Formal Safety Assessment of an Open Loop System

A quantitative risk assessment of an exhaust gas cleaning system

Mari Løvald Andresen
Supervisor: Bjørn Egil Asbjørnslett

NTNU – Trondheim
Norwegian University of Science and Technology

Introduction

On and after January 1st 2020 the sulphur content of any fuel oil used onboard ship shall not exceed 0.50% m/m. However, the implementation date is to be reviewed in 2018 to see if the limit should be postponed to 2025 or not. Additionally, on and after January 1st 2015 the sulphur content of any fuel oil used onboard ship shall not exceed 0.10 % m/m in ECA (IMO 2015).

Installing one or several exhaust gas cleaning system, also known as scrubbers, are one of several solutions for a ship to meet the new requirements. The principle is that the sulphur content in the exhaust gas gets ¨washed¨ with a variety of substances including seawater, chemically treated fresh water or dry substances in a scrubber device. The three most common types of scrubbers are open loop system, closed loop system and hybrid system. An open loop system uses seawater to react with the SOx content in the exhaust gas and discharges the water back to the sea after residual treatment (ABS 2013).

Objective & Scope

The objective with the thesis is to perform a Formal Safety Assessment (FSA) on an open loop system, manufactured by Wärtsilä. The results of the analysis will be evaluated and discussed according to existing guidelines on exhaust gas cleaning systems, MEPC.184(59), published by IMO. Most importantly, the analysis will give awareness on issues regarding risk and safety on this new technology in the maritime industry.

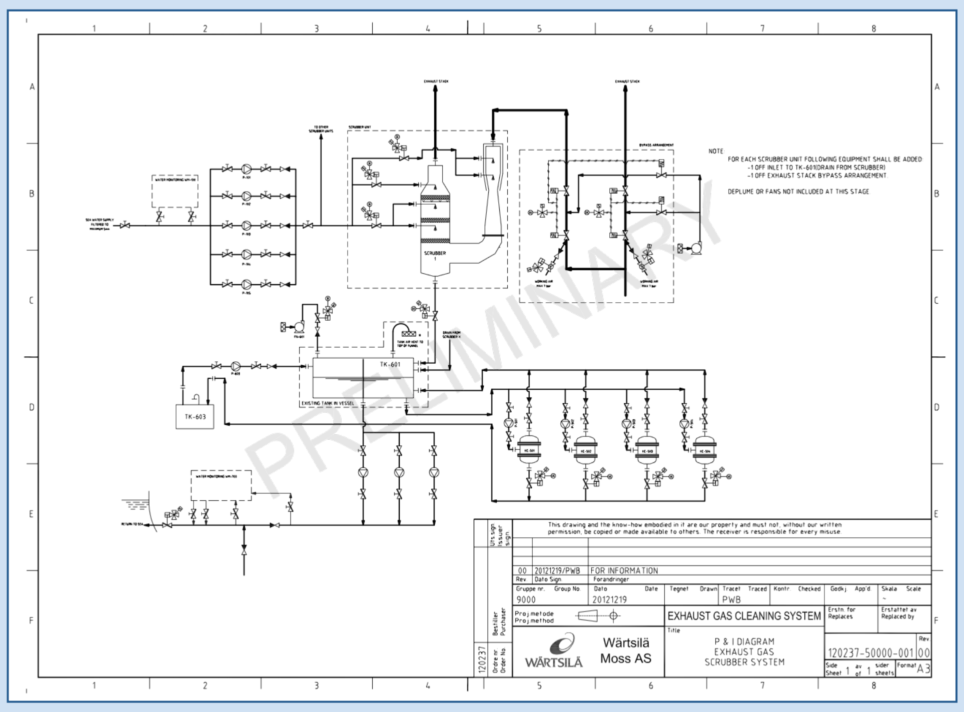

Figure 1 Exhaust gas cleaning system

Modelling & Analysis

The Formal Safety Assessment consists of five steps:

•Step 1 – Hazard Identification
Relevant hazards within the open loop system which could affect operations are identified. A FMECA and risk matrix is created on the basis of the P&ID in Figure 1 and the book Offshore Reliability Data (OREDA).

•Step 2 – Risk Assessment
The second step evaluates the components ranked with medium and high risk quantitatively. A Risk Contribution Tree (RCT) is created, where each fault tree and event tree is categorised within an accident category. The chosen accident categories are overpressure, hazards related to loading/discharging operations and purification failure. Six fault trees are created and simulated by software CARA-FaultTree, which are the following:
•F1: Overpressure in scrubber device and venturi
•F2: No seawater to scrubber device and venturi
•F3: Inlet monitor does not measure pH, PAH, turbidity and temperature
•F4: Outlet monitor does not measure pH, PAH, turbidity and temperature
•F5: Washwater not purified
•F6: Exhaust gas not washed in scrubber device
The three accident categories are the initiation events of the modelled event trees. The barriers are established based on different sources of literature, P&ID (Figure 1) and expert judgement by the author.

•Step 3 – Risk Control Options (RCOs)
The results of the Risk Contribution Tree (RCT) form the basis of finding the risk areas needing control and the following four potential risk control measures are identified:
1.Improve the knowledge on corrective maintenance and increase quantity of spare parts
2.Review the preventive maintenance given in safety manual
3.Redundancy in inlet monitor and outlet monitor
4.The joint between nozzles, pipelines and scrubber casing should be reinforced

The proposed risk control measures are implemented in the existing fault trees and event trees modelled in Step 2 to increase the availability of the open loop system.

•Step 4 – Cost-Benefit Analysis
This step is still in progress. The risk control measures are adopted onto a common scale to select the most cost-effective measures.

•Step 5 – Recommendations for Decision-making
This step is not yet evaluated.

Presentation & Evaluation of Results

• Step 1 – Hazard Identification
The qualitative analysis shows that out of 153 FMECA IDs, 52% are ranked with low risk, 45% with medium risk and 3% with high risk. Two components are assumed to have high risk, which are the drainpipe and injection nozzles in the scrubber device.

		Probability				
		1	2	3	4	5
		Impossible	Remote	Possible	Occasional	Fairly normal
Consequence	5 Catastrophic	0	4	4	0	0
	4 Severe loss	0	9	6	0	0
	3 Major damage	0	28	46	4	0
	2 Damage	0	2	49	0	0
	1 Minor damage	0	0	1	0	0

Figure 2 Step 1, risk matrix

• Step 2 – Risk Assessment
The constructed Risk Contribution Tree (RCT) can be seen in Figure 3. Note, two fault trees are not included due to space limitations and most of the trees originally spans multiple pages. Figure 4 shows the unavailability of each fault tree through one year. The results indicate that fault tree number one and five have the highest top event probabilities to occur at a given point of time.

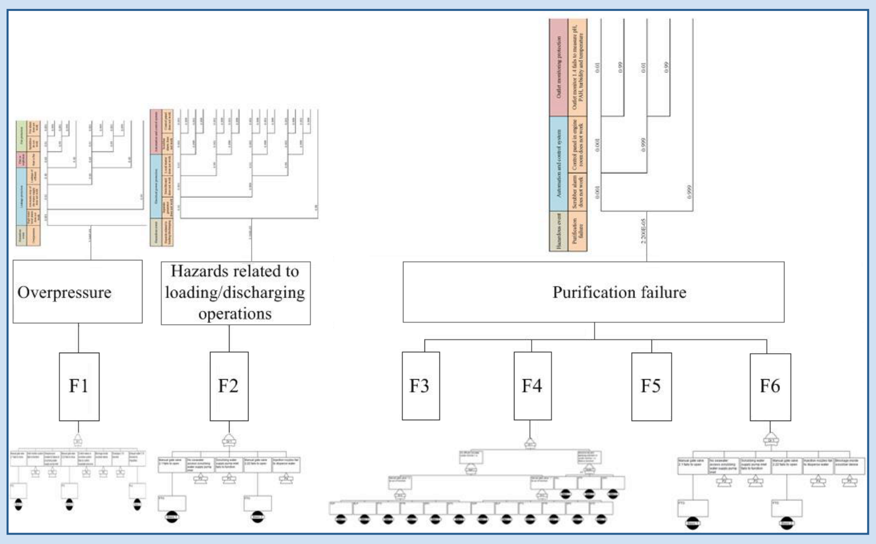

Figure 3 Step 2, Risk Contribution Tree (RCT)

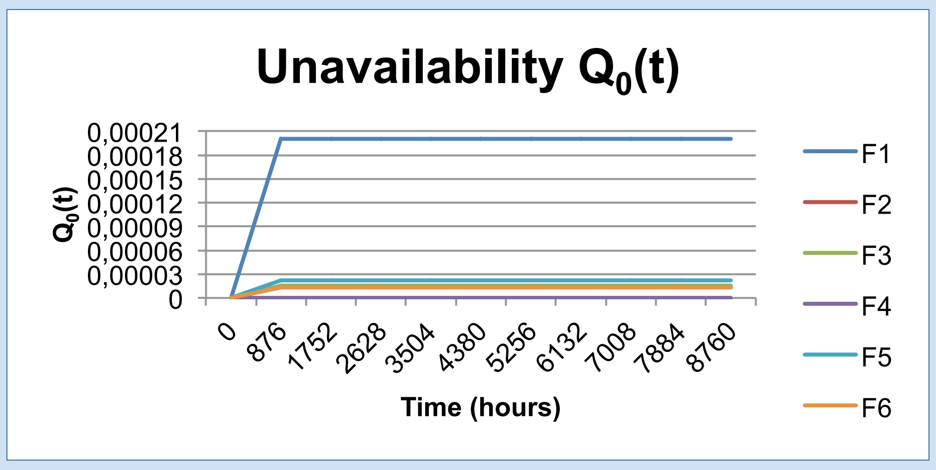

Figure 4 Step 2, fault tree unavailability

• Step 3 – Risk Control Options (RCOs)
Figure 5 presents the decrease in unavailability by each risk control option per accident category.

Accident Category	Decrease in Unavailability RCO 1	RCO 2	RCO 3	RCO 4
Overpressure	10 %	5 %	4 %	75 %
Hazards related to loading/discharging operations	10 %	5 %	0 %	0 %
Purification	9 %	5 %	92 %	0 %

Figure 5 Step 3, decrease in unavailability

Conclusion & Further Work

The most hazardous events are overpressure in the scrubber device and the venturi and difficulties with purifying washwater. Further work, beyond the thesis, should include additional sources, not only P&ID and reliability data from OREDA.

References: IMO (2015). ¨Sulphur oxides (Sox) – Regulation 14.” Retrieved May 4, from http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-(SOx)-–-Regulation-14.aspx , ABS (2013). “Exhaust Gas Scrubber Systems” 17-18.