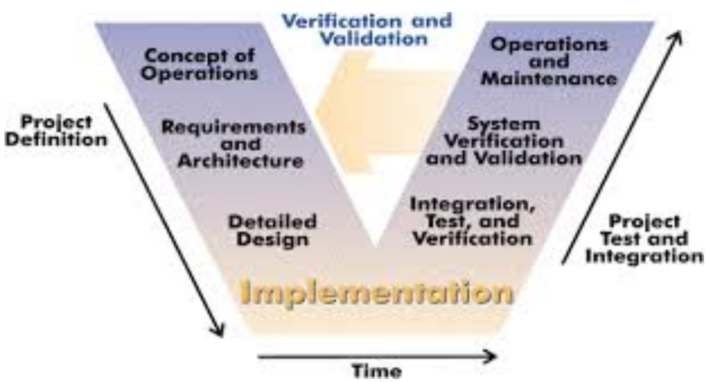
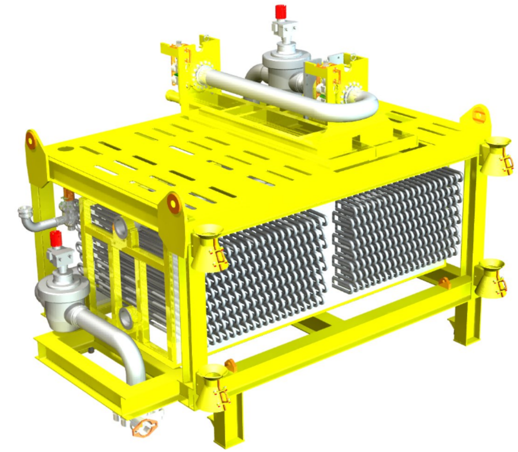
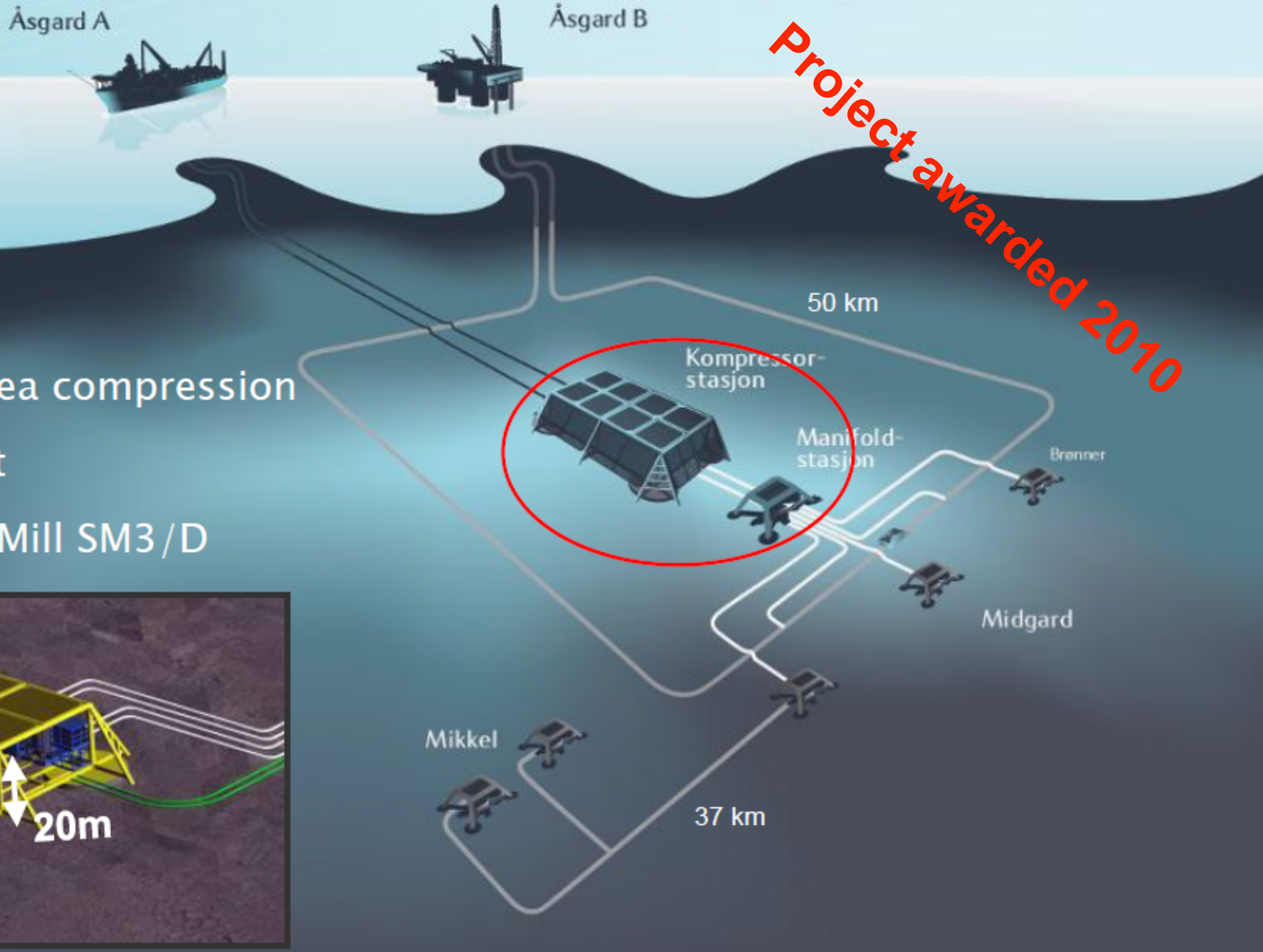
Las Vegas, NV
June 30 - July 3, 2014

«System Engineering Applied to Concept Design Optimization of Subsea Coolers»





Field layout Åsgard subsea compression

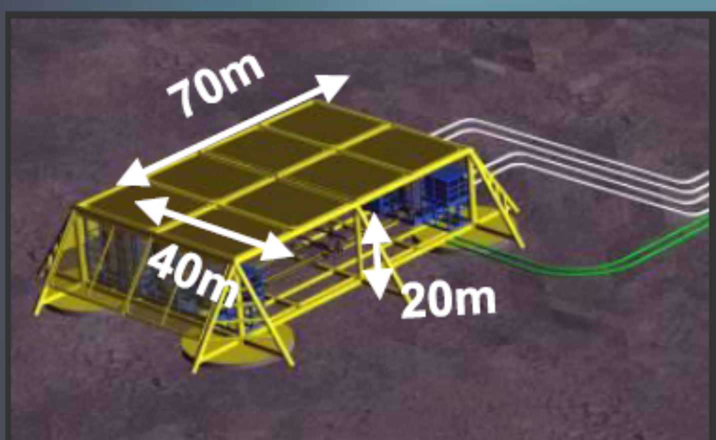


Facts:

2x10 MW subsea compression

40 km step out

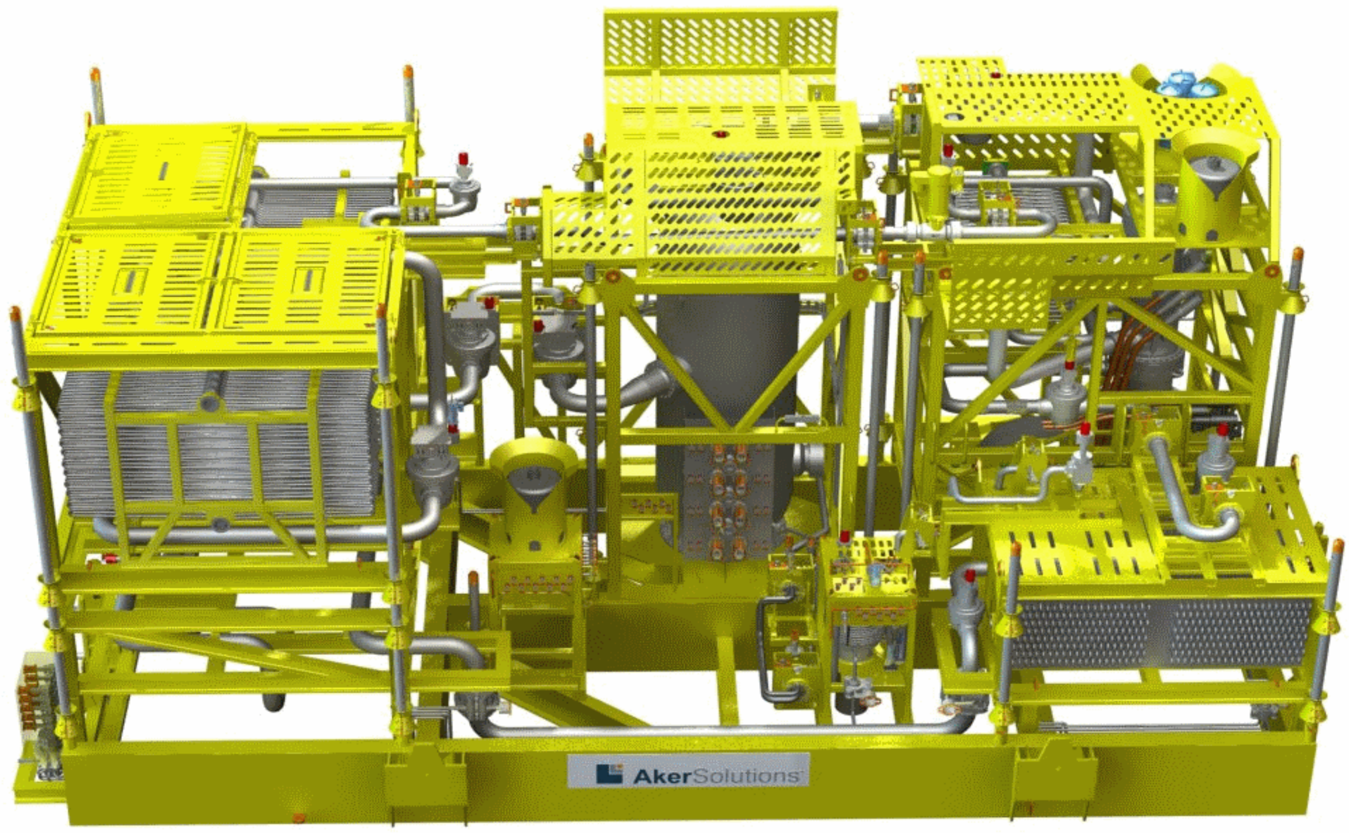
Production 21 Mill SM3/D



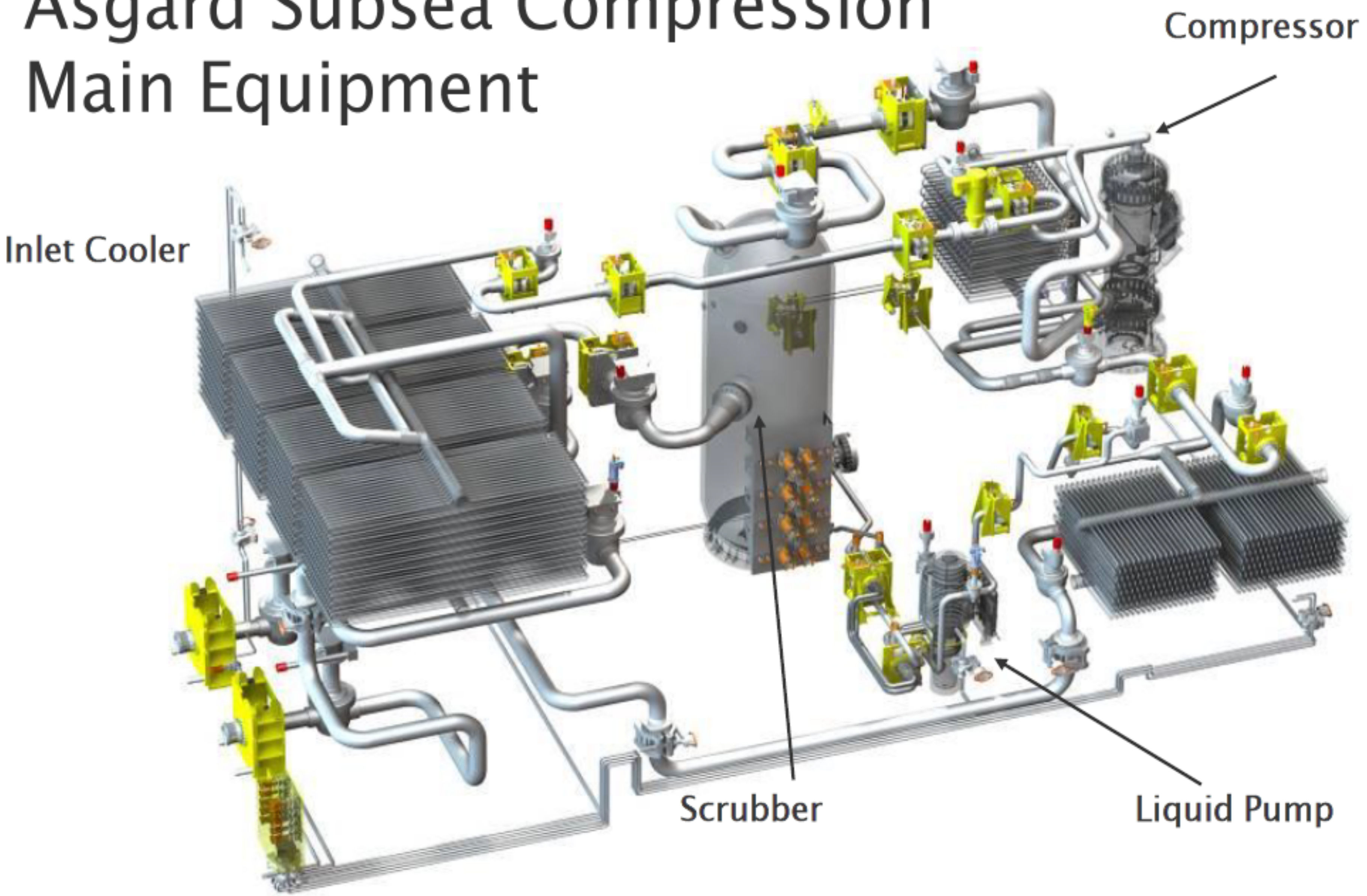
What is Susbea Compression?

- Compressor located by the wellheads
- Increase of hydrocarbon stream
- Enhance reservoir recovery
- Enable transport of wellstream over long distances.

Åsgard Compression Train



Åsgard Subsea Compression Main Equipment

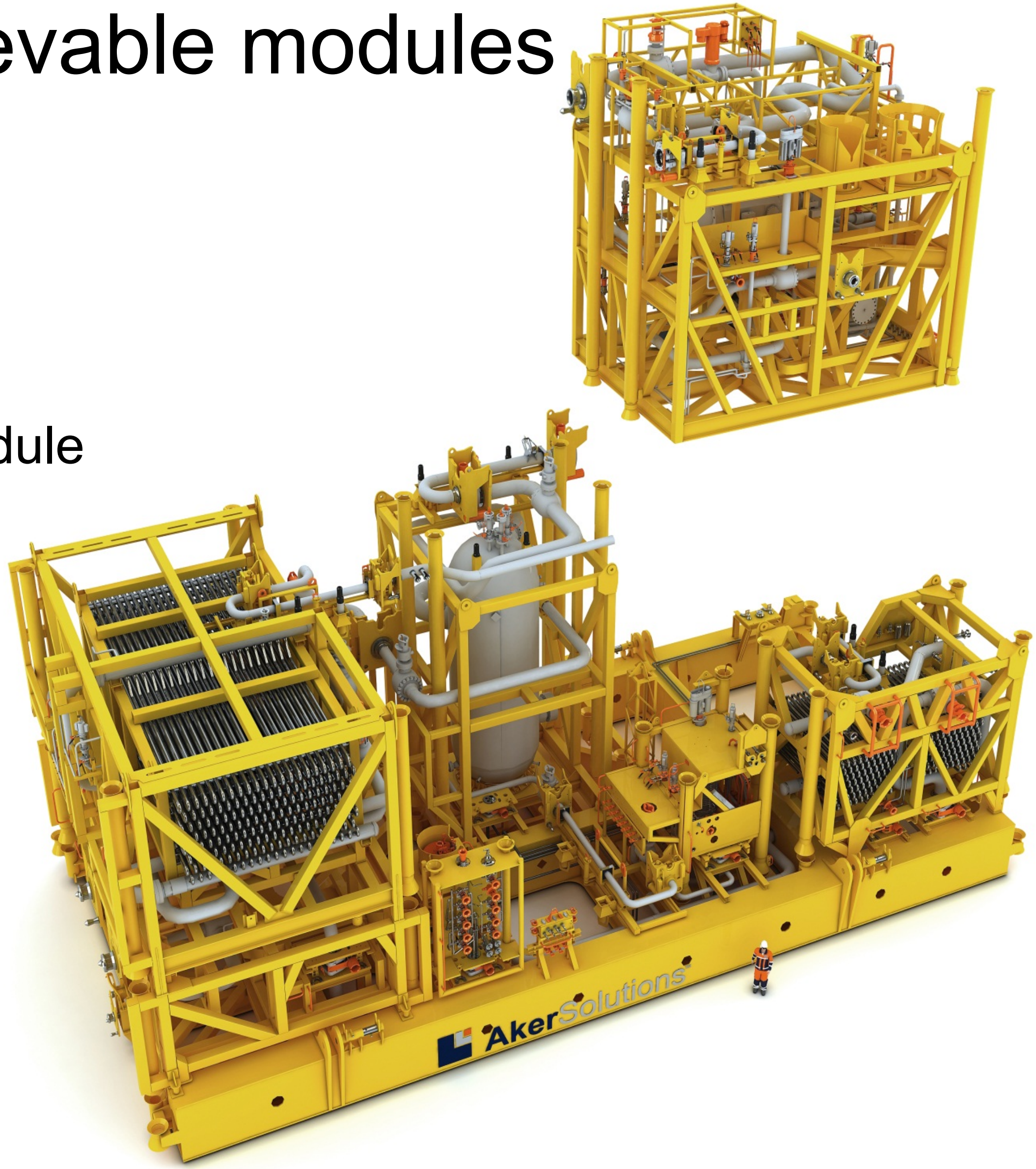



Aker
Hafslund
sammen mot rasisme
VG

Retrievable modules

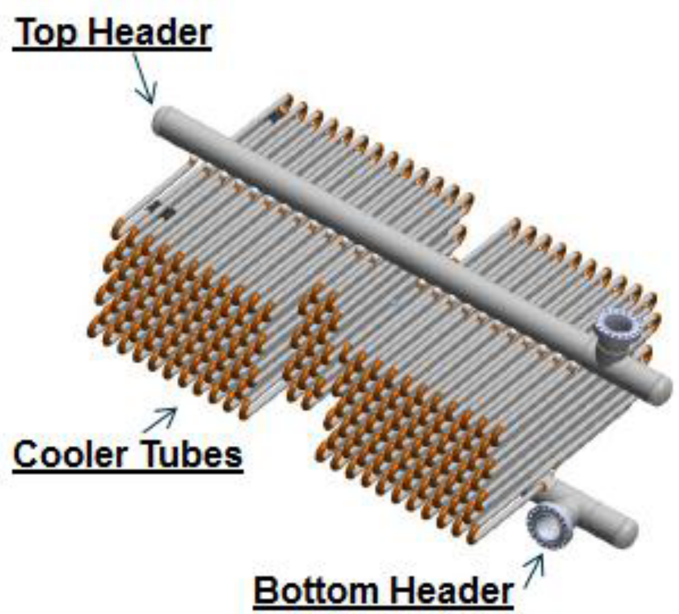
Compressor Module

Cooler Module

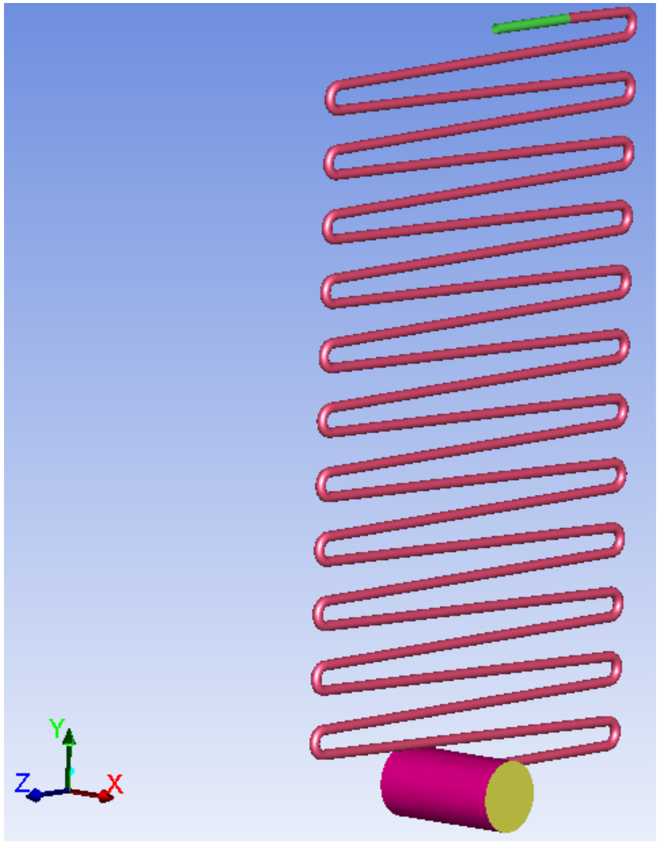


Subsea Passive Cooler

Full Cooler bundle



Single branch

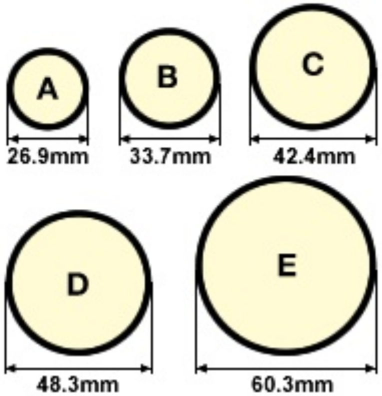


The Basecase

- **<u>New Project</u>**
- Optimized Design
- Client wants:
  - Max. compactness
  - Min. cost
- Optimize Conductivity/ cost

Optimization Parameters

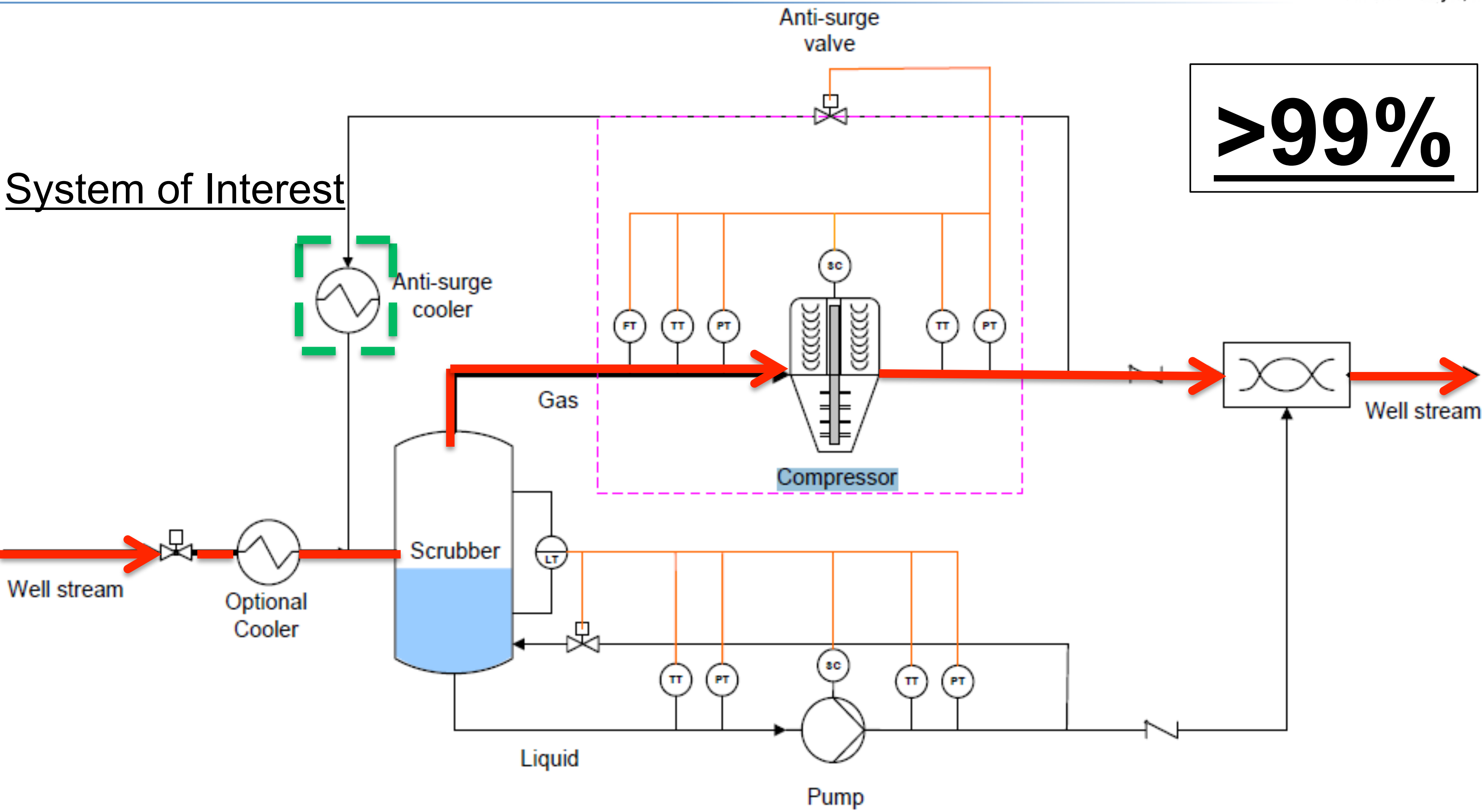
- Cooler
  - Materials Technology
  - Coating Technology
  - Tube Size Design



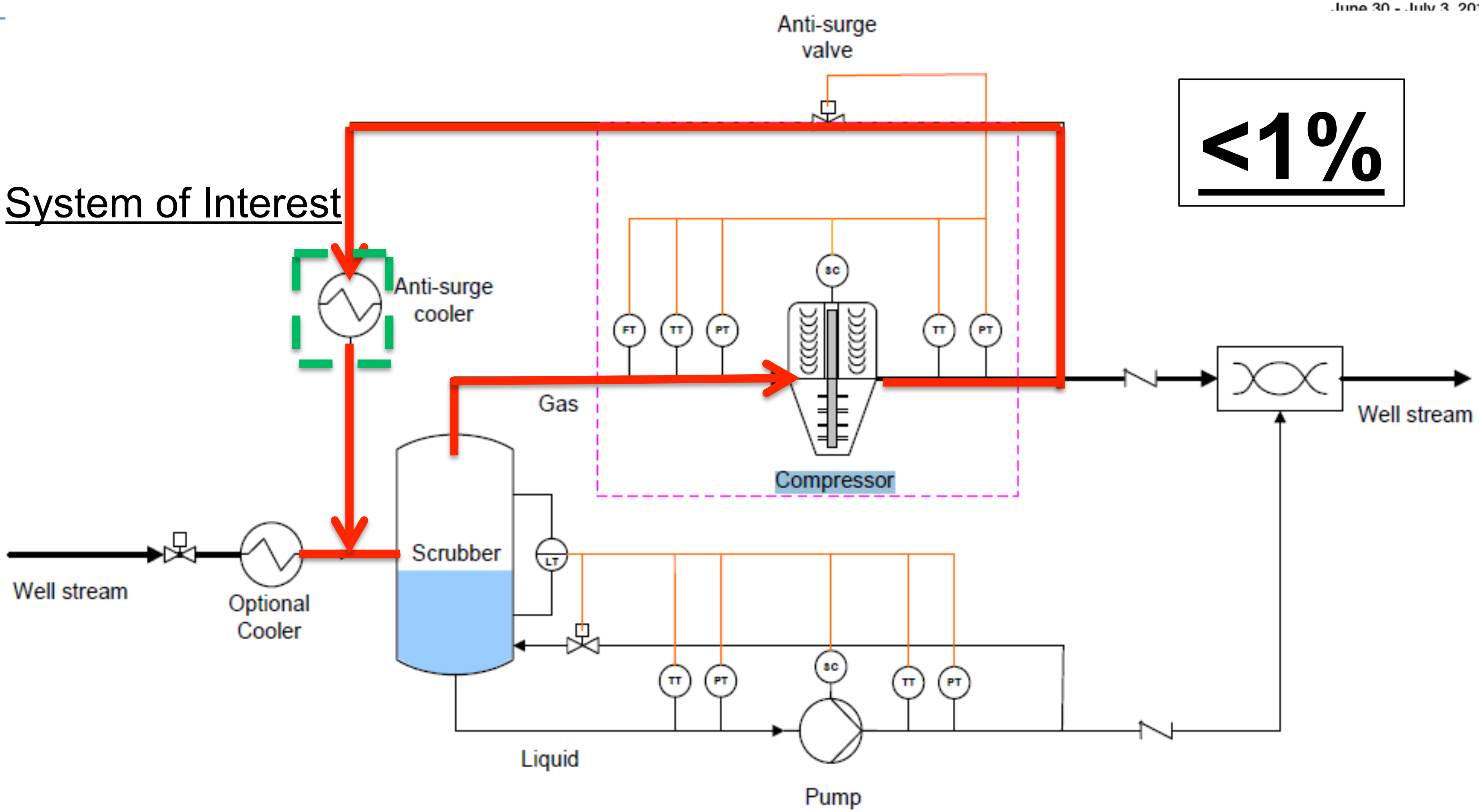
Critical to Quality

- Constructability
- Operational Robustness
- Cost
- Dimensional constraints
- Risk & Opportunity

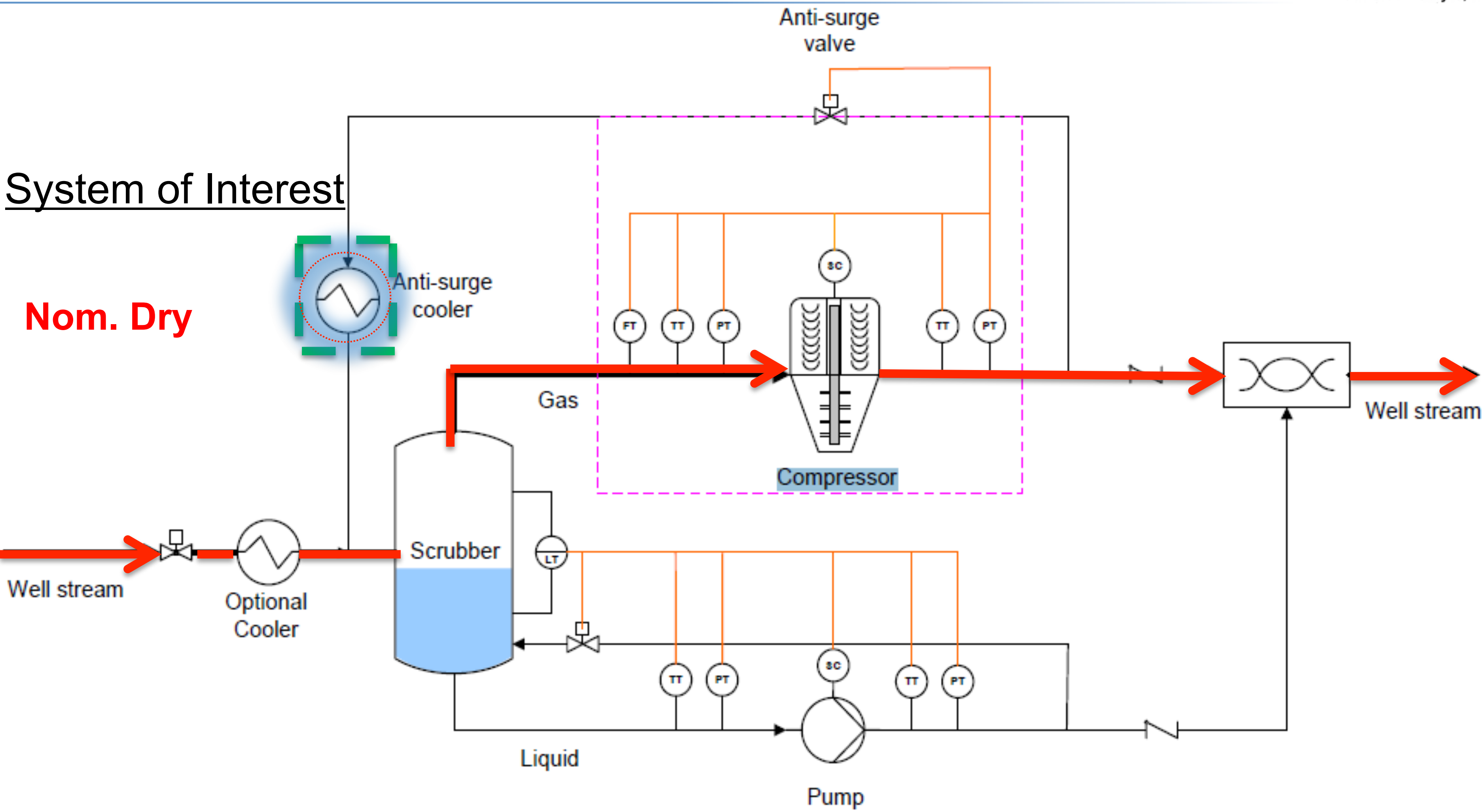
Use Case Analysis



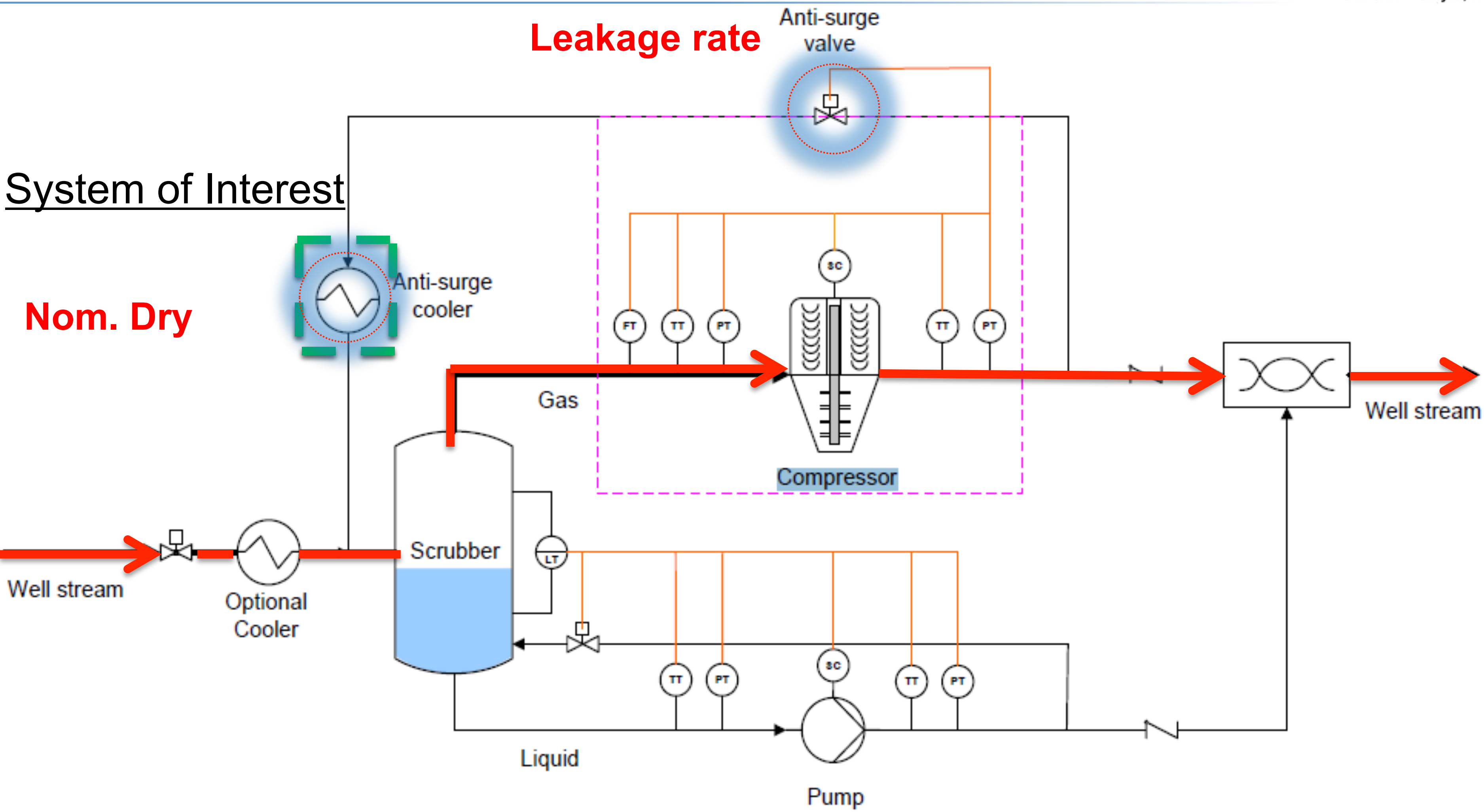
Use Case Analysis



Use Case Analysis

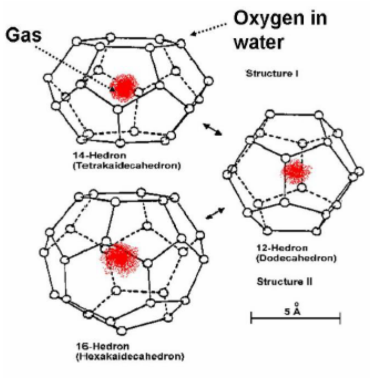


Use Case Analysis



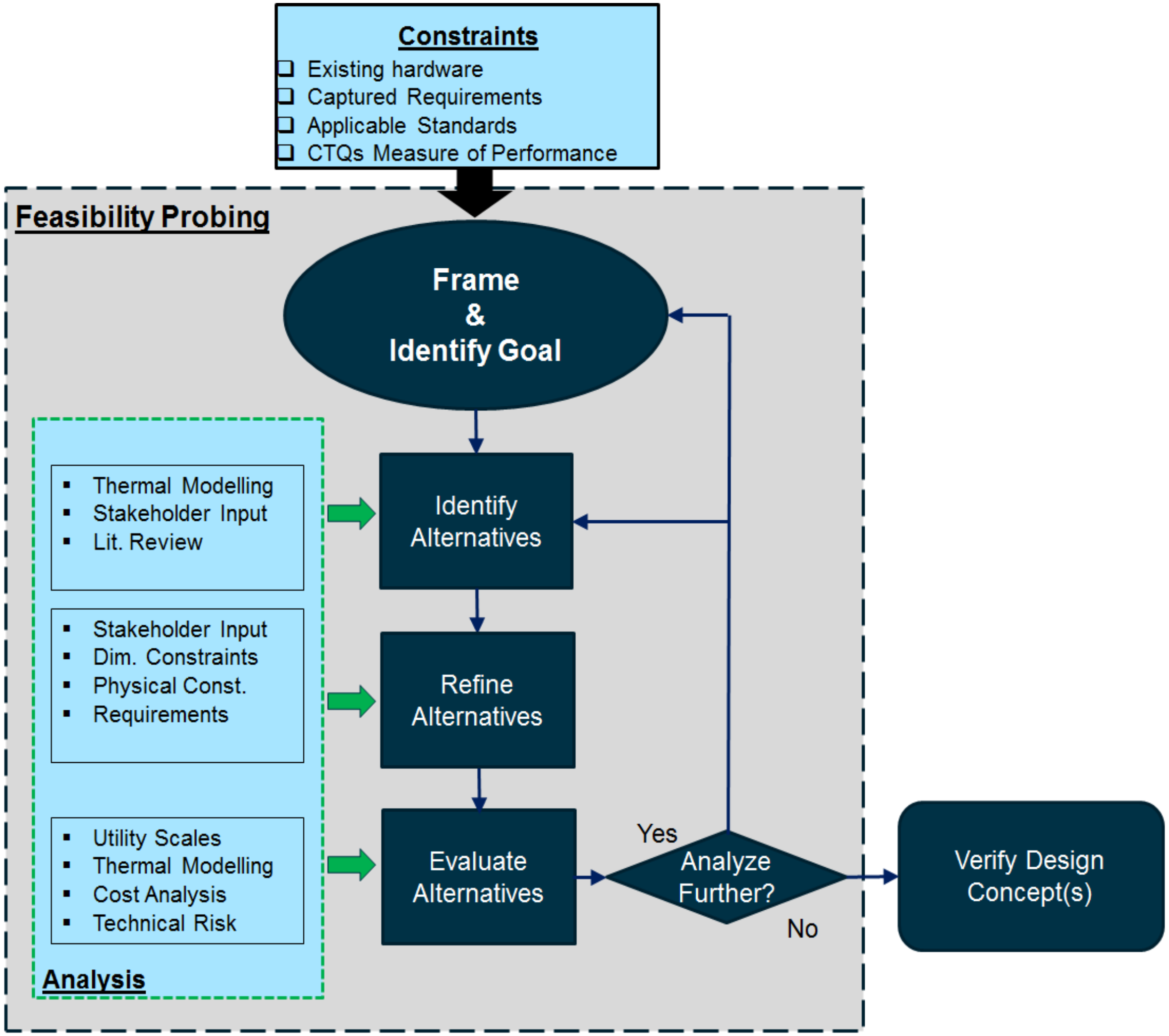
UCA Findings

- Nominally Dry
- Risk of Hydrate plugs

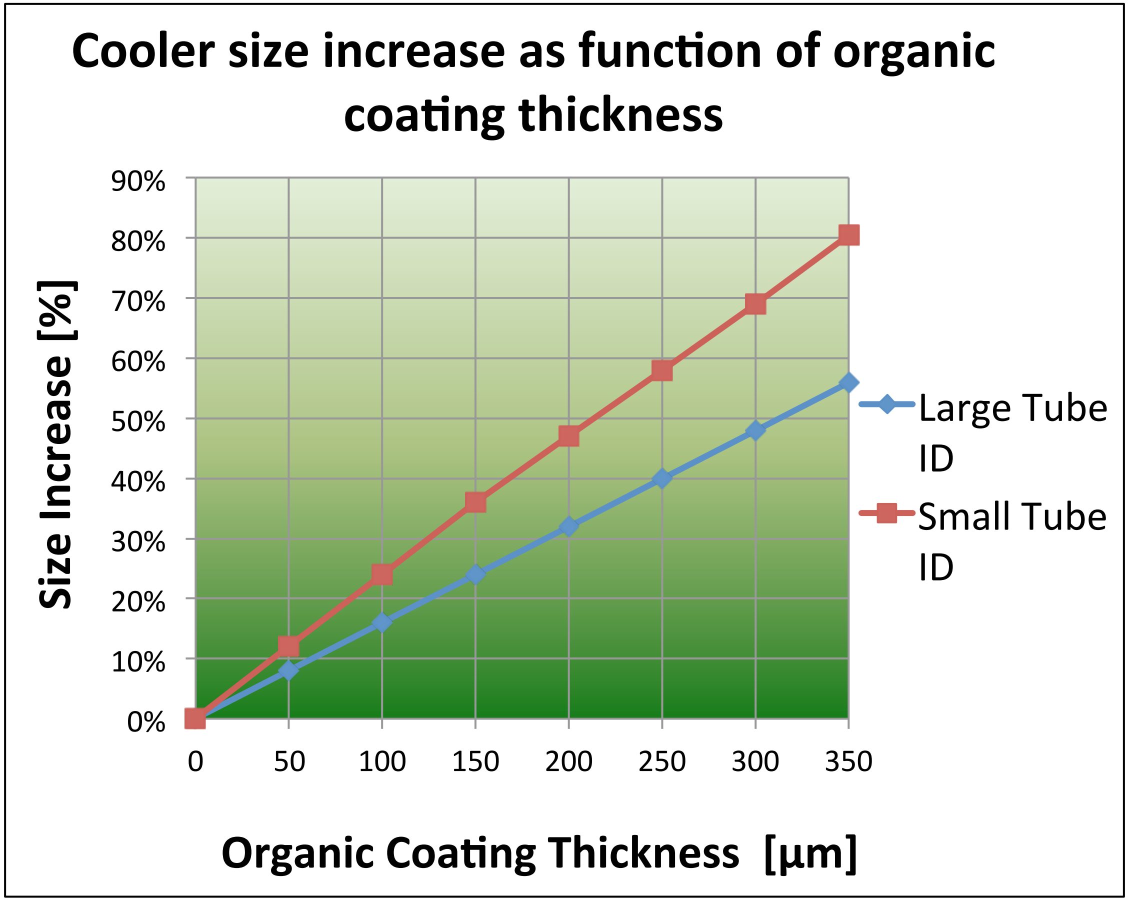


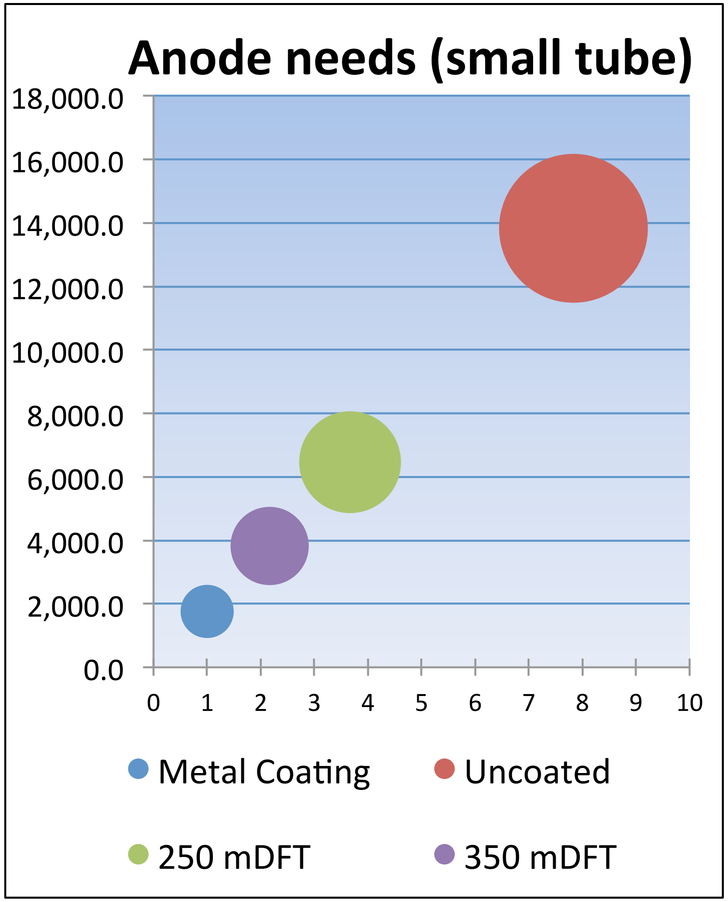
Feasibility Probing

- Chaotic
- Itterative
- Time consuming

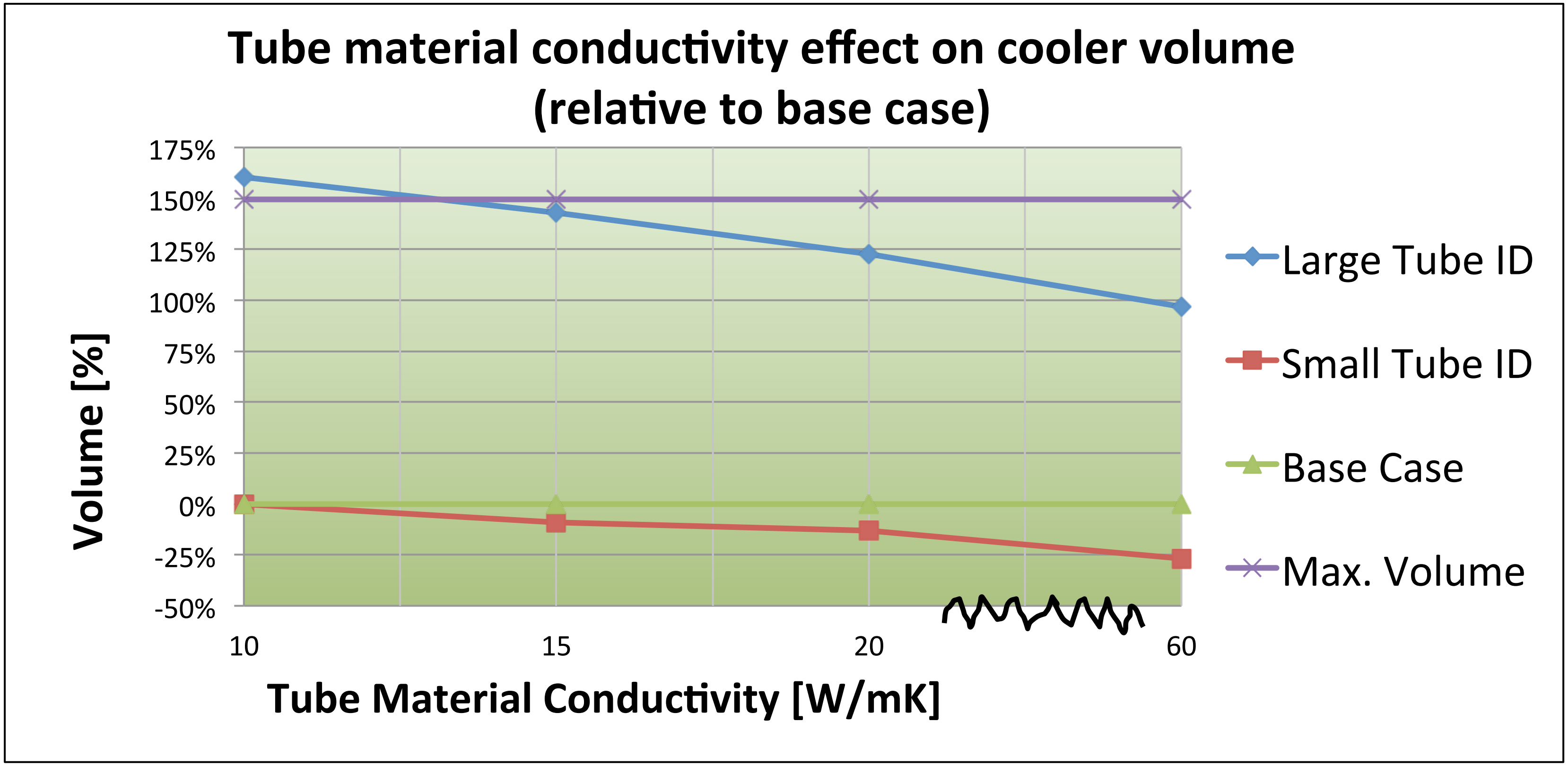


Coatings

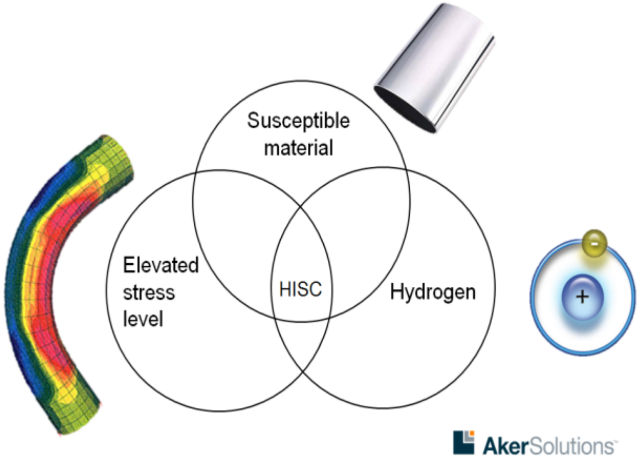

Cooler size increase as function of organic coating thickness
Size Increase [%]
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
50
100
150
200
250
300
350
Large Tube ID
Small Tube ID
Organic Coating Thickness [μm]


Anode needs (small tube)
18,000.0
16,000.0
14,000.0
12,000.0
10,000.0
8,000.0
6,000.0
4,000.0
2,000.0
0.0
0
1
2
3
4
5
6
7
8
9
10
Metal Coating
Uncoated
250 mDFT
350 mDFT

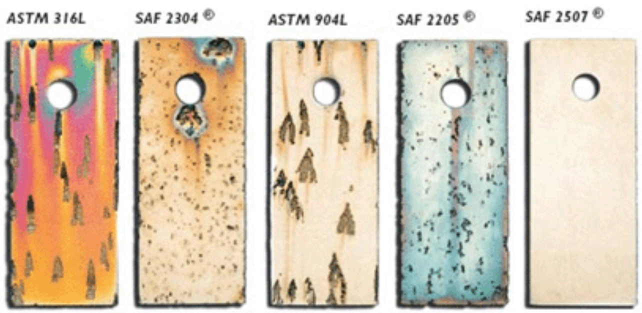
Cooler Compactness

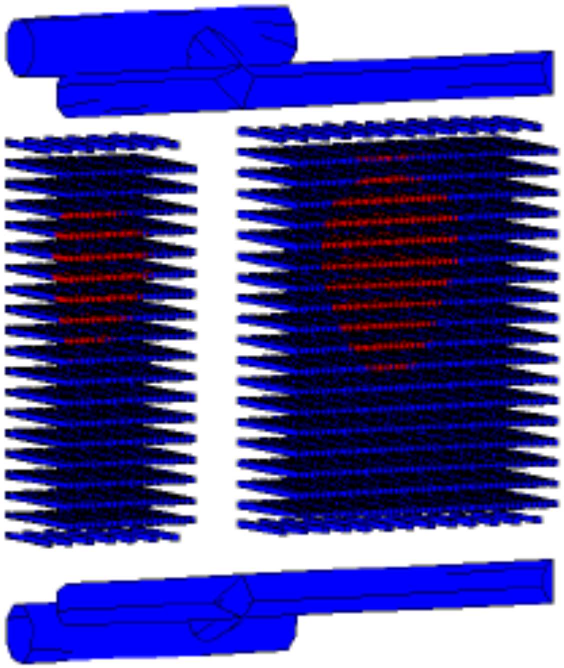


Complexity


Susceptible
material
Elevated
stress
level
HISC
Hydrogen
AkerSolutions

Complexity





Octocoral Umbellula found at 800m depth

AHP: Decision Support Tool

Design Concept

Material – Coating – Tube Diameter – Wall Thickness

Design Concepts		1 - Base Case			2			3			4			5		
		H CRA - Uncoated - S. Tube ID - MW			M CRA - Anodic C. - M. Tube ID - MW			H CRA - Uncoated - L. Tube ID - TW			M CRA - Anodic C. - L Tube ID - MW			LAS - Anodic C. - L. Tube ID - HW		
SubCriteria	Global Weight	Offer	Rating	Score	Offer	Rating	Score	Offer	Rating	Score	Offer	Rating	Score	Offer	Rating	Score
Max. Inner Diameter (min. Hyd plugs)	0,29	Low ID	0,01	0,0029	Medium ID	0,2	0,0588	High ID	0,41	0,1205	High ID	0,41	0,1205	Medium +ID	0,28	0,0823
Max. 2nd Barrier Corrosion Protection	0,15	H CRA	0,2	0,0294	M CRA + Anodic C.	0,41	0,0602	H CRA	0,2	0,0294	M CRA + Anodic C.	0,41	0,0602	LAS + Anodic C.	0,41	0,0602
Min. Anode needs(weight/F. Current)	0,14	51xAn (5000kg/70A)	0,28	0,0389	4xAn (392kg/3A)	0,41	0,0569	57xAn (5600kg/84A)	0,1	0,0139	6xAn (588kg/5,2A)	0,41	0,0569	5xA (490kg/4,1A)	0,41	0,0569
Min. no. Welds	0,09	1500 (bended)	0,1	0,0086	1200 (fittings)	0,2	0,0171	960 (fittings)	0,28	0,0240	960 (fittings)	0,28	0,0240	480 (bended)	0,41	0,0351
Max. Weldability	0,03	Good	0,31	0,0089	Good	0,31	0,0089	Medium	0,2	0,0057	Good	0,31	0,0089	Very Good	0,41	0,0117
Max. Coatability	0,03	Uncoated	0,41	0,0117	Anodic C.	0,1	0,0029	Uncoated	0,41	0,0117	Anodic C.	0,2	0,0057	Anodic C.	0,2	0,0057
Min. Cost (Relative to Initial Concept)	0,29	100 %	0,1	0,0286	89 %	0,28	0,0800	88 %	0,28	0,0800	98 %	0,1	0,0286	81 %	0,41	0,1171
Identified Risk	-	RED - Hydrates Cloging Tube - High Cost - Hydrogen Evolution and CP Induced Calc. Buildup			GREEN - Anodic C. TQP - New Manufacturing Process Headers (HIP)			Yellow - New Manufacturing Process Headers (HIP) - Hydrogen Evolution and CP Induced Calc. Buildup - Unlikely to Fit All Anodes			GREEN - Anodic C. TQP - New Manufacturing Process Headers (HIP)			RED - Anodic C. TQP - Internal Corr. Analysis - Uncertainty Construction of headers (heat input / banana effect)		
Opportunities	-	- Success With Material Selection and Construction process - Modeled Design, partly verified			- Advanatage to have anodic coatings qualified for cooler technology portifolio - Cost Effective			- Advanatage to have anodic coatings qualified for cooler technology portifolio - Cost Effective			- Advanatage to include anodic coatings in - for cooler technology portifolio			- Advanatage to have anodic coatings qualified for cooler technology portifolio - Highly cost Effective - Innovative and competative design		
Total Score		129			285			285			305			369		

Numerical Winner

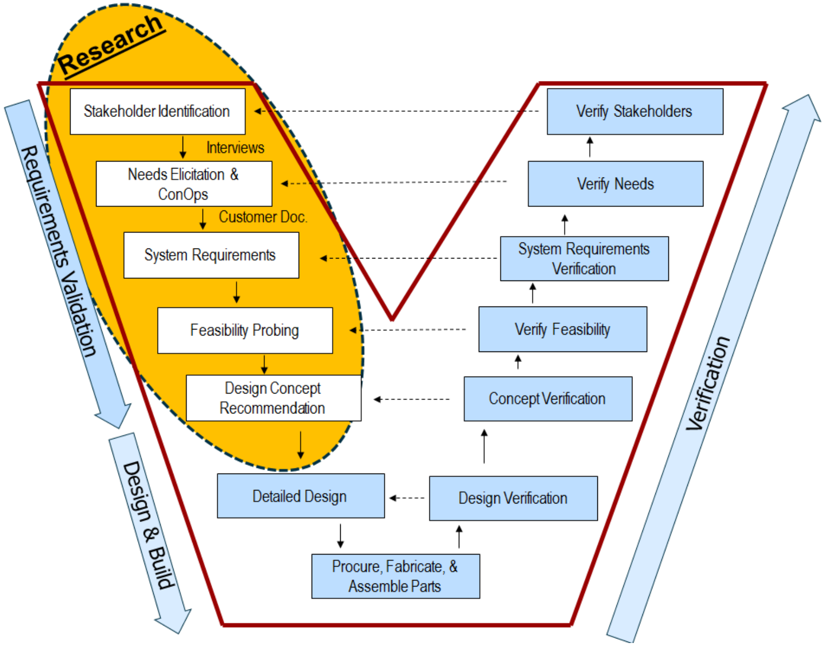
Colour Codes

Red: High Risk
Yellow: Medium Risk
Green: Low Risk

Goal

What SE Tools were utlized?

- Use Case Analysis
- AHP
- Feasibility Probing Process



Conclusion

- UCA opened crucial discoveries
- AHP:
  - Organize thinking & Decision Support
  - Communicate «wholeness»
- Generic Usability of SE approach

The end

Thank you very much for your attention

http://www.gaudisite.nl/MasterProjectPapers.html

Cooler Efficiency