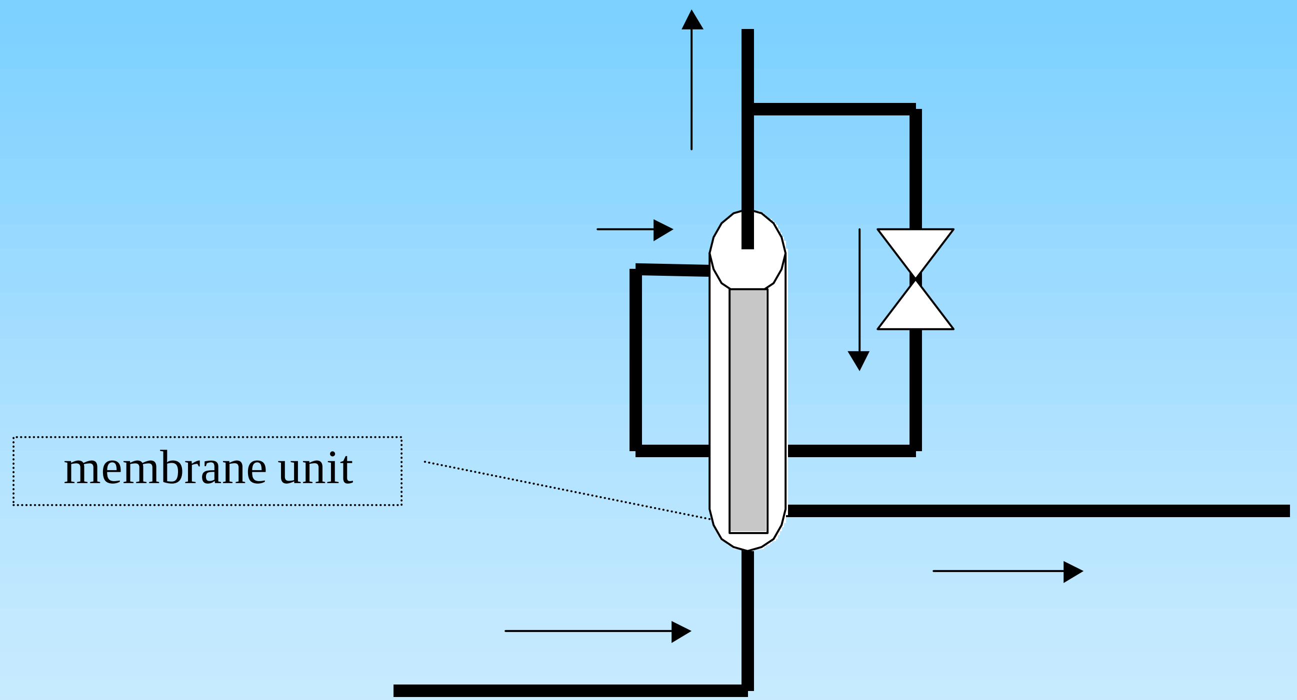
Vapor Permeation Process

- Separation Process
- At a laboratory scale
- Pilot at Laboratory of Process Equipment, Delft University of Technology

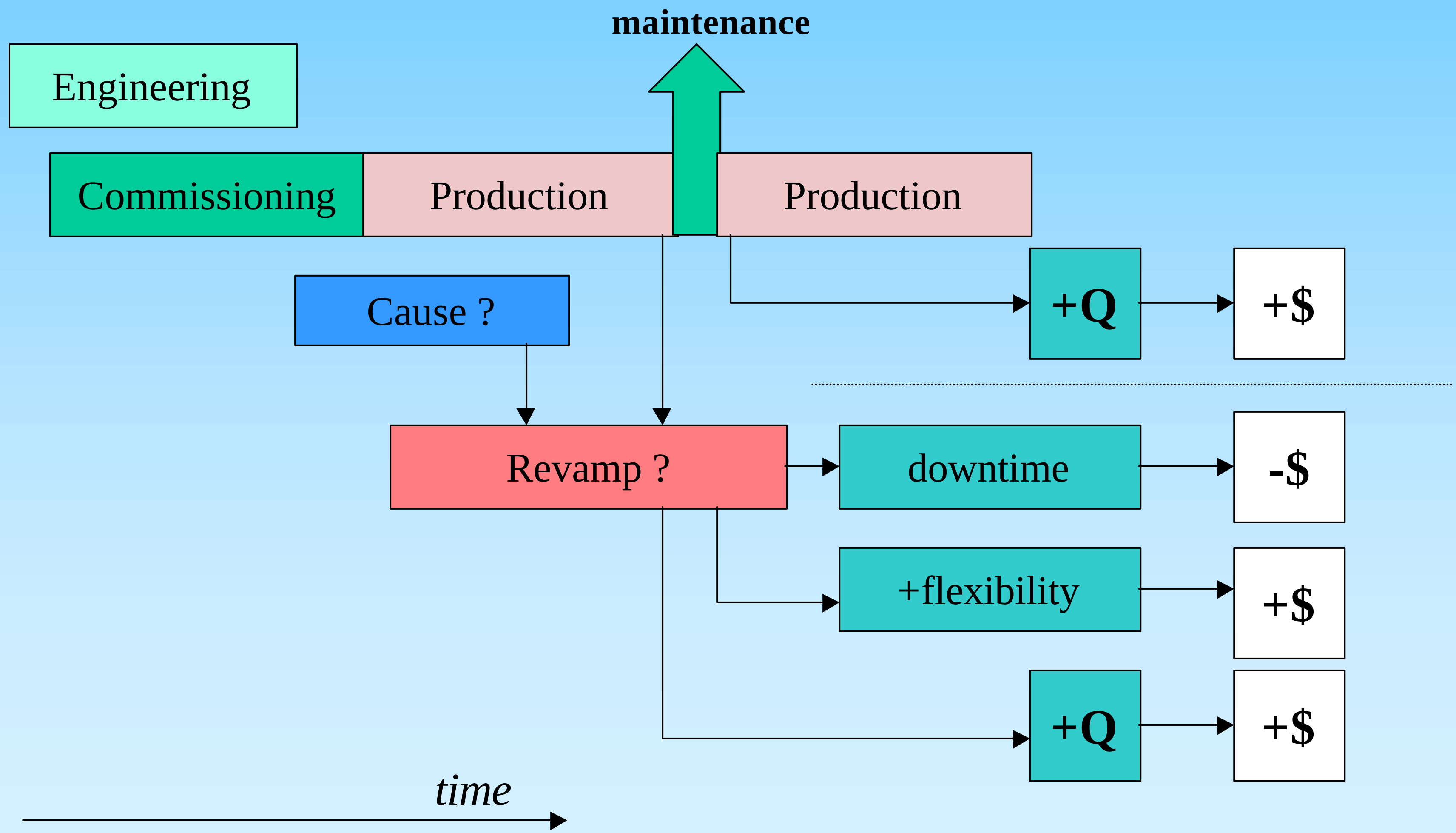
Distillation Process



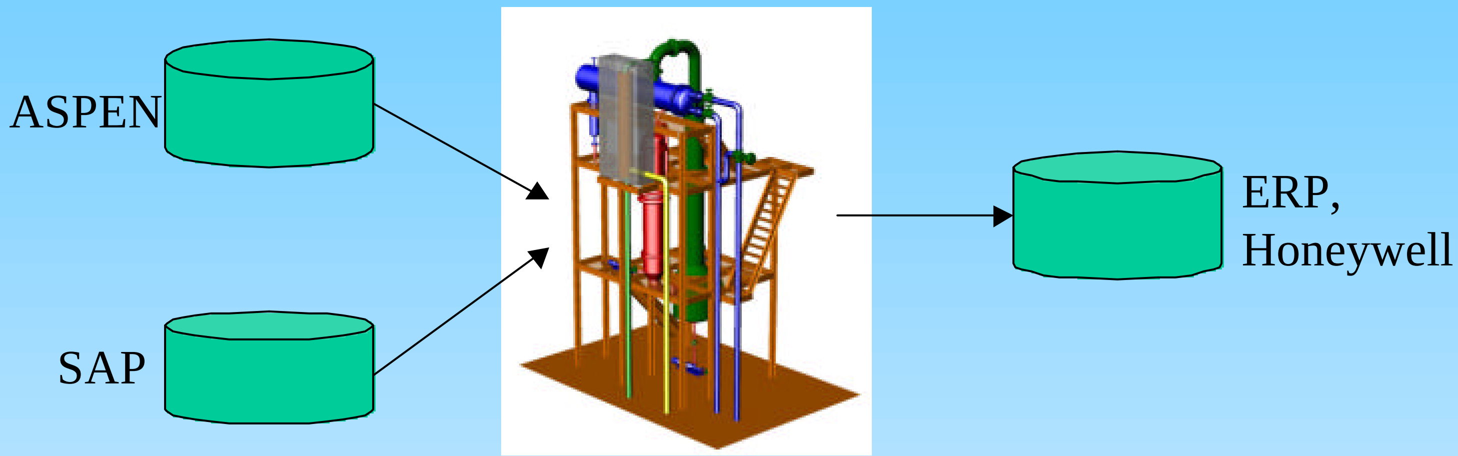
Vapor Permeation



What is Life Cycle?



The Process Life Cycle



1. Process Design (using ASPEN)

2. Process Monitoring (using Honeywell, ERP, etc)

3. Costs, Maintenance and Effectiveness (using SAP)

Project Description

Initiatiate the Life Cycle simulation using the Bayesian Calculation

- **Building Bayesian network model for a chemical process**
- Modeling a database for the process
- Implement the simulation application
- Building a user interface for the application
- Add knowledge-rules for the decision advices

Modeling Uncertainty

- Fuzzy Logic
- Statistical Probabilities (Bayesian Technique)

Why not Fuzzy Logic?

- Misunderstood the term ‘uncertain reasoning’
- No further facts examination
- Not wholy consistent

Bayesian Technique

in contrast…….

- Represents Conditional independence information naturally
- Represents joint probability distribution
- Use a well-known statistical formula, based on the formula:

$$P(E|H) = P(H,E)/P(H)$$

The Bayes' Rule

$$P(E \mid H) = \frac{P(H \mid E).P(H)}{P(E)}$$

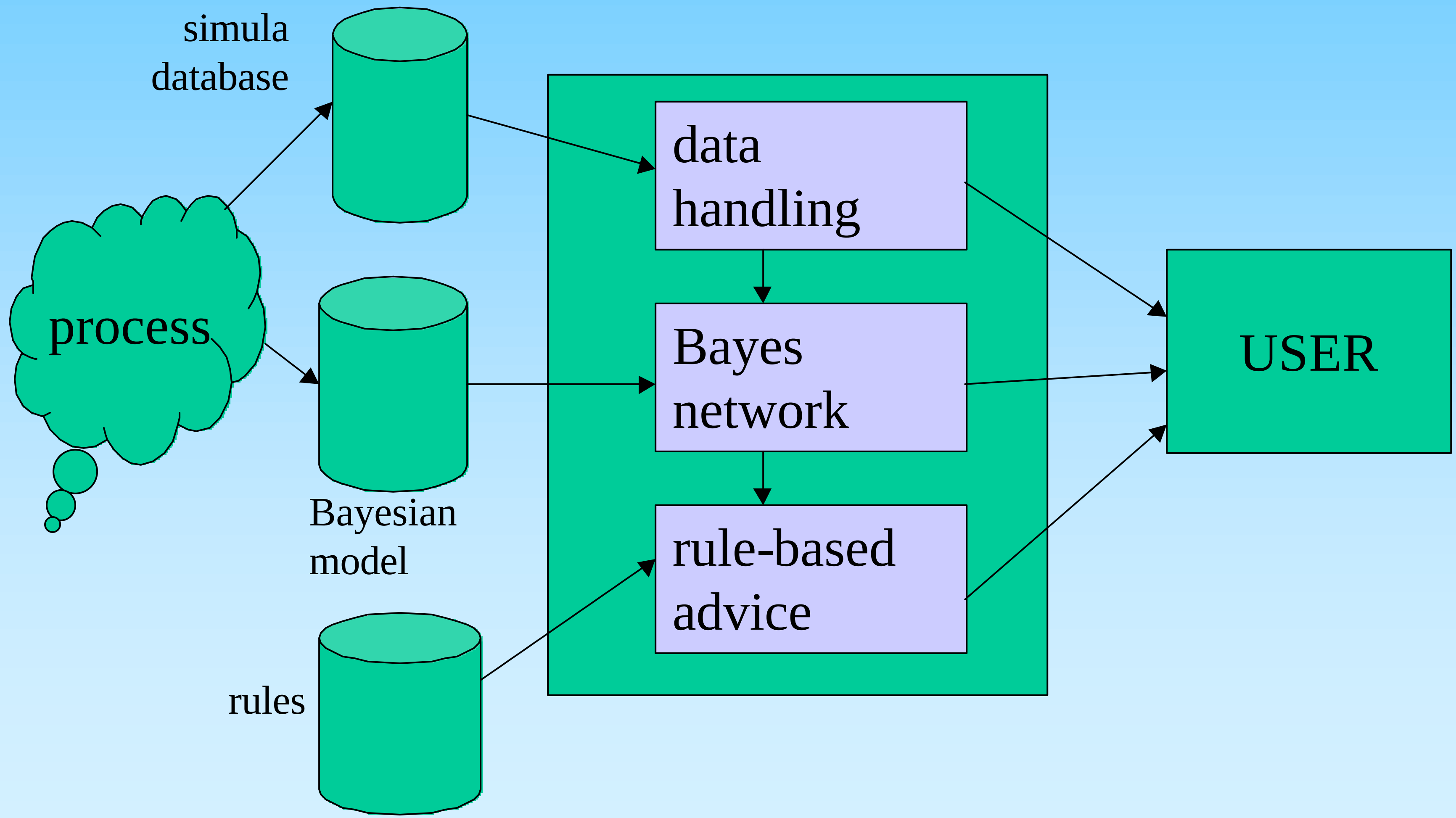
Finding the probability of the evidence based on the facts on the hypothesis when the conditional probabilities between the hypothesis en evidence is known.

Project Description

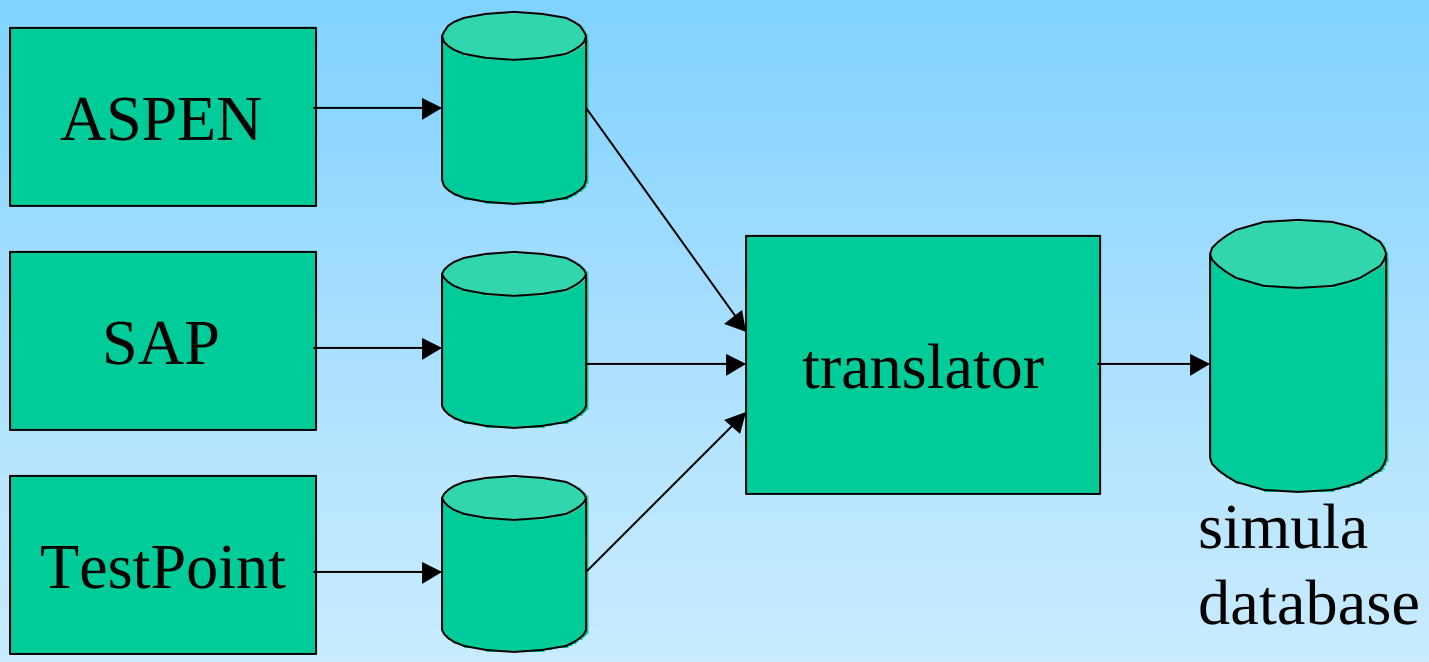
Initiatiate the Life Cycle simulation using the Bayesian Calculation

- Building Bayesian network model for a chemical process
- **Modeling a database for the process**
- Implement the simulation application
- Building a user interface for the application
- Add knowledge-rules for the decision advices

Simulation Application



Data Handling



Coversion Example

4					
5	Display	17	B1	D1	F
6		PMIX	DIST1	DIST1	
7	Format:	MEM		PRHEAT	MIX
8		VAPOR	LIQUID	VAPOR	LIQUID
9	Substream: MIXED				
10	Mole Flow KMOL/HR				
11	IPA	0.000	0.000	31.641	30.829
12	WATER	0.000	174.498	25.888	174.700
13	Mole Frac				
14	IPA	0.100	0.000	0.550	0.150
15	WATER	0.900	1.000	0.450	0.850
16	Mass Flow KG/HR				
17	IPA	0.000	0.000	1901.479	1852.725
18	WATER	0.000	3143.634	466.377	3147.275
19	Mass Frac				
20	IPA	0.270	0.000	0.803	0.371
21	WATER	0.730	1.000	0.197	0.629
22	Total Flow KMOL/HR	0.000	174.498	57.529	205.530
23	Total Flow KG/HR	0.000	3143.634	0.125	5000.000
24	Total Flow CUM/HR	0.000	3.567	612.571	6.163
25	Temperature C	116.058	100.000	111.059	111.521
26	Pressure BAR	0.150	3.000	0.970	3.000
27	Vapor Frac	1.000	0.000	1.000	0.000
28	Liquid Frac	0.000	1.000	0.000	1.000

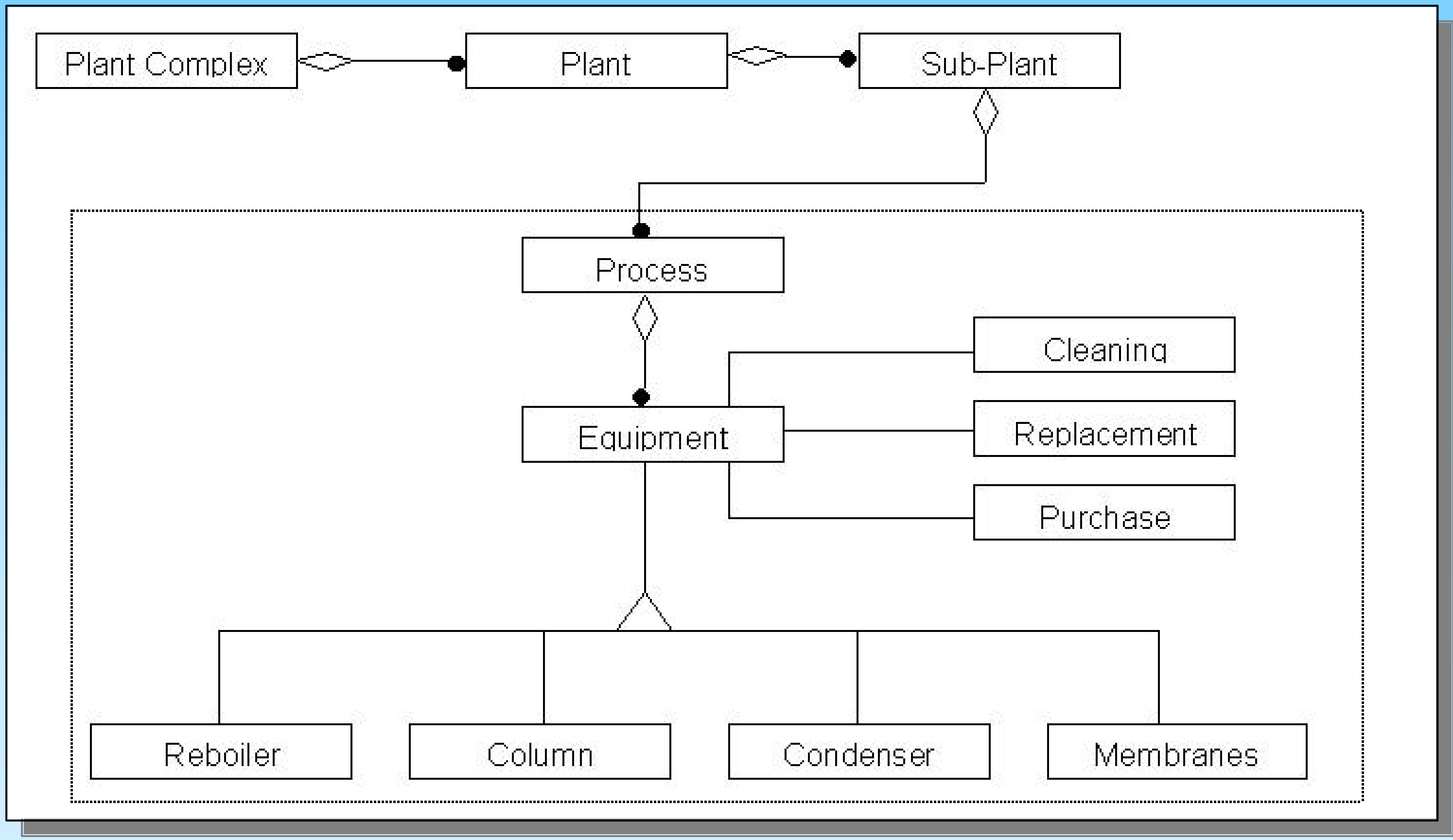
Column.Top_Temp=111

data from ASPEN

Simula Database

- Integration
- Standardization
- Uniformity
- Selected technique: Object-Oriented model

Database Model



Project Description

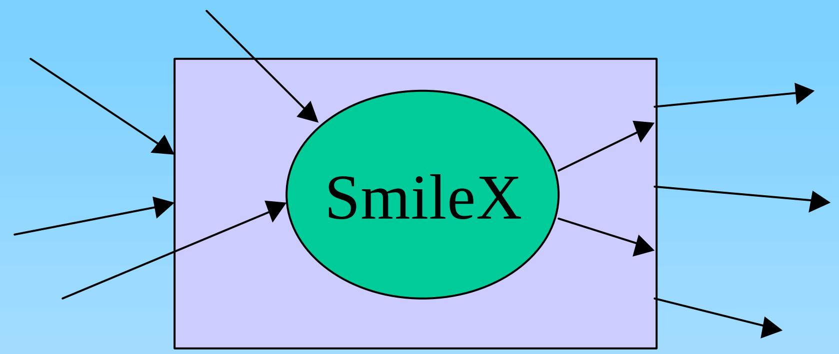
Initiatiate the Life Cycle simulation using the Bayesian Calculation

- Building Bayesian network model for a chemical process
- Modeling a database for the process
- **Implement the simulation application**
- Building a user interface for the application
- Add knowledge-rules for the decision advices

SmileX

- ActiveX component implementing Bayesian network
- Work with application GeNIe
- Basic Bayesian network operations

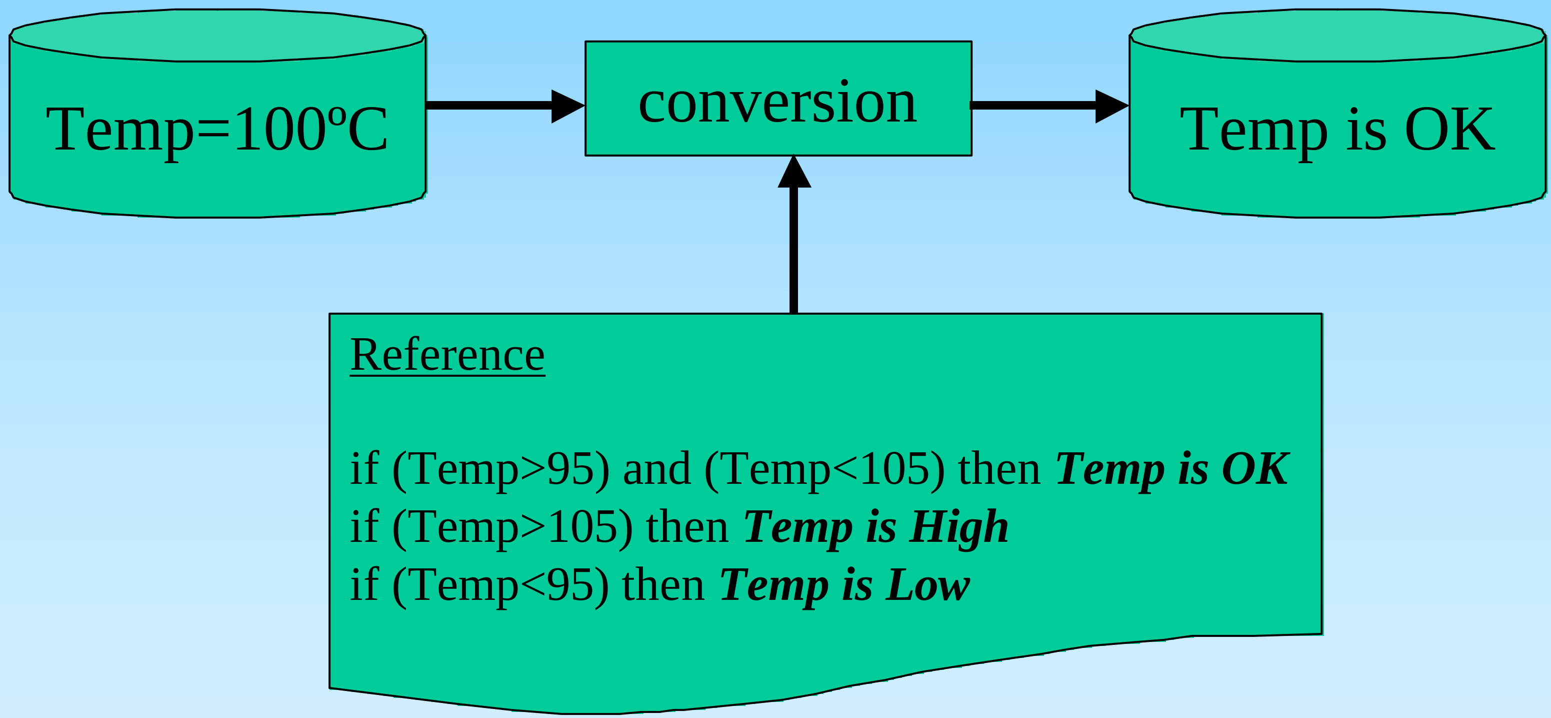
Enhanching SmileX(1)



- Restructuring the network into object classes
- Adding a conversion function

Enhanching SmileX(2)

Adding a conversion function



Applying
The Bayesian Network Model

Design steps:

- Understanding the process principles
- Finding the variables
- Constructing the network
- Validate the model
- Fine tuning

Distillation Process

Reboiler:

- degrades $\rightarrow$ bottom temperature lower
- lower temperature $\rightarrow$ less vapor
- less vapor $\rightarrow$ lower vapor flowrate

Condenser:

- degrades $\rightarrow$ more vapor exiting the process
- more vapor $\rightarrow$ less reflux
- less reflux $\rightarrow$ less/more purity

Vapor Permeation

Membrane Unit:

- Low permeate pressure $\rightarrow$ high quality
- Low distillate flowrate $\rightarrow$ high quality

Bayesian Network Variables

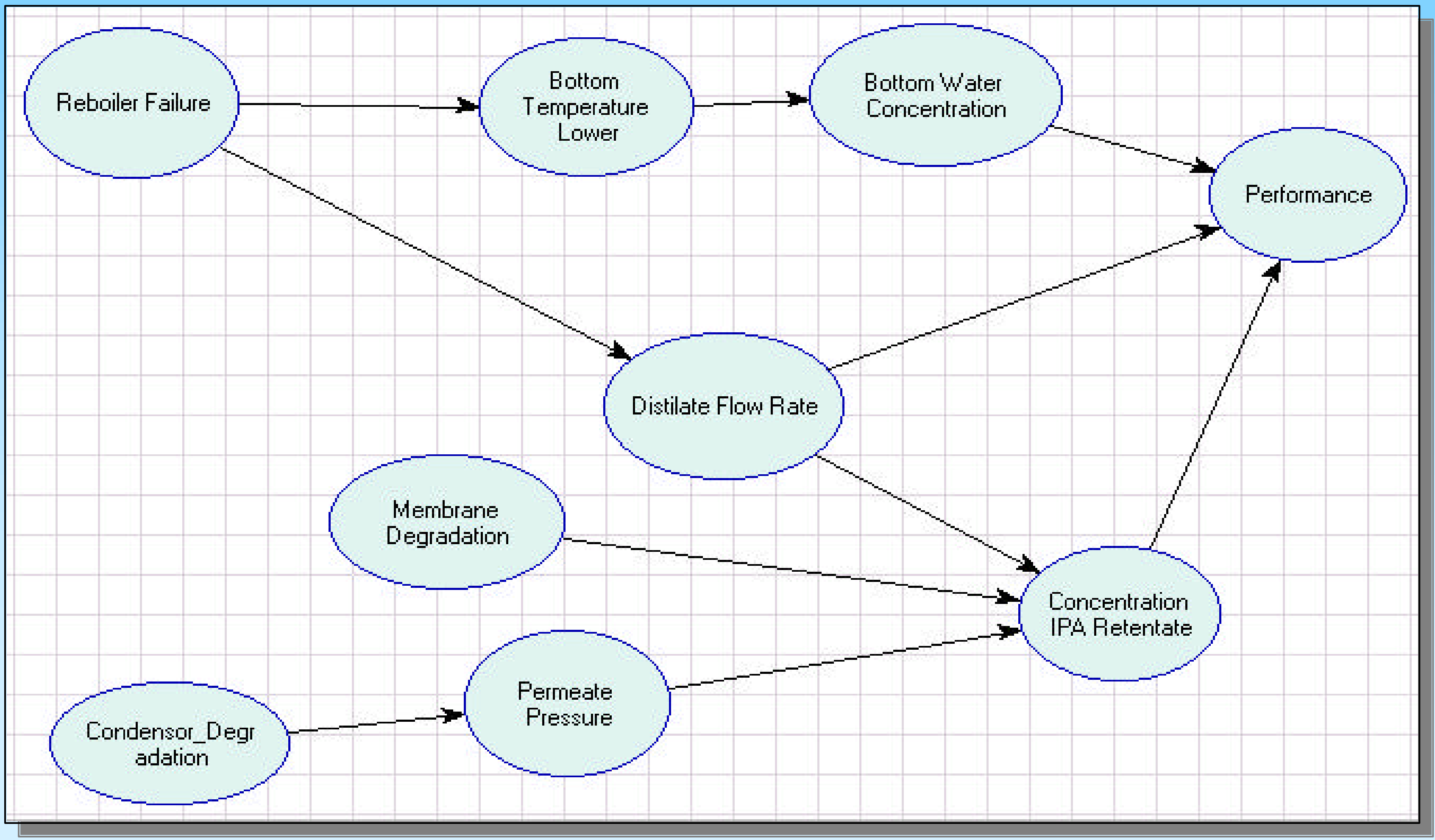
Inputs:

- Bottom Temperature
- Bottom Water Concentration
- Distillate Flowrate
- Retentate Concentration
- Permeate Pressure

Outputs:

- Reboiler Degradation
- Condenser Degradation
- Membrane Degradation
- Performance

Bayesian Network Model for the Process



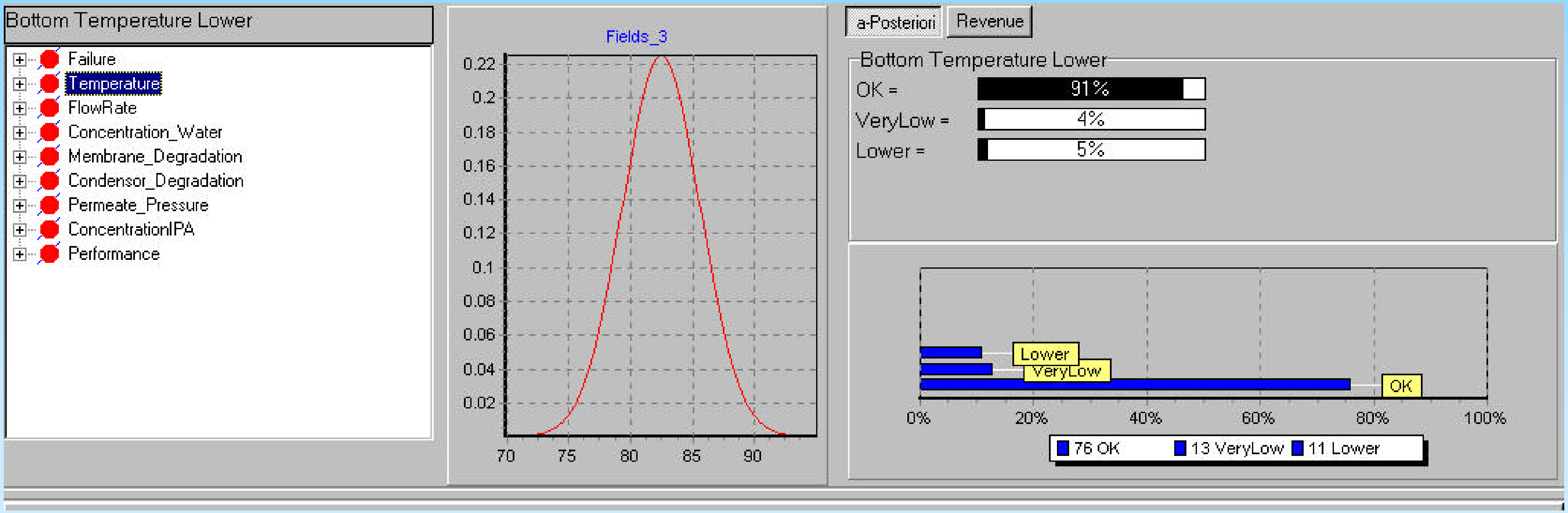
Project Description

Initiatiate the Life Cycle simulation using the Bayesian Calculation

- Building Bayesian network model for a chemical process
- Modeling a database for the process
- Implement the simulation application
- **Building a user interface for the application**
- Add knowledge-rules for the decision advices

Simulation User Interface (1)

Main window



Simulation User Interface (2)

Data tabs

0830mem.dat

	Fields_1	Fields_2	Fields_3	Fields_4	Fields_5	Fields
	Steam Temp	Bottom Temp	Top Temp	Retent Temp	Top Press	Reter
1	116.42	100.73	87.51	21.83	0.97	-0.08
2	116.42	100.77	87.65	21.83	0.97	-0.06
3	116.16	100.59	87.51	21.74	0.97	-0.05
4	116.6	100.59	87.37	21.6	0.96	-0.14
5	116.52	100.91	87.33	21.74	0.97	-0.07
6	116.52	101.1	87.28	21.74	0.97	-0.08
7	116.6	101.15	87.33	22.11	0.98	-0.04

Data Sheet | Aspen Sheet | SAP Sheet | Analysis

Simulation User Interface (3)

Analysis Results

Failure	Failure	Failure	Temperature	Temperature	Temperature	FlowRate	FlowRate	FlowRate	Concentratio	Ca
OK	Fail	Contaminate	OK	VeryLow	Lower	OK	Low	High	Good	Fa
			80.09322	80.09322	80.09322	5.582953	5.582953	5.582953		
0.18	0.37	0.45	0.28	0.38	0.34	0	1	0	0.53	0.
0.18	0.37	0.45	0.28	0.38	0.34	0	1	0	0.53	0.
0.18	0.37	0.45	0.28	0.38	0.34	0	1	0	0.53	0.
0.18	0.37	0.45	0.28	0.38	0.34	0	1	0	0.53	0.
0.18	0.37	0.45	0.28	0.38	0.34	0	1	0	0.53	0.
0.18	0.37	0.45	0.28	0.38	0.34	0	1	0	0.53	0.
0.18	0.37	0.45	0.28	0.38	0.34	0	1	0	0.53	0.
0.18	0.37	0.45	0.28	0.38	0.34	0	1	0	0.53	0.
0.18	0.37	0.45	0.28	0.38	0.34	0	1	0	0.53	0.

AVERAGES :

Failure: OK=46.63%
Failure: Fail=17.03%
Failure: Contaminated=36.34%
Temperature: OK=75.94%
Temperature: VeryLow=12.7%
Temperature: Lower=11.36%
FlowRate: OK=0%
FlowRate: Low=100%
FlowRate: High=0%
Concentration_Water: Good=83.63%
Concentration_Water: Fair=3.67%
Concentration_Water: Poor=12.7%
Membrane_Degradation: OK=98%
Membrane_Degradation: Degradated=2%
Condensor_Degradation: OK=98.83%
Condensor_Degradation: Degradated=1.17%
Permeate_Pressure: OK=99.73%
Permeate_Pressure: Higher=0.27%
ConcentrationIPA: Good=97.96%
ConcentrationIPA: Fair=1.01%
ConcentrationIPA: Poor=1.03%
Performance: Good=74.97%

Data Sheet | Aspen Sheet | SAP Sheet | Analysis

Simulation User Interface (4)

Action window

There are a few pieces equipment that need maintenance job or replacement.

Equipment	Degrad. (%)	Maintenance ($)	Replacement ($)	Action
HE01	82	120	750	REPLACE
MEM	2	500	1200	OK
HE02	1	50	200	OK

Project Description

Initiatiate the Life Cycle simulation using the Bayesian Calculation

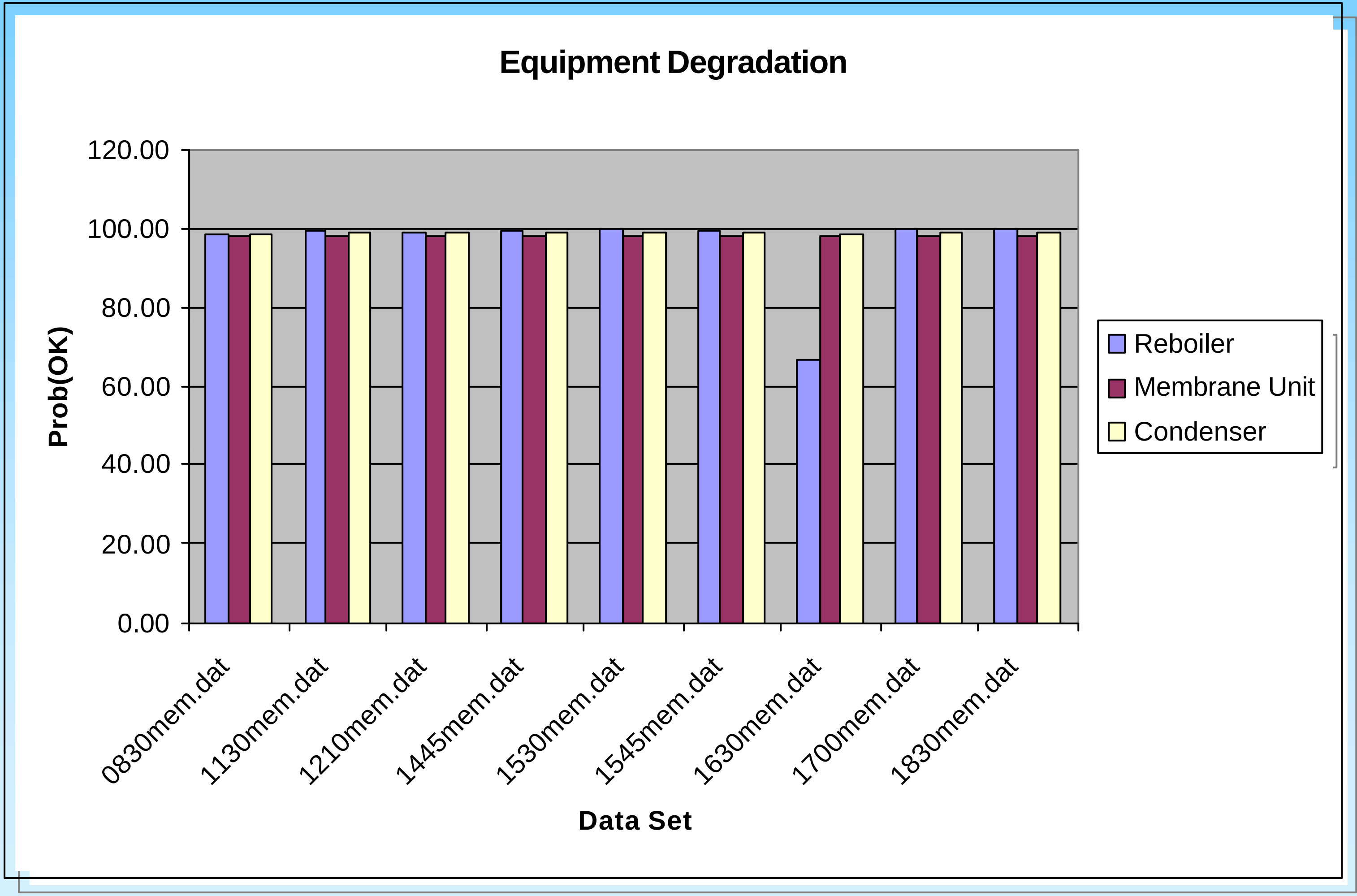
- Building Bayesian network model for a chemical process
- Modeling a database for the process
- Implement the simulation application
- Building a user interface for the application
- **Add knowledge-rules for the decision advices**

Simulation Testing

Assumptions:

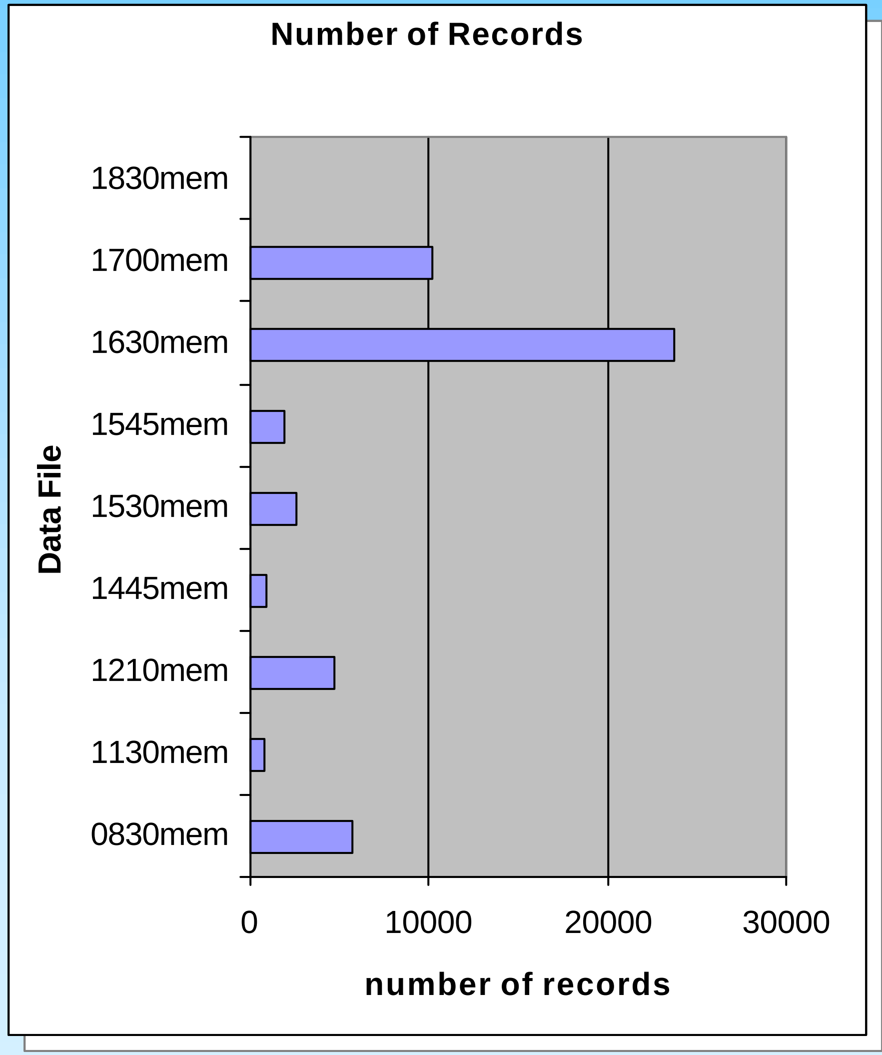
- All in good condition
- Stable state
- Quality as reported
- No process control

Test Results



Reboiler Degrades?

- Againts the assumption
- Analysing the data file:
  - very large record file
  - may includes start-up and shut-down data



Conclusions

- It was possible to apply Bayesian techniques to the Life Cycle simulation
- The tested model lacks of accuracy because of limited measurement
- Although measurements are few, prelimenary result seems to be meaningfull

Further Research

- How to increase the accuracy for larger processes
- Supporting the Bayesian network with statistical correlation analysis (instead of expert review)
- Simulation based on online process data
- More compatible with commercial software pakages