Requirement Specification for Water Distribution Network for Firefighting in a Large Ship

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Contents

1 INTRODUCTION

The system requirements are developed to satisfy the customer's requirements in the systems design. Our Team A2 has developed a System Requirement a water distribution network for firefighting in a large ship with system meeting the customer's demand. The requirements are developed with well analysed, appraised, and amended development to finalized system objective. The system requirement comprises different subsystem and element requirements with justifications and comments. Followed by the requirements, the system architecture is depicted with incorporating all the demanded requirements. We have used Top-Down approach to create the architecture. Next to the architecture diagram, quality function deployment is developed to meet the requirements. We have used Fault tree analysis to evaluate the viability of the system. The failure probability of possible scenarios is carefully evaluated in the feasibility study to reconcile the system's probability with the customer's demand. The system is qualified and accepted to ensure that it complies with the system's requirements, after the verification process being completed, the requirements are assessed in a QFD analysis to determine the customer's requirement with engineering specification. The finalized system design is delivered to the development team, which then initiates the project's construction.

2 SYSTEM OBJECTIVE

The objective of the system is to design a Water Distribution Network for Firefighting System in a Ship with 10 compartments. With considering all the requirements from the customers.

3 TABLES AND FIGURES

4 UPDATED REQUIREMENTS

S NO	CODE	REQUIREMENT TYPE	STATUS
1	A2 00005	Functional requirements	Requirement newly added
2	A2 00010	Functional requirements	Requirement newly added
3	A2 00015	Functional requirements	Requirement newly added
4	A2 00020	Functional requirements	Newly added some points based on the need for system architecture
5	A2 00025	Functional requirements	Requirement newly added
6	A2 00030	Mission requirements	Code and system requirements changed from A2 00035 to A2 00030
7	A2 00035	Mission requirements	Code and system requirements changed from A2 00040 to A2 00035
8	A2 00040	Interface requirements	Requirement modified
9	A2 00045	Interface requirements	Requirement modified
10	A2 00050	Operational requirements	New requirement added
11	A2 00055	Operational requirements	The environmental requirement is removed from the initial report and replaced with the operational requirement
12	A2 00060	Operational requirements	Justification and some points modified
13	A2 00065	Product Assurance (PA) Induced Requirements	Human factor removed from the initial report and replaced with Product assurance
14	A2 00070	Sensor Requirements	Physical requirement removed and updated with new sensor requirement

S NO	CODE	REQUIREMENT TYPE	STATUS
15	A2 00075	Sensor Requirements	Layout requirement removed and updated with new sensor requirement
16	A2 00080	Sensor Requirements	System and safety Assurance requirement removed and updated with sensor requirement
17	A2 00085	Sensor Requirements	Configuration requirement removed and updated with new sensor requirement
18	A2 00090	Human Factor Requirements	New requirement added
19	A2 0095	Nozzle Head Requirements	New requirement added
20	A2 00100	Nozzle Head Requirements	New requirement added

Table 01: Updated Requirements

5 REQUIREMENTS

5.1 FUNCTIONAL REQUIREMENTS

A2 00005 The system shall intake water from both high and low sea chest for the systems usage. The pumps shall also be used for General Services in the ship and be used for firefighting which is connected directly to a fire hydrant.

Justification: Sea chests are located at the bottom of the ship. Right side sea chest is called high sea chest and left side sea chest is called low sea chest. Sea chest is the only opening for pump to intake sea water for the ship.

Comment: The sea water pumps are used for general services like cleaning and other activities in ship, but it shall also be used for firefighting by connecting it directly to the fire hydrants.

A2 00010 The system shall equip a freshwater generator to generate the fresh water for firefighting.

Justification: Sea water cannot be directly used for firefighting, since it contains lot of minerals, which can cause damage to the ship's internal parts and the pipelines.

A2 00015 The system shall have a two independent feed water tanks, located in different locations, where the fresh water is stored in a maximum level.

Justification: Maximum level of feed water stored in the tank can be used for immediate action. These tanks are located at different places in ship, as a protective measure. If one tanks get damaged the other tank in different location can be used.

A2 00020 The firefighting pumps shall be turned on automatically by the control system and shall also have a manual control during the firefighting.

Justification: The emergency pump in the ships is always turned on by the ships firefighting control system for immediate response. It shall be either turned on manually or automatically, but the pump can only be turned off manually.

A2 00025 The system shall use high pressured foam and water mixture for an effective firefighting.

Justification: Since the sea water cannot be used in direct fire action, in highly flammable areas the foam water mixer can have an effective firefighting than the direct water application. This mixture shall be achieved by placing the foam proportioner in both pipelines of the emergency pump.

Comment: Fires like oil fire, electrical fire and other machinery fires can get exacerbated if the sea water is used directly, its due to the minerals content present in the water.

5.2 MISSION REQUIREMENTS

A2 00030 The system shall be operated with an electrically powered pump in case the electrical pump fails to operate it shall be assisted with the diesel-powered pump when the electrical pump fails a probability less than $1x10^{-3}$.

Justification: The system should have a backup operating pump in case the main electrical pump gets failed. The failure probability of the pump should be extremely low as possible by considering all the ramifications.

Comment: The standby pump shall use ships diesel for working.

A2 00035 The system shall have the capability of working continuously for 8 hours of firefighting operation and shall only be activated in only the fire occurred compartment.

Justification: The ship equips a freshwater generator, which can produce sufficient fresh water per day, or the water shall also be bought and stored tanks from seaports. Therefore, there will be sufficient water stored in the tanks for usage for the continuous 8 hours firefights.

5.3 INTERFACE REQUIREMENTS

A2 00040 The system shall have sensors and power-assisted valves connected with the control system for monitoring the system operation like smoke detectors, fire alarm, feed water storage level and flow in the pipeline across the ship to monitor the level and flow of the water to the control system.

Justification: The control system has an HMI panel, which interacts with the machine components like sensors and solenoid valves and gives feedback which helps the user to monitor the entire system and can be controlled.

A2 00045 The control panel shall also equip the MGPS system connected with control a system for controlling the electrode placed in the sea chest.

Justification: The Marie Growth Prevention System (MGPS) is connected to the electrode to prevent mould growth in ship sea chest grills.

5.4 OPERATIONAL REQUIREMENTS

A2 00050 The copper electrode shall be placed in both high and low sea chests to avoid biofouling formation in the system which can potentially cause problems for the system.

Justification: Two copper electrodes are placed in both high and low sea chest which is connected to the control system. The electrode discharges an electric pulse which prevents the formation of moulds and biofouling on the grills of the sea chest.

A2 00055 The priming pump shall be equipped in the system to each pump to ensure the water is discharged continuously in pumps in case if the main pump fails in water suction.

Justification: Priming pumps are used to assist the suction to all pumps in the ship. It recovers the suction pressure of the main pump if it loses suction during operation.

A2 00060 The emergency pumps shall start discharging the water from low to high pressure when the system detects a pressure drop in the pipe.

Justification: The control system initiates an automatic discharge when the pressure maintained in the pipe drops. The pumps can discharge maximum pressure of 140 bars.

5.5 Product assurance (PA) induced requirements

A2 00065 The system shall have redundancy, diversity reliability and engineering principles and methods implemented to strengthen the safety of the system and regulator.

Justification: The ship equips with features like the entire system monitoring and controlling, the system also has an effective fire system connected with HMI and microprocessors which provides redundancy and safety for ship and crewmates.

5.6 Sensor Requirements

A2 00070 The system shall be equipped with Ultra-Sonic Sensor to measure the water level in the feed water tank.

Justification: The ultra-sonic sensor uses high-frequency pulse waves that precisely measure the measurement even in slurries.

A2 00075 The system shall use Pressure transmitter sensors to measure the compressed foam in the tank.

Justification: The pressure transmitter sensors are made with piezoelectric material which can handle high pressure and measure accurately without getting affected by radiation and electromagnetic fields.

A2 00080 The system shall be equipped with a Paddlewheel flow sensor in every pipeline to monitor the flow of water.

Justification: The paddlewheel flow sensor is very efficient and can measure precisely, it only requires low maintenance which gives long working life.

A2 00085 The system shall use photoelectric smoke detectors in the compartments except for machinery areas. The engine room shall be equipped with infrared flame detectors, smoke detectors, and heat detectors.

Justification: The photoelectric smoke detector can be used for smouldering fire detection. The Machinery area shall use infrared flame detectors, which have a speed response of under 30 milliseconds and are immune to optical contaminates like oil, dirt, and dust.

Comment: Temperature in machinery areas usually exceeds 85˚C, therefore infrared detectors are the most suitable for the machinery area and detect smoke precisely.

5.7 HUMAN FACTOR REQUIREMENTS:

A2 00090 The system shall have maintenance activities conducted like testing the smoke detectors and shall have maintained in the feed water tank.

Justification: The smoke detectors can be tested using the Solo smoke test kit. The Feed water tank capacity shall get reduced due to slurries formation.

5.8 NOZZLE HEAD REQUIREMENTS:

A2 00095 The sprinkler nozzle head, and fire hydrants shall be used for the low flame occurrence zones in the ship.

Justification: The Sprinkler head nozzle and fire hydrants can be used for Class A to Class C-type fire zones. Which are sufficient to put off the fire direct water and sea water.

Comment: These fire types can be occurred due to fuels like wood, paper, gasoline, and other low-flammable items.

A2 00100 The Mist sprinkler shall be used for the higher flame occurrence zone.

Justification: The mist sprinkler can be more efficient than the normal sprinklers in Class D to Class K fire types. With this specialised nozzle head, the high-pressure foam and water mixture is sprinkled on the flame which creates a cool mist, which has the potential to put off the fire more efficiently with less water than the normal sprinkler system.

Comment: These classes of fire can occur due to oil fires, electrical fires, and machinery fires.

6 SYSTEM ARCHITECTURE:

The System Architecture is visual representation of a system which shows how components are tied with other systems for synchronize operation. It shows the interaction between the sub system and the external systems. In our Water Distribution Network system in ship for firefighting visually show how the system interact with system components, we have used a top-down approach method to design our water distribution network system. Initially the fire hydrant system has been disintegrated into many subsystems like ships compartment, control system and engine room. Followed by the sub system, the elements are then identified according to requirements and interface between them are established with the other system, which can satisfy the system objective. The elements like fire sprinkle nozzle heads, mist sprinkle nozzle heads and the fire hydrants are established in the sub system. This system interface with the other system like pump house and the control system which interacts between for an effective operation which increase the systems principle factors like redundancy, reliability, diversity, and separation to strengthen the safety which are considered during the design and incorporated these principles in the system architecture of the Water Distribution System for Firefighting in Ship for better fire response.

The system architecture is categorised into different zones, which all together works as a water distribution system. The compartment has been networked with the pipelines to put off the fire risks. The fire nozzles have separated and positioned in the compartments based on the fire risk need of the zones. These systems are classified to mitigate the fire risk.

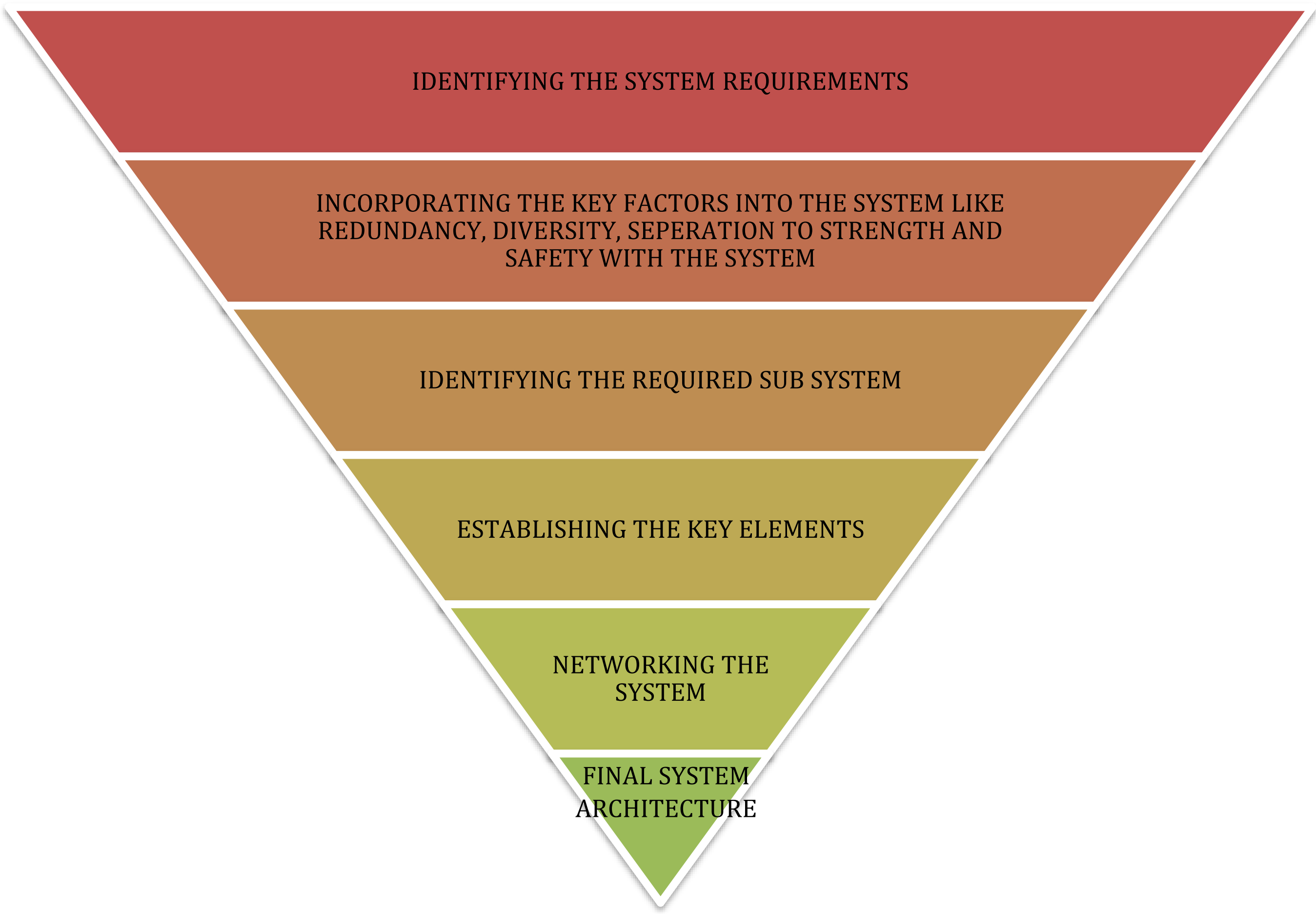

Figure 01: TOP-DOWN APPROACH METHOD

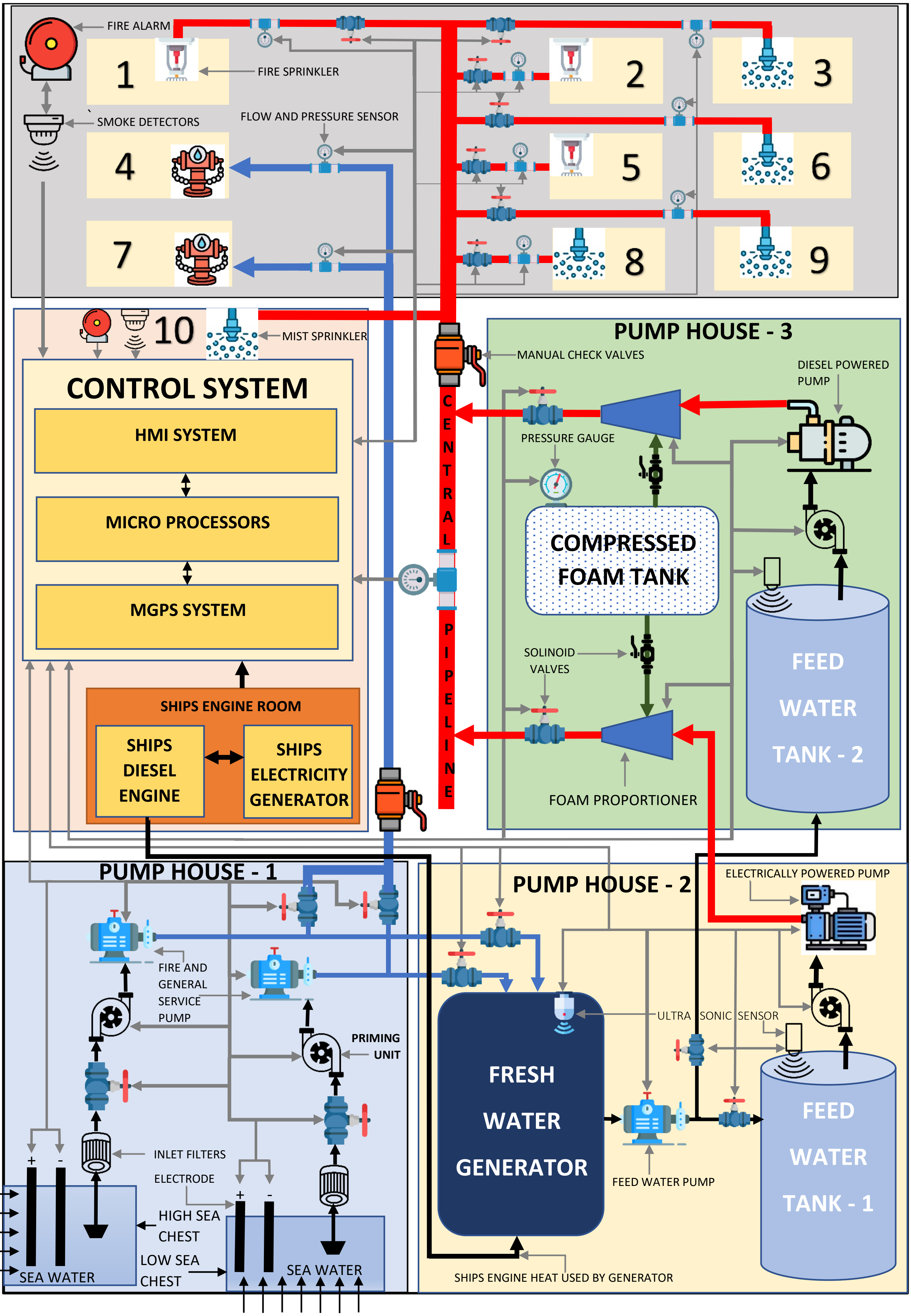

Figure 02: SYSTEM ARCHITECTURE

6.1 SYSTEM ARCHITECTURE BREAKDOWN

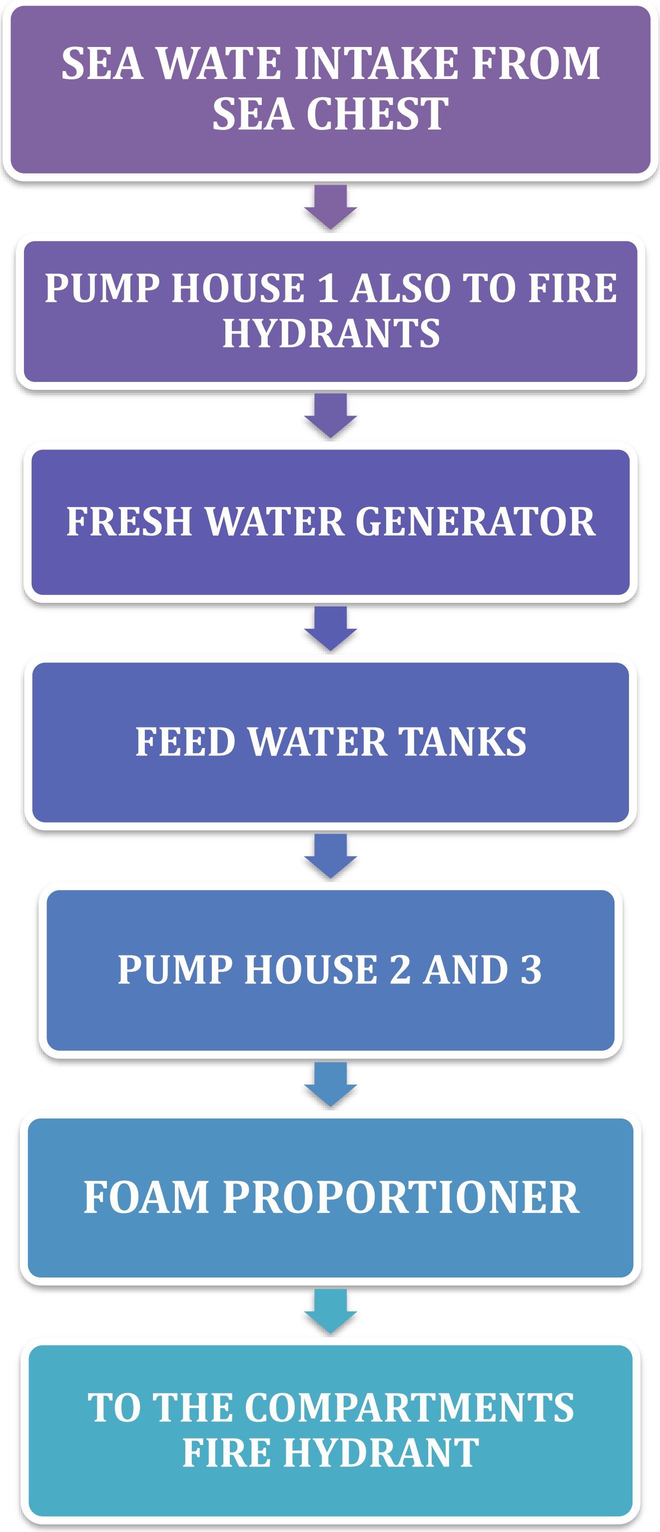

Figure 03: SYSTEM ARCHITECTURE BREAKEDOWN

6.1.1 SYSTEM BOUNDRY

The system boundary incorporates all the systems, sub systems and elements with all interfaces between the system. The system shall also interact outside the boundaries which are called system interface. In our system architecture the sea water is the only system interface which crosses the system boundary for the usage of sea water for the ships sub-system operation.

6.1.2 SUB SYSTEMS AND INTERFACES

Initially in the Pump House 01, The sea water is suctioned from sea chest. The ship has two sea chest High Sea Chest which is located at the right side of the ship also known called as “Star Board Side” in ship language and lower sea chest in located at the left side of the ship also known as the “Port Side” in the ship language.

The sea water is taken through both sea chest by the Fire and General Service Pump. The sea water passes through the electrode and filter which filters the bio fouls and debris from the sea water. The Fire and General Service Pumps are connected to Fire Hydrants, and it also passes to the Feed water Generator in the Pump House 02. If there is need of fire hydrant usage the valve is turned on manually or can also opened by the control system and the water can be used for firefighting. These Sea Water can only be used for lower class fires only, it cannot be used directly to the oil fires and machinery fires which can cause the fire to get furious.

To avoid such hazards the fresh water is used for firefighting. The Fresh water in the pump house 02, uses the Ships Diesel engine heat which ranges from (80˚C to 90˚C) and boils the water to produce the fresh water. The feed water tank is maintained in a vacuum state which reduces the waters boiling point. Therefore, these temperatures are more than sufficient to vaporise. The fresh water is then pumped to both independent feed water tank in the Pump Hose 02 and Pump House 03. These tanks are located indifferent location. This protective measure is taken to use a standby water reserve in case the either one tank gets damaged.

The Pump House 02 contains the electrically powered emergency main pump which pumps the water through the Pump House 03 to the foam proportioners which mixes the compressed foam from the compressed foam tank. This mixture is achieved by the foam proportioners. The Pump House 03 also contains a backup diesel powered pump which uses the diesel from the ship’s engine. The backup also has the same specification as the main electrical pump, which is also conned to a separate foam proportioner. Both the pipes are the conned to Central Pipeline.

The Central Pipeline carries only freshwater and foam mixture not the sea water. These mixtures are then routed to the respective compartments according to the system architecture plan.

The Nozzles Heads are particularly selected according to the applicant area in the ship. For the accommodations and admin areas the normal Fire Sprinklers are enough to put off the fire. For the machinery area and electrical systems, the Mist Sprinklers are used which consumes less water and can provide higher firefighting effect than the fire hydrants and the sprinklers.

All these processes are controlled and can be monitored in the control system compartment. The control system equipped with advance fire control and monitoring systems like HMI (Human Machine Interface) system, MGPS (Marine Growth Protection System) and Microprocessors to control all the elements which are interlinked with the control system to provide the crew members a well detailed data like temperature, pressure, sensors, flow in pipelines, all the pumps and all the type of valves control, smoke detection sensors, Fire alarms in the system. This Control System is powered by the Power Generator located in the Engine room.

This Control system even equipped with controls like turning on the emergency pump automatically when a fire or smoke is detected in a system by the detectors. The pipelines in the system are maintained with a constant pressure of 15 bars. When the pressure in the pipeline reduces the control system verifies fires zone areas if fire is detected the pump starts automatically and reaches the maximum discharge pressure of 140 bars.

The water is only pumped to the detected fire zones, which will not activate the other sprinklers or the fire hydrants in the other compartments. This controls are established by the control system through the power assisted solenoid valves used in the system. Initially all the valves are maintained in open state when a hazard is detected, the control system shuts down all the valves except the fire detected zones valves. This increases the wate usage efficiency and it also give the maximum pressure to put off the fire quickly.

7 FEASIBILITY STUDY

The desirability of the system is analysed by the feasibility study. A feasibility test determines whether the system can satisfy the fundamental functions specified which is illustrated in the system architecture process. A feasibility study is a technique for ensuring that everything is in order before providing access to a project or allocating time or resources. Additionally, it lists the possibilities and reasons that should not be considered or processed.

7.1 FAULT TREE ANALYSIS

The fault tree analysis is a graphical tool used to define the probability of unexpected events of a system and helps to build a proved and safety system. The liability of failure of fire hydrant system can be estimated by using fault tree analysis.

Fault tree analysis uses the combination both 'AND' and 'OR' gates in Boolean logic to map the relationships between failure, subsystems, and safety design features. The FTA is created by considering the possible failure events that could occur in a system, which affects or fails the systems firefighting operation. We have used Top-Down approach in the FTA, where the top event is "System Fails to extinguish the fire". Followed by the top even, the rest of the events are structured below like, intermediate event and basic events.

The Figure 04 depicts the possible flaws that could occur in a system, that can fail or cause problem to the system which affects the systems objective.

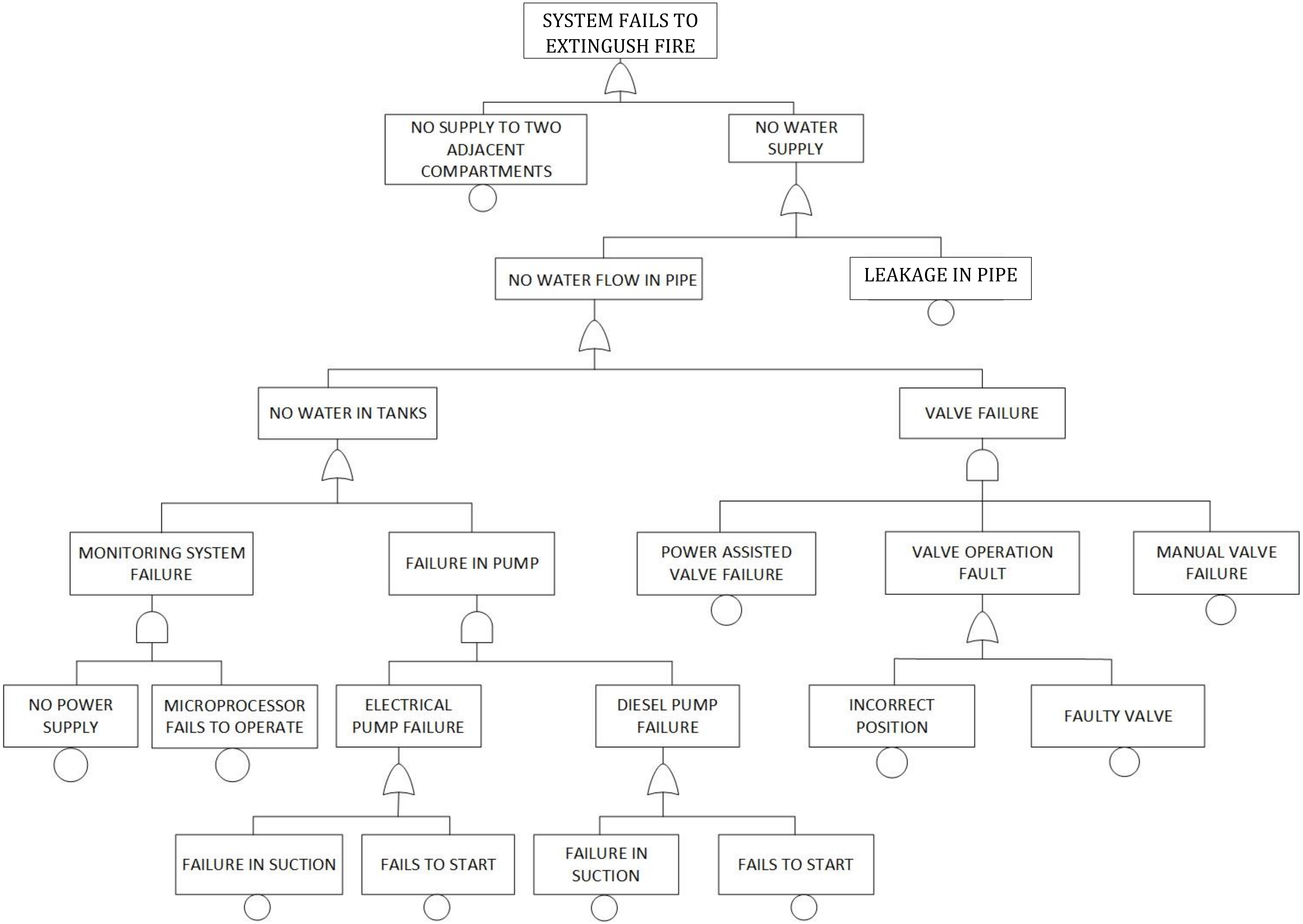

Figure 04: FAULT TREE ANALYSIS

8 VERIFICATION AND VALIDATION

The Verification and Validations in system defines whether the systems plan meets the system objective and the requirement specification. In the Verification and Validations, the system is tested by conducting experiments, analysis, review, and inspections. This process is categorised into Qualification and Acceptance.

S. NO	System Requirement and ID	Qualification	Acceptance
1	A2 00010	The freshwater for the system can be produced by the ships freshwater generator which converts the sea water into fresh water by using the engine heat to produce and restore the fresh water in both feed water tank.	The Fresh water Generator production can vary according to the need of the ship size and consumption level. In this system the fresh water can be capable of producing 18 tonnes water per day to restore the water in the tanks.
2	A2 00020	The automatic Pump turn of system test can be conducted by using a simulation in the control system.	The verification of the pump can be checked by conducting a troubleshooting and checking the output in the control system.
3	A2 00030	Inspection can be made with the standby diesel-powered pump to ensure the pump is in good condition to used when the main electric pump fails.	Both electric and diesel pump can be inspected to check the performance of the pump which can avoid the failure in pump during a required time.
4	A2 00040	The isolation vales and manual valves can be tested physically about the working conditions of the valves open and close position	All valves can be kept closed and can be checked whether there are any leaks occurred in them.
5	A2 00045	The filters can have inspection to get maximum efficiency.	Filter shall be visually inspected to check the usability.

S. No	System Requirement and ID	Qualification	Acceptance
6	A2 00050	Frequent cleaning can be conducted in both sea chest. The sea chest has high possibilities of getting spoiled due to the mould da biofouling.	The copper electrode in the sea chest can have proper maintenance to avoid these issues.
7	A2 00065	The key factors can be check in the systems. Factors like redundancy, diversity and separation and safety must be considered in the system.	These factors can be visually inspected to make sure the specification meets the systems objective.
8	A2 00090	Inspections can be conducted to verify the smoke detectors functionality.	The inspections can be conducted manually by using the Solo Detectors testing kit.
9	A2 00095	The fire hydrants and sprinklers can be inspected to verify the location that placed as per the standard norms of the ship's safety design.	Physical inspection can be conducted to verify the norms.

Table 02: Verification and Validation

9 QUALITY FUNCTION DEPLOYMENT (QFD)

The QFD is an organized way to deal with characterizing the client needs or prerequisites and interpreting them into explicit designs to create items to address those issues. The "voice of the client" is the term to depict these expressed and implicit client needs or prerequisites.

In the QFD diagram, our team has considered all the customer requirements in the firefighting network.

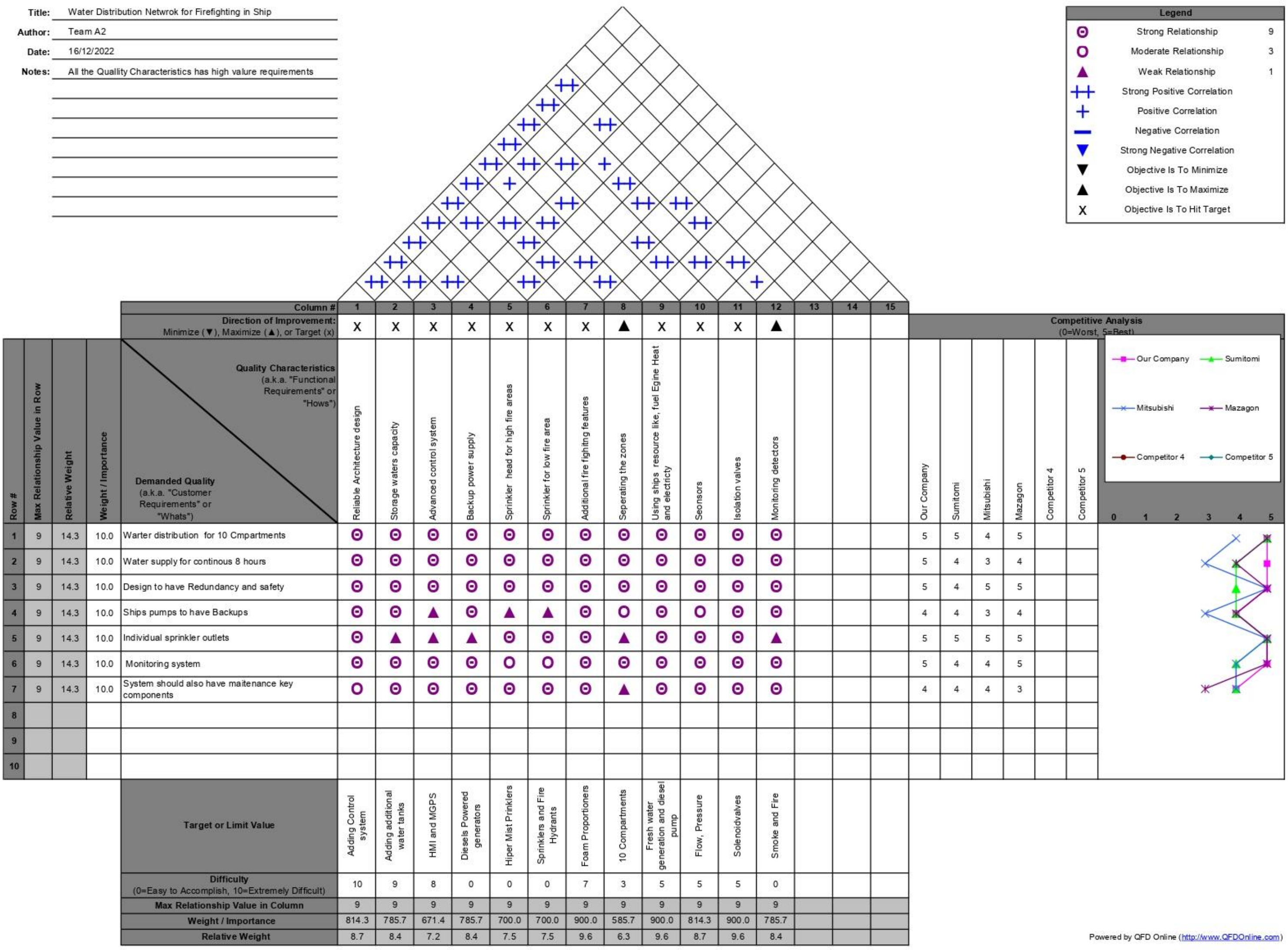

Figure 05: QFD Diagram 01

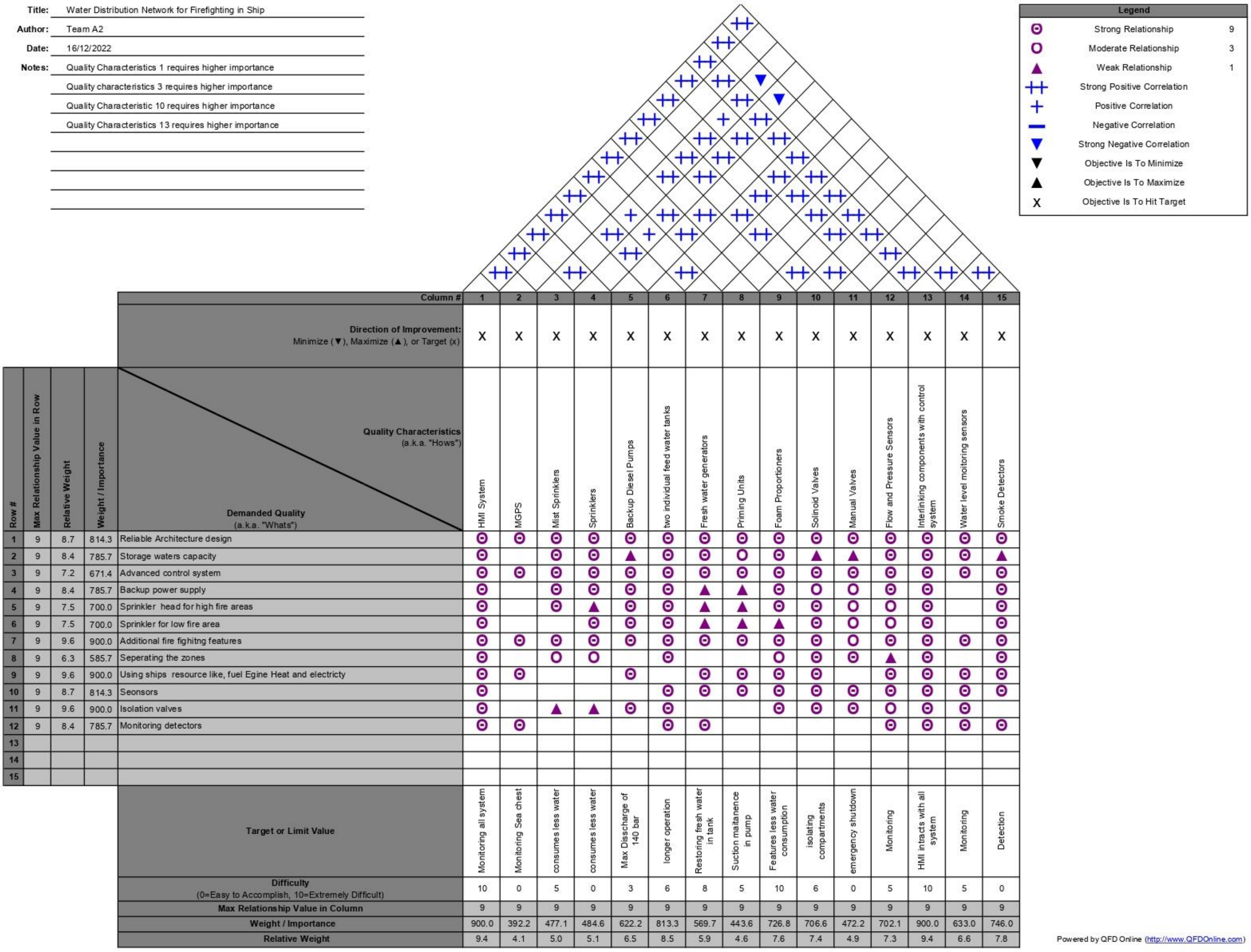

Figure 06: QFD Diagram 02

10 CONCLUSION

In general, we have designed this system requirement report with including all the customer requirements. Also, we have included some other advanced engineering feature in system which can provide an efficient and safety to the system. The report has done with a detailed system requirement, system architecture, feasibility study, QFD and verification plans. This incorporates a fault tree analysis that helps in foreseeing significant hazard in the early stages and the problem in previous design had also been considered and have been mitigated in this new Water Distribution Network system.

Reference Documents

[RD01] MGPS (Marine growth prevention system) (no date) Marine Growth Prevention System - Marine Corrosion Service Limited. Available at: http://www.mcs.cn.com/index.php?m=content&c=index&a=lists&catid=6 (Accessed: December 16, 2022).

[RD02] Sea water pumps on a ship: Sea chest suction filter cleaning procedures and their importance (2009) Bright Hub Engineering. Available at: https://www.brighthubengineering.com/marine-engines-machinery/41043-procedure-of-sw-pump-sea-chest-cleaning/ (Accessed: December 16, 2022).

[RD03] Micheal (2020) Testing fire detectors onboard ships, Echo Sailor. Available at: https://sailor.com.ng/testing-fire-detectors-onboard-ships/ (Accessed: December 16, 2022).

[RD04] Dickinson, M. (2021) What are the 5 different classes of fires?, Vanguard. Available at: https://vanguard-fire.com/what-are-the-5-different-classes-of-fires/#:~:text=Choose%20the%20Right%20Fire%20Extinguisher%20%20%20Fire,%20%20Powder%20%201%20more%20rows%20 (Accessed: December 16, 2022).

[RD05] What are different types of valves in ship (2022) SIO. Available at: https://en.siovalve.com/different-types-of-valves-in-ship/ (Accessed: December 16, 2022).

[RD06] Abhishek, A. (2019) Fire detector types and their working principle, ShipFever. Available at: https://shipfever.com/fire-detector-types-working-principle/#:~:text=A%20smoke%20detector%20can%20be%20based%20on%20photo,radioactive%20isotope%20americium%20241%20as%20an%20ionization%20source. (Accessed: December 16, 2022).

[RD07] Chandrasekhar, B. (2021) SOLAS regulation for Fire Main, fire hydrant, relief valve on ship, MarineSite.Info. Blogger. Available at: https://www.marinesite.info/2021/05/solas-regulation-for-fire-main-fire.html (Accessed: December 16, 2022).

[RD08] Ship's level sensors - types, construction, and use (2011) Bright Hub Engineering. Available at: https://www.brighthubengineering.com/marine-engines-machinery/123689-shipboard-level-sensors-types-and-theory/#:~:text=Ship%27s%20Level%20Sensors%20-%20Types%2C%20Construction%2C%20and%20Use,6%20Capacitive%20Level%20Sensor%3A%20...%207%20References%20 (Accessed: December 16, 2022).

[RD09] makoi6916 (2020) How ships convert sea water to fresh water | chief Makoi Study call EP 04, YouTube. YouTube. Available at: https://www.youtube.com/watch?v=8k56ffiNJ8M (Accessed: December 16, 2022).

[RD10] Anish (2021) A guide to fire pumps on ship, Marine Insight. Available at: https://www.marineinsight.com/tech/guide-to-fire-pumps-on-ship/ (Accessed: December 16, 2022).

[RD11] Marine Bilge Pumps & pumping system - emergency bilge suction (2009) Bright Hub Engineering. Available at: https://www.brighthubengineering.com/marine-engines-machinery/48581-bilge-injection-valve-explained/ (Accessed: December 16, 2022).

[RD12] MEO class 4 coscpool oral preparation notes by Kunjal Shah, part - 2. (no date) Marine engineers knowledge. Available at: https://www.marineengineersknowledge.com/p/meo-class-4-coscpool-oral-preparation_8.html (Accessed: December 16, 2022).

[RD13] How do they fight a fire on a massive cruise ship? (2022) YouTube. YouTube. Available at: https://www.youtube.com/watch?v=mbLRYVbZ5sQ (Accessed: December 16, 2022).

[RD14] Anish (2021) 10 precautions to take after using fixed foam fire fighting system on ships, Marine Insight. Available at: https://www.marineinsight.com/guidelines/10-precautions-to-take-after-using-fixed-foam-fire-fighting-system-on-ships/ (Accessed: December 16, 2022).

[RD15] Webber, R. (2018) Paddling among paddle crabs, Te Papa's Blog. Available at: https://blog.tepapa.govt.nz/2014/02/13/paddling-among-paddle-crabs/ (Accessed: December 16, 2022).

[RD16] Anish (2021) How high pressure water mist fire fighting system for ships works?, Marine Insight. Available at: https://www.marineinsight.com/tech/how-high-pressure-water-mist-fire-fighting-system-for-ships-works/ (Accessed: December 16, 2022).