Automatic Oil Filling Station

Bachelor Assignment spring 2015

AUTOMATIC OIL FILLING STATION

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Project Plan

Part 1

Project Management

Bachelor Assignment spring 2015

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1.0 Introduction

In every project, it is a necessity to develop some kind of a plan. The plan should be a springboard for the rest of the work. For our development of the automatic oil filling station for Precision Subsea, it is no different. The project plan gives the group an indication of how we should proceed and in what way and whom should do what. It is the organizational foundation of everything. The project plan document also includes the vision document, which gives information about the projects purpose, what we are supposed to design and project limitations.

The project plan consists of three different parts. Part one, the project management, which gives a plan of the role responsibilities, GANTT diagram, rules and regulations, a plan for the required resources and several other important issues related to the project initiation.

Part two gives a detailed description of the project model, how it is constructed, how it will aid the group and why we consider that model appropriate for our work.

The last part explains the synergy of the project model, GANTT diagram and activities we will undertake. It demonstrates the use of the project model in the development of the automatic oil filling station.

1.1 Abbreviations

PS	-	Precision Subsea AS
AOFS	-	Automatic oil filling station
MOFS	-	Manual oil filling station
PEP	-	Project Execution Plan
HSE	-	Health, Safety and Environment
FEM	-	Finite Element Method

1.2 Purpose

PS currently have a MOFS that is a critical component in their production. The MOFS is a relatively low efficient apparatus that is very time consuming. Currently, manual execution of the system operations is necessary, which hinders efficient labor use. PS want to increase the productivity of the designated operation. They desire an AOFS in order to free up labor time, while simultaneously minimize the risk for error and faults. The product we will design must be able to dehumidify the AK350 Wacker silicone oil, run vacuum leak tests and fill jumpers. The system must also be capable of pressure testing and pressurizing the respective hoses. These tasks must run automatically and independent of each other in order to do simultaneous operations at different jumpers connected to the system. Our purpose is not to construct, but to develop a functional and final design that Precision Subsea can build.

3.0 Project Management

All of the group members will occupy different roles throughout the project. Each member will swap weekly responsibilities, such as whom is the meeting summoner, meeting report writer, follow-up report writer and meeting administrator.

Separate members throughout the project will head major tasks and these responsibilities are fixed. Section 3.2 presents the fixed responsibilities of each member. The person in charge of the will be the last one to do a quality check of the documents and make sure, with aid from the project leader, that the task is following the agreed plan.

3.1 Project organization

The AOFS Project team consists of the following key personnel:

Name	Study	Contact information
Marius Martinsen	Mechanical Engineering	mariusmartinsen87@gmail.com Phone: 95 21 49 31
Eirik Mæhre	Mechanical Engineering	eirikmaehre@hotmail.com Phone: 97 66 52 39
Henning Henriksen	Mechanical Engineering	eplesinen@gmail.com Phone: 97 54 43 36
Knut Ola Nymoen	Mechanical Engineering	olanymoen@gmail.com Phone: 98 00 11 00

Table 1: Group members

3.2 Group member responsibilities

These are the main responsibilities of each member. If more tasks appear through the phase of product development, we will divide the responsibilities amongst team members based on workload and possible complimentary responsibilities.

Group member:	Responsibility:
Marius Martinsen	Project Manager, Project planning, Financials, Document controller.
Henning Henriksen	3D modeling, System testing, Electronic equipment.
Eirik Mæhre	System requirements, HSE Lead. Homepage.
Knut Ola Nymoen	Risk analysis, Design, Construction, Procurement.

Table 2: Group member responsibility

3.3 Role Responsibilities

1. Project Manager:

Make sure that the project follows the planned schedule. Act as point of contact between Precision Subsea, group members and school administration.

2. Project planning:

Responsible for making sure that all tasks meets their respective deadlines and that the project is following the projected plan. Will monitor the timetable and assess possible discrepancies.

3. System testing:

Responsible for the test specifications and the overall testing of the design. The testing will be performed with the utmost precision according to test specifications. This will mainly be component and system testing documentation, but also includes FEM analysis.

4. System requirements:

Responsible for requirements specifications. Will make sure the requirements are always up to date and accomplished.

5. Homepage:

Responsible for the homepage. Will update the homepage continuously with the latest news and documents.

6. 3D modeling:

Responsible for the 3D model. Makes sure that all necessary requirements are included in the 3D model and that it is possible to analyze and test by FEM.

7. Financials:

Responsible for financial documents including budget, cost analysis, etc. Makes sure all components in the system are cost optimized.

8. Document controller:

Responsible for proof reading and coordinating the final documentation. Also responsible to make sure that all of the documents follows the agreed structure, format and templates.

9. Electronic equipment:

Responsible that all electronic equipment in the system is following the necessary requirements and that they function according to the plan.

10. Construction:

Responsible that all components in the system are verifiable according to the requirement specifications. Also responsible to have full overview of suppliers, component information and system functions. Will also be leading the construction of possible component prototypes.

11. Risk analysis:

Responsible that the risk analysis covers the full scope of project factors. Factors that includes project requirements, probability of failures and risk matrix of task, etc.

12. Procurement:

Responsible that all components that are ordered are per specification and of minimum cost.

13. HSE Lead:

Responsible that the group follows the specified HSE and project rules and regulations.

3.4 Documentation Responsibility

Document type	Responsible	Completion date	Delivery date
Time sheets	Eirik Mæhre	15.05.2015	19.05.2015
Project plan	Marius Martinsen	15.05.2015	19.05.2015
Meeting reports	Marius Martinsen	15.05.2015	19.05.2015
Follow-up reports	Marius Martinsen	15.05.2015	19.05.2015
Requirement specifications	Eirik Mæhre	15.05.2015	19.05.2015
Test specifications	Henning Henriksen	15.05.2015	19.05.2015
Meeting notifications	Marius Martinsen	15.05.2015	19.05.2015
Risk assessment	Knut Ola Nymoen	15.05.2015	19.05.2015
User manual	Henning Henriksen	15.05.2015	19.05.2015
Product design	Knut Ola Nymoen	15.05.2015	19.05.2015
3D modeling	Henning Henriksen	15.05.2015	19.05.2015
Product evaluation	Eirik Mæhre	15.05.2015	19.05.2015
Design document	Eirik Mæhre	15.05.2015	19.05.2015

Table 3: Documentation responsibility

4.0 Strategy

4.1 Project model

Part two of the project plan gives a detailed description of this section.

4.2 Pugh Matrix

A Pugh Matrix is a decision matrix method we use to rank the multi-dimensional options of an option set. This tool will categorize options based on several requirements and entities. We may give a value to each requirement to conclude priority. The highest valued priority gives us an aid in choosing the best alternative. Component selection, concept selections and design selection may be decided using a Pugh Matrix.

4.3 GANTT diagram

The GANTT diagram gives a detailed schedule of the planned timeline of our project. The progress on the project are updated on the GANTT diagram continuously in order to make sure that we are on schedule and are doing the right things. The project model reflects the timeline described in the diagram.

It will record the following information:

- Name of the activity.
- Track the status of the activity.
- Give the start and end date of the activity documentation.
- Estimate the number of hours the activity needs.
- Number the activity so that tracking everything related to the activity is easy.
- Track if the activity has an important milestone.
- Specify who has the responsibility of the activity.

4.3 Iterations

Throughout the project, we predict that no activity will be completely finished by the end of the set activity schedule. Numerous iterations will be necessary because feedback, design problems and other real life impacts will require continuous alterations to the different activities. The group has planned seven iterations trough the project. These iterations are run simultaneously with other activates.

The contents of the iterations are not pre-planned, it is consecutive planned throughout the project based on the previous iteration and on what we deem necessary at that point in time. A plan is written preceding each iteration and a full report will at the end summarize the iterative work.

If, during the iteration, we experience problems that needs more iterative work, but it is not in the plan, we will not work on that problem until the next iteration period. This means that every iteration will follow the plan 100% and obstacles will be included in the report and dealt with in the next period.

Figure 1 illustrate the iteration process:

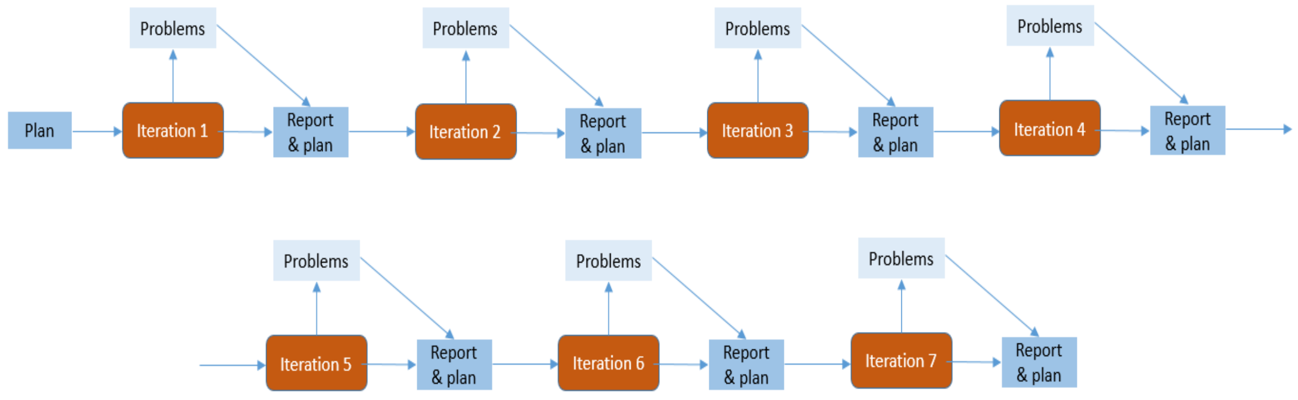


Figure 1: Iteration process

Table 4 illustrates the scheduled date for each of the iterations:

Iteration number	Date
1	16.02 – 01.03
2	02.03 – 15.03
3	16.03 – 29.03
4	30.30 – 12.04
5	13.04 – 26.04
6	27.04 – 10.05
7	11.05 – 19.05

Table 4: Dates of iterations

Each period is scheduled from a Monday and two weeks ahead. The group will hold a meeting at the beginning of each iteration phase where the iteration report and plan is discussed.

5.0 Cooperation

We will be working with our employer Precision Subsea. They will assist us with technical questions and with materials and funding. Additionally we also have an internal supervisor that will help guide us through the process and report our progress.

5.1 Employer

Precision Subsea AS – Merdevegen 3676 Notodden
Bjørn-Tore Bergestig
Deputy General Manager
Mail: bjorntore@precisionsubsea.no | Phone: (+47) 98 87 89 84

5.2 Supervisors and examiners

Internal supervisor:

Frank Helgestad
Mail: Frank.Helgestad@hbv.no
Phone: 31 00 89 02

External supervisor:

Øystein B. Tørre
Mail: oystein@precisionsubsea.no
Phone: 47 23 33 69

Internal examiner:

Karoline Moholt
Mail: Karoline.Moholth@hbv.no
Phone: 31 00 88 98

External examiner:

Bjørn Hallvard Lund
Mail: bjorn@precisionsubsea.no
Phone: 91 14 29 50

5.3 Communication plan

We will implement several methods of communication besides the regular phone and email services. These will be our web page, Facebook page and Google Drive.

5.3.1 Web Page

The web page http://www.subsea-jumper-oil-filler.com is updated with status and documentation continuously.

5.3.2 Facebook

We will use Facebook as an internal group communication tool, brief and non-vital messages are communicated through this channel.

5.3.3 Google Drive

This is a file storage and synchronization service offered by google. It gives cloud storage, file sharing and collaborative editing. We find it easy and safe to use. This will store all our files on the web. Marius Martinsen will have a backup copy on his own computer that includes the identical setup as the one in the Google Drive folder.

6.0 Project rules and regulations

6.1 Ethical conduct

- Each group member is expected to perform at his utmost capability when working with the project. Responsibility to the project plan, quality expectation and ethical conduct is required.
- Each group member is obliged to give the correct and true information regarding the members work when asked by either of the examiners or supervisors.

6.2 Internal

- If there is a disagreement regarding any subject in the project, the person whom holds the responsibility for the subject will have a double vote if democratic means are used to establish a solution.
- Any problem besides aspects directly connected to the project will give the group members equal voting power.
- Each member has a responsibility to communicate their opinion if any obstructions occur. This includes all problems regardless of its nature.
- If disagreements cannot be de solved by democratic means and internal communications fail, the group must contact the internal supervisor to help settle the crisis.

6.3 External

- If there are any problems with external parts that the group cannot settle, the internal supervisor will be contacted to help convey an agreement.
- If unresolvable disagreements occur between the group and the internal supervisor, internal examiner will be contacted.

6.4 Demands from customer

- If the customer has any deviating demands late in our project, we must ourselves consider whether to include these demands. Each group member will assess the request based on current workloads and deadlines and give a vote on the matter.

7.0 Resource Requirements

7.1 Budget

The total system cost has an upper limit at 300 000 NOK. The budget must be specific and documented. Components, assessing of costs and everything related to the budget will be detailed (component costs, miscellaneous expenses, liabilities).
If the project exceeds the set budget, the deviations will be comprehensively explained. PS must approve any procurement and the budget.

7.2 Acquisition Strategy

Finding components for our project established on the guiding principle of three factors:

- **Cost:** To find the least expensive component.
- **Quality:** To find the best quality component.
- **Time:** To find the component that takes the lowest amount of time to acquire.

7.3 Quality Assurance

Controlling the component quality consists of four elements: cost optimization, performance, schedule and safety.

- **Cost optimization:** Lowest cost and best quality component is used.
- **Performance:** Component performs as required.
- **Schedule:** Acquisition of the component can happen within reasonable time.
- **Safety:** The component will meet the necessary safety requirements.

8.0 Project Baselines

8.1 Delimitation

The system PS has requested have some imposed restrictions that we should obey during the design, testing and possible construction. These limits are intended to stay constant during the project:

- **Fully automated:** The product should be fully automatic. After initiation of the operation, every function should run without manual interference.
- **Manually-override possibility:** Manually overriding the process has to be possible.
- **Specialized equipment:** The product only has to fit equipment available by PS. Everything can be made without considering mass scale production or use besides operational function at PS.

8.2 Deadlines

Documentation hand in will precede presentation dates by two business days (48 hours).

1. **Deadline, 09.02.2015:** Supply supervisors and examiners with project plan, requirement sheet and test specification.
2. **Deadline, 11.02.2015:** First presentation.
3. **Deadline, 19.03.2015:** Supply necessary documents.
4. **Deadline, 23.03.2015:** Second presentation.
5. **Deadline, 19.05.2015:** Final submission of all documents.
6. **Deadline, 03.06.2015:** Final presentation.

9.0 Meetings and Reporting

We will conduct formal group meetings at least one time every week. Brief, informal scrum meetings will be carried out at Tuesdays and Thursday's, and video meetings will be performed weekly to keep the group posted on updates and other necessary information. There will also be a meeting every Monday 14.45 with our internal supervisor where we will present documents and questions. When it is necessary we will have meetings with the external supervisor, but these meetings will be arranged without specific planned dates throughout the project.

A notification will be sent at least 24 hours beforehand (48 hours when meeting internal supervisor and/or external supervisor) and a report is made to summarize the contents of each meeting.

We will write follow up documents every week and hand them in to our internal supervisor two business days before our Monday meeting. These documents will include a report on what we have done last week, what our planned work is the coming week and a time sheet of our previous week work. The planned work is based on the iteration report and on the GANTT schedule.

10.0 HSE

HSE is an integral part of our planning and work during our project. As we continue towards a finished system, we will continuously focus on HSE, as it will affect our product in many ways. Our product will be handling silicon oil, use electricity and handle expensive and critical equipment, so it is important to set HSE guidelines.

10.1 Integrated safety management

We have a goal of zero injuries during all work related to AOFS project.
To ensure this we focus on three safety barriers:

- **Human:** A Persons knowledge, attitude and behavior. The most important barrier.
- **Technical:** Technical barriers such as fire alarms/detectors etc.
- **Organizational:** Procedures, documentation, etc.

During project work, the following will be a focus concerning safety management.

- **Work related safety**: If working in a school or office building, refer to local safety regulations.
- **Design related safety:** All applications to minimize safety hazards will be implemented when designing and constructing the AOFS.
- **Hazardous Materials:** AOFS will be using silicone oil, and all measures to reduce contamination, spread and release of this into the environment must be minimized.

10.2 Waste management

During project work, the following will be a focus concerning waste management.

- All waste resulted in work related actions will be recycled to the best of our ability.
- All waste resulted in design related actions such as models etc, will be recycled to the best of our ability.

11.0 Work allocation plan

11.1 Weekly work schedule

We have estimated a weekly time allocation schedule. The set-up will be as followed:

Group time allocation:

From week 1 to week 2 (December 29 – January 11): 32 hours per week. Total: 64 hours.

From week 3 to week 13 (January 12 – March 29): 96 hours per week. Total: 1056 hours.

From week 14 to week 20 (March 30 – May 17): 112 hours per week. Total: 784 hours.

From week 21 to week 22 (May 18 – June 01): 80 hours per week. Total: 160 hours.

Total time: 2064 hours.

Individual time allocation:

From week 1 to week 2 (December 29 – January 11): 8 hours per week. Total: 16 hours.

From week 3 to week 13 (January 12 – March 29): 24 hours per week. Total: 264 hours.

From week 14 to week 20 (March 30 – May 17): 28 hours per week. Total: 196 hours.

From week 21 to week 22 (May 18 – June 01): 20 hours per week. Total: 40 hours.

Total time: 516 hours.

11.2 Activity hour schedule

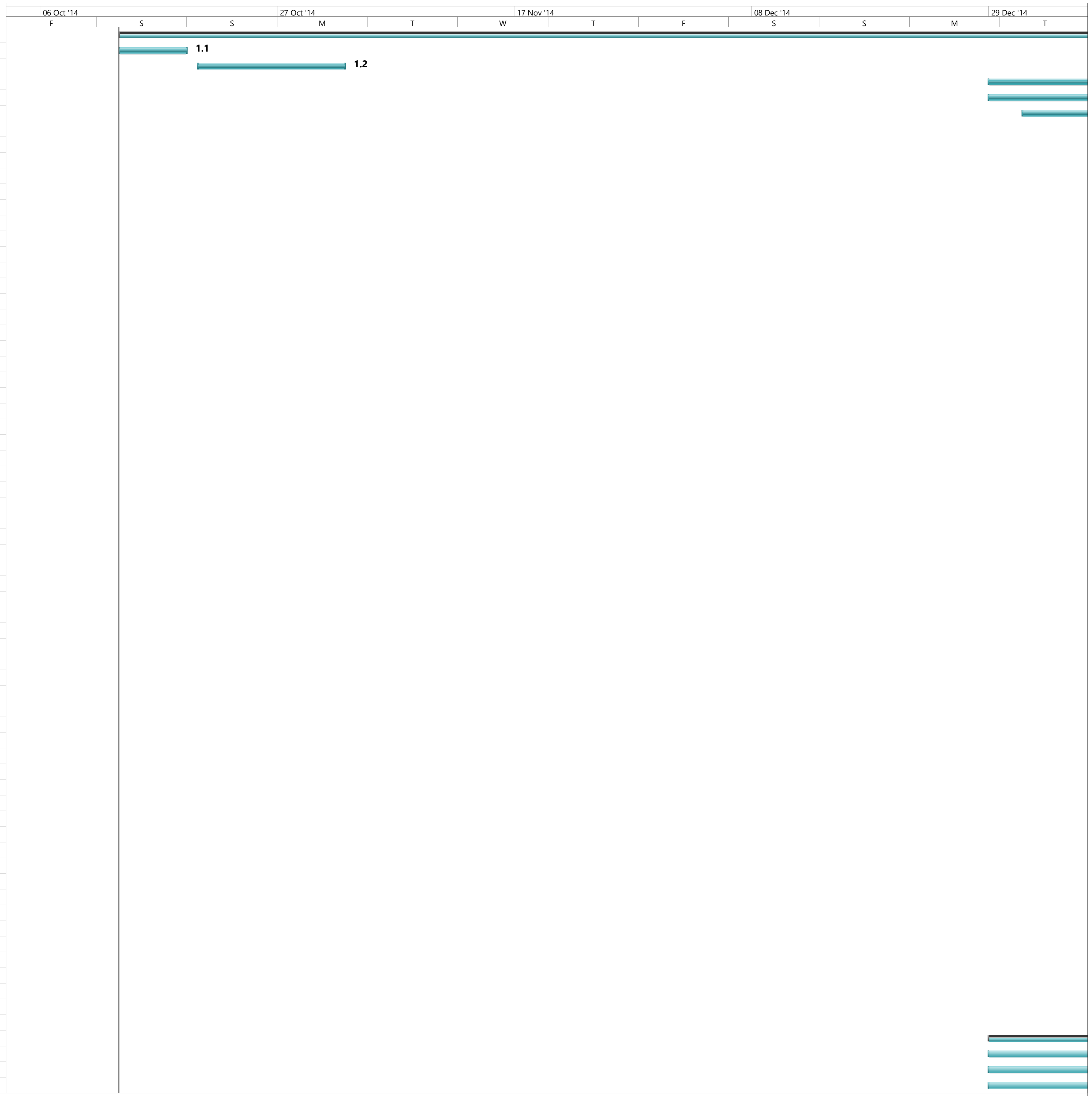
Activity number	Activity	Estimated work hours
2	Project plan	202
3	Requirements	200
4	Testing	200
5	Design	
5.1	Conceptual phase	315
5.2	Detailed design	400
5.3	Final design	200
6	Website	40
7	Risk analysis	40
8	Presentations	280
9	Final documentation	50
10	Iteration plan and report	37
11	Documentation and meetings	100
	Total hours:	2064

The hours designated include hours worked during the iterations and are only estimates. Deviations may occur, but the group will follow the plan as best as possible.

12.0 Attachments

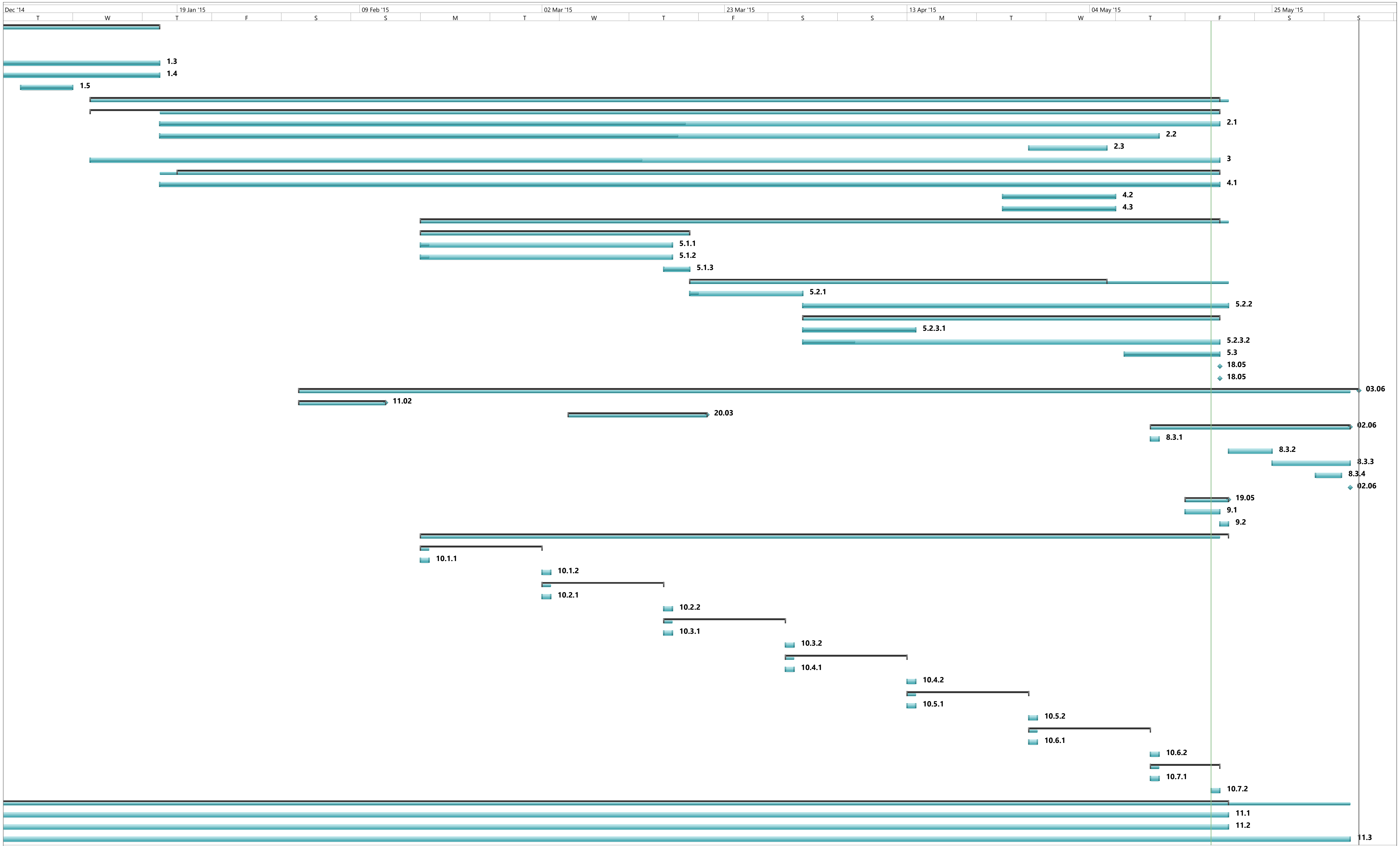
Attachment 1: GANTT schedule

ID	Name	Task Mode	%	Start	Finish	Designated hours	Activity number	Milestone	Responsibility
1	**Initiation process**		**100%**	**Mon 13.10.14**	**Fri 16.01.15**		**1**	**No**	
2	Complete group requirements		**100%**	Mon 13.10.14	Sat 18.10.14		1.1	No	
3	Find project assignment		**100%**	Mon 20.10.14	Sat 01.11.14		1.2	No	
4	Administrative		**100%**	Mon 29.12.14	Fri 16.01.15		1.3	No	
5	Planning		**100%**	Mon 29.12.14	Fri 16.01.15		1.4	No	
6	Website construction		**100%**	Thu 01.01.15	Tue 06.01.15		1.5	No	
7	**Main project tasks**		**100%**	**Fri 09.01.15**	**Mon 18.05.15**			**No**	
8	Project plan		100%	Fri 09.01.15	Mon 18.05.15	**202**	2	No	Marius
9	Process		**100%**	Sat 17.01.15	Mon 18.05.15		2.1	No	
10	GANTT diagram		**100%**	Sat 17.01.15	Mon 11.05.15		2.2	No	
11	Cost management		100%	Mon 27.04.15	Tue 05.05.15		2.3	No	
12	Requirements		**100%**	Fri 09.01.15	Mon 18.05.15	200	3	No	Eirik
13	**Testing**		**100%**	**Mon 19.01.15**	**Mon 18.05.15**	**200**	**4**	**No**	**Henning**
14	Test plan		**100%**	Sat 17.01.15	Mon 18.05.15		4.1	No	
15	Physical testing		0%	Fri 24.04.15	Wed 06.05.15		4.2	No	
16	FEM analysis		100%	Fri 24.04.15	Wed 06.05.15		4.3	No	
17	**Design**		**100%**	**Mon 16.02.15**	**Mon 18.05.15**		**5**	**No**	**Knut Ola**
18	**Conceptual phase**		**100%**	**Mon 16.02.15**	**Wed 18.03.15**	**250**	**5.1**	**No**	
19	Concept design		100%	Mon 16.02.15	Mon 16.03.15		5.1.1	No	
20	Research		100%	Mon 16.02.15	Mon 16.03.15		5.1.2	No	
21	Concept selection		100%	Mon 16.03.15	Wed 18.03.15		5.1.3	No	
22	**Detailed design**		**100%**	**Thu 19.03.15**	**Tue 05.05.15**	**465**	**5.2**	**No**	
23	Preliminary design		100%	Thu 19.03.15	Tue 31.03.15		5.2.1	No	
24	High level design		100%	Wed 01.04.15	Tue 19.05.15		5.2.2	No	
25	**Components**		**100%**	**Wed 01.04.15**	**Mon 18.05.15**		**5.2.3**	**No**	
26	Component investigation		100%	Wed 01.04.15	Mon 13.04.15		5.2.3.1	No	
27	Component selection		100%	Wed 01.04.15	Mon 18.05.15		5.2.3.2	No	
28	Final design		100%	Fri 08.05.15	Mon 18.05.15	200	5.3	No	
29	Website		100%	Mon 29.12.14	Mon 18.05.15	40	6	Yes	Eirik
30	Risk analysis		100%	Mon 16.02.15	Mon 18.05.15	40	7	Yes	Knut Ola
31	**Presentations**		**100%**	**Mon 02.02.15**	**Wed 03.06.15**	**280**	**8**	**Yes**	
32	**Presentation 1**		**100%**	**Mon 02.02.15**	**Wed 11.02.15**	80	**8.1**	**Yes**	
39	**Presentation 2**		**100%**	**Thu 05.03.15**	**Fri 20.03.15**	100	**8.2**	**Yes**	
46	**Presentation 3**		**50%**	**Mon 11.05.15**	**Tue 02.06.15**	100	**8.3**	**Yes**	
47	Book rom		100%	Mon 11.05.15	Mon 11.05.15		8.3.1	No	Marius
48	Planning		50%	Wed 20.05.15	Sun 24.05.15		8.3.2	No	
49	Make .ppt		50%	Mon 25.05.15	Tue 02.06.15		8.3.3	No	Henning
50	Rehearsal		0%	Sat 30.05.15	Mon 01.06.15		8.3.4	No	
51	Presentation		0%	Tue 02.06.15	Tue 02.06.15		8.3.5	Yes	
52	**Final documentation**		**100%**	**Fri 15.05.15**	**Tue 19.05.15**	**50**	**9**	**Yes**	
53	Review and alterations		100%	Fri 15.05.15	Mon 18.05.15		9.1	No	
54	Hand in		100%	Tue 19.05.15	Tue 19.05.15		9.2	No	
55	**Iterations**		**100%**	**Mon 16.02.15**	**Tue 19.05.15**		**10**	**No**	**Marius**
56	**Iteration 1**		**100%**	**Mon 16.02.15**	**Sun 01.03.15**		**10.1**	**No**	
57	Plan		100%	Mon 16.02.15	Mon 16.02.15	2.5	10.1.1	No	
58	Report		100%	Mon 02.03.15	Mon 02.03.15	2.5	10.1.2	No	
59	**Iteration 2**		**100%**	**Mon 02.03.15**	**Sun 15.03.15**		**10.2**	**No**	
60	Plan		100%	Mon 02.03.15	Mon 02.03.15	2.5	10.2.1	No	
61	Report		100%	Mon 16.03.15	Mon 16.03.15	2.5	10.2.2	No	
62	**Iteration 3**		**100%**	**Mon 16.03.15**	**Sun 29.03.15**		**10.3**	**No**	
63	Plan		100%	Mon 16.03.15	Mon 16.03.15	2.5	10.3.1	No	
64	Report		100%	Mon 30.03.15	Mon 30.03.15	2.5	10.3.2	No	
65	**Iteration 4**		**100%**	**Mon 30.03.15**	**Sun 12.04.15**		**10.4**	**No**	
66	Plan		100%	Mon 30.03.15	Mon 30.03.15	2.5	10.4.1	No	
67	Report		100%	Mon 13.04.15	Mon 13.04.15	2.5	10.4.2	No	
68	**Iteration 5**		**100%**	**Mon 13.04.15**	**Sun 26.04.15**		**10.5**	**No**	
69	Plan		100%	Mon 13.04.15	Mon 13.04.15	2.5	10.5.1	No	
70	Report		100%	Mon 27.04.15	Mon 27.04.15	2.5	10.5.2	No	
71	**Iteration 6**		**100%**	**Mon 27.04.15**	**Sun 10.05.15**		**10.6**	**No**	
72	Plan		100%	Mon 27.04.15	Mon 27.04.15	2.5	10.6.1	No	
73	Report		100%	Mon 11.05.15	Mon 11.05.15	2.5	10.6.2	No	
74	**Iteration 7**		**100%**	**Mon 11.05.15**	**Mon 18.05.15**		**10.7**	**No**	
75	Plan		100%	Mon 11.05.15	Mon 11.05.15	1	10.7.1	No	
76	Report		100%	Mon 18.05.15	Mon 18.05.15	1	10.7.2	No	
77	**Documentation and meetings**		**50%**	**Mon 29.12.14**	**Tue 19.05.15**	100	**11**	**No**	Marius
78	Reports		100%	Mon 29.12.14	Tue 19.05.15		11.1	No	
79	Document controlling		100%	Mon 29.12.14	Tue 19.05.15		11.2	No	
80	Meetings		50%	Mon 29.12.14	Tue 02.06.15		11.3	No	



Project: Project plan
Date: Mon 18.05.15

Task · Split · Milestone · Summary · Project Summary · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only · External Tasks · External Milestone · Deadline · Progress · Manual Progress



Project: Project plan
Date: Mon 18.05.15

Task		Summary		Inactive Milestone		Duration-only		Start-only		External Milestone		Manual Progress	
Split		Project Summary		Inactive Summary		Manual Summary Rollup		Finish-only		Deadline			
Milestone		Inactive Task		Manual Task		Manual Summary		External Tasks		Progress			

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Task
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External Tasks
External Milestone
Deadline
Progress
Manual Progress

Project Plan

Part 2

Project Model Design

Bachelor Assignment spring 2015

AUTOMATIC OIL FILLING STATION

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1.0 Introduction

Through the beginning of the project there has been much deliberation regarding the strategy to implement in order to ease and plan the project development in the best possible way. We have reviewed and discussed several different strategic pathways and process models. Initially the plan was to follow an approach guided by the waterfall model, but this was discarded after inputs and discussions made by proper guidance.

Following strenuous work acquiring new knowledge regarding how to properly introduce, interpret and pursue a beneficial project plan. The group has constructed a proper new and efficient plan. This change is in perfect agreement with the new plan; it concludes a complete iterative process of the project plan.

This document will describe the process itself, how we will implement the process as a guiding tool and the benefits. We will also show how we plan our timetable in accordance with the project model.

2.0 Methodology

2.1 Adopting the proper theory

Determining the correct theory to adopt requires more than just a strong theoretical foundation. The theoretical approach we choose must also relate to how we feel a natural way of executing this process would be. The best theory will be a supplement to our natural understanding of project planning and help expand our possible approach in a more thorough way.

The basic structural approach is tailored from project to project, because no specific method will uniquely suit the development of all products. A complete definition of the requirements are not available from the start and they will possibly develop in an incremental fashion. The project introduces a brand new product, and it is reasonable to anticipate numerous modifications to the system throughout the process.

2.2 Discarding theories

The field of project management is constantly changing. Theories improve and can possibly contribute more and more to different project developments. Many of the older theories that may still be valid, have in relation to our project, been improved through other concepts and do not give the best structural aid.

We have revised and discussed several different theories and models concerning the structuring of our project. Dwelling too much, into why we have discarded the different theories is beyond the scope of this task. We will instead give a detailed explanation of why we will structure our project based on the theory chosen.

2.3 Incremental and iterative path

We will follow an incremental and iterative (IID) strategy. All of our requirements, planning, estimates and solutions will *evolve* over the course of several *iterations*. This is in stark contrast to fully defined major up-front specifications before the development iterations begins. Our project will get continuous updates and feedbacks from both our stakeholders, Precision Subsea and internal supervisor. There is also a high certainty of unpredictable discoveries and changes in the product development that will appear during the process.

Every phase throughout the project will *evolve* through *incremental* steps. As we proceed from the beginning to the end, we will enter different focus areas that will require more emphasis than in other periods. The subject, which requires most attention, will be the phase topic at that point in time. Constant revision of these subjects will lead to constant alterations and improvements and therefore big advancing leaps will not happen.

We will perform iterations throughout the project, but the attention to different subjects will vary during the course of the project. Some subjects need a constant level of attention during the whole project, though they will never be the focus topic. This includes report writing, website administration and process documentation.

The IID is a natural path for us to follow. It is in great agreement to what the group initially considered the plan to be, even before we began the project planning. We believe that if we acquire a relative extensive knowledge of this theory and apply it to how we conduct the planning in real life, it will be an immense aid. This requires proper research, understanding and the ability to implement our findings into the project.

3. 0 Structure and strategy

3.1 Intuitive consideration

The framework of the project model is what we consider a natural progression through the development. We believe this is a sequential development approach from the user requirements to the delivery of a complete operational system. The strong focus of iterating each step throughout the process will be a primary consideration throughout the project life cycle. Figure 1 illustrates the framework:

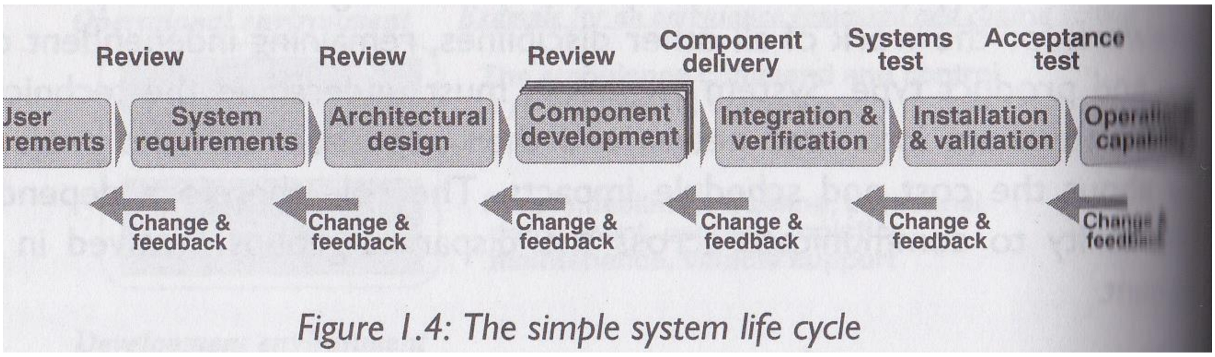

Figure 1.4: The simple system life cycle

Figure 1: The simple system life cycle (Systems Engineering, Coping with Complexity, Stevens et al., 1998)

Our project will barely venture into the integration and verification phase, but each previous step and iterations throughout will be essential. However, taken in isolation this view is illusory, because we are certain that the requirements and working environment will not be stable all the way to the end.

As figure 2 displays, each phase will be defined gradually and not fixed at any given time. We will have different focus points and dwell in different phases at different times. Through iterations, we will continuously develop each previous phase in parallel.

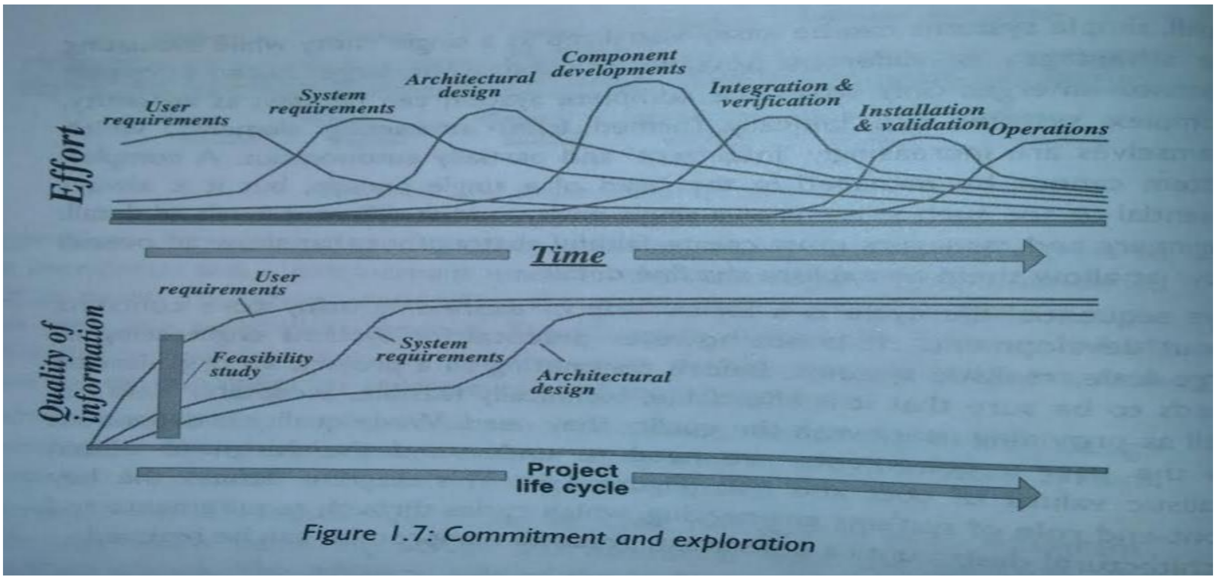

Figure 2: Commitment and exploration (Systems Engineering, Coping with Complexity, Stevens et al., 1998)

3.2 Implementing theory into practice

By thorough research, we have developed a strategy that will assist us in the construction of a proper project model that will be a benefit and not an obstacle during the process. The project model will explicitly illustrate the methodical path from the initiation of the project to the final design and verification phase. That will be the final stage by request of our stakeholder.

Agile and Iterative Development: A Manager's Guide (Larman, 2003) explains the thoughts and factors needed to follow an iterative and incremental development. We believe this to be a logical and sound way to structure our process. The steps described gives the group proper theory, which will aid the structure of the project.

1. **Iterative development:** the overall lifecycle will be composed of several iterations in sequence. Each iteration is composed of activities such as requirement analysis, design, testing and project management. We will have numerous iterations and we will plan each round carefully. A full report after each session in order to consider possible deviations and sections that needs more work.

2. **Incremental development:** the partial system grows incrementally with new features, iteration by iteration. After each two weeks of iteration, we will progress with new and improved modifications to the previous work. This process involves every single task we undertake.

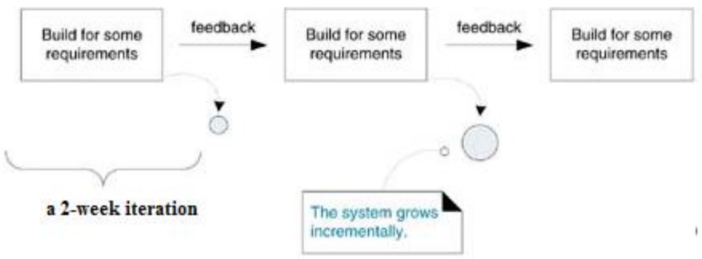

Figure 3: Iterative and incremental development (http://ptgmedia.pearsoncmg.com/images/chap2_0131111558/elementLinks/02fig01.jpg)

3. **Risk-driven and client-driven iterative planning:** our iterative process will be a combination of where we will try to choose the riskiest, most difficult elements for early iterations and iterations based on features that comes from Precision Subsea. The risky element involves elements such as not performing early 3D modeling iterations. By not iterating the 3D model early and confirming that the requirements are feasible, big problems may follow in a later phase.

4. **Timeboxed Iterative Development:** each iterative process will last two weeks (except the last one because of project deadline), before a new iteration will begin with new focus areas. This will be a constant timeframe throughout the project. The group can reduce the scope of an iteration if the timebox deadline cannot be met.

5. **Evolutionary requirement analysis:** our requirements are not forever unbounded and will not always change at a high rate. Our requirements discovery and refinement occurs early in the project and will continue to advance at a slower rate as we proceed further into the later stages. However, we will always keep iterating the requirements in context with the design and testing throughout the development.

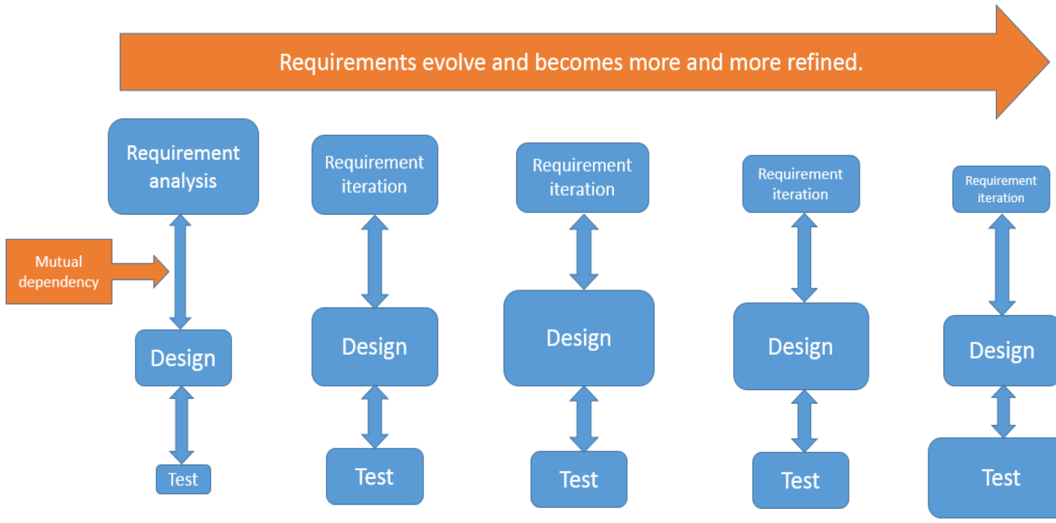

Figure 4: Iterative and incremental growth.

6. **Predictive planning:** an early creation of a schedule that predicts and estimates commitments to the different focus areas. Because this expands the cone of uncertainty, the schedule will not be rigid and exclude *adaptive planning*. The construction of a GANTT diagram with context to the project plan will include iterative procedures, but deviations will almost certainly occur.

Microsoft also uses their own methodology[1] to achieve its objectives named Microsoft Solution Frameworks (MSF). There are eight foundational principles at the core of MSF, and we choose to implement a few of these principles as our own core principles:

1. **Foster open communications**: open and free flow of communication between team members and stakeholders will reduces misunderstanding and risk of redoing work.

2. **Work toward a shared vision:** shared detailed understanding of the goals and objectives between team members and stakeholders.

3. **Empower team members**: team members accept responsibility and ownership of work assigned to them. Helps identify delays early in the project by making the team members feel accountable.

[1] https://technet.microsoft.com/en-us/library/bb497060.aspx

4. **Establish clear accountability and shared responsibility:** all the team members share the overall responsibility for the project because it can fail due to a mistake made by one single member.

5. **Stay agile, expect change:** the group assumes solutions will encounter continues changes before delivering the final product to Precision Subsea. The team should always be prepared to manage such changes.

4. 0 Designing the project model

4.1 Contextual elements

When tailoring our project model we will use inputs from the different IID process theories mentioned and try to avoid a common mistake of superimposing non-IID theories. Our model design draws large parallels to the Unified Process (UP) model design, though our methodology is quite different from a UP development.

4.2 Project model

The model will reflect the plan and theories discussed above, and guide us through the development of the system we are to design. It will ease the workload and make the whole process much more efficient. The structural support of the model is:

1. **Phases:** our project is divided in four different phases;
   a. *Preliminary analysis* → initial process at the beginning of the project where feasibility of the system is checked and performing an analysis of the structural process and inputs from Precision Subsea.
   b. *Inception* → executing a plan according to the analysis previously done and begin forming the requirements given by Precision Subsea. Simultaneously begin with projecting a test plan in relation to the requirements.
   c. *Design* → undertake a conceptual design, perform research on possible system designs and finish a preliminary design. Design the system based on the requirements.

d. *Verification* → testing of the system in SolidWorks and possibly prototype module testing will be performed at the end to verify the system before delivery.

2. **Contents:** we categorize our project work in six different sections. Section *a*, *b* and *c* act in direct dependence to each other. Working through the different topics, we will always combine effort in each subject to produce a result. The contents are as follows:
   a. **Requirement Analysis**
   b. **Model Design & Implementation**
   c. **Test Analysis and Performance**
   d. **Project Management**
   e. **Reports**
   f. **Website**

3. **Iterations:** after the initial process as begun involving preliminary analysis and inception, we will have seven iterations throughout the design and verification phases. The dates of these iterations are shown in table 1:

Iteration number	Date
1	16.02 – 01.03
2	02.03 – 15.03
3	16.03 – 29.03
4	30.30 – 12.04
5	13.04 – 26.04
6	27.04 – 10.05
7	11.05 – 19.05

Table 1: Dates of iterations

While working through the iterative process, we will constantly crosscheck the requirements with the design and testing. If there is any obstructions with the development of one these contents compared to another, we will perform a more comprehensive iteration of the necessary parts in the next iterative period. For each iterative phase, there will be a comprehensive plan and reports will summarize the progressions. These reports develops into successive plans for successive iterations. Iteration of the project management, general report writing and website development goes independently to other sections.

4. **Focus areas:** through the project, the concentration of workload is divided according to the emphasis we have on that particular subject at that particular time. In our model, we illustrate this by showing a curve where the height of the curve represents the emphasis at a given time.

By summarizing all of the above, we can illustrate this in a model that is clear and gives a good overview of the project plan:

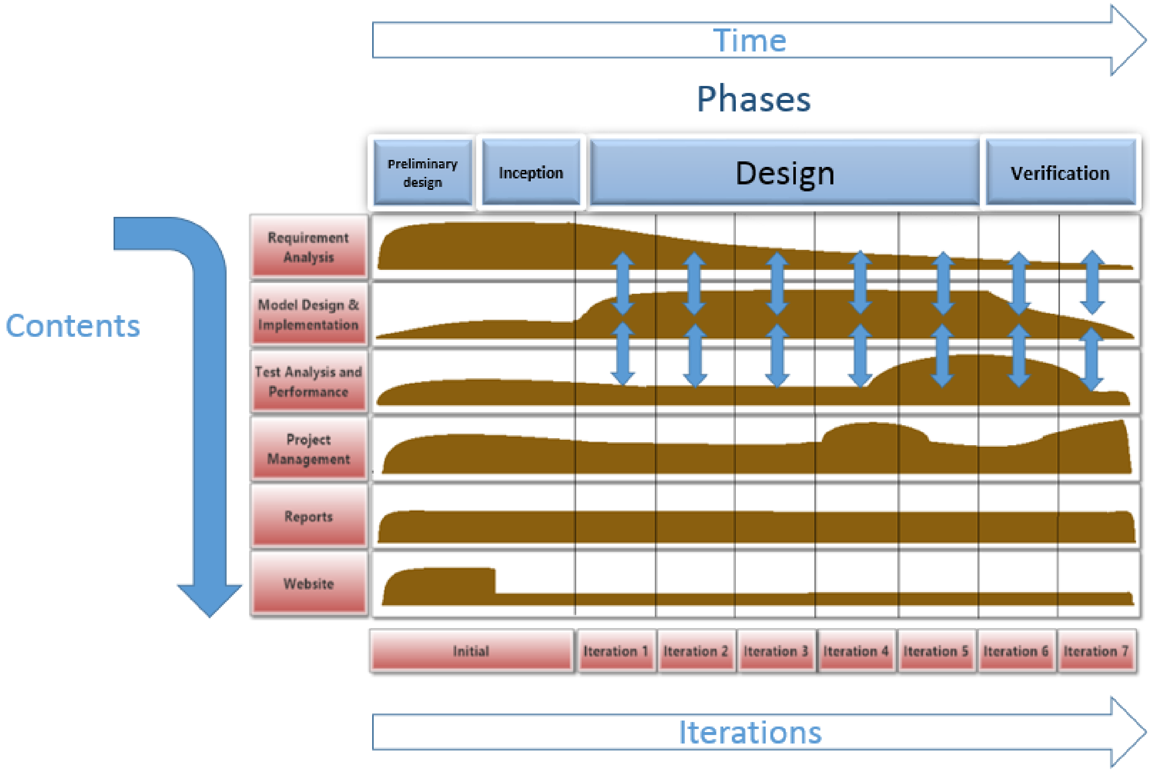

Figure 5: Project Model

This model guides us through the process and is the basis of the GANTT schedule, methodology of the development and system design.

Project Plan

Part 3

Project Model Integration

Bachelor Assignment spring 2015

AUTOMATIC OIL FILLING STATION

EIRIK S. MÆHRE MARIUS MARTINSEN

KNUT OLA NYMOEN HENNING HENRIKSEN

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2.0 Model Introduction 2

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1.0 Introduction

The project plan part 2 gives a detailed description on how we developed the project model. The theories behind the development and our own thoughts on how we considered a natural progression that suited us would be. This third part will demonstrate how the model is implemented in our work and how the model projects the activities we will perform during our task. Different chapters will elaborate the different sections of the project model.

2.0 Model Introduction

Our project model design closely resembles the Unified Process design, but there is no direct link between that model and our model. As part 2 gave a detailed description of the meaning behind each block in the model, this document will only describe its contents in relation to our process.

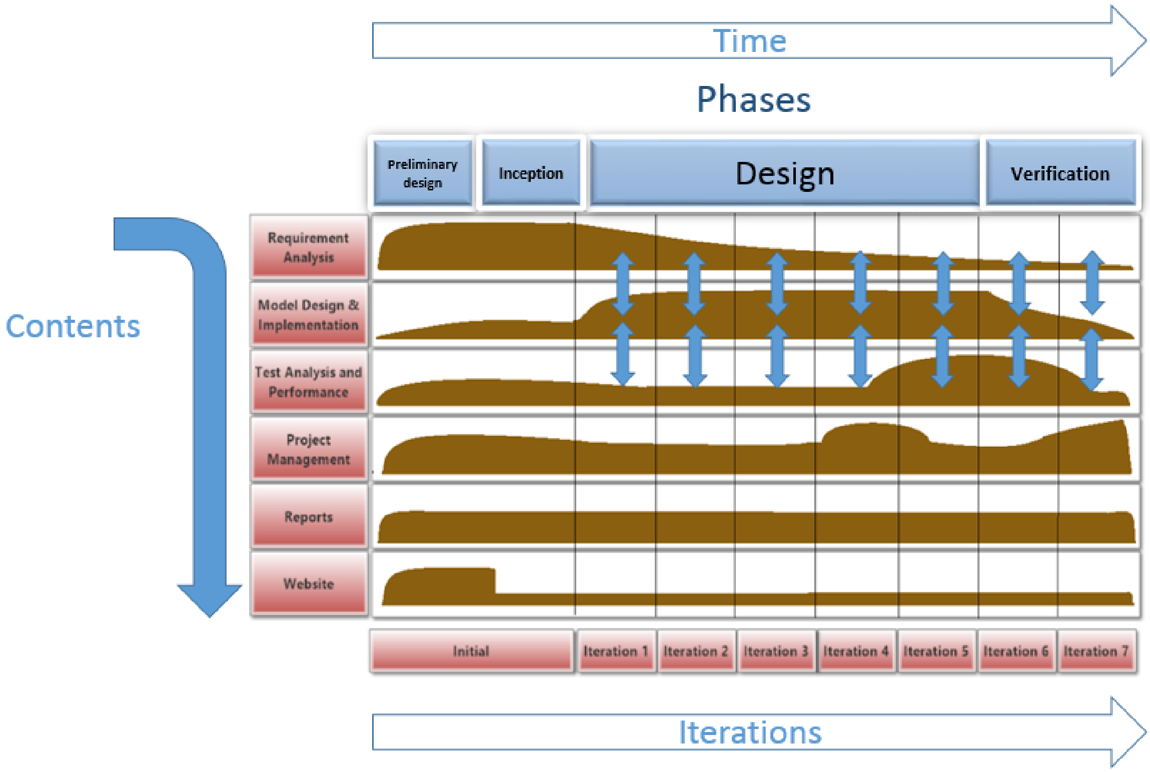

Figure 1: Project Model

Further elaboration sectionalizes the model with the proper sections of the GANTT diagram.

3.0 Incorporating the model

3.1 Pre-project

We omit the initiation process from the project model. Construction of the project plan was after this phase and the project model will only describe the process after the completion of this period.

	Name	Task Mode	%	Start	Finish	Designated hours	Activity number	Milestone	Responsibility
1	**Initiation process**		**100%**	**Mon 13.10.14**	**Fri 16.01.15**		**1**	**No**	
2	Complete group requirements		100%	Mon 13.10.14	Sat 18.10.14		1.1	No	
3	Find project assignment		100%	Mon 20.10.14	Sat 01.11.14		1.2	No	
4	Administrative		100%	Mon 29.12.14	Fri 16.01.15		1.3	No	
5	Planning		100%	Mon 29.12.14	Fri 16.01.15		1.4	No	
6	Website construction		100%	Thu 01.01.15	Tue 06.01.15		1.5	No	

Figure 2: GANTT diagram, pre-project work

3.2 Preliminary design and Inception

The introductory phase in the project model is the preliminary design phase. This includes discussion of the project plan, requirements documentation, test documentation and website creation. There is little emphasis on the design of the new station. Report writing begins and gets an equal amount of attention throughout the process. Activity 2, 3, 4, 6 and 11 initiates, but will not end before the project is to be delivered. Requirement analysis will get the most attention together with the project management.

The preliminary analysis and inception phase do not have a clear boundary, but we consider the inception phase to begin when we have finished brainstorming activities and documentation initiates. These two phases combined are the initial part of the project work, considering the pre-project phase not directly connected to the development of the automatic oil filling station for Precision Subsea.

Documents written during this phase are the project plan, requirement documents and test documents. We will not finalize the documents completely until the final deadline, but these documents will receive less and less attention after the inception phase. At the end of this period, we will hold the first presentation.

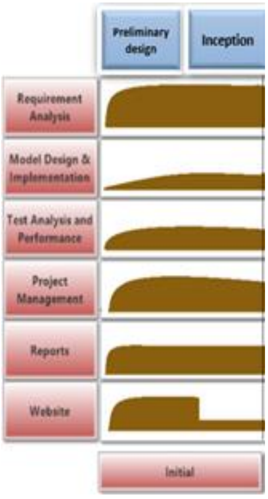

Figure 3: Preliminary design and Inception

	Name	Task Mode	%	Start	Finish	Designated hours	Activity number
8	Project plan		50%	Fri 09.01.15	Mon 18.05.15	**202**	2
9	Process		**50%**	Sat 17.01.15	Mon 18.05.15		2.1
10	GANTT diagram		**50%**	Sat 17.01.15	Mon 11.05.15		2.2
11	Cost management		0%	Mon 27.04.15	Tue 05.05.15		2.3
12	Requirements		**50%**	Fri 09.01.15	Mon 18.05.15	200	3
13	**Testing**		**50%**	**Mon 19.01.15**	**Mon 18.05.15**	**200**	**4**
14	Test plan		**50%**	Sat 17.01.15	Mon 18.05.15		4.1
15	Physical testing		0%	Fri 24.04.15	Wed 06.05.15		4.2
16	FEM analysis		0%	Fri 24.04.15	Wed 06.05.15		4.3
30	**Presentations**		**50%**	**Mon 02.02.15**	**Wed 03.06.15**	**280**	**8**
31	**Presentation 1**		**100%**	**Mon 02.02.15**	**Wed 11.02.15**	80	**8.1**
32	Book rom		100%	Mon 02.02.15	Mon 02.02.15		8.1.1
33	Planning		100%	Mon 02.02.15	Wed 04.02.15		8.1.2
34	Make .ppt		100%	Mon 09.02.15	Wed 11.02.15		8.1.3
35	Hand in		100%	Mon 09.02.15	Mon 09.02.15		8.1.4
36	Rehearsal		100%	Tue 10.02.15	Tue 10.02.15		8.1.5
37	Presentation		100%	Wed 11.02.15	Wed 11.02.15		8.1.6
76	**Documentation and meetings**		**50%**	**Mon 29.12.14**	**Tue 19.05.15**	100	**11**
77	Reports		50%	Mon 29.12.14	Tue 19.05.15		11.1
78	Document controlling		50%	Mon 29.12.14	Tue 19.05.15		11.2
79	Meetings		50%	Mon 29.12.14	Mon 29.12.14	80	11.3

Figure 4: Respective activities

Emphasis on the website is large early on, but attention to this task decreases because only regular updates in the iterative periods is necessary.

3.2 Design

The major part of the project will revolve around the design phase. This is a natural focus because of the main goal of our process, to develop a functional design of the automatic oil filling station. Activity 5 and 7 initiates, whereas number 5 is the main activity that will get the most attention throughout this phase. The concept documents and design documents are written during this phase, though not finalized until we reach the end of the verification phase.

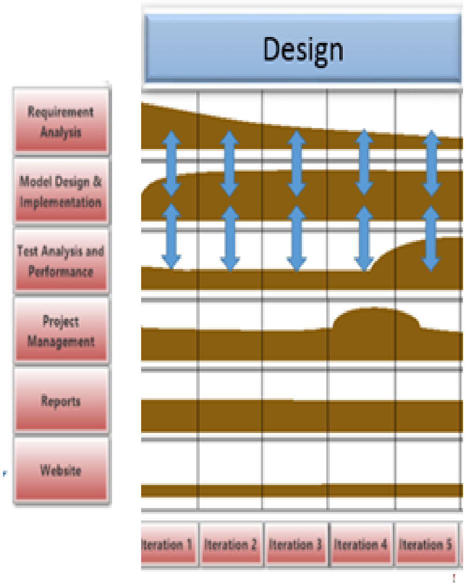

Figure 5: Design

	Name	Task Mode	%	Start	Finish	Designated hours	Activity number
17	**Design**		**50%**	**Mon 16.02.15**	**Mon 18.05.15**		**5**
18	**Conceptual phase**		**50%**	**Mon 16.02.15**	**Wed 18.03.15**	**315**	**5.1**
19	Concept design		50%	Mon 16.02.15	Mon 16.03.15		5.1.1
20	Research		50%	Mon 16.02.15	Mon 16.03.15		5.1.2
21	Concept selection		0%	Mon 16.03.15	Wed 18.03.15		5.1.3
22	**Detailed design**		**0%**	**Thu 19.03.15**	**Tue 05.05.15**	**400**	**5.2**
23	Preliminary design		0%	Thu 19.03.15	Thu 19.03.15		5.2.1
24	High level design		0%	Fri 20.03.15	Thu 07.05.15		5.2.2
25	Component investigation		0%	Mon 27.04.15	Thu 07.05.15		5.2.3
26	Component selection		0%	Thu 30.04.15	Tue 05.05.15		5.2.4
27	Final design		0%	Fri 08.05.15	Mon 18.05.15	200	5.3
29	Risk analysis		50%	Mon 16.02.15	Mon 18.05.15	40	7
38	**Presentation 2**		**50%**	**Thu 05.03.15**	**Fri 20.03.15**	100	**8.2**
39	Book rom		50%	Thu 05.03.15	Thu 05.03.15		8.2.1
40	Planning		0%	Mon 16.03.15	Tue 17.03.15		8.2.3
41	Make .ppt		0%	Tue 17.03.15	Thu 19.03.15		8.2.4
42	Hand in		0%	Wed 18.03.15	Wed 18.03.15		8.2.5
43	Rehearsal		0%	Thu 19.03.15	Thu 19.03.15		8.2.6
44	Presentation		0%	Fri 20.03.15	Fri 20.03.15		8.2.7

Figure 6: Respective activities

Because we estimate a lot of feedback from Precision Subsea after meetings with them, feedback from our presentations and continuous feedback from internal supervisor, we keep monitoring and iterate each previous work throughout the process. If there are any obstacles with the design that are met, earlier work may need to be changed in order to tackle any of these problems. The requirements will be given less and less attention because they are more fixed and clear later in the design phase. By the end of the phase, test procedures for our design prototype or Solid Work model will be constructed. Another thorough review of the project plan will be made in order to see that everything goes according to plan and prepare for any possible deviations that we predict may occur.

We divide the phase into five different iterations, with a different plan for iterative work for each period. The iterative work we do on the requirements, testing and design will be closely related. Any problems that occurs in either of the sections will be analyzed and related problems that may occur because of this in the other sections are checked.

	Name	Task Mode	%	Start	Finish	Designated hours	Activity number	Milestone	Responsibility
54	**Iterations**		**50%**	**Mon 16.02.15**	**Tue 19.05.15**		**10**	**No**	**Marius**
55	**Iteration 1**		**100%**	**Mon 16.02.15**	**Sun 01.03.15**		**10.1**	**No**	
56	Plan		100%	Mon 16.02.15	Mon 16.02.15	2.5	10.1.1	No	
57	Report		100%	Mon 02.03.15	Mon 02.03.15	2.5	10.1.2	No	
58	**Iteration 2**		**50%**	**Mon 02.03.15**	**Sun 15.03.15**		**10.2**	**No**	
59	Plan		50%	Mon 02.03.15	Mon 02.03.15	2.5	10.2.1	No	
60	Report			Mon 16.03.15	Mon 16.03.15	2.5	10.2.2	No	
61	**Iteration 3**		**0%**	**Mon 16.03.15**	**Sun 29.03.15**		**10.3**	**No**	
62	Plan			Mon 16.03.15	Mon 16.03.15	2.5	10.3.1	No	
63	Report			Mon 30.03.15	Mon 30.03.15	2.5	10.3.2	No	
64	**Iteration 4**		**0%**	**Mon 30.03.15**	**Sun 12.04.15**		**10.4**	**No**	
65	Plan			Mon 30.03.15	Mon 30.03.15	2.5	10.4.1	No	
66	Report			Mon 13.04.15	Mon 13.04.15	2.5	10.4.2	No	
67	**Iteration 5**		**0%**	**Mon 13.04.15**	**Sun 26.04.15**		**10.5**	**No**	
68	Plan			Mon 13.04.15	Mon 13.04.15	2.5	10.5.1	No	
69	Report			Mon 27.04.15	Mon 27.04.15	2.5	10.5.2	No	
70	**Iteration 6**		**0%**	**Mon 27.04.15**	**Sun 10.05.15**		**10.6**	**No**	
71	Plan			Mon 27.04.15	Mon 27.04.15	2.5	10.6.1	No	
72	Report			Mon 11.05.15	Mon 11.05.15	2.5	10.6.2	No	
73	**Iteration 7**		**0%**	**Mon 11.05.15**	**Mon 18.05.15**		**10.7**	**No**	
74	Plan			Mon 11.05.15	Mon 11.05.15	1	10.7.1	No	
75	Report			Mon 18.05.15	Mon 18.05.15	1	10.7.2	No	

Figure 7: Iterative activities

About one third into this phase we will hold our second presentation. We estimated that all the work up until the second presentation is approximately 50 - 60 % of the total project.

3.3 Verification

The final phase of our project is the verification part. We do not anticipate any particular work necessary on the requirements. The attention to the design and implementation of components will decrease. Very much focus will be kept on testing the design made and checking how the performance of the system is related to what Precision Subsea wish for. Near the final hand in of all the documents, during activity 9, we will scrutinize the work done and make sure everything is in total agreement to the plan and our considerations.

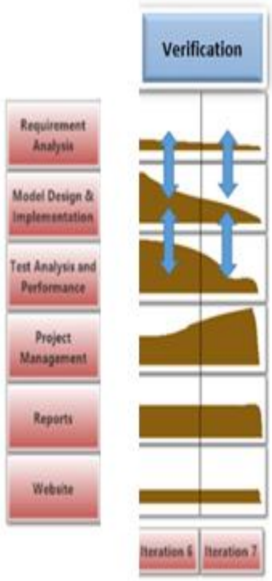

Figure 8: Verification

	Name	Task Mode	%	Start	Finish	Designated hours	Activity number
51	**Final documentation**		**0%**	**Fri 15.05.15**	**Tue 19.05.15**	**50**	**9**
52	Review and alterations		0%	Fri 15.05.15	Mon 18.05.15		9.1
53	Hand in		0%	Tue 19.05.15	Tue 19.05.15		9.2

Figure 9: Respective activities

	Name	Task Mode	%	Start	Finish	Designated hours	Activity number
70	**Iteration 6**		**0%**	**Mon 27.04.15**	**Sun 10.05.15**		**10.6**
71	Plan			Mon 27.04.15	Mon 27.04.15	2.5	10.6.1
72	Report			Mon 11.05.15	Mon 11.05.15	2.5	10.6.2
73	**Iteration 7**		**0%**	**Mon 11.05.15**	**Mon 18.05.15**		**10.7**
74	Plan			Mon 11.05.15	Mon 11.05.15	1	10.7.1
75	Report			Mon 18.05.15	Mon 18.05.15	1	10.7.2

Figure 10: Iterative activities

The phase is divided into two iterative periods that will emphasis testing and project management. If there is any other necessary considerations made, we will plan them in the respective iteration plans and execute a solution.

3.4 Final project phase

We conclude our work with aid from the model at Tuesday 19.05 because no more documentation of our work is necessary. The only remaining part will be to hold the third and final presentation.

	Name	Task Mode	%	Start	Finish	Designated hours	Activity number	Milestone	Responsibility
45	**Presentation 3**		**0%**	**Mon 11.05.15**	**Wed 03.06.15**	100	**8.3**	**Yes**	
46	Book rom		0%	Mon 11.05.15	Mon 11.05.15		8.3.1	No	Marius
47	Planning		0%	Wed 20.05.15	Sun 24.05.15		8.3.2	No	
48	Make .ppt		0%	Mon 25.05.15	Tue 02.06.15		8.3.3	No	Henning
49	Rehearsal		0%	Mon 01.06.15	Tue 02.06.15		8.3.4	No	
50	Presentation		0%	Wed 03.06.15	Wed 03.06.15		8.3.5	Yes	

Figure 11: Final presentation, estimated schedule

The necessary work directly related to this presentation, which includes planning, constructing the PowerPoint and rehearsal will be done without any help from the project model.

Activity 10.1, Iteration plan

Date of iteration: 16.02.2015 – 01.03.2015.

Context

This document presents the plan for the first iteration period. It will run simultaneously as the conceptual phase where we do research and make concept designs. Iteration objectives are reviewed in context with the current main activity and changes implemented will be reflected in progress during this activity.

Objectives

Based on the feedback received after presentation 1 we have some issues that needs to be iterated.

- Project model and GANTT diagram was not properly planned. A review and change is necessary. The integration of the project model needs to improve so that it is clear that it is an aid, not an obstacle. It must reflect our true work process.
- The GANTT diagram must corroborate with the project model and needs a rework.
- A review of the requirements document is necessary based on feedback from Precision Subsea.
- The requirement document changes must be reflected in the test document. In addition.
- Test case procedures needs changes to satisfy test procedure criteria.

Iteration schedule breakdown

Activity	Start Date	End Date	Duration (days)	Assigned to
2	16.02	01.03	14	Marius
2.1	16.02	22.02	7	Marius
2.2	23.02	01.03	7	Marius
3	16.02	22.02	7	Eirik & Henning
4	16.02	18.02	3	Eirik & Henning
4.	19.02	20.02	2	Eirik & Henning

Milestones

1. Finish a new project model design
2. Redesign the GANTT diagram
3. Make sure requirements are according to SMART criteria and satisfies feedback input.
4. Make sure the test plan changes according to requirement changes.
5. Fix all test case procedures.

Other considerations

Any problems or other concerns discovered during this iteration will not be included during this round. The iteration report will document every event, and include a summary of work done during this iteration. A new plan for the next iteration period is constructed with help from this report and other considerations that may be necessary after the two week iteration period.

Activity 10.1, Iteration report

Report purpose

This report is written in order to summarize what has been done through the iteration that lasted from 16.02 – 01.03. It will include all necessary topics that will aid the group with further progression and the plan of the next iteration.

Objective status

Objective	**Status**
Review and change Project model	Project plan document is divided into two parts. Part two only concerns the development and usage of the project model.
Review and change GANTT diagram	GANTT diagram reflects the project model and includes iterative periods as well.
Change requirement documentation according to feedback from Precision Subsea.	Requirement feedback concerning pressure testing and tank containment systems are changed accordingly.
Adjust test document according to changes in requirement documents.	Test document include correct pressure sensitivity and tank containment vacuum test.
Fix all test case procedures so they satisfy the necessary criteria’s.	Every test case procedure are now following the same template and satisfy the necessary criteria’s for a valid test.

Adherence to plan

Objective	Due date	Finish date	Status
Project model fix	01.03	27.02	Complete
GANTT diagram fix	01.03	24.02	Complete
Requirement fix	01.03	17.02	Complete
Test fix	01.03	17.02	Complete
Test case procedure fix	01.03	17.02	Complete

Problems and lessons learned

Using the project model as an aid, not an obstacle and implementing a functional project model into our project is essential for future work. Further iterations must be largely based on directions from the project model, which is also true for other subjects in general. More focus on this must be kept throughout the project.

Suggested changes

No specific changes are currently necessary after the alterations performed during this iteration. Further work should be based on the project model.

Risk assessment

Risk	Mitigation strategy	Contingency plan
Not incorporating presentation 1 feedback into presentation 2.	Follow the current plan which has been altered based on the feedback given.	Present a properly functional and reasonable project model and include more pictures.

Future directions

Follow the current plan which is projected through the project model. Also produce a new iteration plan for the next iteration period which is from 02.03 – 15.03.

Activity 10.2, Iteration plan

Date of iteration: 02.03.2014 – 15.03.2014.

Context

This document presents the plan for the second iteration period. It will run simultaneously as the conceptual phase and finish the day before presentation 2 planning begins. Iteration objectives are reviewed and worked on in context with the current main activity and changes implemented will be reflected in progress during this activity.

Objectives

Based on the report made of the first iteration and current status in the project we will work through these objectives during the iteration:

- Review the requirement specification in context with the concepts made. If there are any requirements that seems to be difficult to manage, identify these requirements.
- Consider possible testing issues with the concepts developed, make sure that it is possible to properly test the outcome of the conceptual designs. Concepts chosen must include factors that are possible to verify and integrate.
- Alter test procedures if it is necessary in order to fulfill testing possibilities of concepts chosen.
- Follow the project plan and review work done during this period in context with project model.
- Make sure website is updated designed according to specifications.

Iteration schedule breakdown

Activity	Start Date	End Date	Duration (days)	Assigned to
2	02.03	15.03	14	Marius
3	02.03	15.03	14	Knut Ola
4	02.03	15.03	14	Henning
6	09.03	15.03	7	Eirik

Milestones

1. Identify problems with requirements in context to concepts chosen.
2. Identify problems with testing the concepts chosen.
3. Identify problems with test case procedures and concepts chosen.
4. Review project plan and make sure work done is according to the plan and model.
5. Update website.

Other considerations

Any problems or other concerns discovered during this iteration will not be included during this round. The iteration report will document every event, and include a summary of work done during this iteration. A new plan for the next iteration period is constructed with help from this report and other considerations that may be necessary after the two week iteration period.

This iteration will revolve mainly about identification of specific problems. If any problems mentioned in the milestones are identified we will assess these problems in the next iterative period.

We still have not received a website address from school and are currently using our own website domain. All the work done on this website must be transferred to the site given to us by the school. This will be done during another iterative period.

Activity 10.2, Iteration report

Report purpose

This report is written in order to summarize what has been done through the iteration that lasted from 02.03 – 15.03. It will include all necessary topics that will aid the group with further progression and the plan of the next iteration.

Objective status

Objective	Status
Review requirement specifications in context with concepts made. Identify problematic requirements.	No requirement conflicts with concepts made. No identifications of any requirements that need alteration is necessary.
Consider testing issues with concepts made. Concepts must be able to follow the testing procedures and criteria's.	All concepts are following test case procedures and criteria's.
Change test procedures if concepts made are unable to fit procedure,	No changes to test procedures were necessary.
Review work done during this period in context with the project model and project plan.	Project is currently in agreement with plan and model.
Update website with necessary information.	Website is updated with the latest status on project.

Adherence to plan

Objective	Due date	Finish date	Status
Requirement identification	02.03	15.03	Complete
Test procedure review	02.03	15.03	Complete
Project plan review	02.03	15.03	Complete
Website update	09.03	15.03	Complete

Problems and lessons learned

The meeting we had with Precision Subsea on Wednesday 04 March narrowed down the amount of concepts we needed to produce for each module. Numerous modules only have one viable conceptual solution. The solution chosen will be based on the original solution with implementation of the necessary new requirements. We could deviate some from the height requirement, but will adhere to it as much as possible. Next iteration round have to include a thorough check of the requirements related to the design information we received at the meeting.

Suggested changes

No specific changes are currently found to be necessary. Everything is going according to plan.

Risk assessment

Risk	**Mitigation strategy**	**Contingency plan**
Not incorporating presentation 1 feedback into presentation 2.	Follow the current plan which has been altered based on the feedback given.	Present a properly functional and reasonable project model and include more pictures.
Not considering input from Precision Subsea meeting with regards to our concepts and further design.	Make sure all information is thoroughly assessed and incorporated into every related concept that will be chosen at the end of iteration 2 period.	Construct a design that integrates every necessary input and requirement from PS, which includes old and new inputs.

Future directions

Follow the current plan that is projected through the project model. Also, produce a new iteration plan for the next iteration period, which is from 16.03 – 29.03.

Activity 10.3, Iteration plan

Date of iteration: 16.03.2015 – 29.03.2015.

Context

This document presents the plan for the third iteration period. It will run simultaneously as the presentation 2 planning, preparing and execution. It will also run one week into the design period. Iteration objectives are reviewed and worked on in context with the current main activity and changes implemented will be reflected in progress during this activity.

Objectives

Based on the report made of the second iteration and current status in the project we will work through these objectives during the iteration:

- Review the requirement specification in context with the feedback from Precision Subsea received at the meeting Wednesday 04.03. Alter the requirement documentation if necessary.
- Review test document in context with possible requirement changes.
- Follow the project plan and review work done during this period in context with project model.
- Make sure the website is up to date according to specifications.
- Review feedback received after presentation 2 and plan possible changes related to this that will be performed during iteration 3.

Iteration schedule breakdown

Activity	Start Date	End Date	Duration (days)	Assigned to
2	16.03	29.03	14	Marius
3	16.03	22.03	7	Knut Ola
4	23.03	29.03	7	Henning
6	23.03	29.03	7	Eirik

Milestones

1. Update requirement information related to feedback from Precision Subsea meeting.
2. Update test specifications in accordance to changes done with requirements.
3. Incorporate feedback from presentation 2 into iteration 3 plan.
4. Review project plan and make sure work done is according to the plan and model.
5. Update website.

Other considerations

Any problems or other concerns discovered during this iteration will not be included during this round. The iteration report will document every event, and include a summary of work done during this iteration. A new plan for the next iteration period is constructed with help from this report and other considerations that may be necessary after the two week iteration period.

Requirement updates and test changes must be performed before handing in necessary documents two days before presentation 2, which is Friday 20 March.

We still have not received a website address from school and are currently using our own website domain. All the work done on this website must be transferred to the site given to us by the school. This will be done during another iterative period.

Activity 10.3, Iteration report

Report purpose

This report is written in order to summarize what has been done through the iteration that lasted from 16.03 – 29.03. It will include all necessary topics that will aid the group with further progression and the plan of the next iteration.

Objective status

Objective	Status
Review requirement specifications in context with PS meeting. Alter document if necessary.	No requirement conflicts with concepts. Inputs to more detailed requirement knowledge received.
Review test document in context with possible requirement changes.	All concepts are following test case procedures and criteria's.
Review work done during this period in context with the project model and project plan.	Project is currently in agreement with plan and model.
Update website with necessary information.	Website is updated with the latest status on project.
Review feedback received after presentation 2 and plan possible changes related to this that will be performed during iteration 3.	A 3D model, part list and flow chart is crucial to PS. Documentation is satisfactory.

-

Adherence to plan

Objective	Due date	Finish date	Status
Requirement identification	16.03	22.03	Complete
Test procedure review	23.03	29.03	Complete
Project plan review	16.03	29.03	Complete

Website update	23.03	29.03	Complete

Problems and lessons learned

After the second presentation, we received numerous feedbacks regarding important elements we must emphasize. Precision Subsea requires a properly constructed 3D model and weekly updates of project status. Improved communication is necessary to satisfy the customer. They also requested that we rehearse the final presentation at their location. Our current documentation is quite a lot, but as long as it is relevant and organized it is OK.

Suggested changes

Improved communication and more focus on 3D modeling.

Risk assessment

Risk	**Mitigation strategy**	**Contingency plan**
Not improving the communication with Precision Subsea.	Keep Precision Subsea continuously updated on our progress.	Call or have a meeting with Precision Subsea at least one time a week.
Produce documents that are not relevant or organized.	Make sure only to produce the necessary documents and keep them organized.	Review and check all documentation and check relevancy.

Future directions

Follow the current plan that is projected through the project model. Also, produce a new iteration plan for the next iteration period, which is from 30.03 – 12.04.

Activity 10.4, Iteration plan

Date of iteration: 30.03.2015 – 12.04.2015.

Context

This document presents the plan for the fourth iteration period. It will run simultaneously as the detailed design process. Iteration objectives are reviewed and worked on in context with the current main activity and changes implemented will be reflected in progress during this activity.

Objectives

Based on the report made of the third iteration and current status in the project we will work through these objectives during the iteration:

- Each member works on a separate sub-system.
- Maintain weekly communication with Precision Subsea.

Iteration schedule breakdown

Activity	Start Date	End Date	Duration (days)	Assigned to
2	30.03	12.04	5	Marius
3	30.03	12.04	5	Knut Ola
4	30.03	12.04	5	Henning
6	30.03	12.04	5	Eirik

Milestones

1. Review requirements in accordance to design progress.
2. Update test specifications in accordance to changes done with requirements.
3. Keep Precision Subsea updated on progress.
4. Review project plan and make sure work done is according to the plan and model.
5. Update website.

Other considerations

Any problems or other concerns discovered during this iteration will not be included during this round. The iteration report will document every event, and include a summary of work done during this iteration. A new plan for the next iteration period is constructed with help from this report and other considerations that may be necessary after the two week iteration period.

We still have not received a website address from school and are currently using our own website domain. All the work done on this website must be transferred to the site given to us by the school. This will be done during another iterative period.

The group will take an Easter brake from 02.04 and rehearse to an exam 10.04. No work on the project will be performed during this period.

Activity 10.4, Iteration report

Report purpose

This report is written in order to summarize what has been done through the iteration that lasted from 30.03 – 12.04. It will include all necessary topics that will aid the group with further progression and the plan of the next iteration.

Objective status

Objective	**Status**
Each member works on a separate sub-system.	Progress on all sub-systems is made, but continuous work must be done.
Maintain weekly communication with Precision Subsea.	Communication is sustained, but no contact was made between Easter and the exam as agreed with Precision Subsea.

Adherence to plan

Objective	**Due date**	**Finish date**	**Status**
Requirement identification	30.03	12.04	Complete
Test procedure review	30.03	12.04	Complete
Project plan review	30.03	12.04	Complete
Website update	30.03	12.04	Complete

Problems and lessons learned

Currently no problems have occurred. Between the vacation and the exam no work was performed so not much progress has been made.

Suggested changes

No changes or alterations are necessary.

Risk assessment

Risk	Mitigation strategy	Contingency plan
Group members not working on their sub-system.	Maintain internal communication and report progress.	Every member must continuously post their work on Google drive.

Future directions

Follow the current plan that is projected through the project model. Also, produce a new iteration plan for the next iteration period, which is from 13.03 – 26.04.

Activity 10.5, Iteration plan

Date of iteration: 13.04.2015 – 26.04.2015.

Context

This document presents the plan for the fifth iteration period. It will run simultaneously as the detailed design process, more specifically the high level design and component investigation. Iteration objectives are reviewed and worked on in context with the current main activity and changes implemented will be reflected in progress during this activity.

Objectives

Based on the report made of the fourth iteration and current status in the project we will work through these objectives during the iteration:

- Each member finishes the design on their separate sub-systems.
- Review and iterate progress on previous design while progressing with new design.
- Review component list and make sure component list is updated.
- Maintain weekly communication with Precision Subsea.

Iteration schedule breakdown

Activity	Start Date	End Date	Duration (days)	Assigned to
2	13.04	26.04	14	Marius
3	13.04	26.04	14	Knut Ola
4	13.04	26.04	14	Henning
5	13.04	26.04	14	All members
6	13.04	26.04	14	Eirik

Milestones

1. Review requirements in accordance to design progress.
2. Review project plan and make sure work done is according to the plan and model.
3. Update test specifications in accordance to changes done with requirements.

4. Monitor progress of design and components.
5. Keep Precision Subsea updated on progress.
6. Update website.

Other considerations

Any problems or other concerns discovered during this iteration will not be included during this round. The iteration report will document every event, and include a summary of work done during this iteration. A new plan for the next iteration period is constructed with help from this report and other considerations that may be necessary after the two week iteration period.

We still have not received a website address from school and are currently using our own website domain. All the work done on this website must be transferred to the site given to us by the school. This will be done during another iterative period.

Activity 10.5, Iteration report

Report purpose

This report is written in order to summarize what has been done through the iteration that lasted from 13.04 – 26.04. It will include all necessary topics that will aid the group with further progression and the plan of the next iteration.

Objective status

Objective	**Status**
Each member finishes the design on their separate sub-systems.	Introductory design is finished on all sub-systems except vacuum and filling and pressurizing.
Review and iterate progress on previous design while progressing with new design.	Sub-system design that is finished will be checked in accordance to the other sub-system designs.
Review component list and make sure component list is updated.	No coherent component list is currently made, design process has been the main emphasis.
Maintain weekly communication with Precision Subsea.	Weekly communication is maintained.

Adherence to plan

Objective	**Due date**	**Finish date**	**Status**
Requirement review	13.04	26.04	Complete
Test procedure review	13.04	26.04	Complete
Project plan review	13.04	26.04	Complete
Design and component	13.04	26.04	Complete
Website update	13.04	26.04	Complete

Problems and lessons learned

Integrating the different sub-systems will be more difficult than anticipated. Finding suppliers for the different required components will also be more difficult than first anticipated.

Suggested changes

Coordinate more and increase communication with Øystein Tørre from Precision Subsea in order to find suppliers. Also allocate more time into finding appropriate components than first considered.

Risk assessment

Risk	**Mitigation strategy**	**Contingency plan**
Not finding proper components for the system.	Begin as early as possible to find necessary components.	Continuously work on keeping the design up to date with required components.

Future directions

Follow the current plan that is projected through the project model. Also, produce a new iteration plan for the next iteration period, which is from 27.04– 10.05.

Activity 10.6, Iteration plan

Date of iteration: 27.04.2015 – 10.05.2015.

Context

This document presents the plan for the sixth iteration period. It will run simultaneously as the detailed design process, more specifically the high level design and component investigation. Iteration objectives are reviewed and worked on in context with the current main activity and changes implemented will be reflected in progress during this activity. It is the last full iteration period of this project (2 weeks).

Objectives

Based on the report made of the fifth iteration and current status in the project we will work through these objectives during the iteration:

- Focus on integrating the different sub-systems.
- Review and iterate progress on previous design while progressing with new design.
- Focus on component list and check if the necessary parts are available as soon as the design is made for it.
- Maintain weekly communication with Precision Subsea.

Iteration schedule breakdown

Activity	Start Date	End Date	Duration (days)	Assigned to
2	27.04	10.04	14	Marius
3	27.04	10.04	14	Knut Ola
4	27.04	10.04	14	Henning
5	27.04	10.04	14	All members
6	27.04	10.04	14	Eirik

Milestones

No change in milestones from last iteration periods milestones.

1. Review requirements in accordance to design progress.
2. Review project plan and make sure work done is according to the plan and model.
3. Update test specifications in accordance to changes done with requirements.
4. Monitor progress of design and components.
5. Keep Precision Subsea updated on progress.
6. Update website.

Other considerations

Any problems or other concerns discovered during this iteration will not be included during this round. The iteration report will document every event, and include a summary of work done during this iteration. A new plan for the next iteration period is constructed with help from this report and other considerations that may be necessary after the two week iteration period.

We still have not received a website address from school and are currently using our own website domain. All the work done on this website must be transferred to the site given to us by the school. This will be done during another iterative period.

Focus component investigation is vital. Many components are very difficult to find and/or receive a proper offer.

Activity 10.6, Iteration report

Report purpose

This report is written in order to summarize what has been done through the iteration that lasted from 27.04 – 10.05. It will include all necessary topics that will aid the group with further progression and the plan of the next iteration.

Objective status

Objective	Status
Integrate the different sub-systems.	Sub-systems are integrated by design, but the integration needs more components.
Review and iterate progress on previous design while progressing with new design.	Design is currently approved by Øystein Tørre at Precision Subsea. Some inputs have been made and are implemented.
Review component list and make sure component list is updated.	Part list for every component found has been made and organized.
Maintain weekly communication with Precision Subsea.	Weekly communication is maintained.

Adherence to plan

Objective	Due date	Finish date	Status
Requirement review	27.04	10.05	Complete
Test procedure review	27.04	10.05	Complete
Project plan review	27.04	10.05	Complete
Design and component	27.04	10.05	Complete
Website update	27.04	10.05	Complete

Problems and lessons learned

No specific problems have occurred, but documentation and finding suppliers to the system is more strenuous and difficult than first considered.

Suggested changes

Increase workload the last week. Put in more man-hours than first planned.

Risk assessment

Risk	**Mitigation strategy**	**Contingency plan**
Not completing the project on time.	Increase workload.	Make sure that enough hours are put into the work so that everything is completed within the deadline.

Future directions

Follow the current plan that is projected through the project model, except increase work hours. Also, produce a final iteration plan for the last iteration period, which is from 11.05–18.05.

Activity 10.7, Iteration plan

Date of iteration: 11.05.2015 – 18.05.2015.

Context

This document presents the plan for the seventh iteration period. It will run simultaneously as the final design process. Iteration objectives are reviewed and worked on in context with the current main activity and changes implemented will be reflected in progress during this activity. This will be the final iteration of the project.

Objectives

Based on the report made of the sixth iteration and status of the project we will work through these objectives during the iteration:

- Review and control all documents.
- Review and make sure final design is according to plan.
- Finish and review the part lists.
- Confirm projects design in accordance to feedback from meeting with Precision Subsea Thursday 14.05.
- Complete the website and confirm it according to any changes made.

Iteration schedule breakdown

Activity	Start Date	End Date	Duration (days)	Assigned to
2	11.05	18.05	7	Marius
3	11.05	18.05	7	Knut Ola
4	11.05	18.05	7	Henning
5	11.05	18.05	7	All members
6	11.05	18.05	7	Eirik

Milestones

Complete all project activities and hand in project work at Tuesday 19.05.

Other considerations

This is the final iterative period before project is finished. All work must be finished and problems that occur must be assessed as they are arise during this period.

Activity 10.7, Iteration report

Report purpose

This report summarizes what work has been done during the final iteration that lasted from 11.05 – 18.05.

Objective status

Objective	Status
Review and control all documents.	Sub-systems are integrated by design, but the integration needs more components.
Review and make sure final design is according to plan.	Design is currently approved by Øystein Tørre at Precision Subsea. Some inputs have been made and are implemented.
Finish and review the part lists.	Part list for every component found has been made and organized.
Confirm projects design in accordance to feedback from meeting with Precision Subsea Thursday 14.05.	Weekly communication is maintained.
Complete the website and review that it is according to any changes made.	

Adherence to plan

Objective	Due date	Finish date	Status
Requirement review	27.04	10.05	Complete
Test procedure review	27.04	10.05	Complete
Project plan review	27.04	10.05	Complete
Design and component	27.04	10.05	Complete
Website update	27.04	10.05	Complete

Problems and lessons learned

No specific problems have occurred, but documentation and finding suppliers to the system is more strenuous and difficult than first considered.

Suggested changes

Increase workload the last week. Put in more man-hours than first planned.

Risk assessment

Risk	**Mitigation strategy**	**Contingency plan**
Not completing the project on time.	Increase workload.	Make sure that enough hours are put into the work so that everything is completed within the deadline.

Future directions

Follow the current plan that is projected through the project model, except increase work hours. Hand in project on time according to scheduled plan.

Risk Management Plan

Bachelor Assignment spring 2015

Automatic Oil Filling Station

-

Eirik S. Mæhre **Marius Martinsen**
Knut Ola Nymoen **Henning Henriksen**

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1.0 Introduction

1.1 Purpose

This risk management plan is developed to identify, assess and monitor all potential risks associated with our project. All risks are analyzed by a qualitative risk matrix, and rated by likelihood and consequence. This approach is implemented as a tool to help us grade and categorize risks. Consistently use of this matrix makes it more evident to see which risks that need extensive monitoring and increased focus.

The risk management plan does not only define risks associated with the system processes, such as requirements and design, but it also emphasizes other internal and non-technical factors. All of the risks are categorized in different sections, depending on the type of risk. These risks are put into a comprehensive risk register that proposes a control and risk mitigation strategy for each respective risk.

1.2 Project rules and regulations

The project plan gives a thorough description of our project rules and regulations. This acts as an aid to control and reduce internal- and external risks.

2.0 Risk Management Procedure

2.1 Risk Identification

The purpose of the risk identification is to determine possible undesirable events or situations that could occur during the process. We classify all events that may obstruct our progress as a potential risk. We have to identify these risks in order to manage them properly. A prepared risk procedure will also make it possible to have a strategy on how to handle risks if we are unable to avoid them.

The identification of our project risks are most of all a result of collaborative group brainstorming and critical thinking, under influence by internal supervisor and Precision Subsea. Because some risks are rather obvious, we can easily identify them early in the project life cycle. These risks are often possible to identify by previous project experience and sensible thinking.
Other risks are a result of continuously iterative processes, and are based on different inputs and sources.

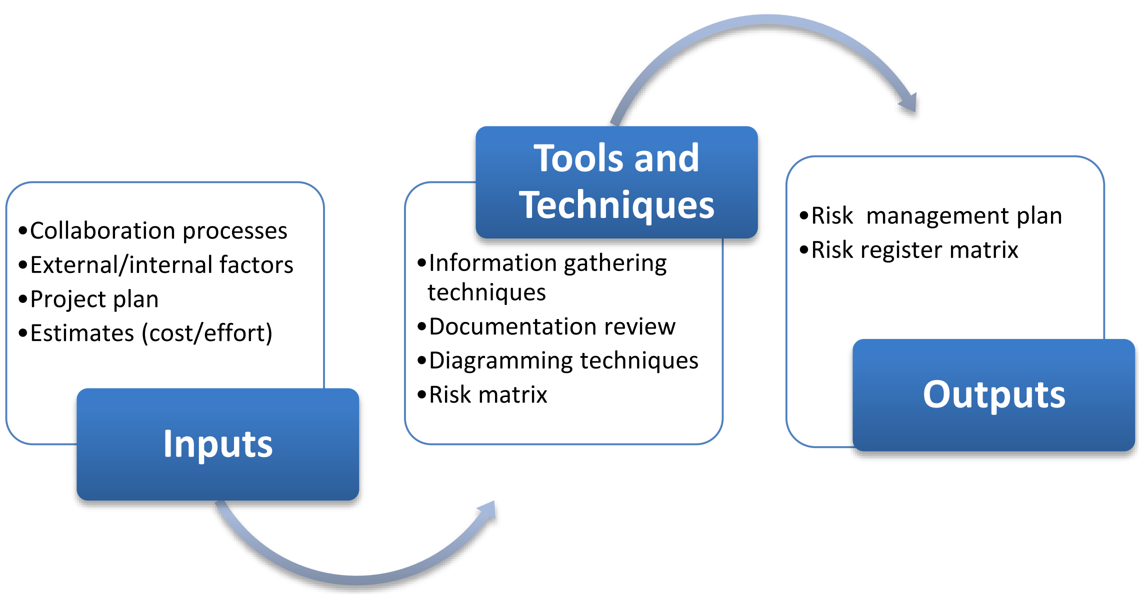

Figure 1: Risk Identification process.

2.2 Risk Analysis

The risk analysis is a crucial part of the preparation of a final risk register. The analysis method is used to systematically measure, categorize and analyze all the risks identified. This makes it possible to grade and prioritize our risks in different levels. Based on how large the consequences (Fig 3) will be for our project, and the likelihood (Fig 2) of the event to occur. A risk-level reading is possible from the matrix, by using these two inputs.

Likelihood (What's the chance the of the risk occurring?)	Consequence (How severe could the outcomes be if the risk event occurred?) 1 Insignificant	2 Minor	3 Significant	4 Major	5 Severe
5 Almost Certain	5 Medium	10 High	15 Very high	20 Extreme	25 Extreme
4 Likely	4 Medium	8 Medium	12 High	16 Very high	20 Extreme
3 Moderate	3 Low	6 Medium	9 Medium	12 High	15 Very high
2 Unlikely	2 Very low	4 Low	6 Medium	8 Medium	10 High
1 Rare	1 Very low	2 Very low	3 Low	4 Medium	5 Medium

Figure 2: Risk Matrix (www.nma.gov.au)

The matrix categorizes the risks from being very low to extreme. The outcome of the risk matrix decides how comprehensive the monitoring, tracking and mitigations strategy will be. Risks in the yellow and red zone need extra attention, green zone may need extra attention and light blue/blue zone may be accepted. In order to track each risk the blocks are numbered.

The risk probability table is the basis for our assumptions on risk probability.

Likelihood	**Probability in %** (that risk will occur)	**Detailed Description**
Almost Certain	76-100 %	Risk has a high likelihood of occurring, even if a mitigation strategy is implemented
Likely	51-75 %	Risk has a high likely hood of occurring
Moderate	26-50 %	Risk has a moderate likelihood of occurring
Unlikely	11-25 %	Risk is considered unlikely to occur
Rare	0-10 %	Risk will only occur in rare circumstances

Figure 3: Risk probability table.

The risk consequences are rated from insignificant to major/extreme:

Insignificant → Minimal or no impact on the project.

Minor → Immaterial reductions to system performance, able to meet milestones and budget.

Significant → Project schedule is affected, significant reduction in system performance, budget is affected.

Major/Extreme → Cannot meet milestones, major impact on system performance and budget.

We tackle the risks using these strategic movements depending on the risk-level:

Accept → No approach is necessary. (Very low – Low risks)

Avoid → Eliminate the threat. (Extreme risks should be avoided)

Mitigate → A strategy on how to reduce the risk impact and the probability of it occurring (Medium /High /Very high- risks)

Transfer → "Outsource" or share the risk and make someone else responsible. E.g. Insurance.

3.0 Risk Types

The different risk types are divided into four main categories. This chapter will give a brief overview over the different risks associated with our project. All risks have their own unique risk number, so they can be traceable. The risk numbers refers to an extensive risk register in Chapter 4.0. The risk categories are project scope risks, technical risks, internal risks and external risks.

3.1 Project Scope Risks

Risk number	**Description**
R-1.0	Delays (deviations from time schedule)
R-2.0	Unable to meet customer requirements
R-3.0	Exceeding budget

3.2 Technical Risks

Risk number	**Description**
R-4.0	Lack of technical resources
R-5.0	Quality issues
R-6.0	Loss of crucial documents due to computer related problems

3.3 Internal Risks

Risk number	Description
R-7.0	Poor communication internally in group
R-8.0	Poor communication with internal Supervisor
R-9.0	Short lasting sickness /absence from group work
R-10.0	Long lasting sickness /absence from group work
R-11.0	Lack of experience and technical knowledge
R-12.0	Major disagreements

3.4 External Risks

Risk number	Description
R-13.0	Poor communication with external supervisor/contracting authority
R-14.0	Precision Subsea goes bankrupt
R-15.0	Component delivery issues
R-16.0	Major changes in customer demands

4.0 Risk Register

After working through the risk identification, it is possible to finalize the risk register matrix. This register is our risk reference table. The table will be continuously checked, updated and improved by all project members. Every project member must be familiar with the risk register. We attach the risk register matrix with this document.

Risk register explanation:

Risk Number	The risks unique tracking number
Risk Description	Provides further insight of the unwanted event (what/ and why this is a risk)
Risk Likelihood	Probability of the risk occurring
Risk Measure	Result from risk matrix (fig 3), with additional number rating. Color-coding illustrates the risk zone.
Risk Mitigation strategy/Control Actions	The strategy on how to reduce the risk impact and decrease the probability of the risk to occur.
Stakeholder affected	Identifies parties that the particular risk concerns.

5.0 Attachments

Attachment 1: Risk register matrix

6.0 References

6.1 Literature

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6.2 Figures

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http://www.nma.gov.au/about_us/ips/policies/collection_care_and_preservation_policy.(Fig2&3)

Risk Number/ Type	Risk Description	Stakeholders affected	Risk Likelihood	Risk Consequence	Risk Measure	Risk Mitigation/ Control Actions
R-1.0 **Project Scope Risk**	Deviations from time schedule, resulting in delays that could affect both milestones, quality and project deliverables.	Project group & Precision Subsea.	Likely (51-75%) -Risk has a high likely hood of occurring	Major consequence (in worst case) Depending of the deviation, >1 moth delay would be critical. Project group run the risk of failing.	**Very High (16)** **Mitigation strategy needed.**	Continuously keeping track of the time schedule. Implementing good control routines: Follow-up reports and frequent status meetings.
R-2.0 **Project Scope Risk**	Unable to meet requirements from Precision Subsea. Resulting in unsatisfied contracting authority and a faulty design.	Project group & Precision Subsea.	Moderate (26-50%) Risk has a moderate likelihood of occurring	Significant. Since our project ends at the design phase. Would be more critical if we had to build a complete system.	**Medium (9)** **Mitigation strategy is highly recommended.**	Design and execute a good_procedure for requirement changes. Use an iterative project model that allows changes in requirements.
R-3.0 **Project Scope Risk**	Exceeding initial budget during the design phase. Resulting in increased costs for Precision subsea.	Precision Subsea	Rare (0-10 %). Risk will only occur in rare circumstances.	Significant. Depending on the deviations. < 30%. >30 % would be major.	**Low (4)** **Risk can be accepted.**	The design of the system must correspond to our estimates and total budget. Managed by cost control document.
R-4.0 **Technical Risk**	Lack of technical resources needed to finalize a satisfying result/design.	Project group & Precision Subsea.	Unlikely (11-25 %) Risk is considered unlikely to occur.	Significant.	**Medium (6)** **Mitigation strategy is recommended.**	Get an overview over resources needed as early as possible. Make sure that all necessary resources are available.
R-5.0 **Technical Risk**	Quality issues, resulting in an unsatisfactory design. System unable to meet expected quality standards and requirements.	Project group & Precision Subsea	Moderate (26-50%) Risk has a moderate likelihood of occurring	Significant. If the quality issues lead to a useless final design. Could potentially be a major consequence in a later project phase (after design).	**Medium (9)** **Mitigation strategy is highly recommended.**	Implementing a good routine (e.g. iterative project model) to continuously verify and validate that quality standards & requirements are met.
R-6.0 **Technical Risk**	Loss of crucial documents due to computer related problems. Resulting in major delays and frustration.	Project Group	Rare (0-10 %). Risk will only occur in rare circumstances.	Significant/ major. Depending of the amount of lost documentation. Could affect milestone and project progress.	**Medium (8)** **Mitigation strategy is highly recommended.**	All group members must save all there documents to at least one back-up hard disk.

R-7.0 **Internal Risk**	Poor communication internally in-group. Resulting in inefficient group work, conflicts, delays and disgruntled team members.	Project Group	Likely (51-75%) Risk has a high likely hood of occurring.	Major. Could potentially threaten the whole project progress.	**Very High (16)** **Mitigation strategy needed.**	Project rules and regulations must be implemented and obeyed. All group members must sign a collaboration contract.
R-8.0 **Internal Risk**	Poor communication with internal supervisor. Causing misunderstandings, dissatisfaction and frustration. Could affect overall project progress and results.	Project Group, Internal Supervisor and the university.	Unlikely (11-25 %) Risk is considered unlikely to occur.	Significant. The group could be left without a functional internal supervisor.	**Medium (6)** **Mitigation strategy is recommended**	Implementing a specified routine for communication failure. Should be managed in the project plan. Contact school authorities for assistance as early as possible.
R-9.0 **Internal Risk**	*Short* lasting sickness/ absence from group work. Could affect planed progress and resulting in an unevenly distributed workload.	Project Group.	Almost certain (76-100 %). Risk has a high likelihood of occurring, even with a planned strategy.	Minor. A short absence from the group should not have more than a minor impact on the project progress.	**High (10)** **Mitigation strategy needed.**	Covered by rules and regulations chapter in Project Plan.
R-10.0 **Internal Risk**	*Long* lasting sickness /absence from group work	Project Group.	Unlikely (11-25 %) Risk is considered unlikely to occur.	Major. Could potentially threaten the whole project progress.	**Medium (8)** **Mitigation strategy is highly recommended.**	Covered by rules and regulations chapter in Project Plan. Group must contact supervisor and School authorities to seek advises.
R-11.0 **Internal Risk**	Lack of experience and technical knowledge leading to an unsatisfactory product and progress. Not being able to meet requirements.	Project Group and Precision Subsea.	Unlikely (11-25 %) Risk is considered unlikely to occur. We should have the prerequisites to finalize a successful project.	Significant.	**Medium (6)** **Mitigation strategy is recommended.**	Get an overview over the competence of group members. Distribute work activities with competence in mind. Use internal and external resources (Supervisors/School) and do proper technical research.
R-12.0 **Internal Risk**	Major disagreements /conflicts internally in the project group. Resulting in poor collaboration and highly reduces productivity.	Project Group.	Unlikely (11-25 %) Risk is considered unlikely to occur. Team members have worked together on previous projects.	Major. Could potentially threaten the whole project progress. A worst case scenario could lead to a group break down.	**Medium (8)** **Mitigation strategy is highly recommended.**	Covered by rules and regulations chapter in Project Plan. Group must contact supervisor and School authorities to seek advises.

R-13.0 **External Risk**	Poor communication with external supervisor/ contracting authority. Causing difficulties to meet requirements. Could also affect milestones.	Project Group and Precision Subsea.	Unlikely (11-25 %) Risk is considered unlikely to occur.	Significant. The group could be left without an external supervisor. Or without necessary inputs/ information from supervisor.	**Medium (6)** **Mitigation strategy is recommended.**	Implement strong communication routines with external supervisor. If communication fails, seek advice from internal sensor and school authorities. Plan a clarification meeting with Precision Subsea.
R-14.0 **External Risk**	Precision Subsea goes bankrupt or another major unforeseen event, leading to a project collapse.	Project Group and Precision Subsea.	Rare (0-10 %). Will only occur in special circumstances.	Major. Could potentially threaten the whole project progress.	**Medium (4)** **Risk can be accepted.** **No strategy needed.**	
R-15.0 **External Risk**	Component delivery issues / or issues with external supplier. Affecting milestone achievements and progression.	Project Group and Precision Subsea.	Unlikely (11-25 %) Risk is considered unlikely to occur.	Minor. Since we probably don’t need physical components to finalize a satisfactory design.	**Low (4)** **No strategy needed.**	
R-16.0 **External Risk**	*Major* changes in demands from Precision Subsea. Causing extensive design and project changes. Resulting in an unsatisfactory product.	Project Group and Precision Subsea.	Unlikely (11-25 %) Risk is considered unlikely to occur. It’s not expected severe changes in demands from PS.	Major. Could potentially result in a faulty or useless design.	**Medium (8)** **Mitigation strategy is highly recommended**	Implement an iterative project model that allows changes in requirements/demands. Secure continuously approval of the requirements document. Write a contract that specifies initial product expectations.

Requirement Specification

Bachelor Assignment spring 2015

Automatic Oil Filling Station

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1.0 Product Perspective

Precision Subsea has requested that we design an Automatic Oil Filling Station (AOFS). They are currently using a manual oil filling station and want to automate as much of this system as possible to save costs. The product we have to design must be able to dehumidify the AK350 Wacker silicone oil, run vacuum leak tests and fill jumpers. The system must also pressurize the respective hoses. Additionally it must be capable of draining oil from used subsea jumpers. These tasks must run automatically and independent of each other in order to do simultaneous operations at different jumpers connected to the system.

This document is therefore a collection of requirements related to the product, its functions and the assignment itself. These requirements will be classified into different categories and priorities labeled **A**, **B** or **C**.

A is the highest priority and is a requirement that is essential for the product to function.
B is the intermediate priority and is a requirement that should be implemented for the product to operate.
C is the lowest priority and are non-crucial, accessory requirements.

2.0 General Capabilities

General capabilities of the AOFS:

- Dehumidify Oil → User will select a tank to fill. The automatic process will then start the vacuum pump; oil flow starts and is automatically regulated with opening of a valve. The oil will then flow, while dehumidifying visually, to the selected tank. When the tank is nearly full the system will stop the dehumidifying process, and the remains of the oil in the system will flow to the tank. The system will automatically stop so the tank is not over-filled.
- Leak test → User will select hose connection. Waste tank will be used for the leak test. The automatic process will then start the vacuum pump and the vacuum process will begin. Residual oil will purge from line. After specified interval the system will start logging sequence. A sensor will continuously monitor the pressure and significant pressure differences will trigger a leak warning.
- Fill hose → User will select hose connection. Filling occurs after leak test. The user will check that vacuuming of one end is running. Accept on screen to continue. Then the user will select a prefilled tank, hose type and length. The automatic process will then calculate amount and start filling. Finished after timer and accept button by user after post-filling inspection.
- Drain hose → User will select hose connection. System will depressurize hose, and drain visually to waste tank.
- Pressurization → User will select hose connection. Pressurizing happens after filling. System will start pressurizing the hose. Pressure is hold at a calculated time depending on hose length (pressure is stable). The automatic process will then start monitoring/logging of significant pressure drop (0,1bar/hour). When finished, the user must push button to accept post-pressurization inspection and check points.

3.0 Requirement Specification

Specification of requirements are without the possibility of subjective interpretation.

All requirements are to an extent measurable and have a clear definition. Requirement testing and evaluation have clear neutral conclusions.

4.0 Break down of the systems key requirements

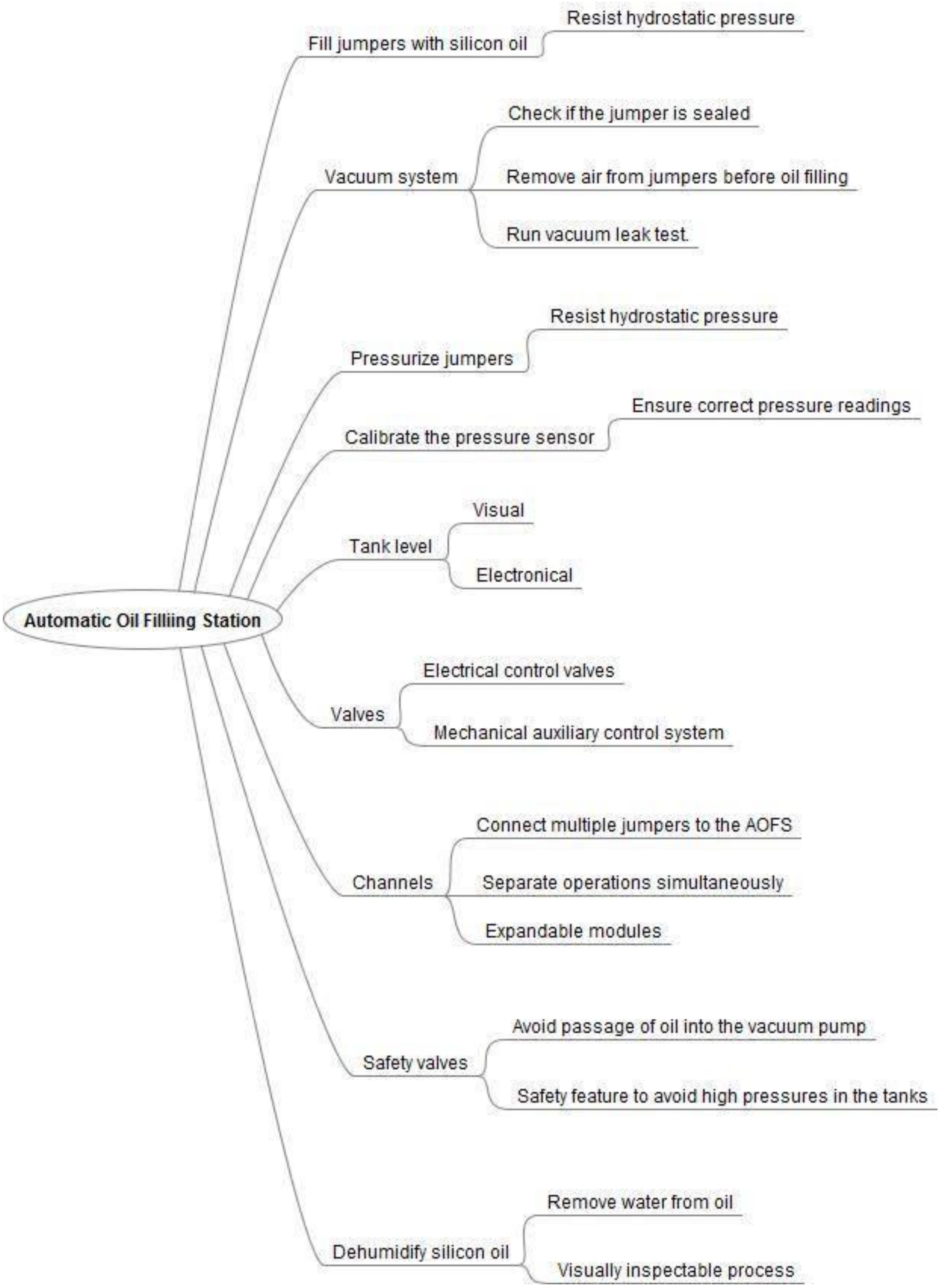

Figure 1: Key system requirements

5.0 General Constrains

Major constrains for the AOFS development:

- Time Schedule → Key constrain because of the limited time available. Our initial assumption is that the development of a complete AOFS probably will require a project schedule that exceeds the project deadline, 19 May 2015. This constrain is closely managed with help of a detailed project plan.

- Cost → The project cost restrictions will be a limitation for the system development. The amount of 300 000 NOK is the imposed restriction set by PS. Exceeding deviations from this amount needs approval from PS.

- Size → The product size is constrained to these limitations. Height of 80 cm, with of 110 cm and length of 250 cm. The system has to fit underneath a specified shelf in the workshop.

- Maintenance → The Product must be easy to maintain and repair. Convenient positioning of components is necessary so that any alteration or repair requires low effort.

6.0 User Characteristics

The technicians at PS are the primary users of the AOFS. This requires that the user interface of the system is practical. This is particularly important since the whole purpose of the system is to increase the efficiency of the process.

The filling station will be in use several times during a week, and a regular filling process could take up to 12 hours, depending on the length of the jumpers. The system should also being able to operate during the night (without the need of supervision).

7.0 Assumptions, Dependencies and Exceptions

We have some assumptions on which the requirements does not depend:

- Power Usage → The System will not use more electrical power that the grid of the facility cannot support.

- User → The user of the product should be familiar with its operation. A thorough and well-explained user manual will be available.

We have exceptions in the product.

- Contamination → The product does not require any filters to clean the oil. The supplied oil has an approved cleanliness level.

8.0 Operational Environment

The operating environment for the AOFS will primarily be on the workshop at PS. This obviously excludes exposure from most of the external impacts on the system (rain, wind, snow etc.).

Proposed location for the AOFS will be underneath a shelf in the PS workshop, hence the specific dimension requirements. This is most likely a permanent location for the system, but the new design of the AOFS will make it possible to move the whole station if necessary.

The AOFS will work independently in its operational environment, with no cooperating or competing systems. The AOFS is a *unique* system that will give PS a major benefit in the market.

9.0 Specific Requirements

To better understand and use requirements it is necessary to divide them in several categories. Implementation of these categories in different processes during the design phases.
We have therefore divided requirements into these groups:

- Functional (what the systems is doing)
- Performance (how well/efficient the system shall act)
- Physical (properties, equipment, dimensions)
- Environmental (storage, interacts with surroundings)
- Resource (usage, consumption by the system)
- Administrative (project tasks, etc.)

9.1 Functional Requirements

1.1 Priority: A Date: 12.01.2015

Requirement: Fill subsea jumpers containing optical fibers or electrical conductors with AK350 Wacker silicone oil at different pressures.

- 0.2 bar for jumpers with optical fibers
- 2 bar for jumpers with electrical conductors.

From: Precision Subsea

1.2.1 Priority: A Date: 12.01.2015

Requirement: Dehumidify AK350 Wacker silicone oil.

From: Precision Subsea

1.2.2

Requirement: Visual inspection of the dehumidifying process.

From: Precision Subsea

1.2.3

Requirement: Dehumidifying oil flow $\geq \mathbf{1}\ \frac{\boldsymbol{liter}}{\boldsymbol{min}}$.

From: Precision Subsea

1.3 Priority: A Date: 12.01.2015

Requirement: Vacuum leak test of subsea jumper hoses.

From: Precision Subsea

1.4 Priority: A Date: 12.01.2015

Requirement: Pressurization of subsea jumper hoses up to 15 bar.

From: Precision Subsea

1.5.1 Priority: A Date: 12.01.2015

Requirement: Six separated channels for functions such as vacuuming, filling, pressurizing and draining of subsea jumper hoses.

From: Precision Subsea

1.5.2

Requirement: Extension of channels by blocks of six.

From: Precision Subsea

1.6 Priority: B Date: 12.01.2015

Requirement: Pressure pump system for filling and pressurization of subsea jumper hoses.

From: Precision Subsea

1.7 Priority: B Date: 12.01.2015

Requirement: System shall include a pressure accumulator, preferably using N2 for filling optical jumpers with 0.2 bar pressure, but also for filling oil across tanks.

From: Precision Subsea

1.8 Priority: A Date: 04.02.2015

Requirement: All system tanks must be able to withstand dimensional changes from 1 bar air pressure when inside pressure is 2 mbar.

From: Precision Subsea

9.2 Performance Requirement

2.1 Priority: A Date:12.01.2015

Requirement: Sensors able to be calibrated.

From: Precision Subsea

2.2 Priority: A Date: 12.01.2015

Requirement: Sensors and regulators communicate at either 4-20 mA, 0-10 V or I/O.

From: Precision Subsea

2.3.1 Priority: B Date: 12.01.2015

Requirement: Sensors at relevant control points.

From: Precision Subsea

2.3.2

Requirement: Prevent leakage during filling.

From: Precision Subsea

2.3.3

Requirement: Pressure sensors minimum sensitivity of ±0.25% BFSL. (AST4400 sensor)

From: Precision Subsea

9.3 Physical Requirements

3.1.1 Priority: A Date: 12.01.2015

Requirement: Four tanks: 2x vacuum, 1x holding and 1x waste.

From: Precision Subsea

3.1.2

Requirement: Include both electrical and visual level inspection.

From: Precision Subsea

3.1.3

Requirement: Include electrical and visual pressure indicators.

From: Precision Subsea

3.2.1 Priority: A Date: 12.01.2015

Requirement: Holding tank volume of 100 liters.

From: Precision Subsea

3.2.2

Requirement: Vacuum- and waste tank volume of 50 liters.

From: Precision Subsea

3.2.3

Requirement: Pressure safety valves set to 1 bar.

From: Precision Subsea

3.3 Priority: A Date: 12.01.2015

Requirement: All valves operates both automatically and manually.

From: Precision Subsea

3.4.1 Priority: A Date: 12.01.2015

Requirement: Include a vacuum pump

From: Precision Subsea

3.4.2

Requirement: Vacuum system safety valve set to 1 Bar.

From: Precision Subsea

3.4.3

Requirement: Safety system to prevent oil flow into vacuum pump.

From: Precision Subsea

3.5 Priority: A Date: 12.01.2015

Requirement: Include a pressure pump system for filling and pressurization of subsea jumpers.

From: Precision Subsea

3.6 Priority: A Date: 12.01.2015

Requirement: Product size maximum height of 80 cm, width of 110 cm and length of 250 cm.

From: Precision Subsea

3.7 Priority: A Date: 12.01.2015

Requirement: Include valves.

From: Precision Subsea

3.8 Priority: B Date: 12.01.2015

Requirement: Include piping.

From: Precision Subsea

3.9 Priority: C Date: 12.01.2015

Requirement: Vacuum connections located on top of the module.

From: Precision Subsea

9.4 Environmental Requirements

4.1	Priority: B	Date: 12.01.2015

Requirement: Closed system. No measurable leakages.

From: Precision Subsea

4.2	Priority: C	Date: 19.01.2015

Requirement: Drip tray to contain oil spill.

From: Precision Subsea

4.3	Priority: C	Date: 19.01.2015

Requirement: Fork lift grip holes under module to ease transport of system.

From: Precision Subsea

4.4	Priority: C	Date: 25.01.2015

Requirement: All electrical cabling connected to one junction box.

From: Precision Subsea

9.5 Resource Requirements

5.1	Priority: A	Date: 12.01.2015

Requirement: Electrical usage within factory grid limit. (3600W, 3Phase max).

From: Precision Subsea

5.2	Priority: C	Date: 12.01.2015

Requirement: Hose inner diameter of 8 mm to reduce cost.

From: Precision Subsea

9.6 Administrative Requirements

6.1	Priority: A	Date: 12.01.2015

Requirement: English language on project report.

From: Precision Subsea

6.2	Priority: A	Date: 12.01.2015

Requirement: **3**D Modell in SolidWorks.

From: Precision Subsea

Test Specifications

Bachelor Assignment spring 2015

AUTOMATIC OIL FILLING STATION

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1.0 Introduction

This document contains the test specifications derived from the requirements set for the project. The requirements are essential for the project's success and every requirement needs to be tested and verified before accepting the final product. Performing the test procedures in environment that resembles the working conditions is essential as well. With test specifications, it will be possible to determine if the finished product will meet the requirements based on the test results

In the requirements document, the requirements are uniquely numbered. The tests in this document have reference numbers that correlate to the requirements they to test. It will be able to distinguish the test from the requirement by the "T" in front of the test reference, the requirements related to the test is also mentioned in each test.

1.1 Abbreviations

PS -	Precision Subsea AS
AOFS -	Automatic oil filling station
MOFS -	Manual oil filling station
PEP -	Project Execution Plan
HSE-	Health, Safety and Environment
TC -	Test Case

2.0 Goals and objectives

We have distinguished three different main goals for the test procedure:

- Primary goal is to gain acceptance and approval from the end user of the quality, usability, reliability and performance of the system.
- Secondary goal is to test and verify final product of all relevant requirements to such extent found necessary to gain acceptance by end user.
- Third goal is to set a framework so that all tests are feasible within their test schedule with focus on level of acceptance.

2.1 Statement of scope

The overall scope of the test plan is to give an efficient and easy test process that verifies the system component requirements. To assess the requirements and needs of the end user, a test plan is constructed. Factors influencing the test scope are; size, complexity, budget and testing time.

- ❖ **Size:** No test issues is expected to occur related to dimensional factors of our system.

- ❖ **Complexity:** Our system is an independent system not interacting or interfacing with other systems. The programming and development of control system is outsourced.

- ❖ **Budget:** Budgeting will most likely not pose a problem because equipment at PS can already conduct the different test operations.

- ❖ **Time:** Available time to system-, subsystem- and component tests is restricted due to the project period. Testing will most likely be performed by PS at a later date.

2.2 Major constraints

The Major constraints faced during testing of the product are:

- **Progress:** Completion of the system before project deadline. Thus, tests based on requirements should be as clear and concise as possible in order for the end user to continue the test process.

- **Requirements:** Some requirements may be so simple and clear that no test would be required to verify its status. A small check may be included.
  Example: "Include valves" -> *"Visual Inspection".*

- **Resources:** The cost of all tests should not exceed the estimated project budget.

3.0 Test Plan

This section describes the overall testing strategy and test management.

3.1 Testing strategy

The overall strategy for testing is to execute the appropriate collection of tests required to validate the product quality and demands set by end user. A test will assess the products ability to function per requirement and will give results that will judge its performance.

1. **Operating Conditions:**
   To test each unit or component correctly, a known state must be set. This known state is the systems normal operating environment.

2. **Performance:**
   To test each unit or component by its ability to perform its function.

3. **Repeatability:**
   Being able to test the components in different ways and still produce the same results in order to gain acceptance.

4. **Clarity:**
   To eliminate any doubt about tests validity, all tests must be clear, complete, detailed, and attainable per requirement.

5. **Acceptance:**
   A successful test is a test that has no deviations or faults. This verifies requirements tested.

The system is built in modules, each module and subsystem will be tested before being integrated as the whole system. This is a bottom-up testing strategy and we believe it will decrease the failure rate before complete system assembly.

The system 3D model will be top-down tested to uncover faults during the design process. By combining the top-down testing of the model with the bottom-up testing of the subsystems and modules we will take full advantage of both test methods.

After the bottom-up tests, the complete system should be stress tested and it is critical for the end user to know how the system behaves under stress. This will uncover system faults and increase the understanding of the system behavior when overloaded. This is important because the dependency of system “up time” and function.
Results may be misleading because of the system overload, but the faults possibly uncovered can give vital information for the systems normal operation.

This strategy has the advantage of saving the time and money spent on building dummy models. Therefor it encourages and boosts the project and building progress as well as the design.

The strategy for physical testing relies on TC procedures that test a set of requirements. Attachment 1 to 7 show the different test case documents affiliated with the different requirements.

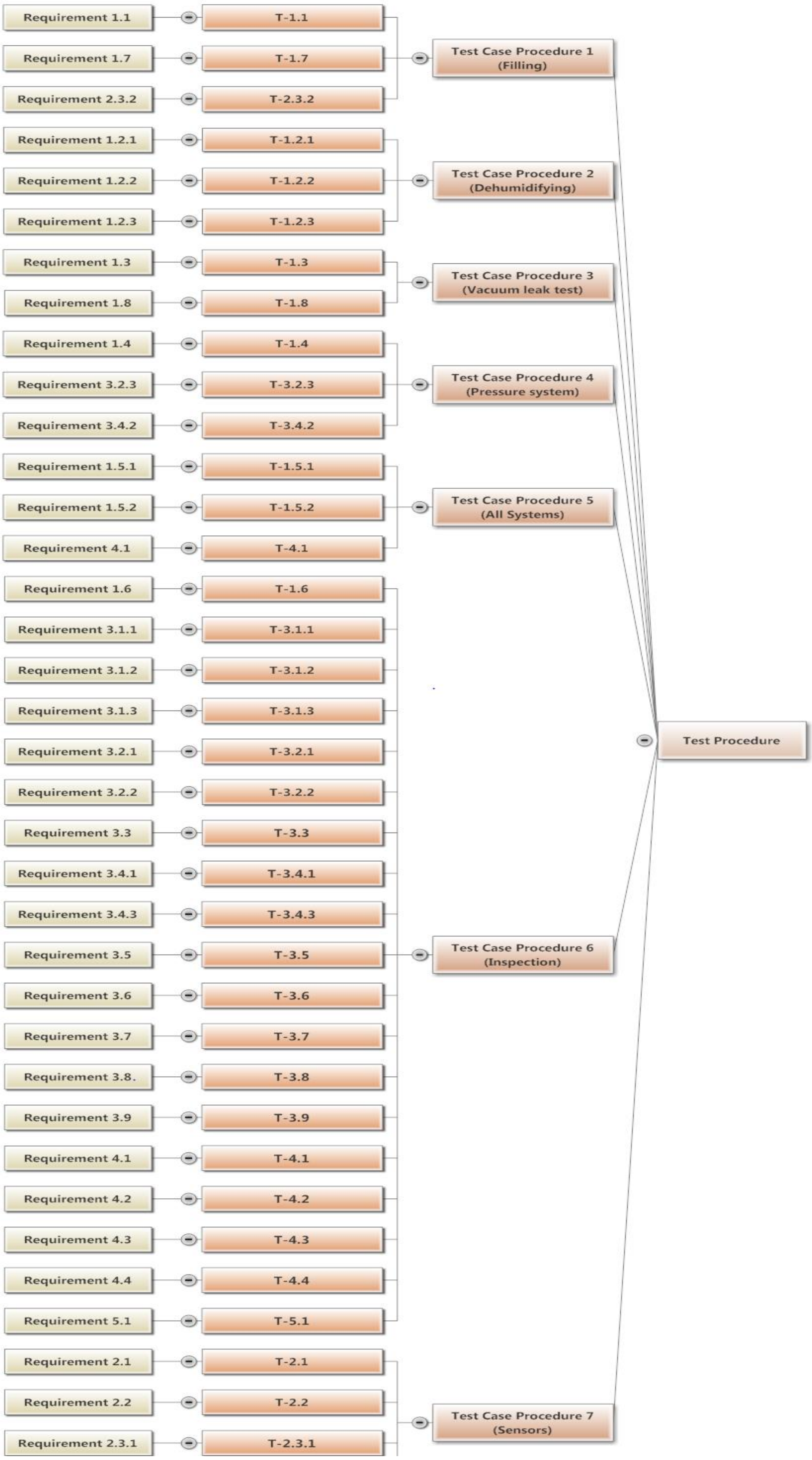

Figure 1: Test Strategy Overview

3.2 Test Scope

The test scope is to carry out all tests necessary to approve the system. The testing conditions and requirements vary. Therefore we distinguish between static and dynamic test settings.

For the static tests the system does not have to be operational or running. These tests are in general tests of document specifications, walkthroughs, component inspections, feasibility analysis to determine the degree of working functions and using Finite element analysis on subsystem or even the system as a whole to approve calculations and concepts.

Dynamic tests require the system to run, either as a computer simulation or as a physical test. These tests will approve the systems capabilities or functions. Operational functions, such as oil flow, filling pressure, etc. Dynamic tests starts often with unit testing, then integration testing of two or more components interacting with each other and final system testing.

3.3 General description of Tests

- **Visual Inspection:** Inspection of equipment, structures and system integrity using vision, hearing, touch and smell.
- **Monitoring:** Observe and check the progress or quality of the system with a systematic view, to verify the behavior of the system in normal running conditions. Performed over a period of time.
- **Leak testing:** Using a vacuum pump to create pressure close to vacuum inside system and monitoring pressure testing after closing valves to exterior environment.
- **Pressure Testing:** Testing by pressurizing working fluid to check that system can handle the normal working pressures.
- **3D Modeling:** Create a computer model of the product to check component locations and applications in SolidWorks.

- **FEM Analysis:** An analysis with a finite element method to discover how applied stresses will affect the material or design. Used in synergy with 3D model in SolidWorks.

- **Other Tools:** Flow-simulator etc. (add-on to SolidWorks). Fluid dynamics analysis to further verify process functions.

3.4 Testing resources and staffing

Resources used during tests are:

- **Simulations:** Computer (Solid Works CAD, Finite Element method, Simulink)

- **Leak & Pressure testing:** Tools and necessary equipment provided by Precision Subsea

Detailed description of resources required will be included in each of the Test Case Procedures attached to this document.

4.0 Test Procedure

4.1 Scope of test procedure

This chapter includes general component testing procedures as well as general integration procedures for each component and general system testing procedures.
Testing procedures in this section are general descriptions and steps used to write specific TC procedures. The specific TC attached are procedures used to test the subsystem and the system as a whole.

4.2 Validation Testing

To validate tests easier, we have split tests into two groups based on their preferences.

- **Essential tests:** Tests that needs approval for acceptance of total product.
- **Non-essential tests:** Tests that not necessarily needs approval for acceptance of total product.

Each step in TC procedures will be marked either essential or non-essential test to ensure testing quality. During tests, it will be necessary to validate end product to the degree of accepted tests. The degree of accepted tests is based on:

- **Great Acceptance:** All essential and non-essential tests are accepted and achieved.
- **Low Acceptance:** All essential, but not all non-essential tests are accepted and achieved.

- **Low Failure:** Not all essential and non-essential tests are accepted and achieved.
- **Great Failure:** Almost all or all essential and non-essential tests are not accepted and achieved.

4.3 Test record keeping and test log

The TC procedure will store every data gained from the test results.

5.0 Test Specification

The test specification will describe how each requirement should be tested and results expected in each test.

Test categories:

- **Functional tests:** Testing of the system in order to verify operational actions.
- **Performance:** These are system efficiency tests. This may includes parameters such as speed, range, flow, pressures, running hours etc.
- **Physical:** These are tests of physical properties, dimensions such thickness, length etc.
- **Environmental:** These are tests of how the system will interact with the environment. Such as dealing with leakages, spills, pollution, etc.
- **Resource:** These are tests of system consumption.
- **Administrative:** Checks and tests of project tasks, documents etc. are completed.

5.1 Functional tests

T-1.1

Requirement: 1.1

Test:

1. Fill optical jumper hose at 0.2 bar pressure
2. Check pressure stability and deviation
3. Check flow
4. Ensure hose is properly filled

5. Fill electrical jumper hose at 2 bar pressure
6. Check pressure stability and deviation
7. Check flow
8. Ensure hose is properly filled

Refer to TC procedure **TC-1** attachment for details.

Result:

Pass Criteria: System able to do all steps with parameters within limits.

Fail Criteria: System not able to do all steps with parameters within limits.

T-1.2.1

Requirement: 1.2.1

Test

1. Run dehumidifying sequence.
2. Visually inspect that the water within the silicone oil is boiling.

Refer to TC procedure **TC-2** attachment for details.

Result:

Pass Criteria: Visually verify oil is dehumidifying.

Fail Criteria: Visually verify oil is not dehumidifying.

T-1.2.2

Requirement: 1.2.2

Test:

Verify dehumidifying process is visual during operation.

Refer to TC procedure **TC-2** attachment for details.

Result:

Pass Criteria: Oil is dehumidified visually.

Fail Criteria: Not visible.

T-1.2.3

Requirement: 1.2.3

Test:

1. Attach flow sensor or make manual reading of liters passing through piping.
2. Record readings.
3. Calculate average and compare with minimum requirement.
    a. 1 liter/min

Refer to TC procedure **TC-2** attachment for details.

Result:

Pass Criteria: Oil is flowing at an average 1 liter/min or more.

Fail Criteria: Oil is flowing less than an average of 1 liter/min.

T-1.3

Requirement: 1.3

Test:

1. Run vacuum leak test on system without jumper hose connected.
2. The pressure should not raise more than 5 mbar.
3. Visually inspect for leakages.

Refer to TC procedure **TC-3** attachment for details.

Result:

Pass Criteria: Pressure less than required limit

Fail Criteria: Pressure increases to more than required limit or system leakages found.

T-1.4

Requirement: 1.4

Test:

1. Pressure test the high pressure section at 15bar for one hour without jumper hose connected, using the systems own high pressure pump.
   a. Monitoring: The pressure should not drop at all.
2. Check pressure readings for changes in pressure that relates to leakages.
3. Control the pump and pressure regulator for extensive heat after test.
4. Pressurize subsea jumper hose to 15bar.

Refer to TC procedure **TC-4** attachment for details.

Result:

Pass Criteria: System is able to pressurize subsea jumpers up to 15 bar.

Fail Criteria: Not able to pressurize subsea jumpers up to 15 bar.

T-1.5.1

Requirement: 1.5.1

Test:

Visual and functional inspection of six separated connections for vacuum, filling, pressurizing and draining of subsea jumper hoses.

Refer to TC procedure **TC-5** attachment for details.

Result:

Pass Criteria: All connections located and functional.

Fail Criteria: Not enough connections, not separated or not functional.

T-1.5.2

Requirement: 1.5.2

Test:

Visual and functional inspection of extension connections.

Refer to TC procedure **TC-5** attachment for details.

Result:

Pass Criteria: Connection visible and functional.

Fail Criteria: Not found, not functional or both.

T-1.6

Requirement: 1.6

Test:

Visual inspection of pressure-pump system.
Functional test of pump.

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: Pump inspected and functional.

Fail Criteria: Not found, not functional or both.

T-1.7

Requirement: 1.7

Test:

Visually inspect that the system includes a pressure accumulator for filling purposes. Inspect that the accumulator is capable of delivering at least 0.2 bar pressure for filling optical subsea jumper hoses and also is capable of delivering pressure to transfer oil across holding and vacuum tanks.

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: Accumulator is installed and capable of delivering required pressure.

Fail Criteria: Accumulator is not installed and/or is not capable of delivering required pressure.

T-1.8

Requirement: 1.8

Test:

When close to vacuum condition (2 mbar) within pipes and tanks verify system dimensions

Refer to TC procedure **TC-8** attachment for details.

Result:

Pass Criteria: Measurement of dimensional changes does not exceed 1 mm.

Fail Criteria: Measurement of dimensional changes exceeds 1 mm.

5.2 Performance test specs

T- 2.1

Requirement: 2.1

Test:

Control and verify that all sensors can be calibrated.

Refer to TC procedure **TC-7** attachment for details.

Result:

Pass Criteria: Calibration possible for all sensors.

Fail Criteria: Calibration not possible for all sensors.

T- 2.2

Requirement: 2.2

Test:

Control and verify that the design of the system allows sensor communication at 4-20 mA, 0-10 V or I/O.

Refer to TC procedure **TC-7** attachment for details.

Result:

Pass Criteria: Sensor communicates at either 4-20 mA, 0-10 V or I/O.

Fail Criteria: Sensor does not communicate at 4-20 mA, 0-10 V or I/O.

T- 2.3.1

Requirement: 2.3.1

Test:

Visually verify sensors positioning at relevant control points as per design.

Refer to TC procedure **TC-7** attachment for details.

Result:

Pass Criteria: Sensors installed and correctly placed at control points per design.

Fail Criteria: Sensors not installed and correctly placed at control points per design.

T- 2.3.2

Requirement: 2.3.2

Test:

Filling shut-off valve (pressure drop)

1. Monitor shut-off valve during enforced pressure drop.
2. Shut-valve closes within 1 sec (±0.5 sec).
3. Record readings.

Refer to TC procedure **TC-1** attachment for details.

Result:

Pass Criteria: Shut-valve closes within limit.

Fail Criteria: Shut-valve not able to close within limit

T- 2.3.3

Requirement: 2.3.3

Test:

1. Monitor all pressure sensors.
2. Add control pressure sensor to verify readings are within ±20 mbar.

Refer to TC procedure **TC-7** attachment for details.

Result:

Pass Criteria: Sensors within limit.

Fail Criteria: Sensors not within limit

5.3 Physical test specs

T-3.1.1

Requirement: 3.1.1

Test:

Visually inspect that system has four tanks. 2x Vacuum, 1x Holding and 1x Waste tank

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: System contains 4 tanks.

Fail Criteria: System does not contain 4 tanks.

T-3.1.2

Requirement: 3.1.2

Test:

Visually inspect that all tanks have electrical and visual level indication.

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: All tanks have electrical and visual level indication.

Fail Criteria: Not all tanks has electrical and visual level indication.

T-3.1.3

Requirement: 3.1.3

Test:

Inspect that all tanks have electrical and visual pressure indication.

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: All tanks have electrical and visual pressure indication.

Fail Criteria: Not all tanks has electrical and visual pressure indication.

T-3.2.1

Requirement: 3.2.1

Test:

1. Measure inner dimensions of holding tank and calculate the volume.
2. The volume should be equal to or greater than 100 liters.

Refer to TC procedure **TC-6** attachment for details.

Result:
Pass Criteria: Holding tank volume is 100 liters or more.
Fail Criteria: Holding tank volume is less than 100 liters.

T-3.2.2

Requirement: 3.2.2

Test:

1. Visually inspect that the three smaller tanks have same dimensions
2. Calculate the volume of one.
3. The volume should be equal to or greater than 50 liters.

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: Vacuum and Waste tank volumes are 50 liters or more.

Fail Criteria: Vacuum and Waste tank volumes are less than 50 liters.

T-3.2.3

Requirement: 3.2.3

Test:

1. Visually inspect pressure safety valves on all tanks and check set point.
2. Pressure test all safety valves.
3. Record opening pressure of valve is within limit of at 1 bar (±0.1 bar).

Refer to TC procedure **TC-4** attachment for details.

Result:

Pass Criteria: Pressure safety valve opens at limit.

Fail Criteria: Pressure safety valve does not open at limit.

T-3.3

Requirement: 3.3

Test:

Test manual and automatic operation of all valves.

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: All valves open manually and automatically.

Fail Criteria: Not all valves open manually and automatically.

T-3.4.1

Requirement: 3.4.1

Test:

Visual inspect that system has vacuum pump.

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: System has a vacuum pump.

Fail Criteria: System does not have a vacuum pump.

T-3.4.2

Requirement: 3.4.2

Test:

Test vacuum system pressure safety valve opens at 1 bar.

Refer to TC procedure **TC-4** attachment for details.

Result:

Pass Criteria: Vacuum pressure safety valve opens at limit.

Fail Criteria: Vacuum pressure safety valve does not open at limit.

T-3.4.3

Requirement: 3.4.3

Test:

Fill oil into the vacuum pump hose and confirm that the safety system prevents oil from passing.

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: Oil does not flow through the system.

Fail Criteria: Oil flow through the system.

T-3.5

Requirement: 3.5

Test:

Visual inspection and functional test of pressure pumps system for filling and pressurization of subsea jumper hoses.

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: Pressure pumps able to fill and pressurize subsea jumper hoses.
Fail Criteria: Pressure pumps not able to fill and pressurize subsea jumper hose.

T-3.6

Requirement: 3.6

Test:

1. Measure product size.
2. Height, width and length. Compare to maximum limits:
    a. Height of 80 cm, width of 110 cm and length of 250 cm.

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: Dimensions less than limit.

Fail Criteria: Dimensions greater than limit.

T-3.7

Requirement: 3.7

Test:

Visual inspect product for valves.

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: Valves found.

Fail Criteria: Valves not found.

T-3.8

Requirement: 3.8

Test:

Visual inspect product for piping.

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: Piping found.

Fail Criteria: Piping not found.

T-3.9

Requirement: 3.9

Test:

Verify top mounted vacuum connections. Verify 3D model in SolidWorks.

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: Vacuum connections found at correct position.

Fail Criteria: Vacuum connections not found at correct position.

5.4 Environmental test specs

T-4.1
Requirement: 4.1
Test:
Verify system integrity by visual inspection. Check for measureable leakages.
Refer to TC procedure **TC-5** attachment for details.
Result:
Pass Criteria: No leakages.
Fail Criteria: Leakages found.

T-4.2
Requirement: 4.2
Test:
Inspect that drip tray at bottom of product does not allow oil spill to the workshop floor.
Refer to TC procedure **TC-6** attachment for details.
Result:
Pass Criteria: Drip tray fluids do not spill on floor.
Fail Criteria: Drip fluids spills on floor.

T-4.3
Requirement: 4.3
Test:
Visual inspect that the design/ product has integrated forklift holes.
Refer to TC procedure **TC-6** attachment for details.
Result:
Pass Criteria: Forklift holes found.
Fail Criteria: Forklift holes not found.

T-4.4

Requirement: 4.4

Test:

Verify product cabling entering one junction box.

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: All cabling connected to one junction box.

Fail Criteria: Cabling does not end at only one junction box.

5.5 Resource Tests.

T-5.1

Requirement: 5.1

Test:

Check Electrical usage of all components are within factory grid limit.
(3600W, 3phase max).

Refer to TC procedure **TC-6** attachment for details.

Result:

Pass Criteria: Within grid limit.

Fail Criteria: Not within grid limit.

6.0 Test Case attachments

Attachment 1: Test case procedure 1

Attachment 2: Test case procedure 2

Attachment 3: Test case procedure 3

Attachment 4: Test case procedure 4

Attachment 5: Test case procedure 5

Attachment 6: Test case procedure 6

Attachment 7: Test case procedure 7

Concept Overview

Bachelor Assignment spring 2015

Automatic Oil Filling Station

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1.0 Introduction

Precision Subsea has requested that we design an automatic oil filling station. They are currently using a manual oil filling station and want to automate as much of this system as possible to save costs.

This document contains all possible solutions and concepts to the product functions, components and operations. It is a collection off all concepts. It will focus on the selection of concepts based on a set of criteria filtered by decision Pugh matrixes.

1.1 Abbreviations

PS - Precision Subsea AS
AOFS - Automatic oil filling station
MOFS - Manual oil filling station
HSE - Health, Safety and Environment
DP - Dehumidifying process

2.0 Concept Baselines

The concept baselines are the criteria and foundation that all concepts will be judged. This means that this chapter will discuss all functions and factors which affect the selection of each concept. Some criteria and functions will affect in different manners depending on the concepts discussed.

Concepts are divided into several functions and systems.

1. Dehumidifying
2. Leak Test and vacuum system
3. Filling and pressurizing
4. Reservoir tank system

Each concept sheet is numbered with "C-X.X" to signify the concept group.

2.1 Standard Concept criteria

To compare concepts, we need to have set reference to compare with. We are using a Pugh concept selection matrix. This is a quantitative technique used to rank the multi-dimensional options of an option set. We have divided these options sets into;

- Weight points, the value of each criterion.
- Grade, the concepts ability to match criteria.

Weight Points

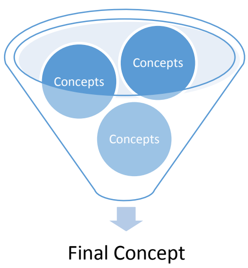
3. Crucial
2. Important
1. Non-essential

A weighted decision matrix operates in the same way as the basic decision matrix, but introduces the concept of weighting the criteria in order of importance.

Example of selection criteria:

- **Strength**, lifetime of the concept, resistance to wear and tear.
- **Cost,** expensive to produce, buy and acquire.
- **Construction,** easy to build, expected delivery time, etc.
- **Complexity,** difficulty to realize and create.
- **Maintenance,** easy to repair, maintain, install, inspect, etc.
- **HSE,** ergonomic, handling, weight, recycling.

The advantage of the decision-making matrix is that subjective opinions about one alternative versus another can be made more objective. Under each concept, we have written a specialized selection criteria list that will judge only that group of concepts. Simply put, we are using the Pugh matrix to filter out the best concepts and removing the poor ones.



Figur 1: Concept selection

3.0 Dehumidifying concepts

The dehumidifying process of the oil starts with creating a vacuum condition in the supply line. The vacuum condition will boil the water in the oil at room temperature.
A dehumidifying sequence is needed for the AOFS to dehumidify the silicone oil the system before the system fills subsea jumper hoses.

3.1 Factors and functions

Because of the small height of the AOFS the process should use as little height as possible. Therefore it is preferable if the concept enables as much internal surface area on as little as possible height. The large area will increase the dehumidifying rate of the oil relative to the oil flow and increase the efficiency.

The principle behind the dehumidifying process is, as seen in figure 2, that water boils at low temperatures when exposed to low pressures. Therefore, the process is carried out in pressures around 2 mbar.

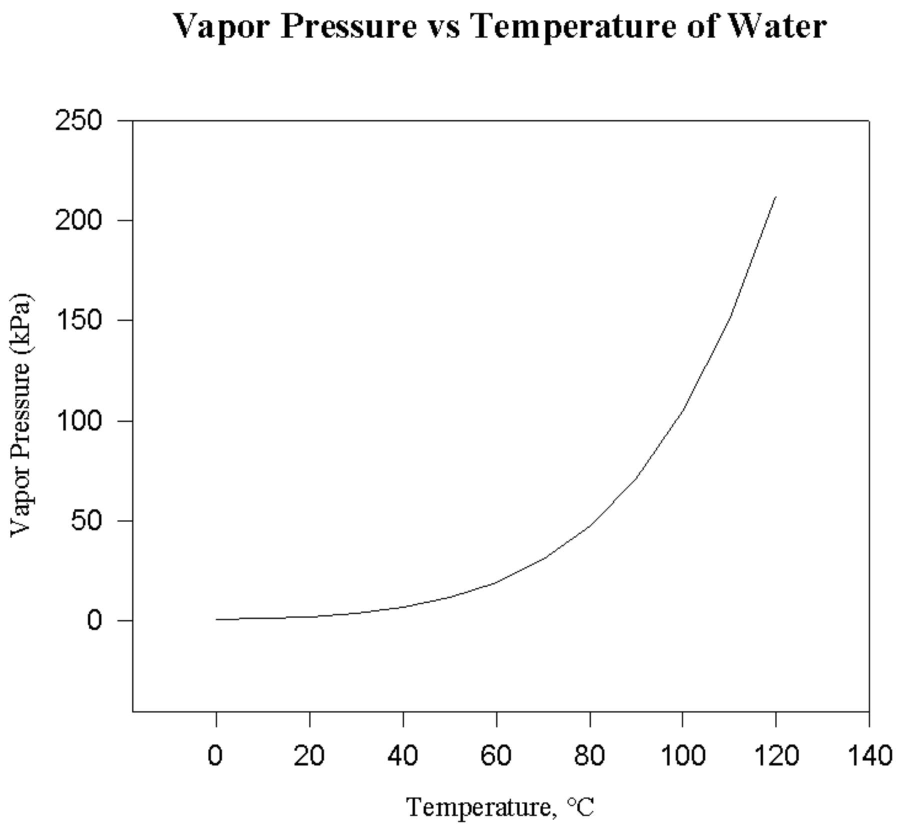


Figure 2: Pressure and Boiling points (http://www.umsl.edu/~orglab/documents/distillation/dist.htm)

3.2 Requirements

Relevant requirements to Dehumidifying process concepts:

1.2.1 – Requirement: Dehumidify AK350 Wacker silicone oil.

1.2.2 – Requirement: Visual inspection of the dehumidifying process.

1.2.3 – Requirement: Dehumidifying oil flow ≥ 1 $\frac{liter}{min}$

1.8 – Requirement: All system tanks must be able to withstand dimensional changes from 1 bar air pressure when inside pressure is 2 mbar.

3.6 – Requirement: Product size maximum height of 80 cm, with of 110 cm and length of 250 cm.

3.3 Concepts

Current concepts gathered and sorted in concept sheets.

C-1.1 The Spiral Dehumidifier	C-1.5 The Hat
C-1.2 The Plate Stairs Dehumidifier	C-1.6 The Hat Collector
C-1.3 The Tube Dehumidifier	C-1.7 The Mesh
C-1.4 The Circular Plates	C-1.8 The Jarlsberg

3.4 Specialized Concept criteria

Oil flow

Precision Subsea prefers the oil flow to be as much as possible, with a lower limit of one liter per minute. The oil flow is therefore crucial to the selection of dehumidifying concept and is weighted 3. Reference point is the original DP with a ~1liter/min flow.

Criteria number: 1
Criteria weight: 3

Concept grading
+1, Faster
0, Same
-1, Less

Visual inspection

The visual inspection is important to verify that the oil is properly dehumidified. Therefore, it is important that the dehumidifying concept has the possibility of exposing the process, without compromising the structural strength and process itself. The criteria are weighted 3 because of requirement 1.2.2. The reference point is the visual inspective possibility of the original DP.

Criteria number: 2
Criteria weight: 3

Concept grading
+1, Better
0, Similar
-1, Worse

Structural strength

Some parts of the system will be exposed to near vacuum pressures. The concept should therefore allow easy design and construction based on structural strength. This criterion is weighted 2 because design and construction of a complex concept not is unacceptable. The reference point is the original DP.

Criteria number: 3
Criteria weight: 2

Concept grading
+1, Better
0, Similar
-1, Worse

Internal surface area per height

Because the AOFS compact dimensions, it is preferable that the height of the DP is as low as possible, but at the same time achieve large internal surface areas for the oil to flow. Surface area per height is weighted 3 because of requirement 3.6. The reference point is the surface area of the original DP.

Criteria number: 4	**Concept grading**
	+1, Larger surface area
Criteria weight: 3	0, Same
	-1, Smaller surface area

Cost

Cost of the AOFS is limited and should preferably be as low as possible. Therefore, the cost of the dehumidifying equipment is also important. The ability of a concept to be constructed in a way that saves cost is therefore useful, but since the dehumidifying process is essential for the system, this criterion is weighted 1. Costs are graded in percent of total budget.

Criteria number: 5	**Concept grading**
	+1, Low (<5% of tot bud.)
Criteria weight: 1	0, Neutral (5- 15 %)
	-1, High (>15%)

Construction

Construction should be easy, the concept should also enable the use of pre-made parts to reduce construction complexity, but also cost. This is a non-essential criterion, therefore it is weighted 1. Reference point is the original DP.

Criteria number: 6	**Concept grading**
	+1, Easier
Criteria weight: 1	0, Similar
	-1, Harder

Complexity

Concept should not be so complex that calculations and overall design is too difficult. Simple concepts are favorable. This criterion is weighted 1. Reference point is the original DP.

Criteria number: 7	**Concept grading**
	+1, Lower
Criteria weight: 1	0, Similar
	-1, Higher

Maintenance

Overall maintainability of the AOFS should be easy and not very time consuming; therefore, this also affects the dehumidifying process. This may be hard to confirm on a concept, but important to consider. This criterion is weighted 2. Maintenance of the original DP is the reference point.

Criteria number: 8	**Concept grading**
	+1, Easier
Criteria weight: 2	0, Similar
	-1, More difficult

3.5 Concept Selection

We have in accordance with the results from the Pugh matrix, decided to implement concept **C-1.3, Tube vacuum dehumidifier**. See attached matrix. Even though C-1.8 received a higher score, the difficulty to calculate oil flow and visual inspection is too large.

This means that we will proceed to next design phase with this concept. We have the possibility to review concepts in a later iteration phase, if we meet any major unforeseen issues.

4.0 Leak test and vacuum system

The vacuum leak test of jumpers is generally described as a process where it is applied vacuum to a hose and then checked for pressure deviations.

Vacuum system which consists of a vacuum pump, filter and a safety system, provides vacuum condition in the dehumidifying process as well as in the hoses during leak test and filling.

4.1 Factors and functions

Leak testing of subsea jumper hoses is a function that is vital to the AOFS and is conventionally done by vacuum leak testing the hoses. This means draining the hoses of as much air as possible and see if any air leaks into it.

Advantages of leak testing with vacuum are:

- ❖ Pressure rise indicates faulty hose.
- ❖ No elastic expansion of the hose giving false positives.
- ❖ No introduction of foreign fluid or gas to the hose.
- ❖ No introduction of air or humidity to the system, giving greater safety to the already dehumidified oil.
- ❖ Vacuum pump already installed in system, less components needed.

The leak test is done by draining as much air/gas out of the hose as possible (as close to vacuum as the pump allows), sealing off the hose from the system by closing a valve, and then monitor the pressure rise within the hose to determine if the hose is leak proof.

The leak test is the first operation done by the system on the hoses, if the hose is not drained first. Common practice today is to leak test the hoses approximately 15 minutes, and the aim for a leak test concept should be equal or shorter time consumption. This depends on a number of factors, such as the vacuum pressure inside the system, and the inner diameter of hoses and pipes used for leak testing. Today an 8 mm tube is used, which apparently is satisfying enough even though the optimal diameter is a bit larger.

4.2 Requirements

Relevant requirements to the leak testing process concepts:

1.3 – Requirement: Vacuum leak test of subsea jumper hoses

1.5.1 – Requirement: Six separate channels for functions such as vacuuming, filling, pressurizing and draining of subsea jumper hoses.

3.4.1 – Requirement: Include a vacuum pump.

3.4.2 – Requirement: Vacuum system safety valve set to 1 bar.

3.4.3 – Requirement: Safety system to prevent oil flow into vacuum pump.

3.6 – Requirement: Product size maximum height of 80 cm, width of 110 cm and length of 250 cm.

3.9 – Requirement: Vacuum connections located on top of the module.

5.2 – Requirement: Hose inner diameter of 8 mm to reduce cost.

4.3 Concept Summary

The vacuuming and leak testing of the new AOFS will be carried out after the same principles as the original system. There is a limited ways of actually perform this process, and the present system works well.

We felt it would be unnecessary to go through a concept selection progress on this particular subsystem. The process will be conducted as described in section 4/4.1.

The automation aspect and the computer interface will obviously be implemented to the vacuum system. Further details of the vacuum system will be provided in a block diagrams and a component specification document.

5.0 Filling and pressurizing

The purpose with the filling and pressurizing process is to fill jumper hoses with dehumidified silicon oil, and pressurize them up to 15 bars. The reason is to ensure enough internal pressure inside the hoses, so they can withstand hydrostatic pressure.

Process:

- Filling: both valves are open. Vacuum at A-line and specified filling pressure at B-line. Optical hoses must be filled with 0,2 bar. Hoses with electrical conductors 2 bar.
- Pressurizing: A-line closed. B-line pressurized with 15 bar

The filling and pressurizing system must be capable to fill and pressurize multiple jumpers at once, so the system will consist of 6 x A-lines and 6 x B-lines.

Figure 2: Subsea Jumper Hose Connections

5.1 Factors and functions

The filling and pressurizing process is the most essential part of the AOFS, and its function fulfills the overall purpose of the automatic oil filling station. Desirable system factors and functions are highlighted by the specialized concept criteria's.

A comprehensive description of different factors and functions can be found in *chapter 2.3 Design function and factors document*.

5.2 Requirements

Relevant requirements for filling concepts:

1.1– Requirement: Fill subsea jumper hoses containing optical fibers or electrical conductors with AK350 Wacker silicone oil at different pressures.

1.4 – Requirement: Pressurization of subsea jumper hoses up to 15 bar.

1.5.1 – Requirement: Six separated channels for functions such as vacuuming, filling, pressurizing and draining of subsea jumper hoses.

1.6 - Requirement: Pressure pump system for filling and pressurization of subsea jumper hoses.

1.7 - Requirement: System shall include a pressure accumulator, preferably using N2 for filling optical jumpers with 0,2 bar pressure, but also for filling oil across tanks.

2.3.2 - Requirement: Prevent leakage during filling.

3.6 – Requirement: Product size maximum height of 80 cm, width of 110 cm and length of 250 cm.

5.3 Concepts

Current concepts gathered and sorted in concept sheets.

C-3.1 The pressure filler
C-3.2 The loop filler and pressurizer
C-3.3 Double accumulator
C-3.4 One pump filler

5.4 Specialized Concept criteria

Energy consumption

The energy consumption will be graded in relation to concept C-3.4. We use this concept as our reference point, since we initially assume this concept to be the best.

The criteria are weighted 1, since the total increase in energy consumption will non-essential.

Criteria number: 1
Criteria weight: 1

Concept grading
+1, Lower
0, Similar
-1, Higher

Cost

Costs are graded with the reference in percent of total budget. The cost criteria is weighted 2, since is important to choose a concept that meet our cost constrains.

Criteria number: 2
Criteria weight: 2

Concept grading
+1 Low (<5% of tot. bud)
0, Neutral (5-15%)
-1, High (>15%)

Complexity

The complexity of the concepts are defined by factors such as number of interacting/moving parts, design demands, manufacturing issues, etc.

Complexity will be graded in relation to concept C-3.4. We use this concept as our reference point, since we initially assume this concept to be the best.

Criteria number: 3	**Concept grading**
	+1, Less
Criteria weight: 2	0, Similar
	-1, More

Error sources

Encompasses all potential error sources associated with the proposed concept. The criteria reflect factors from complexity criteria. Concept C-3.4 is the reference point.

Criteria number: 4	**Concept grading**
	+1, Less
Criteria weight: 3	0, Similar
	-1, More

Maintenance

Overall maintainability of the AOFS should be easy and not very time consuming; therefore, this also affects the filling process. This criterion is weighted 3, based on the essential maintenance requirement. Our reference point is the original AFOS.

Criteria number: 4
Criteria weight: 3

Concept grading
+1, Easier
0, Similar
-1, Harder

5.5 Concept Selection

We have in accordance with the results from the Pugh matrix, decided to implement concept **C-3.4, one pump filling system**. See attached matrix.

This means that we will proceed to next design phase with this concept. We have the possibility to review concepts in a later iteration phase, if we meet any major unforeseen issues with the respective concept proposal.

6.0 Reservoir tank system

The reservoir tank system consists of all oil tanks included in the AFOS.

- 2 x 50 liters vacuum tanks
- 1 x 100 liters holding tanks
- 1 x 50 liters waste tanks

The purpose of the tank system is to accumulate all the silicon oil in the AOFS. Dehumidified oil is delivered from holding tanks to jumper hoses, while used oil is drained from jumper hoses to a specified waste tank.

6.1 Factors and functions

Important factor and functions for the reservoir is space efficiency, scale reading, oil drain cycle, volume etc. These factors provide the foundation of our concept criterias. The requirements in the next section do also outlines crucial factors and functions.

6.2 Requirements

Relevant requirements for filling concepts:

1.1– Requirement: Fill subsea jumper hoses containing optical fibers or electrical conductors with AK350 Wacker silicone oil at different pressures.

3.1.1 – Requirement: Four tanks: 2 x vacuum, 1x holding and 1 x waste.

3.1.2 – Requirement: Include both electrical and visual inspection

3.1.3 – Requirement: Include electrical and visual pressure indicators

3.2.1 – Requirement: Holding tank volume of 100 liters.

3.2.2 – Requirement: Vacuum- and waste tank volume 50 liters.

3.2.3 – Requirement: Pressure safety valves set to 1 bar.

3.6 – Requirement: Product size maximum height of 80 cm, width of 110 cm and length of 250 cm.

6.3 Concepts

C-3.1 Horizontally tilted tank
C-3.2 The spherical tank

6.4 Specialized concept criteria

Dimensional efficiency

This grading compares the space efficiency of the original system (vertical standing tank) with a proposed concept. There is an important point to utilize space available given our dimensional constraints. Hence, the high criteria weight.

Criteria number: 1	**Concept grading**
	+1, Higher
Criteria weight: 3	0, Similar
	-1, Lower

Scale reading

Concept grading differentiates original scale reading with the scale reading of a new concept.

Criteria number: 2	**Concept grading**
	+1, Better
Criteria weight: 1	0, Similar
	-1, Worse

Oil drain cycle

It is important to avoid oil particles to gather in the tank. This concept grading compares the original oil drain cycle with the new concept. We want a tank system with an optimal oil drain cycle, hence the criteria weight.

Criteria number: 3		**Concept grading**
		+1, Better
Criteria weight: 2		0, Similar
		-1, Lower

Volume

We want our tanks to have the most volume on the smallest area possible.

The following concept grading compares the original tank system with a new tank concept. This is a crucial criterion for the reservoir system, since it addresses multiple customer requirments.

Criteria number: 4		**Concept grading**
		+1, Higher
Criteria weight: 3		0, Similar
		-1, Lower

6.5 Concept Selection

We have in accordance with the results from the Pugh matrix, decided to implement concept **C-3.1, horizontally tilted tank.** See attached matrix.

This means that we will proceed to next design phase with this concept. We have the possibility to review concepts in a later iteration phase, if we meet any major unforeseen issues with the respective concept proposal.

7.0 Attachments

Attachment 1 – Pugh matrix, dehumidifying process

Attachment 2 – Pugh matrix, filling

Attachment 3 – Pugh matrix, holding tanks

C-1.1

Automatic Oil Filling Station – Dehumidifying Process

The Spiral Dehumidifier

PROCESS DESCRIPTION

Process starts from opening oil supply into vacuum condition in the dehumidifying line. Dehumidifying process to be visual. Water in the oil will boil visually in this section. One of two selected tank will be filled. When reservoir is full. System will stop.

CONCEPT DESCRIPTION

The oil flows from the supply line into the spiral dehumidifier vertically downwards. The oil then flows spirally downwards through the tubing until all the oil has been dehumidified. The input tubing radius will be the same as the output. The oil flow will be regulated to accumodate the vacuum process over the oil inside the tubing. This means that the oil will cover or fill the tubing completely.

CHARACTERISTICS AND FEATURES

The features will allow the user to visually see the process while the oil flows down the system.

The spiral tubing will take less space than the straight forward tubing (original type) in length and width but will be higher leaving less height to go on towards the tanks.

The tubing will have to be specially made since this is not to be expected shelf wares.

SUMMARY

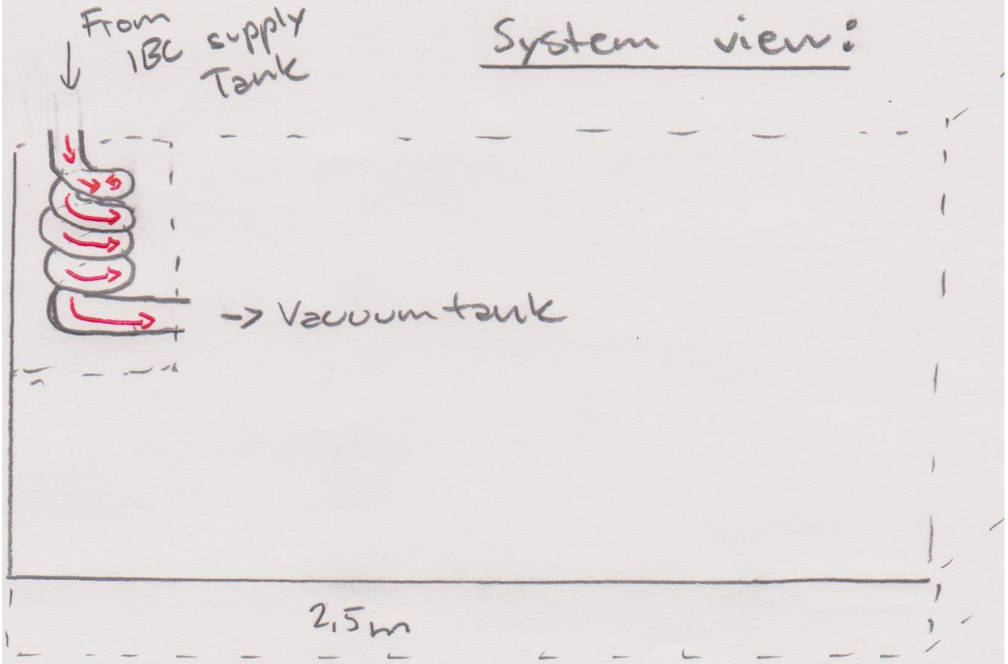
Spiral dehumidifier is like a water slide.

We will also execute further calculations and simulations of this process, if we find this concept applicable.

Pictures are attached to this concept sheet.

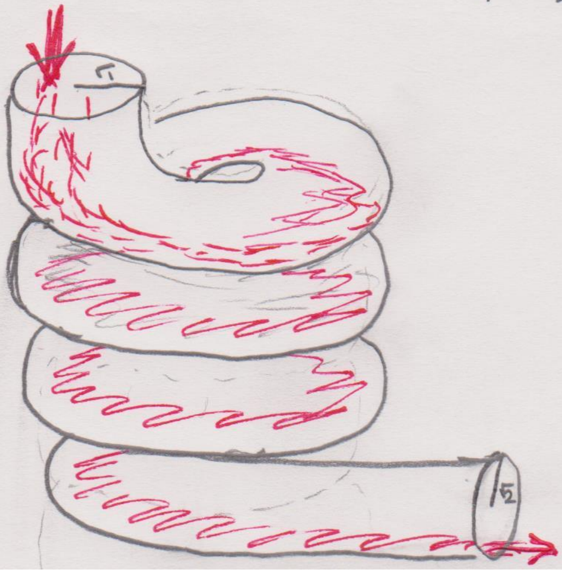
The Spiral dehumidifier

System view:



Close up view:

$r_1 = r_2$



C-1.2

Automatic Oil Filling Station – Dehumidifying Process

The Plate Stairs Dehumidifier

PROCESS DESCRIPTION

Process starts from opening oil supply into vacuum condition in the dehumidifying line. Dehumidifying process to be visual. Water in the oil will boil visually in this section. One of two selected tank will be filled. When reservoir is full. System will stop.

CONCEPT DESCRIPTION

The oil flows from the supply line into the plate stair dehumidifier vertically downwards in the top left corner. The plate stair dehumidifier consists of see-through plates and some stairs. The plates show the process happening between them as the oil flows down the stairs from side to side until it reaches the bottom end. The angle of the stairs and the size of the dehumidifier can be adjusted to the process.

CHARACTERISTICS AND FEATURES

The system will need to be designed and tested to fully ensure integrity towards the pressure. The two plates needs to be joined together by bolting or similar. The suction pressure (vacuum) will pull the plates towards each other and create a good seal.

SUMMARY

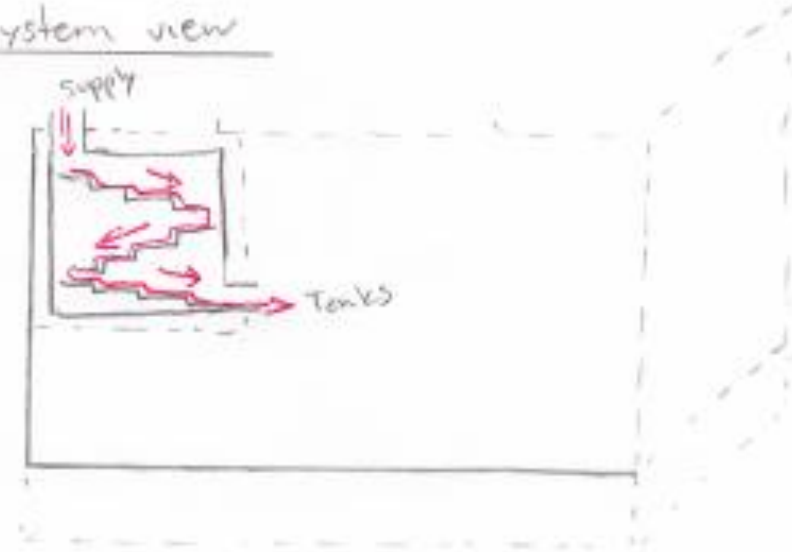
Stair plate type allows for flow like the original type with great width gains surface area to dehumidifying process.

We will also execute further calculations and simulations of this process, if we find this concept applicable.

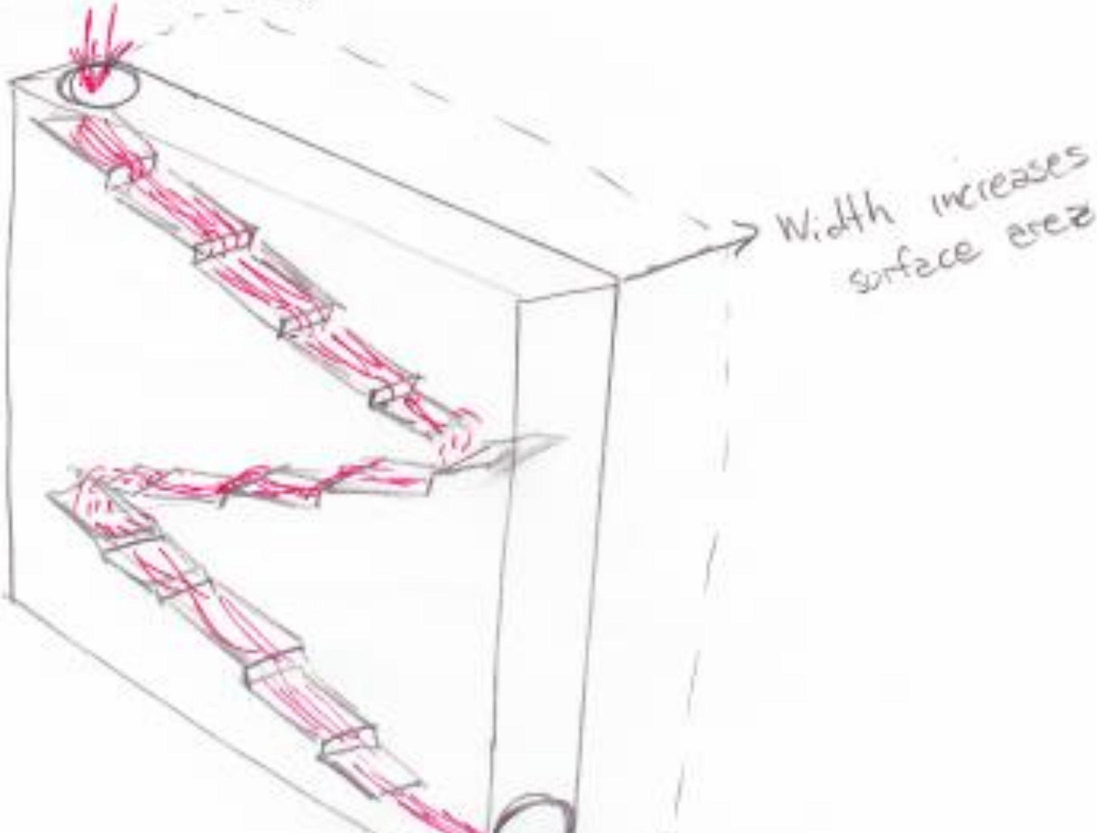
Pictures are attached to this concept sheet.

The Plate Stairs Dehumidifier

System view



Close up view



C-1.3

Automatic Oil Filling Station – Dehumidifying Process

Tube concept

PROCESS DESCRIPTION

Process starts from opening oil supply into vacuum condition in the dehumidifying line. Dehumidifying process to be visual. Water in the oil will boil visually in this section. One of two selected tank will be filled. When reservoir is full. System will stop.

CONCEPT DESCRIPTION

Concept 1.1 is a modified version of the original dehumidifying process of the AOFS.

The thought behind this concept, is that the humidity in the oil will evaporate as the silicon oil flows (≥ 1 l/min) down a transparent tube with an internal vacuum of 2mbar. The transparent tube will make it possible to verify that the moisture is completely evaporated when it enters the selected tank.

CHARACTERISTICS AND FEATURES

The tube concept is a relatively simple concept, without any special or prominent features or characteristics. The concept is similar to the present DP, but with some changes in dimensional parameters; like the length of the tubes, tube diameter, slope angle etc. These changes are necessary to meet system requirements and dimensional constraints.

SUMMARY

Moisture in the silicon evaporates as the oil flows down through a transparent vacuum tube with an optimized length, slope angle and diameter.

We will use experience values (factors mentioned above) from the original AOFS to improve a new DP. We will also execute further calculations and simulations of this process, if we find this concept applicable.

ATTACHMENT

Figure 1 illustrates a simplified outline of the DP, within our system boundaries. (Note: The drawing is only an illustration, so dimensions may deviate). The thought is that the vacuum tube is mounted in the front of our AOFS, so a visual inspection can be done through a transparent plexiglas front.

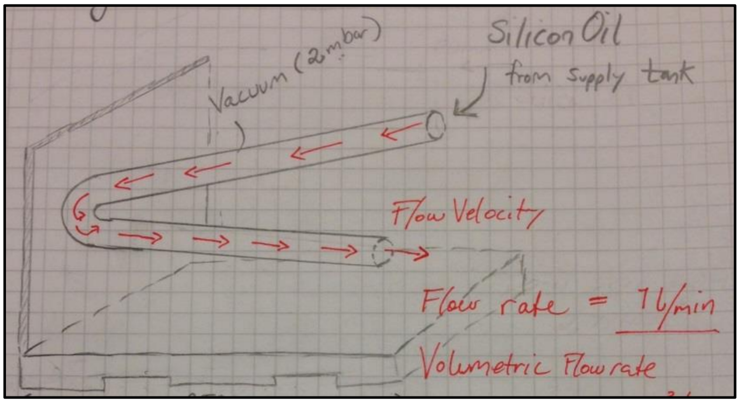


Figure 1: Concept 1.1

C-1.4	**Automatic Oil Filling Station – Dehumidifying Process** **The circular plates**

PROCESS DESCRIPTION

Process starts from opening oil supply into vacuum condition in the dehumidifying line. Dehumidifying process to be visual. Water in the oil will boil visually in this section. One of two selected tank will be filled. When reservoir is full. System will stop.

CONCEPT DESCRIPTION

Oil flows from intake directly on a circular plate. The oil distributes around the plate and pours over the edge where it possibly drips onto next plate. The plates can be placed in series and allows great area on limited height, where the radius of each plate can be increased to increase the area per step. Concept is simple, easy to design, not complex and can be low-cost. A huge disadvantage is that the oil will only flow over the edge of the next step, decreasing the efficiency.

CHARACTERISTICS AND FEATURES

Positive characteristics are; Large are on small height, simplicity in design and construction, low cost, easy to make the process visible.

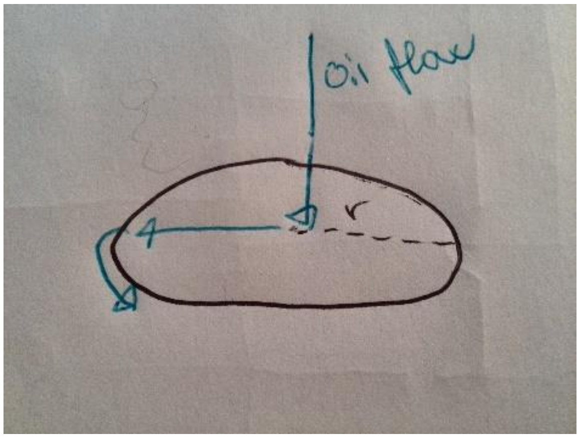
Negative; Low efficient, many disks needed to achieve large oil flow that is dehumidified.

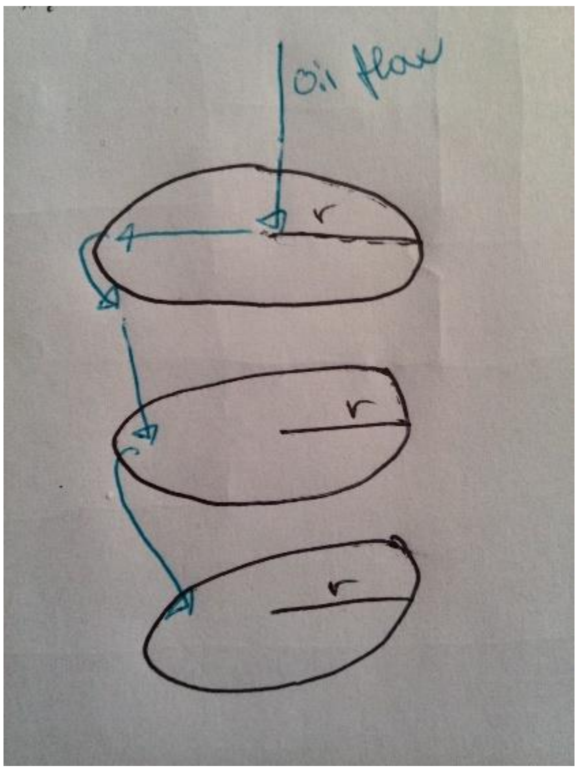
SUMMARY

This is a simple concept, but a little too simple to be implemented in the system. With some alterations this can be a great way to dehumidify the oil.

We will also execute further calculations and simulations of this process, if we find this concept applicable.

Pictures are attached to this concept sheet.


Oil flow
r


Oil flow
r
r
r

C-1.5

Automatic Oil Filling Station – Dehumidifying Process

The hat

PROCESS DESCRIPTION

Process starts from opening oil supply into vacuum condition in the dehumidifying line. Dehumidifying process to be visual. Water in the oil will boil visually in this section. One of two selected tank will be filled. When reservoir is full. System will stop.

CONCEPT DESCRIPTION

Oil flows from intake on to a cone plate with an optimized angle, where the angle decides the flow rate over the plate. This concept is based on one stage where the area of the plate needs to be large to dehumidify the oil before it flows further into the tanks. The surface are and height of oil on the plate can also be optimized by calculating the optimal angle and area of the cone plate

CHARACTERISTICS AND FEATURES

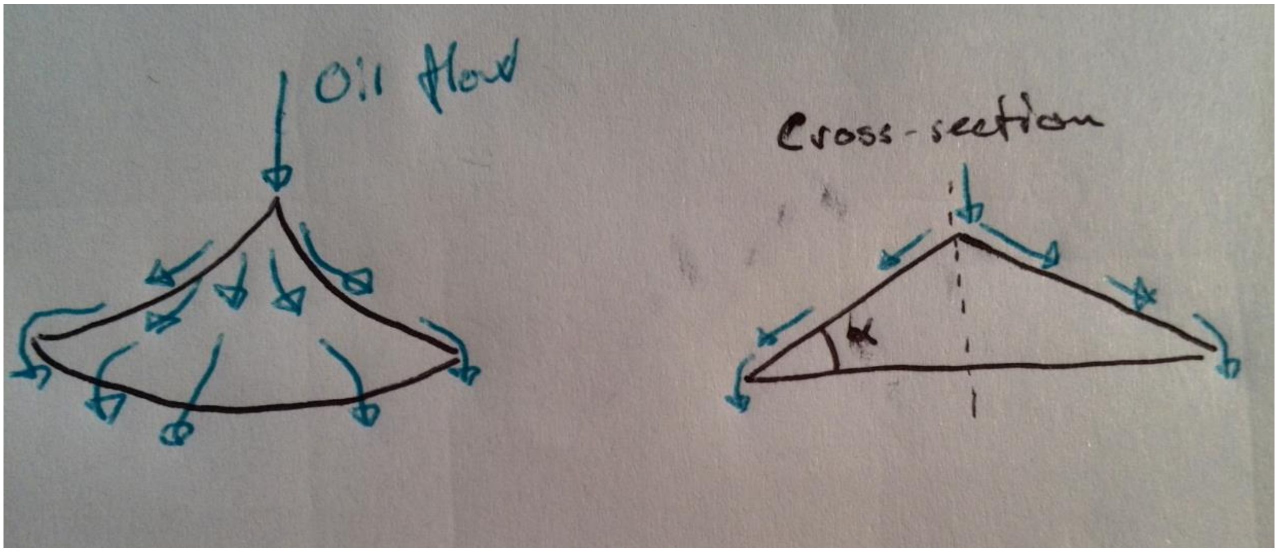
One step dehumidifying, large area achievable on small height, oil flow can be optimized, hard to make whole process visual but parts of the process are not as hard.

SUMMARY

The hat is a concept that needs much work to function properly and as intended, but may be a great concept if it is implemented.

We will also execute further calculations and simulations of this process, if we find this concept applicable.

Pictures are attached to this concept sheet.


Oil flow
Cross-section

C-1.6

Automatic Oil Filling Station – Dehumidifying Process

The hat collector

PROCESS DESCRIPTION

Process starts from opening oil supply into vacuum condition in the dehumidifying line. Dehumidifying process to be visual. Water in the oil will boil visually in this section. One of two selected tank will be filled. When reservoir is full. System will stop.

CONCEPT DESCRIPTION

The hat collector is based on the hat, but also consists of a second similar plate upside down under the first plate, with a hole in the center. This second plate allows the area to be further increased when collecting the oil, and also makes the last step of the dehumidifying process contribute (the step of collecting the oil before leading it to the tanks). Multiple hat collectors can easily be placed above each other in a circular transparent tube to make the process efficient and visual.

CHARACTERISTICS AND FEATURES

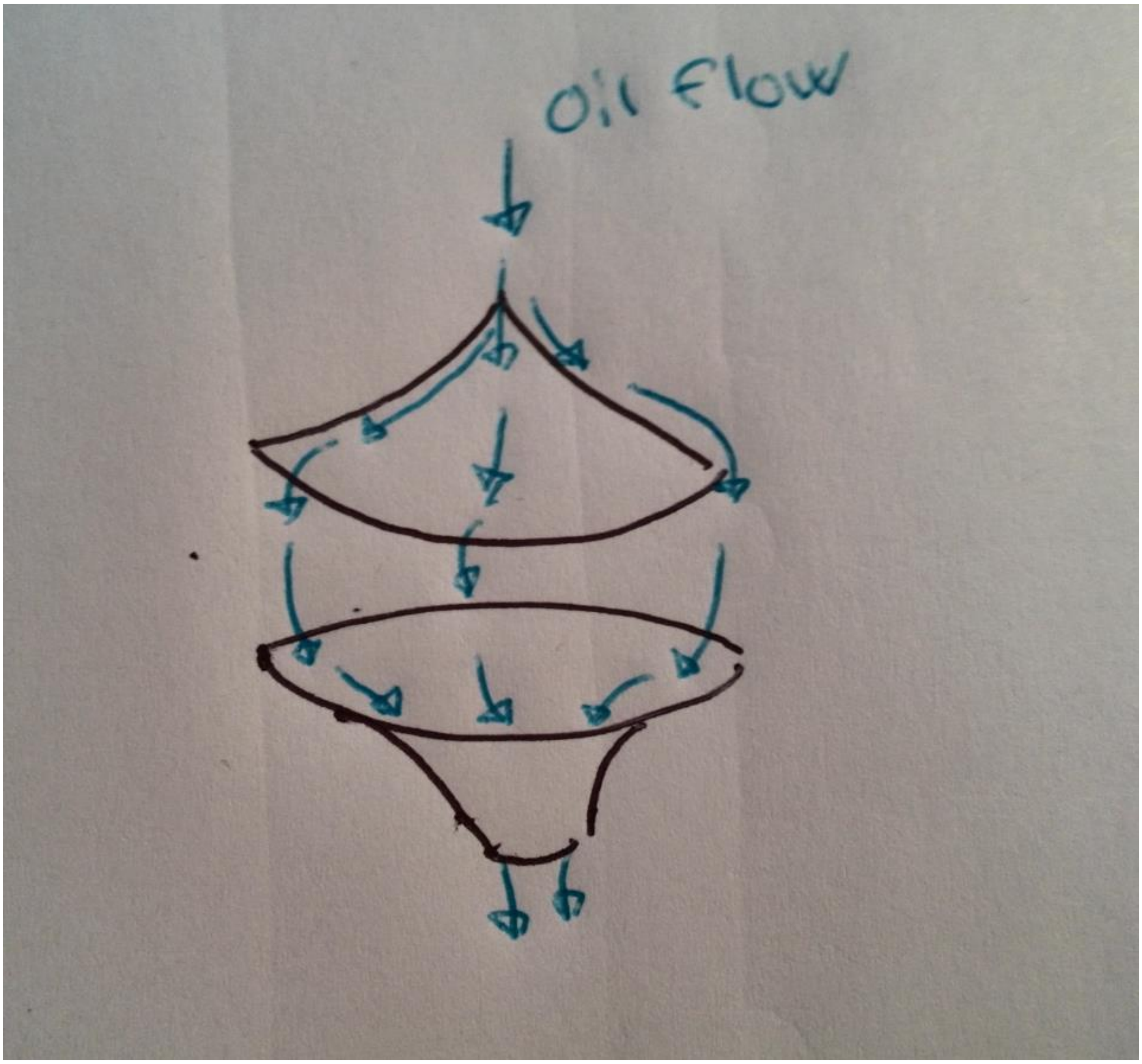
Large area on small height, enables large area-low height oil flow, enables visibility of the process, time costly to design.

SUMMARY

The hat is a concept that may be the one we are looking for, enabling large oil flows to be dehumidified on small heights.

We will also execute further calculations and simulations of this process, if we find this concept applicable.

Pictures are attached to this concept sheet.


Oil Flow

C-1.7

Automatic Oil Filling Station – Dehumidifying Process

The mesh

PROCESS DESCRIPTION

Process starts from opening oil supply into vacuum condition in the dehumidifying line. Dehumidifying process to be visual. Water in the oil will boil visually in this section. One of two selected tank will be filled. When reservoir is full. System will stop.

CONCEPT DESCRIPTION

The mesh is simple, it is a filter mesh in a tank that reduces the flow rate so the oil rests on top of it. It does not contribute to the structural strength of the tank, but is easy to design and cheap.

CHARACTERISTICS AND FEATURES

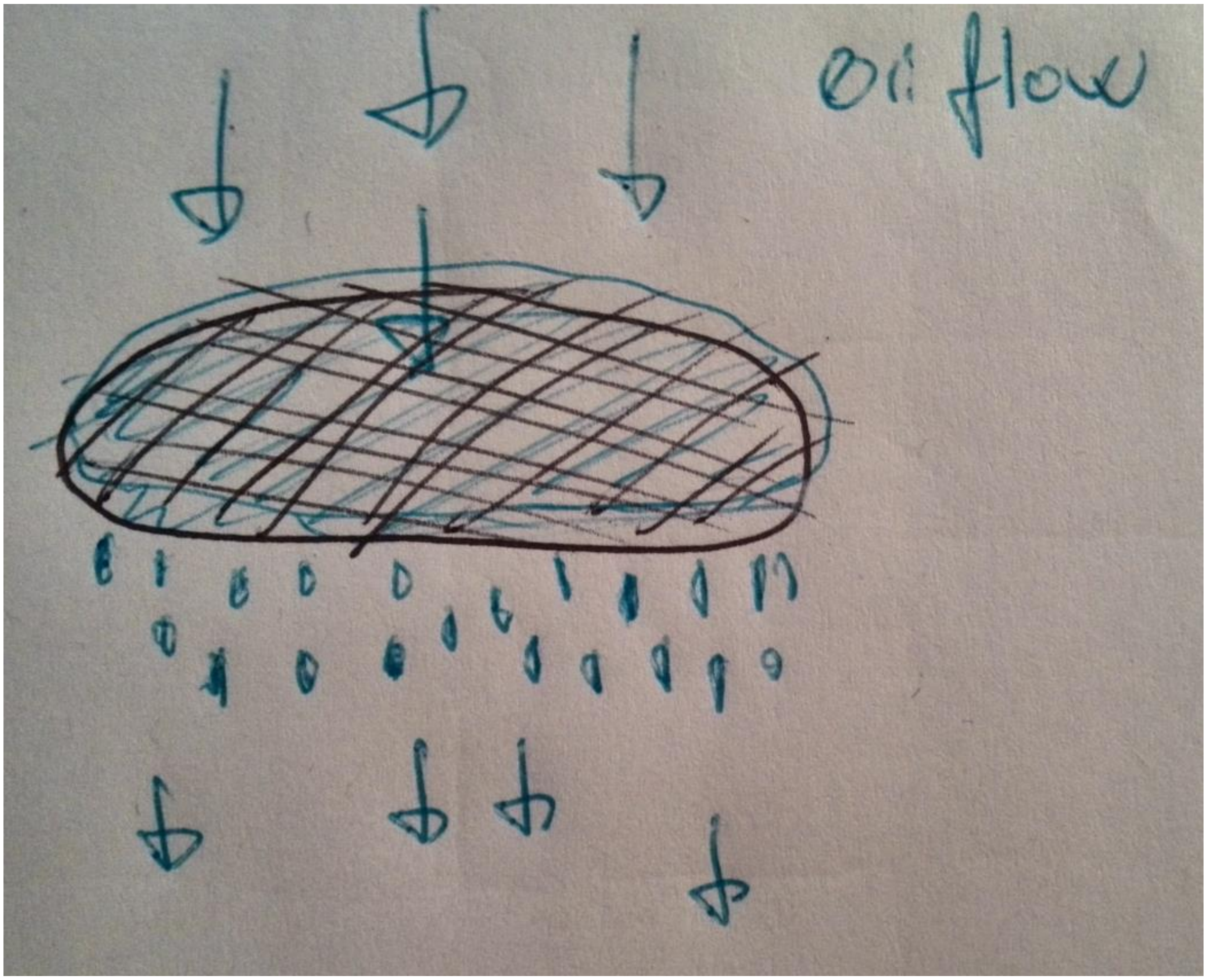
Cheap, easy to design, unpredictable oil flow, unpredictable dehumidifying abilities.

SUMMARY

The mesh is simple, but may lead to problems with the visual part of the process because of drips and constant turbulence in the oil. On the other hand it, the turbulence contributes to the oil surface area and therefore also contributes to the process.

We will also execute further calculations and simulations of this process, if we find this concept applicable.

Pictures are attached to this concept sheet.


Oil flow

C-1.8

Automatic Oil Filling Station – Dehumidifying Process

The Jarlsberg

PROCESS DESCRIPTION

Process starts from opening oil supply into vacuum condition in the dehumidifying line. Dehumidifying process to be visual. Water in the oil will boil visually in this section. One of two selected tank will be filled. When reservoir is full. System will stop.

CONCEPT DESCRIPTION

The Jarlsberg is a combination of the circular plates and the mesh. It consists of several solid circular plates with holes. The plates slow the oil flow down and creates a layer of oil on top, while the holes allows the oil to flow through the plate to the next to continue the process.

CHARACTERISTICS AND FEATURES

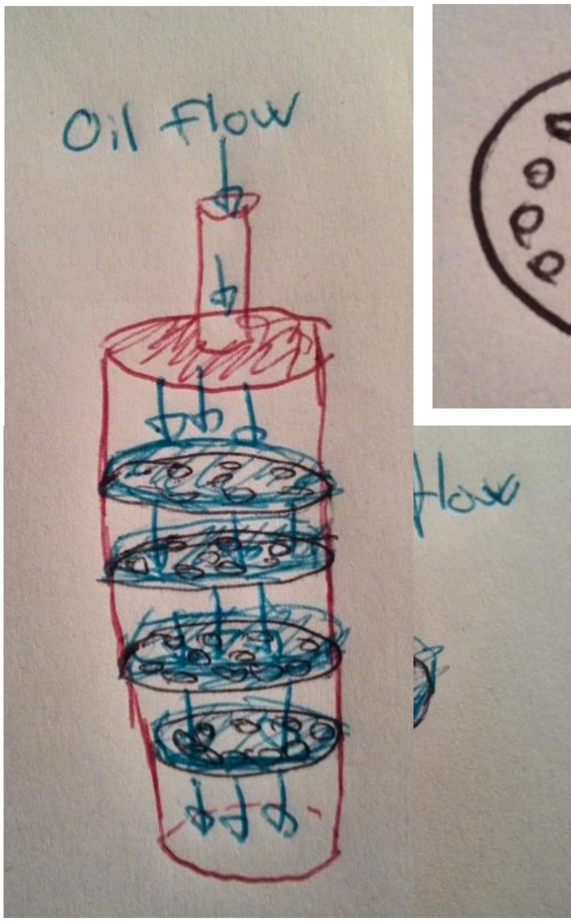
Large area on small height, resting oil and droplets from plate holes contributes to the area, simple design, cheap, easy to make visible.

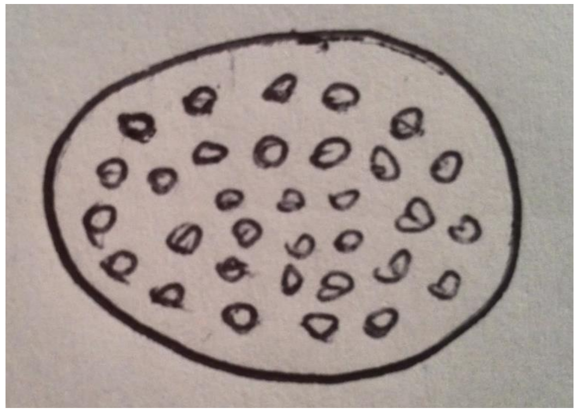
SUMMARY

[Short summary of your concept]

We will also execute further calculations and simulations of this process, if we find this concept applicable.

Pictures are attached to this concept sheet.


Oil flow
flow



C-3.1

Automatic Oil Filling Station – Filling & Pressurization System

The Filler Pressure

PROCESS DESCRIPTION

Process starts when jumper is connected to the system and by push of button. Vacuum is applied to hose while other end is filling hose with oil. Oil will travel from holding tank into the pressure system and into the jumper hose. Once hose is filled, and no bubbles are visible at other end. Process stops. Finished.

System will fill different pressures. Filling with 0.2 bar optical and 2 bar electrical hoses. System will include a pump, motor, accumulator (filling) etc. System will deliver these lines to the channel connection system.

CONCEPT DESCRIPTION

The filler pressure system uses a 02 bar preset accumulator on the main supply line going from the holding tank to the channel connections system. Two other lines connected to the main supply line are both connected to each pump delivering 2 bar filling pressure and 15 bar for pressurizing. The pressurizing line goes to a regulator.

CHARACTERISTICS AND FEATURES

The system splits into three functions. 0.2 bar and 2 bar filling and up to 15bar pressurizing. The two latter functions are enabled using pumps while the first one is gained using an accumulator. The two pumps have pressure bypass valves preventing overpressure as well.

SUMMARY

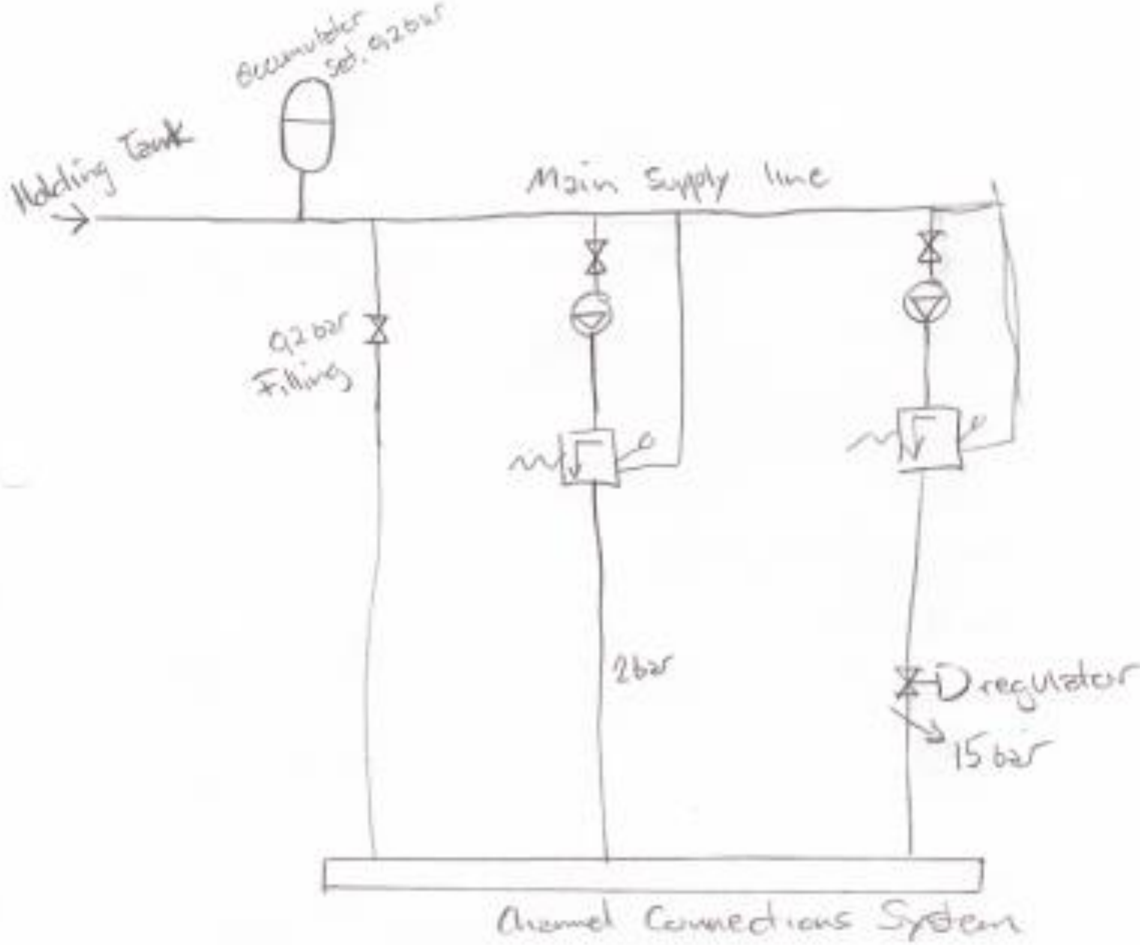
Original filling and pressure system (simple drawing).

We will also execute further calculations and simulations of this process, if we find this concept applicable.

Pictures are attached to this concept sheet.

The Filler Presser

System overview:



Simple drawing not including
sensors etc.

C-3.2	**Automatic Oil Filling Station – Filling & Pressurization System** **The Loop filler & Presser**

PROCESS DESCRIPTION

Process starts when jumper is connected to the system and by push of button. Vacuum is applied to hose while other end is filling hose with oil. Oil will travel from holding tank into the pressure system and into the jumper hose. Once hose is filled, and no bubbles are visible at other end. Process stops. Finished.

System will fill different pressures. Filling with 0.2 bar optical and 2 bar electrical hoses. System will include a pump, motor, accumulator (filling) etc. System will deliver these lines to the channel connection system.

CONCEPT DESCRIPTION

The loop filler and presser consists of several bypass loops so that only one pump is needed. The pump delivers a max pressure at 18 bar regulated loop. Then it is split into 3 lines with each a regulator giving the three pressures needed. 0.2, 2 and 15 bar. The 15 bar line has a secondary regulator to control the ramp from 0-15bar.

CHARACTERISTICS AND FEATURES

The system splits into three functions. 0.2 bar and 2 bar filling and up to 15 bar pressurizing. All is done with one pump and some regulators. This will save the usage of another secondary pump. This does not give redundancy which two pumps will give.

SUMMARY

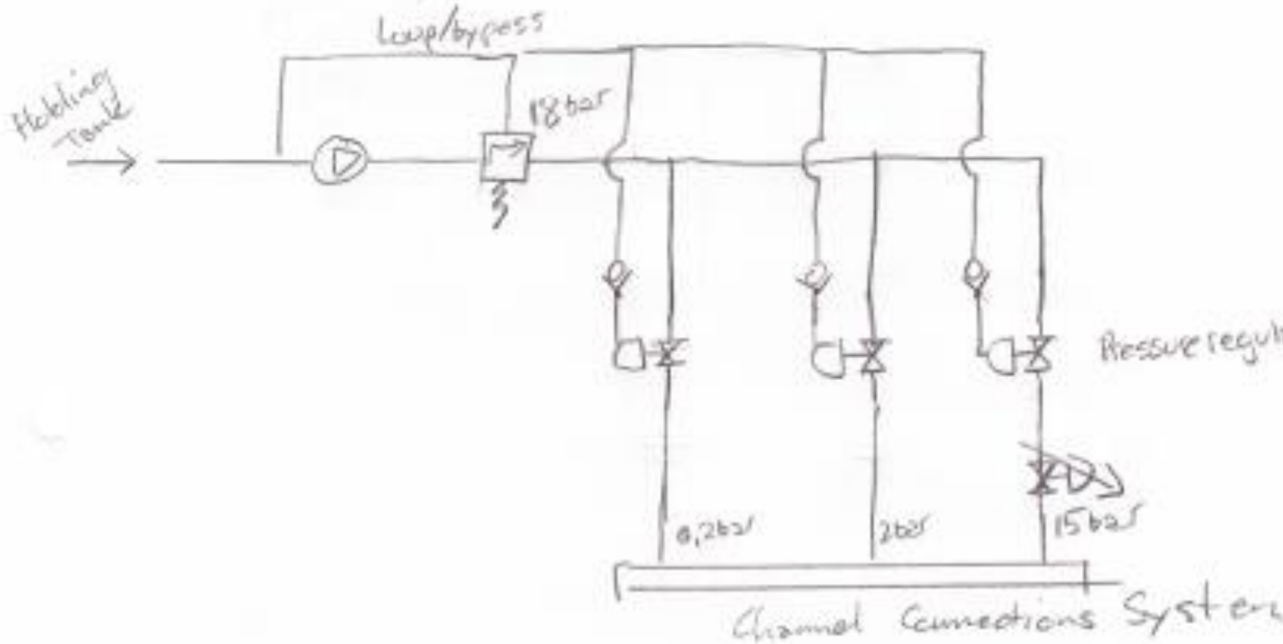
Modified filling and pressurizing system. (simple drawing)

We will also execute further calculations and simulations of this process, if we find this concept applicable.

Pictures are attached to this concept sheet.

The loop filler & Presser

System view



Simple drawing not including sensors etc.

C-3.3

Automatic Oil Filling Station – Filling & Pressurization System

Double accumulator

PROCESS DESCRIPTION

Process starts when jumper is connected to the system and by push of button. Vacuum is applied to hose while other end is filling hose with oil. Oil will travel from holding tank into the pressure system and into the jumper hose. Once hose is filled, and no bubbles are visible at other end. Process stops. Finished.

System will fill different pressures. Filling with 0.2 bar optical and 2 bar electrical hoses. System will include a pump, motor, two accumulators (filling), etc. System will deliver these lines to the channel connection system.

CONCEPT DESCRIPTION

Nitrogen is released with 0.2 bar and tank valves are open. A junction with three connections divides the oil. Jumpers are connected to each of the divided connections. Two jumpers are connected to the end of two pipes with a pump that delivers 15 bar and 2 bar, followed by a safety valve. Each of these pipes are connected to an accumulator. One one-way valve precedes the accumulators. The tube connecting the third jumper is a pure tube without any other items connected. Pressure transmitter placed at the end of the pipes.

CHARACTERISTICS AND FEATURES

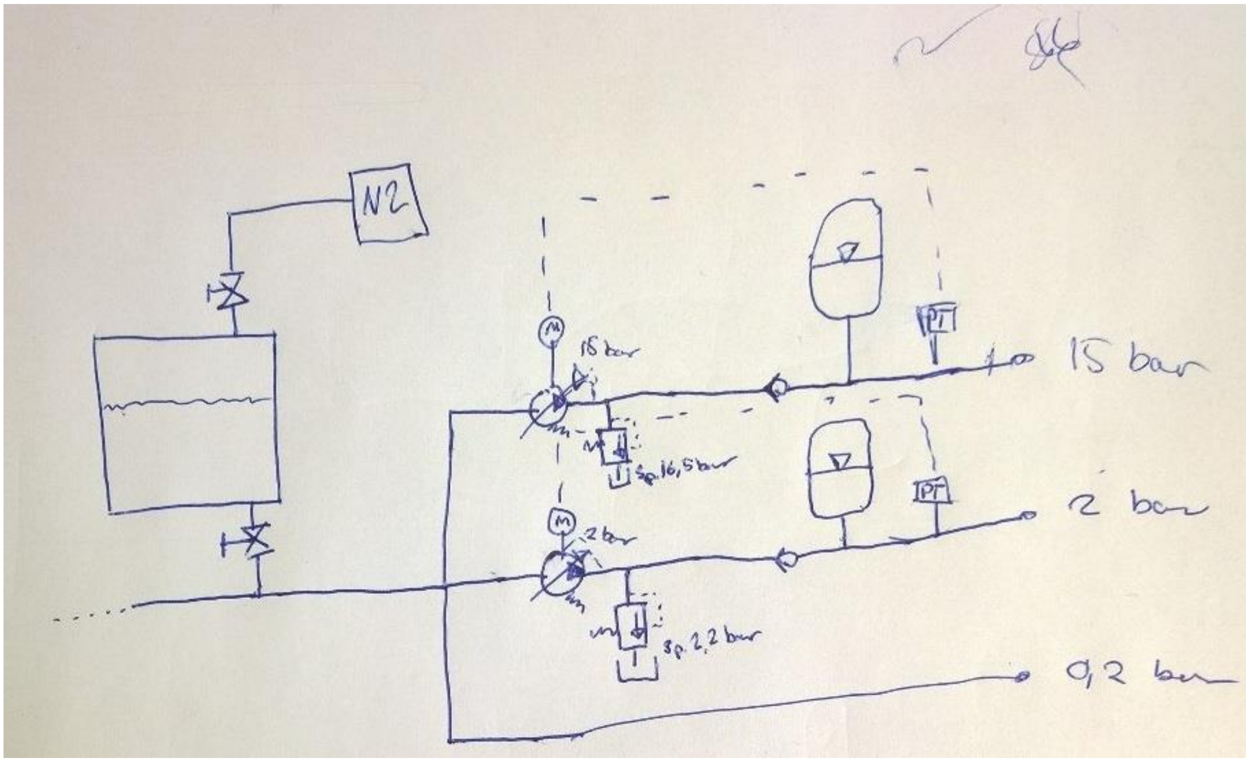
Two accumulators, two pumps and two pressure transmitter.

SUMMARY

The extra accumulator, motor and pressure transmitter will make the concept more complex, but if it is built properly, very stable.

We will also execute further calculations and simulations of this process, if we find this concept applicable.

Pictures are attached to this concept sheet.



N2
15 bar
Sp.16,5 bar
2 bar
Sp. 2,2 bar
PT
PT
15 bar
2 bar
0,2 bar

C-3.4

Automatic Oil Filling Station – Filling & Pressurization System

One pump

PROCESS DESCRIPTION

Process starts when jumper is connected to the system and by push of button. Vacuum is applied to hose while other end is filling hose with oil. Oil will travel from holding tank into the pressure system and into the jumper hose. Once hose is filled, and no bubbles are visible at other end. Process stops. Finished.

System will fill different pressures. Filling with 0.2bar Optical and 2bar Electrical hoses. System will include a Pump, motor, accumulator(filling) etc. System will deliver these lines to the channel connection system.

CONCEPT DESCRIPTION

The idea is that a one pump system will deliver both 2 bar filling pressure and 15 bar pressurization pressure. The pump will deliver approximately 20 bar that a accumulator will store so that pump energy consumption goes down, because the pump can be stopped as long as the pressurization pressure at the accumulator(before regulating valve lowering pressure to 15 bar) is above a set pressure. The pump will also be able to run constantly while it is required, for 2 bar filling purposes. The 0,2 bar filling will still be handled by nitrogen pressure from the tank.

CHARACTERISTICS AND FEATURES

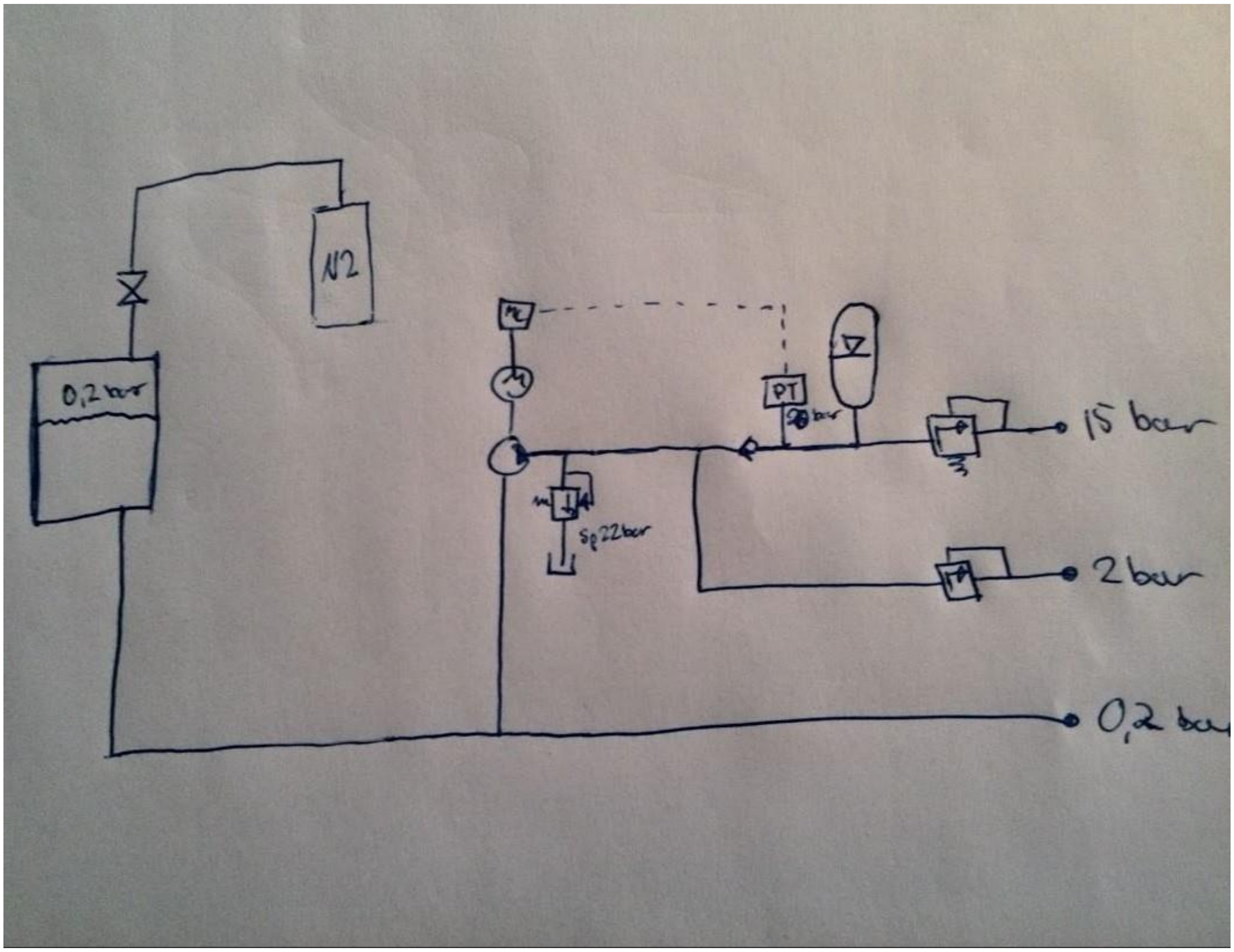
One pump, high pressure capabilities, simple setup, simple construction, constant 2 and 15 bar, low energy consumption, low nitrogen consumption, high flow capabilities.

SUMMARY

This concept will use less energy and will consist of fewer parts than a two pump system. The regulating valves will ensure stable filling pressure and pressurization pressure.

We will also execute further calculations and simulations of this process, if we find this concept applicable.

Pictures are attached to this concept sheet.



N2
0,2 bar
PT
15 bar
2 bar
0,2 bar

C-8.1

Automatic Oil Filling Station – Reservoir Tank System

Tilted cylindrical tank

PROCESS DESCRIPTION

System reservoir (tanks) will have several connections and features. Sensors connected showing vital information to prevent system failure and provide system control and safety. Tanks will need level sensors and indicators, pressure sensors, safety valve, filling inputs and outputs and nitrogen supply input.

CONCEPT DESCRIPTION

The idea behind concept 8.1 is to use cylindrical tanks that are exploiting available floor area more effectively. The proposed concept consists of tanks that are tilted horizontally, and mounted with a small slope i.e. the bottom of the tank is a few degrees higher than the outlet valve. The purpose with this slope it to prevent dirt particles to pile up in the bottom of the tank. And to ensure sufficient oil level at outlet valve.

CHARACTERISTICS AND FEATURES

- Space efficient (especially height).
- Tank and connection inputs must be customized or specially ordered from manufacturer.
- Incline feature to reduce gathering of dirt particles.
- Cylindrical characteristics to withstand vacuum.

SUMMARY

Horizontal lying tanks with an incline. The intention is to reduce total height and oil sludge.

We will also execute further calculations and simulations of this process, if we find this concept applicable.

Pictures are attached to this concept sheet.

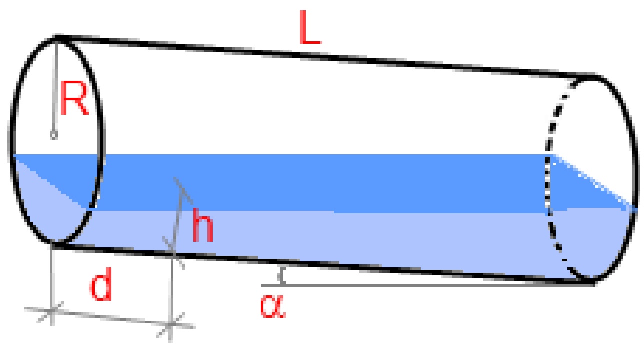


Figure 1: Concept 8.1 (http://planetcalc.com/users/1/1305667792.png)

C-8.2

Automatic Oil Filling Station – Reservoir Tank System

Spherical tank

PROCESS DESCRIPTION

System reservoir (tanks) will have several connections and features. Sensors connected showing vital information to prevent system failure and provide system control & safety. Tanks will need level sensors and indicators, pressure sensors, safety valve, filling inputs and outputs and nitrogen supply input.

CONCEPT DESCRIPTION

Spherical tank with connections on top and bottom. Oil will drain easily and not stick. Transparent tube connected to bottom and leveled at equal height for visual inspection.

CHARACTERISTICS AND FEATURES

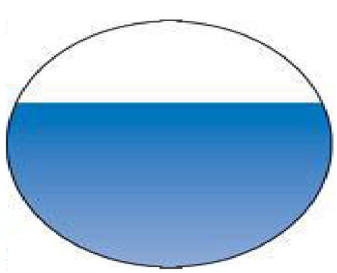
- Simple system
- Similar to the original system
- Manual level reading
- Visual process

SUMMARY

Spherical tank

We will also execute further calculations and simulations of this process, if we find this concept applicable.

Pictures are attached to this concept sheet.



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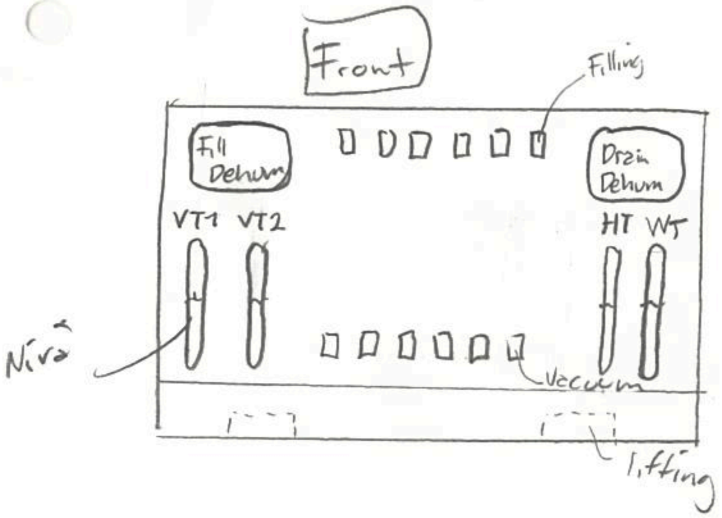
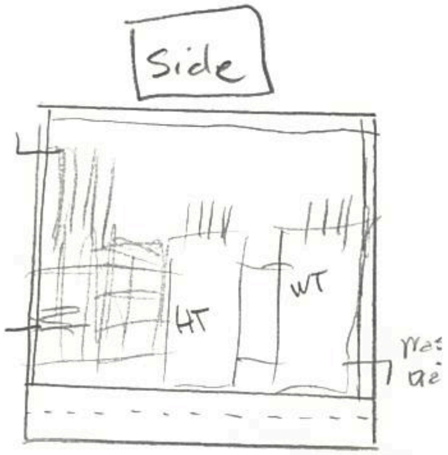
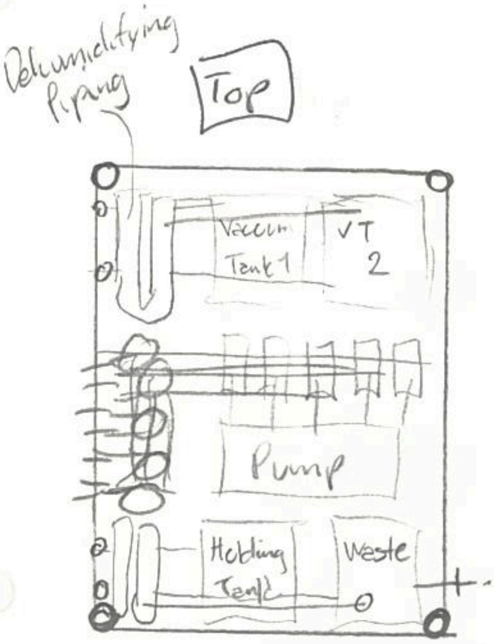
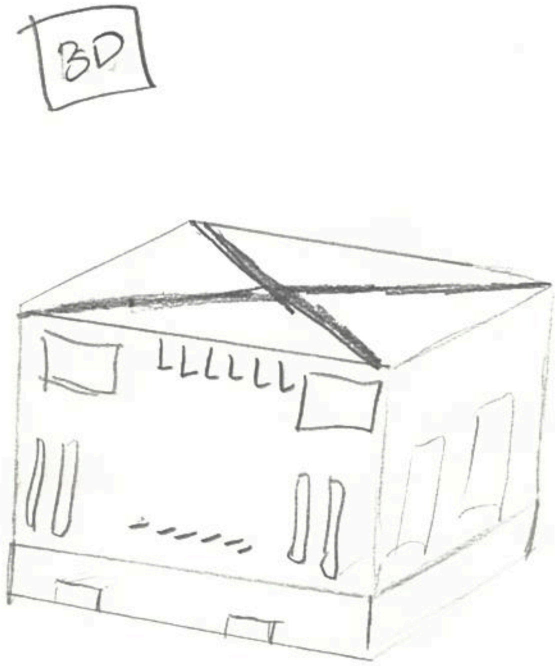




WT - Waste Tank
VT - Vacuum Tank
HT - Holding Tank





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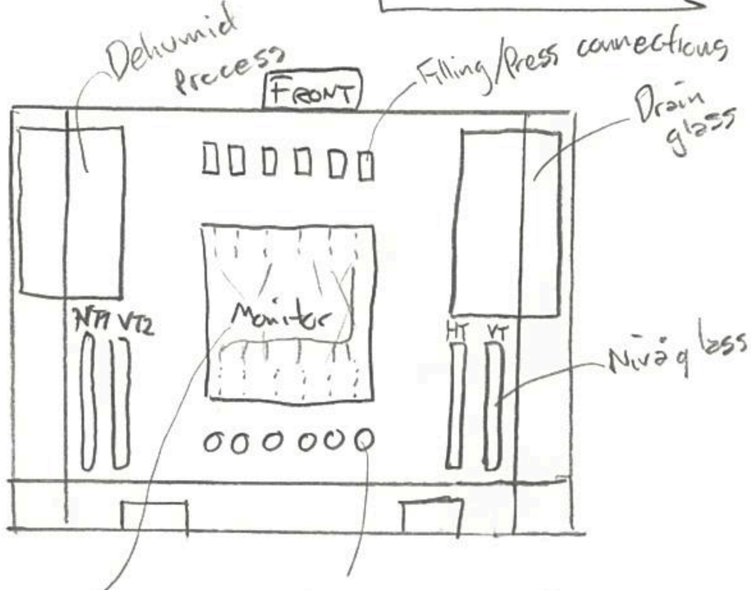
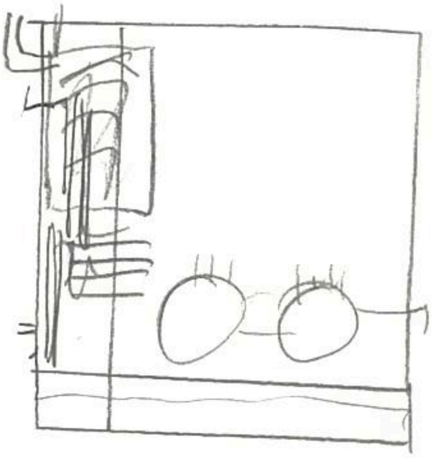
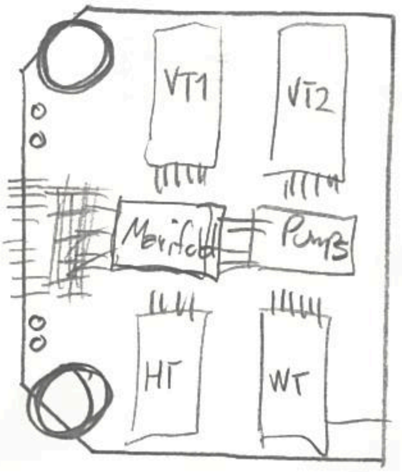


(Active Monitor showing what connections are in use)

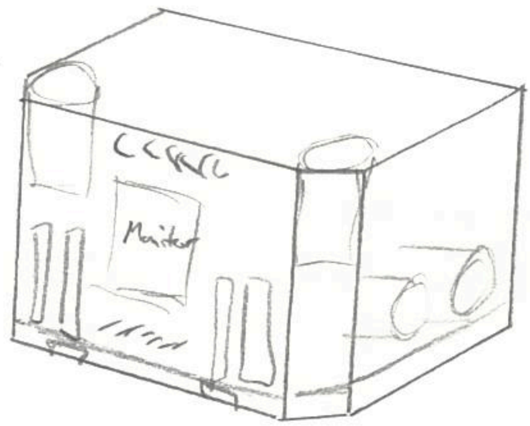
CHANGE: Can be 'clear' Tubing illuminated to show flow process.



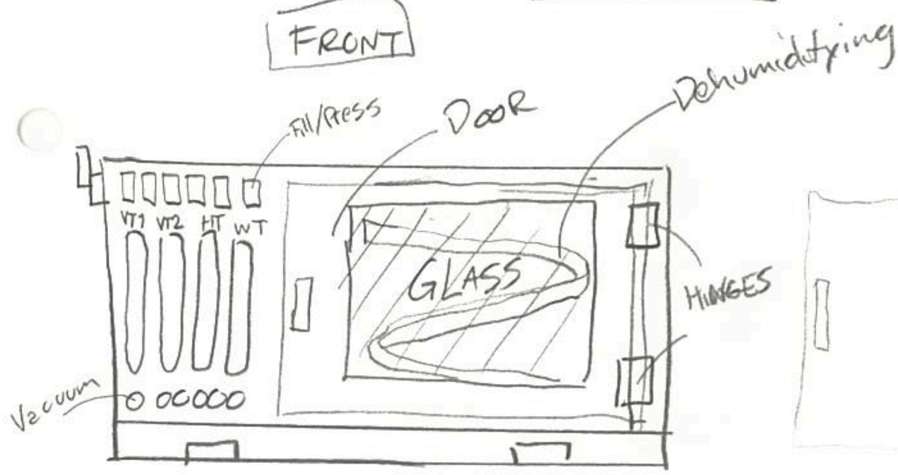
TOP

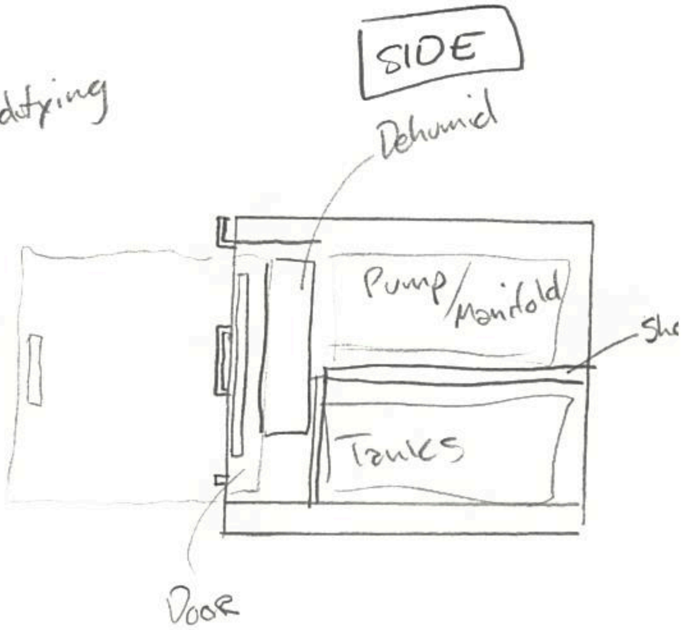


3D

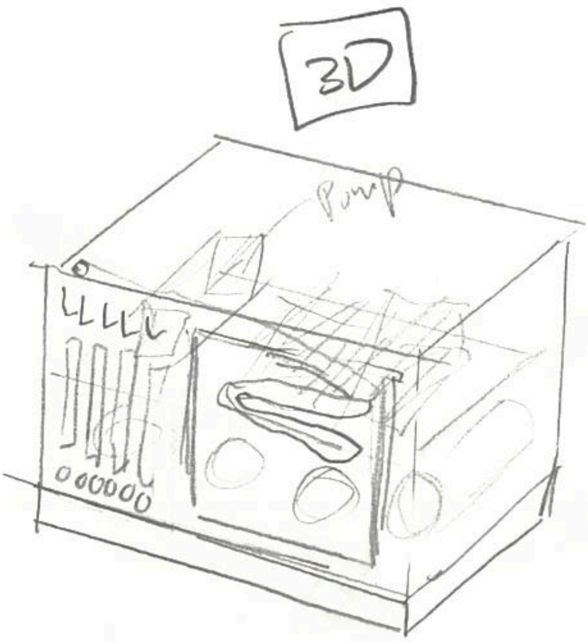


DRAFT 3


FRONT
Fill/Press
DOOR
Dehumidifying
VT1 VT2 HT WT
GLASS
HINGES
Vacuum


SIDE
Dehumid
Pump/Manifold
Tanks
Door


TOP
Pump F
Dehumidifying
Pump V


3D
Pump

Design

Functions and factors

Bachelor Assignment spring 2015

Automatic Station Oil Filler Subsea Jumpers

AUTOMATIC OIL FILLING STATION

-

EIRIK S. MÆHRE MARIUS MARTINSEN
KNUT OLA NYMOEN HENNING HENRIKSEN

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1.0 Introduction

Precision Subsea has requested that we design an Automatic Oil Filling Station. They are currently using a manual oil filling station and want to automate as much of this system as possible to save costs.

This document contains a general introduction with possible solutions to the technical challenges related to the product, its functions and operations. It will focus on the major functions and factors surrounding the design.

To better view certain aspects of these topics, we have split the document in several sections.

1. Introduction to the different systems in the design.
2. Revolve around design factors.
3. Cover design functions and processes
4. Introduction to the flow charts of the different operations.
5. Design schematic given by Precision Subsea.

1.1 Abbreviations

PS -	Precision Subsea AS
AOFS -	Automatic oil filling station
MOFS -	Manual oil filling station
PEP -	Project Execution Plan
HSE-	Health, Safety and Environment
TC -	Test Case
IBC -	Intermediate Bulk Container.
P&ID -	Piping and Instrumentation Diagram
PFD -	Process Flow Diagram

2.0 Product Systems

Product factors and systems are divided into sections as shown below.

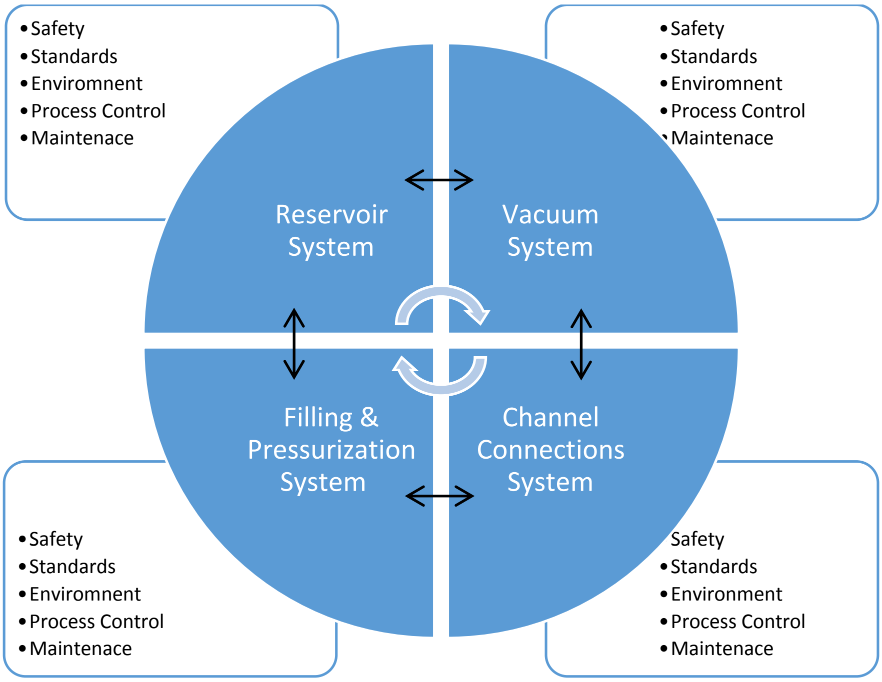


Figure 1: Product factors and systems

Arrows show the piping system going between the blue major systems of the product such as the storage reservoirs, vacuum, filling, pressurization and channel connections system.

The surrounding factors of these major components are safety, environment and process control, etc. discussed in the next chapter, design factors.

2.1 System Reservoirs

System reservoir section covers the system tanks and the dehumidifying process.

- The dehumidifying process is a process where the oil is dried in a vacuum condition. This process is described in more detail in chapter 2.2.
- The oil is supplied and fed through the dehumidifying process and into the storage reservoirs of the system, either vacuum tank 1 or 2. Once these tanks are full, the system will pump the oil onwards to the holding tank.
- Tanks will have sensors and indicators showing vital information to the system and user to prevent system failure and provide system control and safety.
- Nitrogen system will give positive pressure on top of oil in tanks and act as a preservative blanket and assist processes such as oil transfer from vacuum tank to holding tank.
- Holding Tank is a 100 liter reservoir containing dehumidified oil before filling sequence. There are several connections and piping connected to the holding tank, such as electrical level sensor, mechanical level indicator, a pressure sensor and overpressure safety valve. Other connected system components are the filling input (from vacuum tanks) and output (to pump system) and a supply of nitrogen.
- Vacuum tank (2 on each assembly) is a 50 liter reservoir either used for vacuum leak-test or receiving dehumidified oil before being pumped into the holding tank. Several connections and piping are connected to the vacuum tanks.
- Waste tank is a 50 liter reservoir used for drained oil. This can be old oil from old jumper hoses or residual liquids from the system during purging. Attached to the waste tank is an electrical level sensor and mechanical level glass. A pressure sensor and overpressure safety valve is also attached.

2.2 Vacuum system

Vacuum system which consists of a vacuum pump, filter and a safety system, provides vacuum condition in the dehumidifying process as well as in the hoses during leak test and filling.

- Vacuum pump delivers suction pressure to the system. It has a filter which inhibits oil vapor from reaching the vacuum pump.
- Safety system will be incorporated in the vacuumed line going to all the tanks. This safety system will prevent any oil from reaching the vacuum pump.

2.3 Filling and Pressurization System

Filling and pressurization system will consist of several components providing the ability to fill hoses and pressurize hoses at different pressures.

- The system will be designed with thoughts to prevent pump cavitation.
- Pump will be selected on a vast majority of variables such as type (centrifugal, etc.), flow, standards, viscosity, air/electrically driven etc. This will be showed in the detail design process and component specification.
- The power and efficiency will also be showed in the component specification. This will affect greatly the selection of pumps used in design.
- Self-lubricating pump is needed as silicone oil will not lubricate the pump internally.
- Noise of the pump selected will also be judged as the system will be inside a workshop.
- Pressure pump is needed in the system to deliver a total of 15 bar.
- The system includes a pressure accumulator for filling purposes.
- The accumulator is capable of delivering at least 0.2 bar pressure for filling optical subsea jumper hoses and also is capable of delivering pressure to transfer oil across holding and vacuum tanks.

2.4 Channel Connections System

From our initial understanding we see that each subsea hose is connected at each end through all product functions described in chapter 4. Below is a visual representation of a subsea jumper hose (orange) and the two connections, A-line and B-line represented by the (X). Each end also has a pressure transmitter used during different operations as described below.

Figure 2: Subsea Jumper Hose Connections

During the different functions, each end behaves and operates differently.

- **Leak test,** the B-line is closed, and vacuum is applied at A-line.
- **Filling,** both are open, vacuum at A-line, filling pressure at B-line.
- **Pressurizing,** A-line is closed, B-line is pressurized.
- **Draining,** both are open, draining at A-line.

Six separate channels results in 12 connections for the different functions. To make this easier we have split these 12 connections into two groups resulting in six connections in each group. (Hence 6 x A-lines and 6 x B-lines).

The reason for this is that if each connection where to represent all functions, the valve housing would be massive because of six or more input ports at each connection. (12 x 6 = 72 lines)

A-line: (6 connections)

- Two filling lines (0.2 and 2 bar).
- Single pressuring line

B-line: (6 connections)

- Vacuum line: Two vacuum tanks. Single line choosing from two vacuum tanks.
- Draining line: Single line going from waste tank.

Process Line Selection

To give a better view of the system lines we have created a simplified connection drawing.

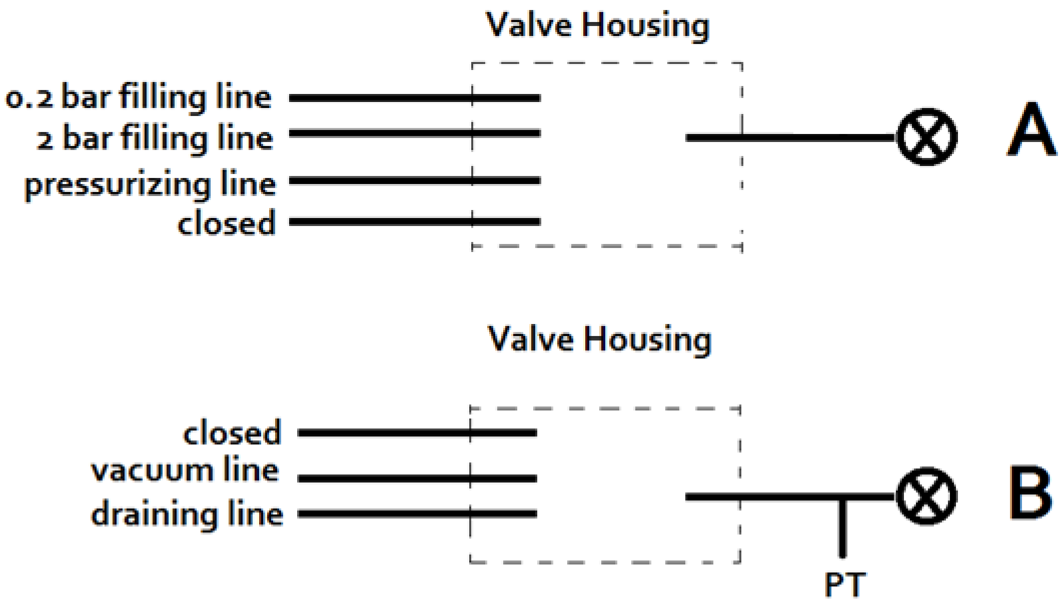


Figure 3: Process valve connections

First valve (top location) covers all A-line features and will choose according to sequence and process operation. Second valve (bottom location) will also act according to sequence and process operations, but will cover all B-line features. It will also include a pressure transmitter.

2.5 Piping Systems

Piping systems covers all valves and piping sizes, connections, fittings etc. going between the major systems such as the reservoirs, vacuum process etc. The following considerations are made.

- Pressure ratings of the piping system will vary between the vacuumed system and the pressure system and as such the system will be designed to handle these pressures.
- Thermal expansion due to sudden temperature changes in piping will be evaluated during the component placement in the detail design process.
- Dimensions of the piping system are confined to the size of the module and will be evaluated during detail design to accommodate flow rates and pressures.
- Valve specifications and selections will be evaluated during detail design process.
- As silicone oil will be dehumidified early in the system, no internal corrosion will be expected from the working fluid during operation. Selection of piping able to resist silicone oil will be prioritized.
- Piping sizes before and after pumps will be designed to prevent cavitation.
- Piping system will be showed in the P&I Drawings and PF Drawings.
- Type of piping such as hoses, tubing, blocks will be evaluated per function during detail design.

2.6 Nitrogen System

During oil transfers from the vacuum tanks to the holding tanks, the nitrogen system act as a stabilizing force to prevent vacuum and pressure conditions on top of the oil.

Each tank will also have a valve connected, supplying nitrogen to act as a blanket on top of the oil. During vacuuming sequence, the tank will be depressurized and the respective nitrogen supply valve will close.

3.0 Design Factors

We have classified design factors regarding our product as safety, standards, environment, process control and maintenance.

3.1 Safety

Other than the HSE focus described in the project plan, we have several considerations that will affect safety.

- When starting and stopping the AOFS, almost all valves are and will be in normally closed position as per P&ID drawings.
- Sensors in the system will always be active and shown in the system overview on the PC monitor. This will alert the user to unordinary situations and events.
  - We also incorporate light signals to show operations status. For instance; Green for finished, Yellow for user checks and Red for failure.
- Each sequence will be shown on the PC monitor during operation and which step it is on. These features will provide more information to the user by highlighting each running step.
- Noise levels of the final design product, from pumps etc. will be judged to prevent high noise in the factory area as people will be working in close proximity to the product.

3.2 Standards

To create a product, certain standards and directives have been set by the government.

- The system will follow EU Pressure Equipment Directive 97/23/EC (PED) and PED 1997L0023
- The system will also follow the Norwegian Legislative documents covering pressurized equipment. ("Forskrift om trykkpåkjent utstyr. (Lovdata)")
- The system will also follow ISO standards and other ruling documents affecting our product.

3.3 Environment

The system is designed with considerations to the environment.

- Requirements such as drip tray and closed system, to prevent leakages, are solid considerations which we have focused on in our design.
- Heat loss and insulation are not needed as the system is considered to be based inside a structure, in this case on the factory floor with room temperature.
- Surface corrosion caused by weather conditions and other factors will also be eliminated by the fact that the unit is to be placed on the factory floor.
- Shielding and other protective plating will be added where suitable on the product to give internal products the protection needed against falling objects, etc.

3.4 Process Control

To gain total control of system processes, a set of control valves, regulators, accumulators, etc. will be placed within the system.

- Fluid flow meters, pressure sensors, temperature probes, will be placed on relative control points to further assist system processes and sequences.
- Manual override of all valves will be possible as manual control of the system will be available in case the automatic system fails or in other required incidents.
- Automatic flow regulator valves will determine the rate at which some of the fluid will flow. These valves will be automatically regulated by the software during commissioning of the system and will regulate based on a set of parameters.
- If suitable, fixed flow valves or orifices will be used in our design to regulate flow and pressure.
- Automatic shut valves will be used to select or deselect certain connections to prevent and allow oil from passing during different sequences.

3.5 Maintenance

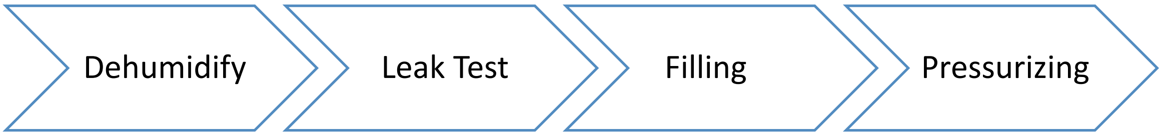
Maintenance is described as the operation to fix mechanical or electrical devices if they are In need of repair. To better preserve equipment functionality, operating conditions and do maintenance on a product, several considerations have to be made.

- Access to the components and how to reach the components during maintenance is important. This will affect the location of components and more importantly the time it takes to do maintenance.
- Space between and of each component will affect the accessibility of tools to be used during removal and installation.
- Modular view of maintenance relies on the foundation of component buildup inside a small module, and that the system is constructed by several modules.
    - In our design, such modules might be reservoir system, leak testing (vacuum) system, extensions and filling and pressurization system.
- Ergonomics and handling of systems component during maintenance focuses on applying features such as weight reduction (lifting), eliminating sharp (cutting) edges etc. to prevent injury to the user.
- During operation, some components may need to be changed. A redundancy system will implemented wherever possible.

4.0 Product Processes

We split the product processes in two different sections, new and old hoses.

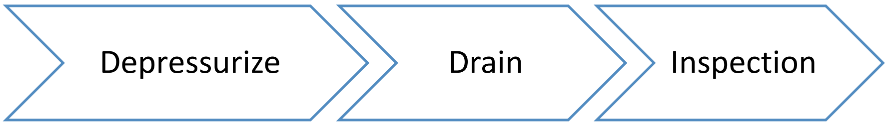
New Hoses:



Figur 4: New hose process

When dealing with new hoses the first process starts with dehumidifying the oil, this is to preset the oil with the needed qualities before you can use it. The system will then leak test and make ready the hose to be used. Once hose and oil is ready, the filling process can begin. After the filling process, the hose can be pressurized.

Old Hoses:



Figur 5: Old hose process

When dealing with old hoses, the process will consist of depressurizing the hose, draining of oil and inspection of the oil quality. This is a solidary action and requires none of the other processes described above such as dehumidifying, leak testing etc.

Extensions

The oil filling station has six separate channels for the system processes. These functions can be extended by a block with six extra channels.

4.1 Dehumidify Process

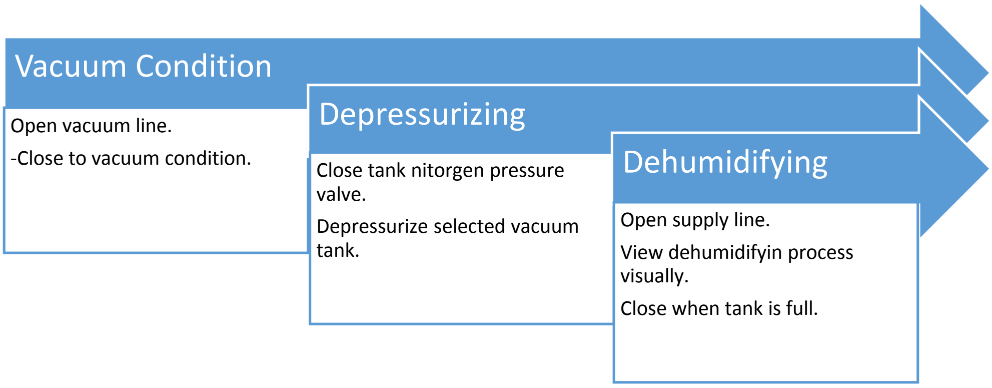
General Description

The dehumidifying process of the oil starts with creating a vacuum condition in the supply line. The vacuum condition will boil the water in the oil at room temperature.

The user selects a vacuum tank to be filled. The tank is then depressurized, and a direct line from the IBC to the vacuum tank is created by automatic valves opening. The oil will then flow, while dehumidifying visually in transparent vacuum tubes, to the selected tank.

When the tank is nearly full the system will stop the supply of oil through the filling valve. The remaining oil and the dehumidifying process will end.

Dehumidifying Sequence



Figur 6: Dehumidifying process illustration

4.2 Leak Testing

General Description

The vacuum leak test of jumpers is generally described as a process where it is applied vacuum to a hose and then checked for pressure deviations.

Vacuuming Sequence

1. Ensure all hoses are drained for oil: Select waste tank for leak test. Apply vacuum at connections and purge residual oil.
2. Ensure MKII filling adapters does not leak. (The MKII filling adaptor connected to each hose needs a temporary "cut hose" to lock/block so that it does not close when vacuum is applied.)
3. Connect to hose. Apply vacuum on the line in one end, while the other end is sealed.
4. Vacuum stabile time:

$$Time_{vacuum} = 15\,\mathrm{min} + \frac{2min}{meter}$$

5. A timer will indicate when the vacuuming process is finished and the monitoring begins. A differential pressure sensor will continuously monitor the pressure and significant pressure differences will trigger a leak warning.
6. Input acceptance criteria: hold time for vacuum leak test and acceptance criteria for pressure change is project specific and is adjusted in the software.

Once the test has been completed and accepted by the user and dehumidified oil is in the holding tank. Filling sequence can be initiated.

4.3 Filling

General Description:

The filling sequence is where the silicone oil is taken from the holding tank, pressurized and pushed into a hose while vacuum is sucking on the other end. The user will select the hose connections used. As this usually happens after the vacuum leak test, a vacuum connection is already connected and used in one end. The filling line will be connected at the other end.

Now that the subsea jumper hose is connected at both ends, one filling and one vacuuming point, the process can begin. The vacuum line will pull oil into the jumper hose while the filling line will push the oil.

Filling Sequence

1. Open MKII filling screws and vacuum valve.
2. Vacuum 5-10min after vacuum leak test is done.
3. Select filling connection to be used.
   - 3.1. Valves will automatically close and open respectively.
4. Select hose type and length.
   - 4.1. Automatic process will then calculate amount of oil needed.
   - 4.2. Hose type: 0.2 bar optical, 2 bar electrical cable in hose.
     - 4.2.1. The accumulator will give a 0.2 bar pressure to fill optical hoses.
     - 4.2.2. A pump will initiate if 2 bar pressure is needed for electrical type.
5. Filling begins.
   - 5.1. Shutoff-valve closes if filling pressure drops significantly
   - 5.2. Oil detected at vacuum side:
     - 5.2.1. Normally: here it will go to vacuum tank until we cannot see any bubbles.
     - 5.2.2. CHANGE: Own recycle loop so that the oil will go to the holding tank?
   - 5.3. Filling time varies: length, number of splice canisters etc.
6. Observe oil coming out of jumper. Filling complete when no bubbles are detected..
7. Close vacuum line.

Once filling is completed and accepted by the user, pressurizing sequence can start.

4.4 Pressurization

General Description

The pressurization sequence is where the silicone oil is inside the subsea jumper hose while connected to the AOFS and pressure is applied. The user will select the hose connections used. As this usually happens after filling, it is already connected. One end of the hose will be sealed while the other end (filling connection) will be pressurized.

Pressurization Sequence

1. User will select connection used for pressurization.
   1.1. Valves will automatically close and open respectively.
2. User will input hose specific pressures to be used (project defined).
3. System will start pressurizing the hose.
   3.1. Graph will appear in the software to show pressure level.
4. Pressure is held at a calculated time depending on hose length (pressure is stable).
   4.1. 2-12 hours is preferred.
5. The automatic process will then start logging of significant pressure drop.
   5.1. General rule is a pressure drop below 0,1 bar/hour.
   5.2. Pressure drop formula:

$$PD = \frac{P_1 - P_2}{T_1} * 60 \left[\frac{bar}{h}\right]$$

$P_1 = Start\ pressure$ $T_1 = Measuring\ time\ in\ minutes$

$P_2 = Stop\ pressure$ PD = Pressure Drop in an hour

6. When finished, the user must push button to accept post-pressurization inspection and check points.
   6.1. Filling connection valve will automatically close.
   6.2. User will disconnect MKII filling adapters.
   6.3. Push button by user – finished with disconnecting lines.
   6.4. System automatic vacuuming and draining of lines into tank.

The hose is now pressurized and sealed at each end.

4.5 Draining

General Description.

The draining sequence is where an old subsea jumper hose is connected to the system, depressurized and drained of old oil into a waste tank. This is a solitary action compared to the other sequences like pressurizing, filling, etc.

Draining Sequence

1. User will select connection used for draining sequence.
   1.1. Valves will automatically close and open respectively.
2. User will input hose specific pressures and length of hose (old hose inputs).
3. System will start depressurizing the hose by gradually opening a valve.
   3.1. Software will record original hose pressure.
4. Oil will flow from hose into waste tank visually through drain line with transparent tubing to see the coloring of the old oil.
   4.1. This will give indication of degree that the oil is contaminated.
   4.2. The used oil will pass a different line than the filling line to avoid contaminations affecting the new oil during oil filling.

4.6 Extension

General Description

The oil filling station has six channels that can be used for dehumidifying, vacuuming, filling, draining, pressurization, all at the same time. These functions can be extended by six more channels on the system.

1. User will connect the extension block to the extension connections on the AOFS.
2. User will then activate the extension application in the software.
   2.1. Valves will automatically close and open respectively.
3. The software can now accommodate the extension block through the AOFS.
4. Channels that can be selected have now expanded from 6 to 12.

5.0 Flow Charts

Flow charts are to be created in the detail design phase. These will include boxes of different shapes to differentiate between actions and processes such as.

- Commands and interactions the user will have with the computer system. These interactions may include starting each process, selecting tanks and accepting completion of manual tasks such as hose connection.
- System sensors readings to be taken. These readings may include pressure, oil level checks, etc.
- Valves automatically opening and closing in the sequence.
- Timers that will give delays from one step to the next.

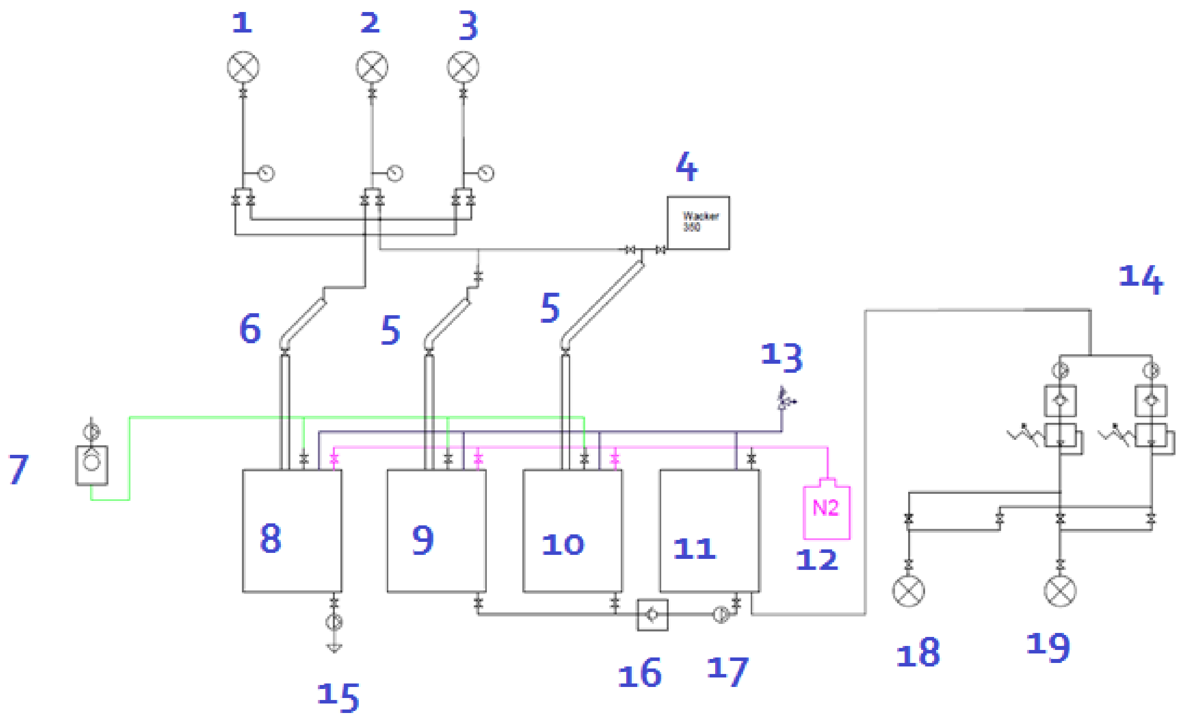
The process charts will be split into each process such as dehumidifying, leak testing, filling, pressurization, draining, etc. A flow chart combining several processes will also be added at the end to better visualize from start to finish all the product capabilities

Flow charts to be created are.

- Dehumidifying
- Leak testing
- Filling
- Pressurization
- Draining
- Overview

6.0 Design Foundation

This is the original drawing received from PS. It gives a simple indication of the system P&ID they are envisioning and for us a good foundation to further develop the system concept.



Figur 7: System layout

1. Vacuum connection 1.
2. Vacuum connection 2.
3. Vacuum connection 3.
4. Silicone oil supply (IBC)
5. Dehumidifying system (visualization)
6. Draining system (visualization)
7. Vacuum pump system
8. Drain reservoir
9. Vacuuming reservoir 1
10. Vacuuming reservoir 2
11. Holding tank
12. Nitrogen blanket tank
13. Tank overpressure valve
14. Filling and pressure system
15. Drain tank valve and pump
16. One-way-valve
17. Tank oil transfer pump.
18. & 19. Filling and Pressure connection.

Dehumidifying Process

Bachelor Assignment spring 2015

Automatic Oil Filling Station

-

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Henning Henriksen

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6.0 Pipe brackets 7

7.0 Drawing 7

1.0 Introduction

This document covers the process, component list, manual and explanations related to the new suggested dehumidifying process. This process covers:

1. Oil inflow from external holding tank.
2. Dehumidifying of the oil in very low pressure (approx. 2 mbar).
3. Oil outflow to internal holding tanks.
4. Vacuum pump tube connection.

2.0 Relevant liquid specifications

Name: Wacker AK 350 silicon fluid.

$$Kinemativ\ viscosity\ (\nu)\ \approx\ 350\frac{mm^2}{s}$$

$$Density\ (25\ °) \approx 0.968\frac{g}{cm^3}$$

3.0 Tube specifications

3.1 Material

Currently the tube material is PMMA, extruded acrylic pipes. Changing the material is unnecessary because the cost is irrelevant and the compressive strength is safely above the necessary strength:

Typical properties of acrylic PMMA		
ASTM or UL test	*Property*	*Acrylic*
D695	Compressive Strength (psi)	11,000 – 19,000

Table 1: Acrylic PMMA properties (http://www.boedeker.com/acryl_p.htm)

The compressive strength in psi equals approximately 758 – 1310 bar.

3.2 Geometry

The tubes will be circular because of the relatively high surface to volume ratio of the tube. A circular tube also withstand outer pressure efficiently and it is easy to find different fittings and bends for the tube.

3.3 Diameter

The tube diameter will increase because it is necessary to increase the surface area of the oil flow. Because of the pipe fitting size the new increased diameters are:

	Original diameters	**New diameters**
Outer diameter	Ø50	Ø76
Inner diameter	Ø40	Ø66

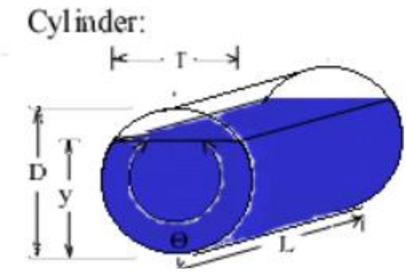
Table 2: Tube diameter change

The oil is immiscible with polar solvents such as water. Water is heavier $\left(density\ (25\ °) \approx 0.997 \frac{g}{cm^3}\right)$ so we can assume most of the contained water is at the very bottom of the pipe when dehumidifying process is ongoing. Increasing the surface area will put the water closer to the surface. This will help dehumidify the oil quicker because the water must rise over a shorter distance in order to escape from the oil. More oil above the water means increased water volume adhering to the oil and more oil molecules that the water molecules needs to push away in order to escape.

Figure 1: 1 meter tube segment

This figure shows a 1 meter segment of the tube at the current oil filing station. The oil covers approximately 50% of the tubes cross section, so the volume is $V = \frac{\pi r^2 l}{2} \approx 0.00063\ m^3$.

The current surface area over this length is:



$T = 2\sqrt{y(D-y)} = 2\sqrt{0.02(0.04-0.02)} = 0.04\,m$

Surface area: $A = T * L = 0.04m * 1m = 0.04\,m^2$

Figure 2: Measurement lines for cylinder calculation

If the flow is constant then the oil volume of that section will remain the same even if there is an increase in tube diameter. By increasing the tube inner diameter from Ø40 mm to Ø66 mm the surface new surface area can be calculated as followed:

From figure 2: $V = (L, R, y) = L\left[R^2 \cos^{-1}\left(\frac{R-y}{R}\right) - (R-y)\sqrt{2Ry - y^2}\right]$

The volume is unchanged at $V = 0.00063\,m^3$. By inserting different heights in order to arrive at this volume when $D = 0.066\,m \rightarrow R = 0.033\,m$, the height must be $y = 0.0158\,m$.

From figure 2: $T = 2\sqrt{0.0158(0.066 - 0.0158\,)} = 0.056\,m$

New surface area: $A_{new} = T * L = 0.056\,m * 1\,m = 0.056\,m^2$.

This is a $\left(\frac{0.056-0.04}{0.04}\right) * 100\% = 40\%$ increase in surface area.

3.3.1 Meeting the volumetric flow rate requirement, $\dot{V} \geq 1\frac{l}{min}$

The original system has a flow of approximately $1\frac{l}{min}$. With an increase in oil surface area and inserting more sections that increases turbulence the new system will be able to handle a larger flow rate than the original system. This meets the requirement of $\dot{V} \geq 1\frac{l}{min}$.

3.4 Length

The original tube length is approximately $4\ tubes\ *\ 2\ m\ each\ =\ 8\ m$ total. The dehumidifying process is satisfied at approximately the green line shown in the illustration:

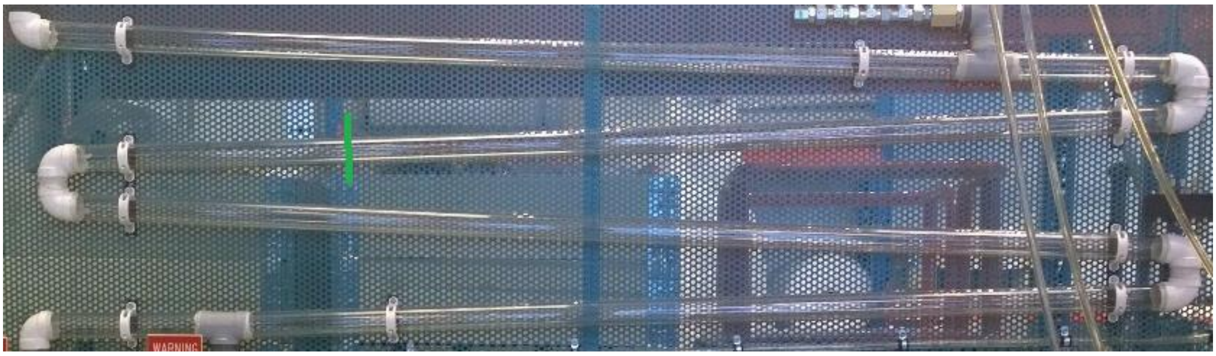


Figure 4: Dehumidified satisfactory limit

This total tube length is approximately 3.5 meters. The top two tubes are required to for the dehumidifying process. Only a total of 4 meters of tubes in the new system is necessary because of the increased surface area of the oil and maintaining a 0.5 meter safety factor. *This requires that the angle of the tubes relative to the horizontal either stays the same or decreases.*

The dehumidifying process will be satisfied at a shorter distance when increasing the cross section area of the tube and increasing turbulence. By keeping the length at the recommended distance, it is possible to increase the flow rate to more than the current $1\frac{l}{min}$ and still be certain that the dehumidifying process is satisfied.

An extra pipe of approximately 1 meter will be connected in order to receive and dehumidify flow from oil flowing through the jumpers in the filling process.

3.5 Bending

The inlet, turns and outlets will have a 90 degree smooth bend on the pipe elbows. A sharp bend will have a higher minor coefficient loss K_L, but because of the stress concentration that will develop in the corners it is safer to incorporate a smooth bend. It is also much easier to find appropriate fittings with a smooth bend.

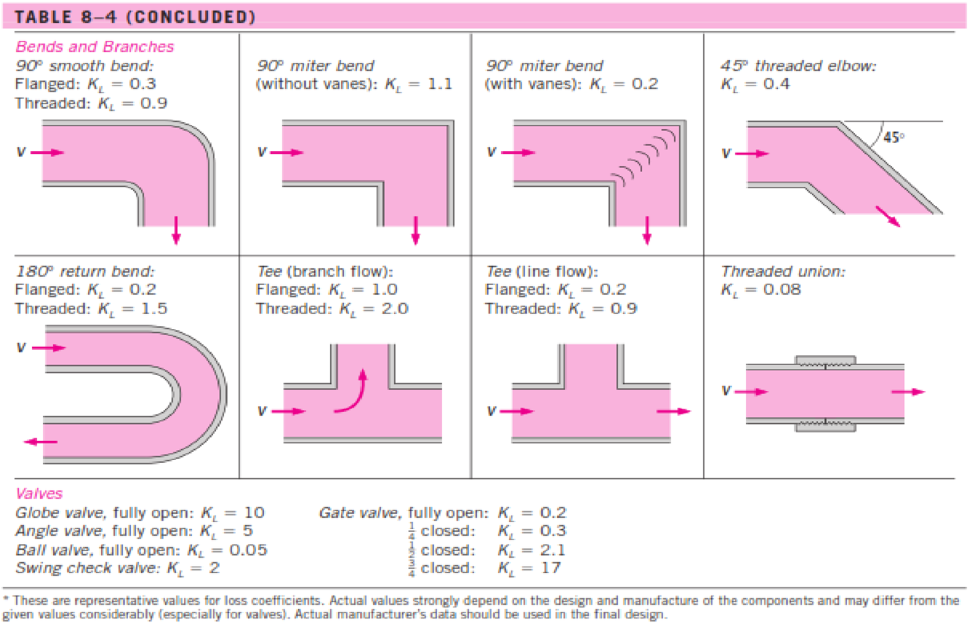


TABLE 8–4 (CONCLUDED)

Bends and Branches

90° smooth bend: Flanged: K_L = 0.3 Threaded: K_L = 0.9	90° miter bend (without vanes): K_L = 1.1	90° miter bend (with vanes): K_L = 0.2	45° threaded elbow: K_L = 0.4
180° return bend: Flanged: K_L = 0.2 Threaded: K_L = 1.5	Tee (branch flow): Flanged: K_L = 1.0 Threaded: K_L = 2.0	Tee (line flow): Flanged: K_L = 0.2 Threaded: K_L = 0.9	Threaded union: K_L = 0.08

Valves

Globe valve, fully open: K_L = 10	Gate valve, fully open: K_L = 0.2
Angle valve, fully open: K_L = 5	$\frac{1}{4}$ closed: K_L = 0.3
Ball valve, fully open: K_L = 0.05	$\frac{1}{2}$ closed: K_L = 2.1
Swing check valve: K_L = 2	$\frac{3}{4}$ closed: K_L = 17

* These are representative values for loss coefficients. Actual values strongly depend on the design and manufacture of the components and may differ from the given values considerably (especially for valves). Actual manufacturer's data should be used in the final design.

Table 4: Minor coefficient table. Fluid Mechanics, Fundemental and Applications 2006 – Cengel, Cimbala

T-bends and reduction bends are also necessary to include.

Bending material is PVC.

4.0 Valves

The dehumidifying module needs three valves, one at the inlet and two at the outlet connected to the holding tanks. The inlet valve must be mechanical, while the two outlets are electrical.

5.0 Pipe and bending connections

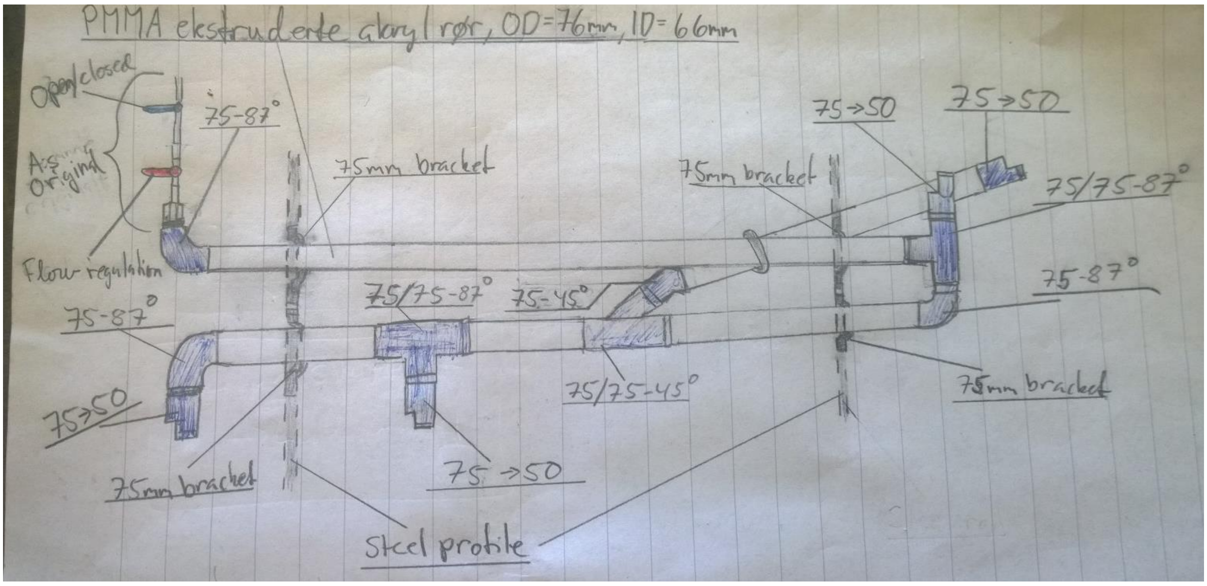
The pipes OD is 76 mm while the fittings ID is 75 mm, so the pipes must be grind down 1 mm. This will also make the adhesive between the pipe and bends stronger.

By recommendation from a Loctite representative, a Loctite 406 should be used to glue the pipes and bends together.

6.0 Pipe brackets

Four pipe brackets are required to fasten the tubes at the appropriate height. A split pipe bracket will fasten the dehumidifying tube connected to the outflow from the jumpers to the main dehumidifying tube.

7.0 Drawing



Vacuum System

Bachelor Assignment spring 2015

AUTOMATIC OIL FILLING STATION

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1.0 Introduction

1.1 General Information

This document covers the process, component list, manual and explanations related to the new suggested vacuum system. This process covers:

1. Vacuum Pump and Motor
2. Vacuum Pump Filter
3. Oil Prevention Safety System
4. Valves
5. System connections
6. Parts List

1.2 Abbreviations

in. Hg	-	Inches Mercury
cfm	-	cubic feet per minute
psi	-	pounds per square inch

2.1 General Description

Vacuum system which consists of a vacuum pump, filter and a safety system, provides vacuum condition in the dehumidifying process as well as in the hoses during leak test and filling. The vacuum condition created in the hoses is done through the vacuum tanks.

3.0 Vacuum Pump & Motor

3.1 Vacuum

Compressors and vacuum pumps are principally the same thing, as compressors in which the discharge rather than the intake is at atmospheric pressure. As compressors increase the number of molecular impacts per second (compression), vacuum is the reduction of these impacts.

A vacuum is created when the removal of air from the enclosed system decreases the air density to a point where the absolute pressure of the remaining gas is almost zero.

3.2 Vacuum pumps. Basic operation

A vacuum pump converts the mechanical input energy of a rotating shaft into pneumatic energy by evacuating the air contained within a system. The internal pressure level thus becomes lower than that of the outside atmosphere.The amount of energy produced depends on the **volume** evacuated and the **pressure** difference produced.

The maximum pressure difference produced by pump action can never be higher than 29.92 in.Hg (inch mercury), 14,7 psi or 1,01bar.

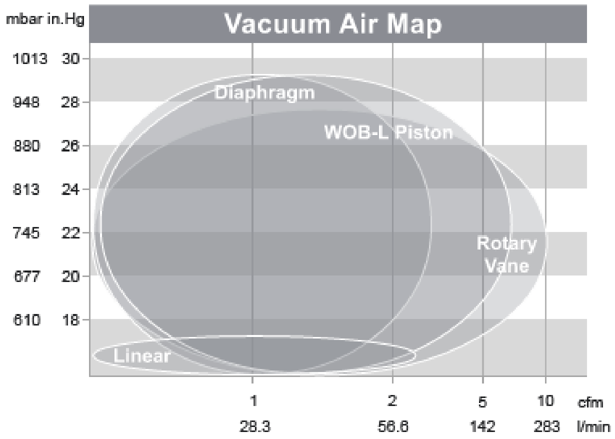


Figure 1:Vacuum Air Map for Different Pumps

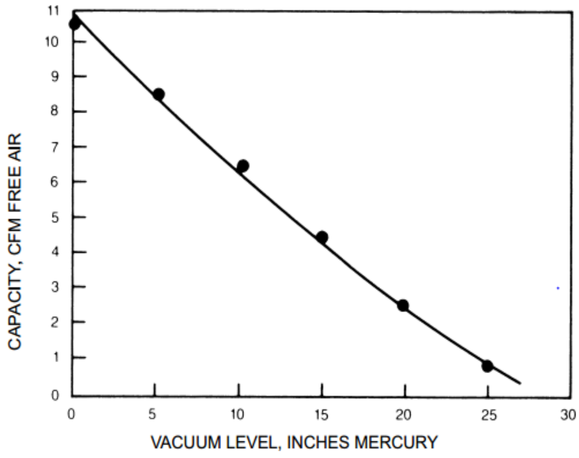


Figure 2:Vacuum level vs Vacuum Air Removal Rate

The mass of air draw into the pump on each suction stroke, and hence the absolute pressure change, decreases as the vacuum level increases. And at high vacuum levels there is significantly less air passing through the pump.

3.3 Vacuum stages

The vacuum process can be accomplished in just one pass through a pumping chamber or several stages may be required to obtain the desired vacuum.

3.4 Lubrication

We have two different types of pumps. Oil-less and Oil-lubricated pumps.

- **Oil-less:** Used when processes cannot tolerate any oil vapor. More maintenance. Leakage through housing. Subjected to corrosion from condensed water vapor.
- **Oil-lubricated:** 20% higher vacuum generated. Oil works as sealant. Less maintenance, oil change out at intervals and less corrosion.

3.5 Pump Types

Figure 3: GD-Thomas.com Compressor & Vacuum Pumps

3.6 Evaluating vacuum Pump performance

Vacuum pump performance characteristics needs to be evaluated to select type of pump required for its intended purpose. The primary criteria are:

- Vacuum level produced
- Rate of air removal
- Power requirement

3.6.1 Vacuum level produced:

A pumps vacuum rating is the maximum vacuum level for which it is recommended. The rating is usually expressed in **in. Hg** and is specified for either continuous or intermittent duty (running) cycles. Internal leakage and clearance volume establish the highest vacuum a pump can produce.

3.6.2 Air Removal Rate:

Vacuum pumps are rated according to their open capacity, the volume of air (cfm) exhausted when there is no vacuum or pressure load on the pump. Effectiveness of the vacuum pump in removing air from the closed system is given by its volumetric efficiency, a measure of how lose the pump comes to delivering its calculated volume of air.

To determine the free air that must be removed, the total volume needs to be calculated. The capacity rating of the equipment selected should be at least 10-25% over the calculated requirement.

<u>Original system capacity is</u>:

$$cfm = 3.8\frac{ft^3}{min} = 107.6\ l/min \qquad time_{vacuum} = 3min$$

$Total\ volume\ of\ original\ system\ is$:

$$Volume_{total} = 107.6\frac{l}{min} * 3min$$

$$Volume_{total} = 322.8liters \quad (0.323m^3)$$

New System capacity is:

A fair estimation of our system will be to double the cfm, thus the total volume of the system to be vacuumed is 170liters. Required capacity is then: **cfm = 7.6** (215.2 l/min)

Calculations:

Volume:

- Dehumidifying piping:

  Length: 10m

  Inner Diameter: 0.066m

  Volume: $V_{Dehumidifying} = l * \frac{d^2\pi}{4} = 10m * \frac{0.066^2 * \pi}{4} m^2$

  $V_{Dehumidifying} = 0.03421m^3$

- Reservoirs (Tanks)

  3x 50 Liter tanks

  1x 100 Liter tank.

  Volume: $V_{Tanks} = 3 * 50l + 100l = 250liters = 0.25m^3$

- System Tubing: Accounted for in the safety margin.

Max volume of system :

n = 2 (100% safety margin)

$$V_{max} = (V_{Dehumidifying} + V_{tanks}) * n$$

$$V_{max} = (0.034 + 0.25) * 2$$

$$V_{max} = 0.568m^3$$

Time to reach vacuum condition is then (with selected pump):

$$cfm = 10.5 \frac{ft^3}{min} = 297{,}3 \; l/min$$

$$Time_{vacuum} = \frac{297.3}{568} min$$

$$Time = 0.52min = 31.4 \; seconds.$$

3.6.3 Power Requirement:

The drive unit (motor) must be able to meet the pumps peak power requirement. In other words, it must be powerful enough to assure satisfactory operation under all rated operating conditions.

A general rule is that about 1 horsepower (0.7457kW) is needed for each 20 cfm of air pumped. Normally the pump is integrated with the motor in smaller sizes, while on larger sizes the motor is separated by a rotating shaft.

3.7 Vacuum Pump selection

Vacuum pump selection in our system is done by these steps:

Step	Selection Parameter	Result
1	What degree of vacuum is required?	27,5 in Hg
2	What flow capacity (cfm) is required?	7.6
3	What power and speed requirements are needed to meet vacuum level and capacity values?	Pump/motor combined.
4	What power is available?	Electrical
5	Will duty cycle be continuous or intermittent?	Intermittent.
6	What is the atmospheric pressure at the work site?	1000mbar avg.
7	What is the ambient temperature?	Indoors
8	Are there any space limitations?	0.125m^2

The selected pump/motor assembly is Adixen Pascal Series 2015SDTLAM. (Attachment 1, 2 and 3). This vacuum pump selection is based on the parameters above and coordination with PrecisionSubsea recommendations and requirements.

Figure 4: Adixen Vacuum Pump with Motor

SD 2005-21 PASCAL Series 2 Stages

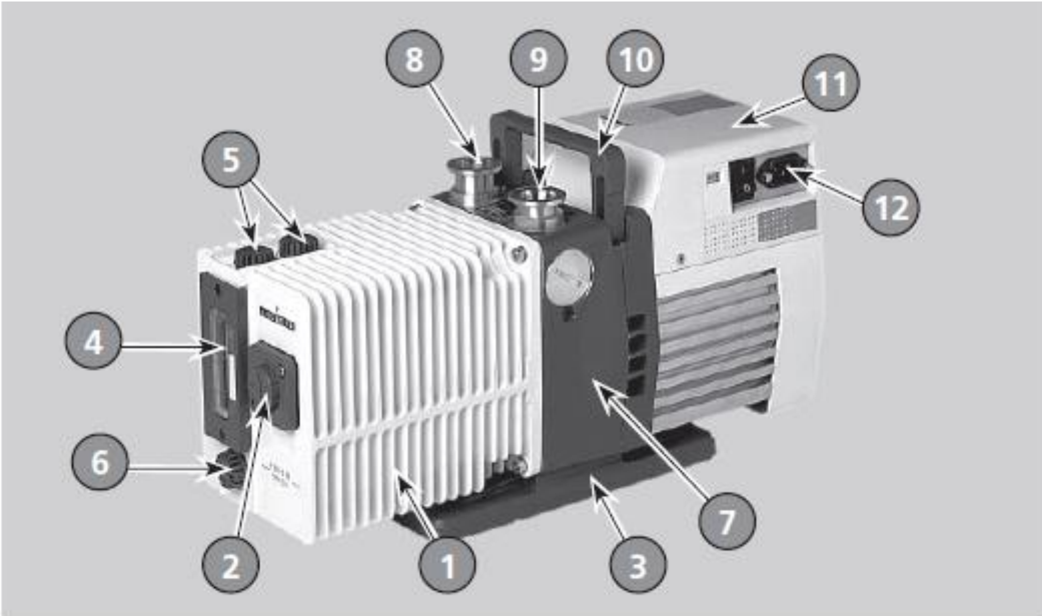
applications in diverse

Specifications		Units	2005SD	2010SD	2015SD	2021SD
Part Number			P102308	P102309	P102310	P102311
New Pump Price (2008 List Prices)			$2,080.00	$2,340.00	$2,760.00	$3,190.00
Nominal pumping speed	50Hz	m³/h	5.4	9.7	15	20.7
	60Hz	cfm	3.8	6.8	10.6	14.6
Pneurop pumping speed	50Hz	m³/h	4.8	8.5	12	15.5
	60Hz	cfm	3.4	6	8.8	11.8
Ultimate partial pressure		mbar	10^{-4}	10^{-4}	10^{-4}	10^{-4}
Ultimate total pressure closed gas ballast		mbar	2.10^{-3}	2.10^{-3}	2.10^{-3}	2.10^{-3}
Ultimate total pressure open gas ballast		mbar	10^{-2}	10^{-2}	10^{-2}	10^{-2}
Water vapor capacity	50/60Hz	g/h	120/110	125/100	110/100	90/90
Water vapor pressure	50/60Hz	mbar	35/25	20/15	12/10	7/7
Weight (max)		kg (lbs)	25 (55)	26 (57.2)	27 (59.4)	28 (61.6)
Pump Dimensions		BackPage	BackPage	BackPage	BackPage	BackPage
Electrical motors Universal 1 or 3 phase		3 phase 342V to 460V 50hz, 342V to 520V 60hz, 170V to 254V 50hz, 170V to 300V 60hz 1 phase 180V to 254V 50/60hz, 90V to 132V 50/60hz				
Max nominal power rating	50/60Hz	kW	0.45/0.55	0.45/0.55	0.45/0.55	0.45/0.55
Min ambient temperature		°C (°F)	12 (54)	12 (54)	12 (54)	12 (54)
Max ambient temperature		°C (°F)	45 (113)	45 (113)	45 (113)	45 (113)
Oil capacity		l	0.83	0.95	0.95	0.98
Inlet flange		ISO-KF	DN 25	DN 25	DN 25	DN 25
Exhaust flange		ISO-KF	DN 25	DN 25	DN 25	DN 25

Figure 5: Adixen Vacuum Pump Specifications

3.8 Pump Major Components

View Attachment 2 & 3 for more information.

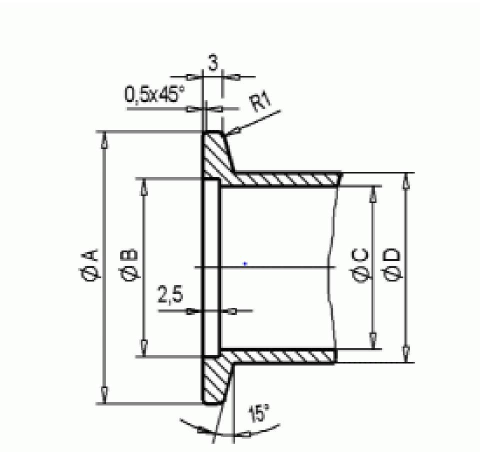


1. Oil case
2. Gas ballast control
3. Base
4. Oil level sight glass
5. Filling plugs
6. Draining plug
7. Frame
8. Inlet end fitting
9. Exhaust end fitting
10. Fold-away handle
11. Electric motor
12. IEC electric socket

Figure 6: Vacuum Pump components

3.9 Pump Connections

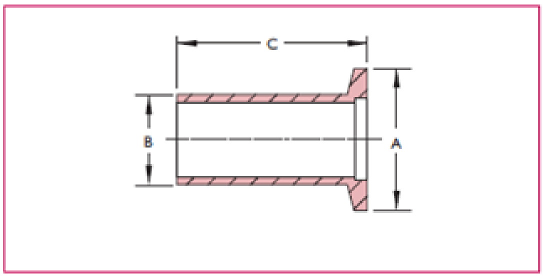
View Attachment 4 for more information.



Type	A mm	B mm	C mm	D mm	E mm	No of Lugs
DN 10	30	12.2	10	14	48	2
DN 16	30	17.2	16	20	48	2
DN 20	40	17	21	25		2
DN 25	40	26.2	24	28	58	2
DN 32	55	34	34	38		
DN 40	55	41.2	40.5	44.5	73	4
DN 50	75	52.4	51	57	93	4
DN 60	75	62	60	64		4

Figure 7:Inlet and Exhaust Fitting KF type DN25

KF Clamp style



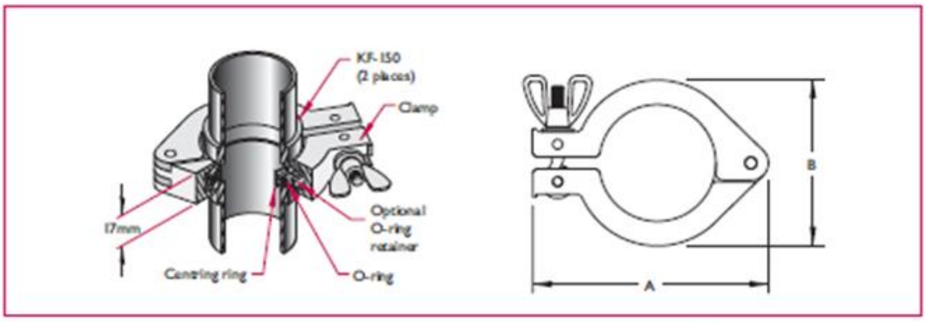
Features

- DN16KF through to DN50KF sizes
- Requires hinged clamp or bulkhead clamp
- Custom lengths available on request

Flange ISO ref.	Flange OD	Tube OD	Tube length	Reference	Part number	£	€
Short							
K16-SWS	30	20	30	K16-SWS	7715101	4	6
K25-SWS	40	28	30	K25-SWS	7715102	5	8
K40-SWS	55	44.5	30	K40-SWS	7715103	7	11
K50-SWS	75	57	30	K50-SWS	7715104	12	18
Long							
K16-LWS	30	20	70	K16-LWS	7715106	7	11
K25-LWS	40	28	70	K25-LWS	7715107	6	9
K40-LWS	55	44.5	70	K40-LWS	7715108	7	11
K50-LWS	75	57	70	K50-LWS	7715109	14	21

Figure 8: KF Flange Style Sizes

Hinged clamp



Features

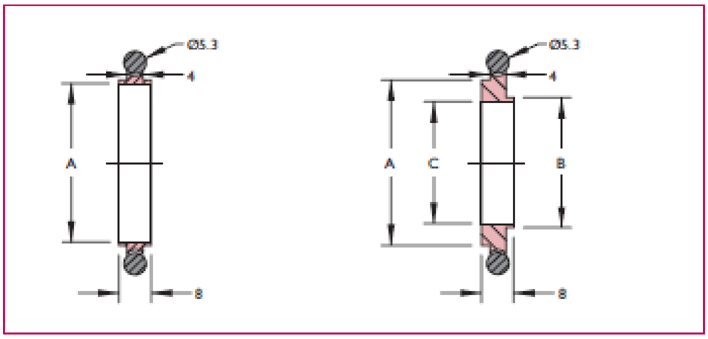
- Fastens ISO KF of comparable size
- Quick make and break
- Stainless steel wing nut and bolt
- Aluminium construction
- Requires centring ring with elastomer gasket

Flange size	Tube size	A	B	Wt kg	Reference	Part number	£	€
DN10/16KF	12.7-19.0	71	45	0.2	K16-C	**7701000**	2	3
DN20/25KF	25.4	80	55	0.2	K25-C	**7701001**	2	3
DN32/40KF	38.1	96	70	0.3	K40-C	**7701002**	3	5
DN50KF	50.8	123	95	0.5	K50-C	**7701003**	4	6

Hinged clamp assemblies are the most commonly used method for making ISO KF vacuum seal connections. Prior to clamping, flanges can be rotated 360° and accept self-centring centring ring seals. Pressure is applied uniformly around the 15° outer surface of both flanges by finger-tightening the single wing nut until the first metal-to-metal contact is made between the spacing lips of the centring ring and the inner surface of the mating flanges. This compresses the O-ring between the flanges and makes the vacuum seal.

Figure 9: Hinged Clamp Assembly for DN25 KF

Centring rings



Features

- Standard ring mates ISO KF of equal size
- Adaptor ring mates ISO KF of unequal size
- Includes elastomer O-ring
- Stainless steel or aluminium construction

Centring ring assemblies are placed between two ISO flanges with matching outer diameters. The widest portion of the centring ring rests inside a capture groove on the flange and the O-ring rests on the flat polished surface outside the capture groove. On a blank flange, the groove seen on the face of a flange is the capture groove, with the O-ring making contact with this flange face just outside the groove.

Figure 10: Centerring O-rings (Gaskets) for DN25 KF

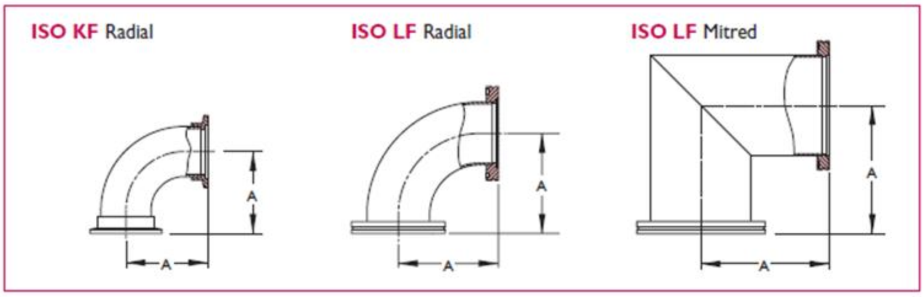
Aluminium Buna-N® O-ring

- Maximum bakeout temperature 100°C
- Sustained use to 80°C
- Aluminium

KF Flange	A	Reference	Part number	£	€
DN16KF	16	K16-CRAB	**7710017**	1	2
DN25KF	25	K25-CRAB	**7710018**	2	3
DN40KF	40	K40-CRAB	**7710019**	2	3
DN50KF	50	K50-CRAB	**7710020**	2	3

Figure 11: O-ring Selected

90°



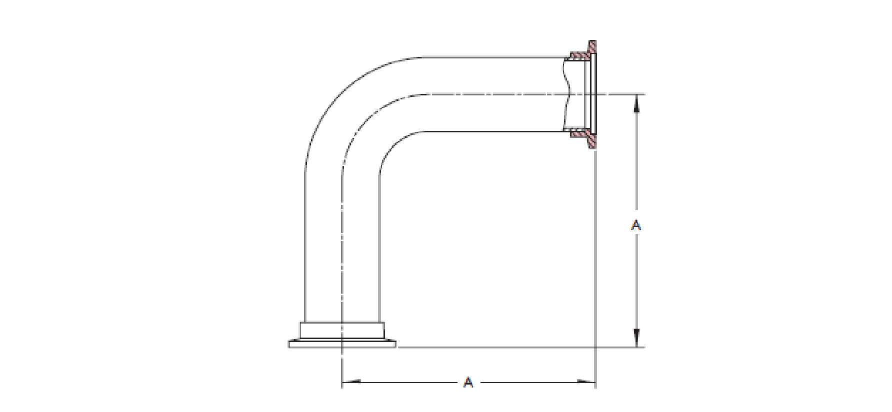
Features

- DN16KF through to DN250LF sizes
- Radial or mitred tube
- Welded construction
- Custom lengths available on request

Flange ISO ref.	Flange OD	Bend type	Min. tube ID	A	Wt kg	Reference	Part number	£	€
Stainless steel									
DN16KF	30	Radial	16	40	0.2	KL-16	7723000	20	31
DN25KF	40	Radial	22	50	0.2	KL-25	7723001	21	32
DN40KF	55	Radial	34	65	0.2	KL-40	7723002	22	33
DN50KF	75	Radial	47	70	0.4	KL-50	7723003	45	68

Figure 12: 90degree Tubing Bend with DN25 KF

90° with tangents



Features

- DN16KF through to DN100LF sizes
- Radial tube
- Welded construction
- Custom lengths available on request

Flange ISO ref.	Flange OD	Nominal tube ID	A	Wt kg	Reference	Part number	£	€
Stainless steel								
DN16KF	30	16	49	0.2	KLL-16	7723018	41	62
DN25KF	40	22	57	0.8	KLL-25	7723019	50	75
DN40KF	55	34	80	1.0	KLL-40	7723020	56	84
DN50KF	75	48	108	1.0	KLL-50	7723021	66	99

Figure 13: 90degree Tubing Bend with DN25 KF and Tangents

How to Measure NPT National Pipe Thread

KF TO NPT

National Pipe Thread NPT

NPT DIMENSIONS

C Fraction	C Decimal	NPT SIZE
5/16”	0.3125	1/16”
13/32”	0.4050	1/8”
35/64”	0.5400	1/4”
43/64”	0.6750	3/8”
27/32”	0.8400	1/2”
1 3/64”	1.0500	3/4”
1 5/16”	1.3150	1”
1 21/32”	1.6600	1 1/4”
1 29/32”	1.9000	1 1/2”

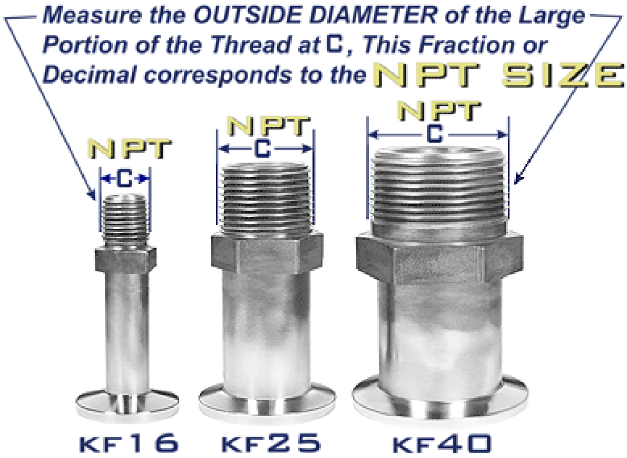


Figure 14: DN25KF to 1/2"-14 NPT Male

4.0 Filters & Oil Traps

To prevent contamination, all lines to the vacuum source must be equipped with filtration or other trapping as appropriate.

- **Particulates**: use filtration capable of efficiently trapping the particles in the size range being generated.
- **Biological Material**: use a High Efficiency Particulate Air (HEPA) filter. Liquid disinfectant (e.g. bleach or other appropriate material) traps may also be required.
- **Aqueous or non-volatile liquids:** a filter flask at room temperature is adequate to prevent liquids from getting to the vacuum source.
- **Solvents and other volatile liquids**: use a cold trap of sufficient size and cold enough to condense vapors generated, followed by a filter flask capable of collecting fluid that could be aspirated out of the cold trap.
- **Highly reactive, corrosive or toxic gases:** use a sorbent canister or scrubbing device capable of trapping the gas.

4.1 Filter

A filter is a device (membrane or layer) that is designed to physically block certain objects or substances while letting others through.

There are several different types of filters. The two different types we need for our vacuuming system is:

1. Filter that collects the silicone vapor that comes with the air
2. Filter that collects the exhaust oil from pump, and feeds it to the pump reservoir.

4.2 Required Filters

Oil mist Eliminator supplied by the same company (Adixen) as the pump/motor unit <u>is preferred.</u>

The oil mist eliminator collects the oil in the exhausted gases with and over pressure valve.
Attachment 5 for more information.

4.3 Non-Required Filter

Inlet dust filter will prevent particles from entering the pump. This however will not be preferred as there will mainly be oil/water vapor coming from the process to the inlet.

Inlet oil separation filter will prevent oil particles (vapor) from entering the pump. This however will not be preferred as there will be oil trap upstream of the vacuum pump. Attachment 6 for more information on inlet oil vapor filter, VisiTrap.

4.4 Oil Trap

To prevent silicone oil or other liquids from entering the vacuum pump has several purposes. Protects the pump, pump oil and piping from the potentially damaging effects of the silicone oil or water and protects people who must work on the vacuum lines or system.

- **Cold Trap**: Using dry ice to cool the liquid to block the passage way to pump inside trap housing, while being separated.
- **Water Aspriators**: Provide a source of vacuum by water, mixed with the working fluid.
- **Biological Material Traps**: A suction flask collects the liquid while A second flask serves as a fluid overflow collection vessel and an in-line HEPA filter.
- **Mechanical Trap:** A flask containing an overflow check valve that restricts flow of liquids into the suction line.

For our purpose, a mechanical trap, as described below is preferred because of low cost, simple operation and good quality.

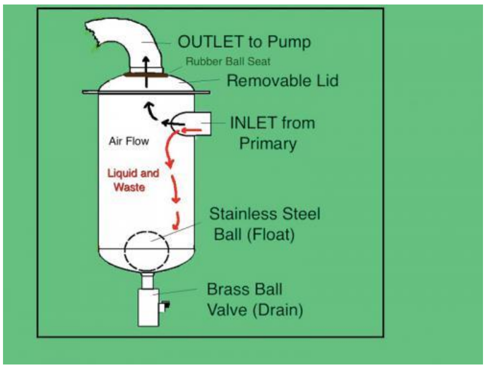


Figure 16: Mechanical Ball Trap Principle

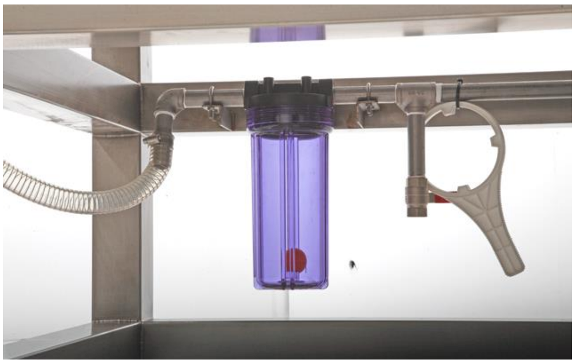


Figure 17: Water Trap Simple design

Figure 15: Q-Vac Liquid Trap

4.4 Selected Oil Trap

The selected oil "safety" prevention system is a liquid trap that is installed in the main vacuum line to provide protection against flooding of the vacuum pump system as well as separation of oil mist to a small degree.

Choice: 1NG

PN: 713590

Pyrex bottle PN: 615441.

Refer to attachment 7 for more information.

5.0 Tubing & Valves

Tubing and Valves are not discussed in this document.

6.0 Documents & Drawings

Attachment 1:	Rotary Vane Vacuum Pump Adixen SD_Series
Attachment 2:	Adixen Pascal series ppm5-21_ed07_en
Attachment 3:	215SDTLAM.en
Attachment 4:	ISO KF Fittings_sec1.2
Attachment 5:	Alcatel OME 25 HP
Attachment 6:	VisiTrap
Attachment 7:	MILS_Liquid Trap
Drawing 1:	Vacuum System Item Drawing
Drawing 2:	Vacuum System 2D Drawing

7.0 Sources & References

Vacuum Pump

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Filling and pressurizing

Bachelor Assignment spring 2015

AUTOMATIC OIL FILLING STATION

-

EIRIK S. MÆHRE

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1.0 Introduction

This document covers the design, parts and functions related to the filling and pressurizing of subsea jumper hoses by the automatic oil filling station.

For the processes described in this document, the control system will not be described, only the sub-system control, process execution and functions of the pressurizing and filling sub-system. Furthermore, the P&ID of the sub-system is described in detail, as well as the parts specification and specific function.

The described processes are:

- Pressurizing of subsea jumper hoses up to 15 bar
- High-pressure filling of subsea jumper hoses at 2 bar
- Low-pressure filling of subsea jumper hoses at 0.2 bar

1.1 Abbreviations

AOFS – Automatic Oil Filling Station

HPF – High pressure filling

LPF – Low pressure filling

2.0 System

2.1 Main functions, from concept to product

The main functions of the system will be:

- Pressurizing
- HPF
- LPF

The concept chosen for these tasks is C-3.4[1], the one pump filler. The main feature of this concept that differs it from other concepts, is that it completes the tasks with only one pump while the pressurized holding tank delivers the pressure for LPF.

The hydraulic configuration has been altered from the concept stage through iterations to meet the requirements as best as possible.

The idea of the one pump concept was to have a pump delivering a pressure of approximately 20 bars, with an accumulator conserving the pressure until it dropped below 16 bars and pressure regulating valves limiting pressure to the needed values. The advantage with this system would be that the pump only had to run in intervals. Therefore, when for example only pressurizing one subsea jumper hose, the pump would not operate much of the time. This reducing noise and vibrations and energy consumption relative to if the pump would run continuously during all operations.

As seen in figure 1, a check valve is placed between the 15 and 2 bar line outputs. When filling, a higher flow is required therefore the pump would run continuously, whereas when pressurizing the pump would run in intervals.

[1] Concept sheet C-3.4, AOFS Concept overview document

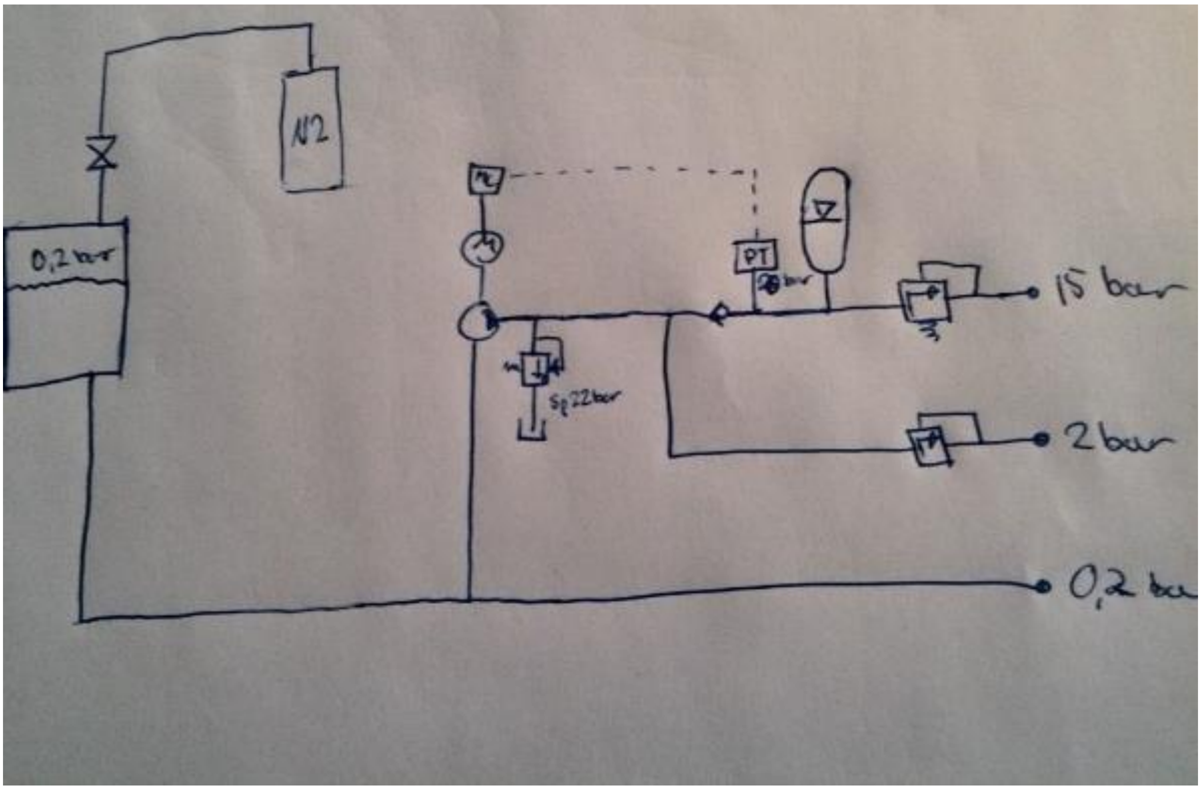

Figure 1: Concept 3.4 basic hydraulic sketch

In the filling system as it is now, the pump runs in intervals as long as needed, at the same time it has the ability to run continuously if higher flow capabilities are required. The system includes four pressure transmitters where three of them gives feedback on the final pressure in the system. Both to calibrate the system so it delivers the required pressures, but also to inspect that the system works accordingly.

The last pressure transmitter gives feedback to the control system; this enables precise control of the pump to optimize the pressure and flow as required.

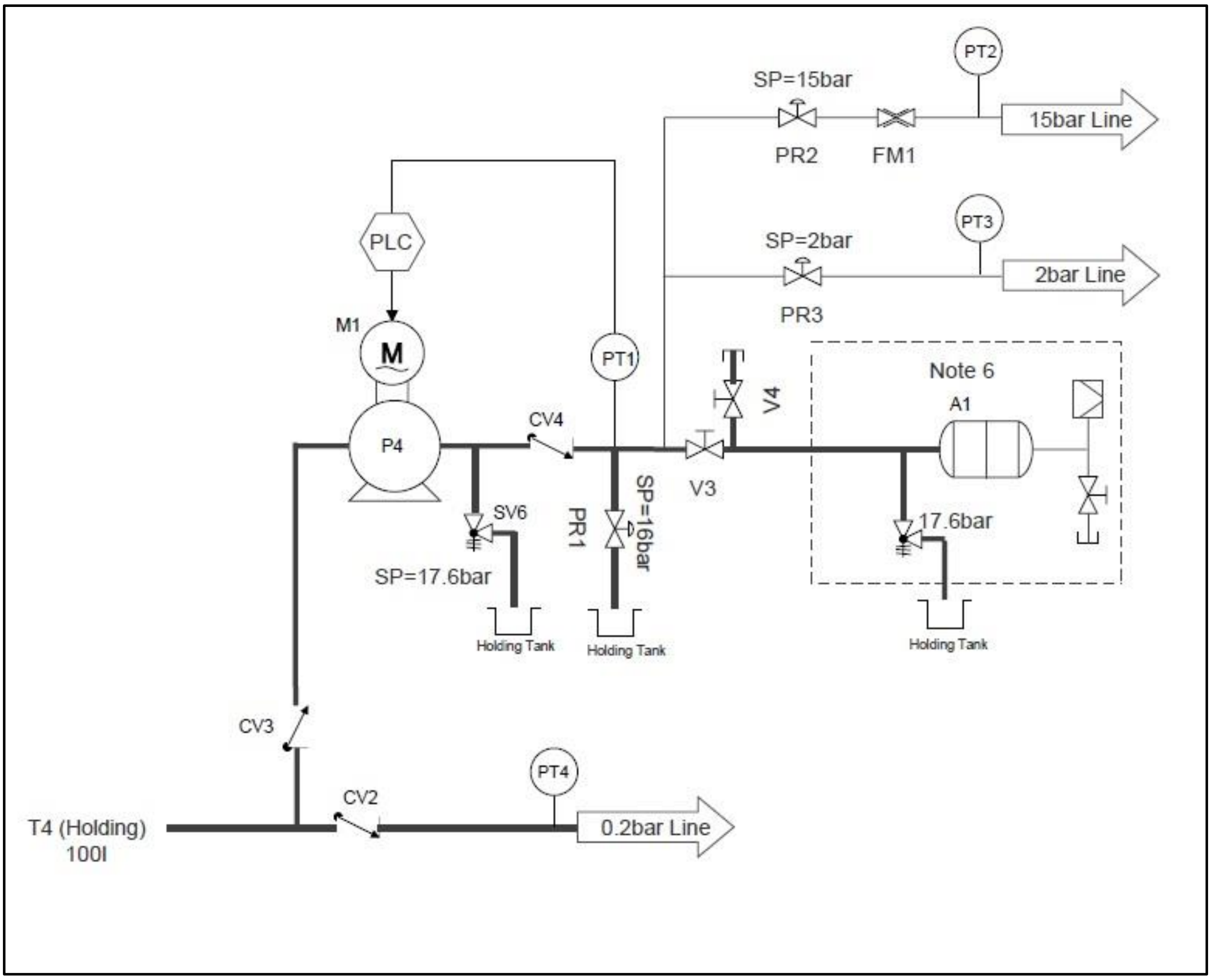

Figure 2: Filling and pressurizing P&ID, ref. AOFS P&ID

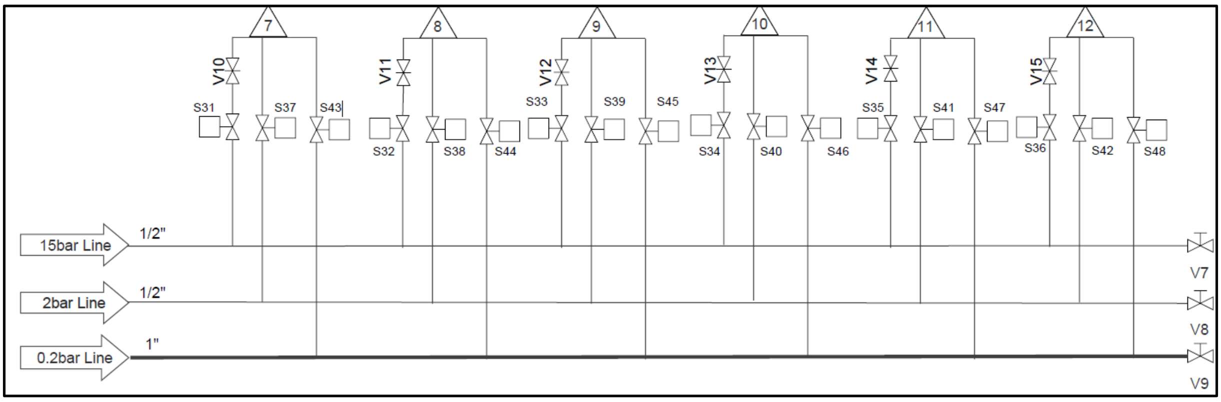

Figure 3: Filling and pressurizing connection system P&ID, ref. AOFS P&ID

The final design of the filling system has some changed functions compared to the concept. For instance the accumulator purpose is now not to conserve pressurized oil, but to dampen pressure pulses from the pump. This is due to the pump that was selected and the facts that this pump enables precise flow control and produces pressure pulses, unlike the centrifugal pump.

The hose pump is also vulnerable to backflow, therefore check valves had to be added before and after the pump. The principles of pressure regulating are still the same, only the pressure is somewhat smaller on the main line. Also, the pump will not deliver a pressure at 20 bars, but 16 bars.

The main pressure line has an outline pressure-reducing valve that will reduce the main line pressure and flow if it exceeds the given limits. The LPF and HPF lines are further pressure regulated with inline pressure-regulating valves to ensure the end pressure on each line is correct, the lines also include separate pressure transmitters to confirm and monitor the pressure. The HPF line has a flow meter that is meant to monitor the flow during pressurization operations so that the operation can be shut down automatically if a hose ruptures and the flow increases. The feedback from the flow meter has to be ignored from a hose pressurization start-up until the hose reaches an internal pressure of approximately 15 bars, or user defined pressure, at the top of the jumper.

3.0 Components

3.1 Components

Tag	Component	Purpose
CV2	Check valve	0,2 bar filling line backflow prevention
CV3	Check valve	Backflow prevention through pump
CV4	Check valve	Backflow prevention to pump
P4	Hose pump	Pressure generation for filling and pressurizing purposes
SV6	Safety valve	Hydraulic safety valve
PT1	Pressure transmitter	Pump control pressure feedback
PT2	Pressure transmitter	Pressurization pressure monitoring, user and system feedback
PT3	Pressure transmitter	HPF-pressure monitoring, user and system feedback
PT4	Pressure transmitter	LPF-pressure monitoring, user and system feedback
A1	Accumulator	Pump pressure pulse dampening
V3	Manual valve	Accumulator liquid side isolation for maintenance purposes
V4	Manual valve	Accumulator liquid side draining for maintenance purposes
PR1	Pressure regulating valve	Main line pressure and flow regulation
PR2	Pressure regulating valve	HPF-line outlet pressure regulation
PR3	Pressure regulating valve	LPF-line outlet pressure regulation
FM1	Flow meter	Hose rupture safety for HPF
S31-48	Solenoid valve	Open/close lines to connections
V10-15	Throttle valve	Pressurizing flow restriction to protect optical fibers
V7-9	Valve with plug	Channel extension
7-12	Channel connection	Jumper hose channel connection

Table 1: Components and purpose, tags refer to P&ID

3.2 Pump

Main functions

The pumps main function is to deliver pressurized Wacker 350 silicone oil at 15 bar. Since the pressure will be regulated down before HPF and pressurization, the optimal pressure would be somewhat above 15 bar. The estimated maximum flow the pump has to deliver is 4.4 $\frac{l}{min}$, but this figure is not certain and may be increased during the life cycle of the AOFS. Uncertainties as to how many and how large jumper hoses might be filled at once, and alterations outside the system such as increasing the diameter of the oil inlet on hose connector might also contribute to this.

Therefore the main requirements for the hydraulic pump main functions is:

- Delivering minimum pressure of 15 bar
- Flow capabilities from close to 0 up to above 4.4 $\frac{l}{min}$ or higher
- Flow regulation capabilities
- Lubricant free, because of the Wacker oil

The pump should also:

- Require little maintenance and be easy to maintain
- Have low noise characteristics, considering HMS in the workshop

For a lubricant free pump, a centrifugal pump would be the natural choice. The centrifugal pump in general has large flow capabilities, can be used for most liquids (does not need lubrication from the working fluid), but does not have great pressure capabilities.

Centrifugal pump

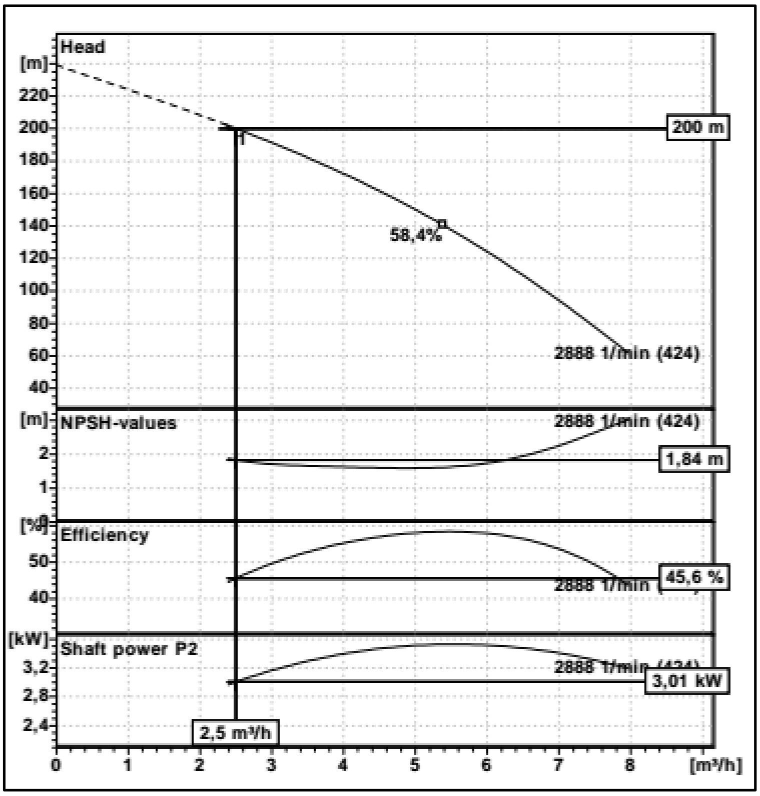

Figure 4: SV 424 F 40 T Technical pump chart[2]

The pump chart in figure 4 shows the characteristics of a SV 424 centrifugal pump, that was the closest match to the pump requirements in terms of a centrifugal pump. As first thought in the concept stage, the pump would deliver a pressure of 20 bars.

[2] Pump offer sheet, PSSI Group AS, Quotation no. PS-2098/MH/EP

Converting the pressure to pump head;

$$p = 0{,}0981 * h * SG \rightarrow h = \frac{p}{0{,}0981 * SG}$$

Where;

h = head in meters, p = pressure in bar, SG = specific gravity

For Wacker 350, SG = 0,968

At 20 bar; $h \approx 210{,}6\ m$

At 15 bar; $h \approx 157\ m$

To compare the chart to these numbers, the pump does not deliver a head of 210 m, that was the first required pressure, and if we settled for a head of 200 m, the flow would be close to ten times as high as the estimated maximum requirement. Regulating this much flow back to the reservoir would cause not only heat and excessive tear on regulating valves, but also leave much energy in form of heat in the oil.

These are the reasons that a centrifugal pump does not fit this system, and therefore our only reasonable choice is a hose pump.

Hose pump

The selected pump is the hose pump Bredel 25.

The Bredel 25 has completely different characteristics than the centrifugal pump because of its working principles.

As seen in figure 4, the flow and pressure rates of the centrifugal pump is dependent on each other, while the hose pump delivers the same pressure regardless of revolution rate and the flow is determined by it. This means the pressure only has to be regulated down from a constant to the two pressures needed, 2 bar and 15 bar. Also the flow can easily be controlled without affecting the pressure using a frequency converter to control the pump engine speed.

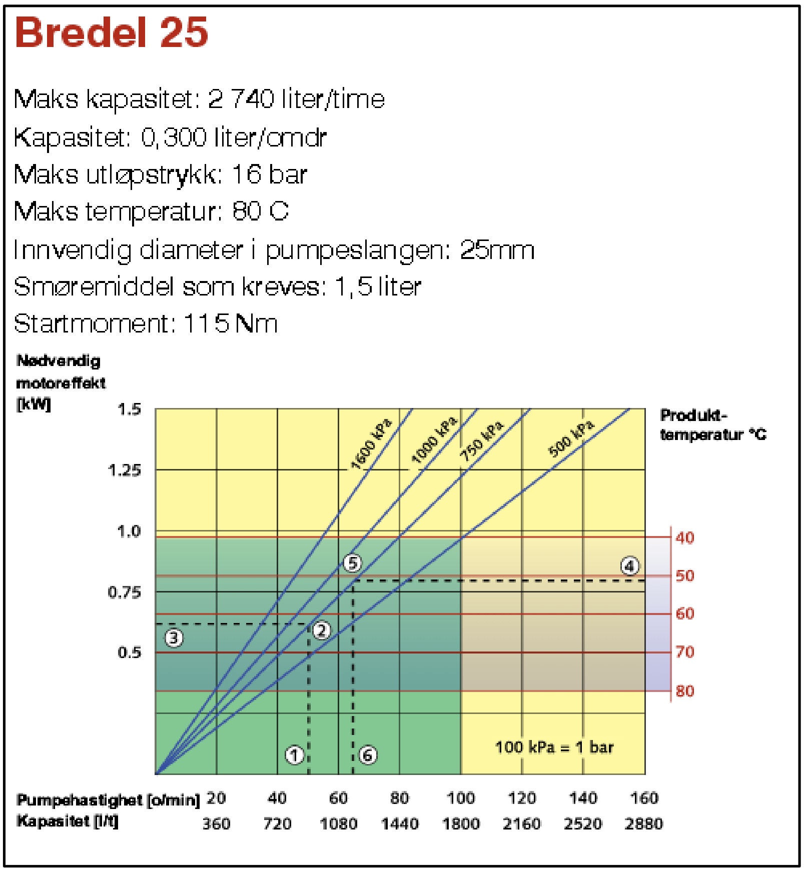

Figure 4: Bredel 25 performance and pump chart[3]

[3] Bredel Hovedbrosjyre 2015, http://www.axflow.com/no/site/produkter/kategori/pumper/slangepumper/

Bredel 25 delivers 16 bar max, and that is enough for this system thus satisfying the pressure requirement. The accumulator on the pressure line was originally intended to conserve pressure so the pump could run in intervals instead of continuously, but is now intended to eliminate the pressure pulses from the pump instead. This also means a smaller accumulator can be used, therefore space and cost can be reduced.

This hose pump has many advantages;

- Low noise
- Robust, meaning little maintenance needed
- Easy maintenance
- Long lifetime on the hose
- Simple inspection
- No rotary seals and therefore handles the silicone oil
- High and low flow capabilities
- Smaller in height than the suggested centrifugal pump

Therefore the Bredel 25 is the pump of choice for the filling and pressurizing system.

3.3 Accumulator

As mentioned, the main accumulator function was to conserve pressurized oil to enable interval pump control. But with the Bredel 25, the pump runs quietly and the flow can be regulated directly by the revolution rate. The Bredel hose pump does also generate higher pressure pulses than a centrifugal pump, due to the fact that it squeezes a hose to force oil to the pressure and filling part of the system. Therefore, the main function of the accumulator in the system will now be to dampen the pressure pulses from the pump.

This means that the accumulator can now be smaller in size, the accumulator capacity does not have to be calculated due to the new main function.

We found that Hydac.com delivers many different accumulators and found one that was fit for our purpose. The accumulator has a volume of 2,5 liters and the nitrogen pressure can be adjusted on site to the needed configuration. The accumulator is a bladder type with a rubber membrane. This because of the bladder accumulator's superior properties to dampen even small pressure pulses compared to piston accumulators.

An offer for the "SB40-2,5A/112U-40B" accumulator was requested. The model code tells that it is a shock absorber type with a nominal volume of 2,5 liters, standard threaded connection, carbon steel fluid connection and accumulator shell, a NBR20 type bladder, pressure rating of 40 bar and a DIN 13 or ISO 965/1 metric fluid connection.

Hydac.com recommended an accumulator with the similar specifications, except the pressure rating and fluid thread connection.

This is the "SB 330-2,5A1/112U-345A" and has a max pressure rating of 345 bar, way above what is needed. But this accumulator serves the purpose just as good as the 40 bar rated one, except that, with both a safety valve for the fluid side and rupture disk on the gas side, the cost is roughly a third and they have it in stock.

3.4 Piping

Recommended max velocity through hydraulic pipes (Ref. Paul Vis, Hydraulic expert and teacher at HBV):

Suction: V = 0,5 m/s

Pressure: V = 5,5 m/s

Return: V = 1,0 m/s, *return is not relevant in this case*

A 70 m. long hose with an inner diameter of 20 mm. takes about one hour to fill, that gives an oil flow of approximately 0,367 l/min. Considering that a maximum of twelve jumpers might be filled at once, max oil flow is 4,4 l/min assuming pressurizing jumpers gives a lower flow than filling.

Max working pressure is 20 bar. As a safety factor for hydraulic systems, the pipes must withstand a minimum internal pressure of 4x working pressure (bursting pressure), 64 bar.

Piping has to withstand - $64\ bar = 6{,}4\ MPa = \ 6{,}4 \frac{N}{mm^2}$

To calculate the minimum inner diameter of the pipes for an ideal low viscosity hydraulic fluid;

$$Q = 4{,}4 \frac{l}{min} = 4\ 400\ 000 \frac{mm^3}{min} \approx 73\ 333 \frac{mm^3}{s}$$

$$V_{suction} = 0{,}5 \frac{m}{s} = 500 \frac{mm}{s}$$

$$A_{suction} = \frac{Q}{V_{suction}} \approx 146{,}67 mm^2$$

$$d_{min-suction} = \sqrt{\frac{4A}{\pi}} \approx 13{,}67 mm$$

$$V_{pressure} = 5{,}5 \frac{m}{s} = 5500 \frac{mm}{s}$$

$$A_{pressure} = \frac{Q}{V_{pressure}} \approx 13{,}33 mm$$

$$d_{min-pressure} = \sqrt{\frac{4A}{\pi}} \approx 4{,}12 mm$$

The pump inner hose has a diameter of 25 mm. To simplify construction in accordance to the pump hose diameter, component selection, to prevent cavitation and compensate for the high viscosity of the Wacker 350 silicone oil, the final diameters of the filling system piping are;

System area	Piping inner diameter
Inlet	25 mm
LPF-line	25 mm
HPF-line	25 mm
Pressurization line	12 mm
Main pressure line	25 mm
Return line	25 mm

Table 2: Piping inner diameter

Tank reservoir system

Bachelor Assignment spring 2015

AUTOMATIC OIL FILLING STATION

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1.0 Introduction

This document covers all technical information concerning the complete tank reservoir system. Including; process description, technical data, components, safety features and part list.

1.1 Abbreviations

AOFS – Automatic Oil Filling Station

PS - Precision Subsea

2.0 System overview

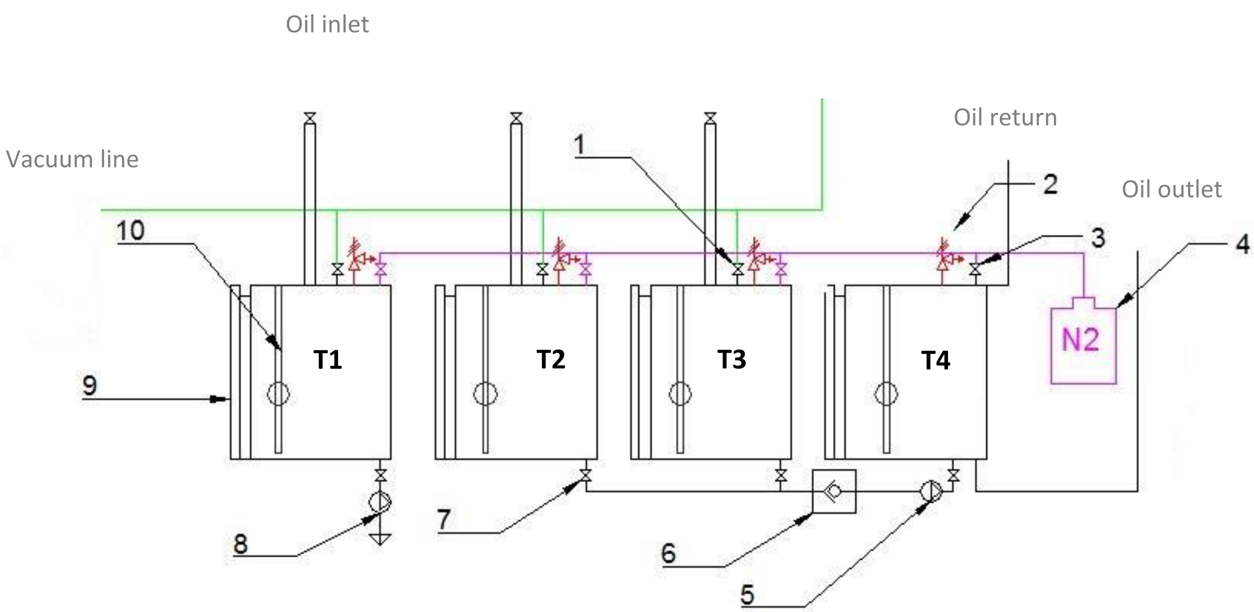

Fig.1 Tank reservoir system

Components:

1- Vacuum inlet valve

2- Safety pressure valve

3- Nitrogen valve

4- Nitrogen container

5- Feeding pump (holding tank)

6- One-way valve

7- Tank outlet valve

8- Draining pump

9- Manual inspection level tube

10- Electrical level indicator

Tanks:

T1- Drain tank 50l

T2- Vacuum tank 50l

T3- Vacuum tank 50l

T4- Holding tank 100l

2.2 Safety features

- All tanks are mounted with a safety relieve valve that releases pressures if internal tank pressures rises > 1 bar.

Justification of choice:

- Valve specifications meet our requirement
- Low price
- Size
- Availability

Figure 1: SIK-0402 Safety valve (Sletteboe.no)

- Oil tanks are mounted within the protective wall of the AOFS. This, to prevent flying parts from an eventual explosion / major pressure leakages.

3.0 Components

3.1 Tanks

The reservoir system consists of four separate oil tanks and one Nitrogen tank (see fig.1). The oil tanks are proposed mounted horizontally and with a ~1 degree tilt. The purpose of the oil tanks is to act as the systems oil accumulators. The Nitrogen tank provides external pressures to the tanks, and to the low pressure filling processes (0,2 bar).

Important factors for the tank selection:

1. Dimensional constraints and volume requirements

T1,T2 and T3 must have a volume of 0,05 m^3 (50 l). T4 must have a volume of 0,01 m^3 (100 l). Nitrogen tank dimension are given. The N2 may be mounted outside the given system boundaries.

2. Designing tanks for vacuum conditions

Tanks must withstand the pressure difference caused by the 2 mbar internal pressure (near vacuum) and 1 bar external atmospheric pressure.

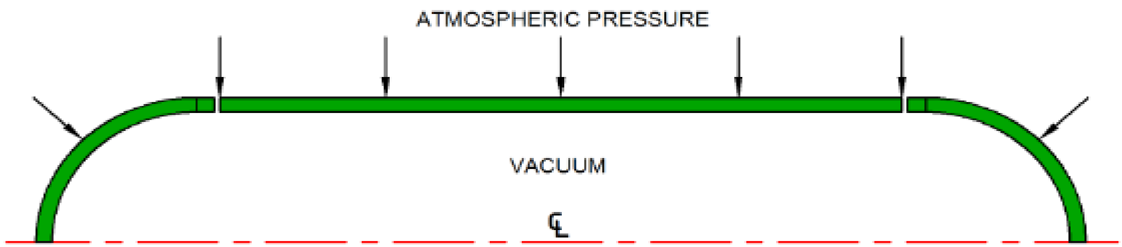

Figure 2: http://www.pveng.com/ASME/ASMEComment/ExternalPressure/ExternalPressure.php

Design variabeles that impacts on the tank strength:

- Length of the tank → If length is increased, it becomes less durable.
- Tank radius → If radius is increased, it becomes less durable.
- Material of the tank → Low yield strength and E-module makes the tank less durable.
- Wall thickness → Increase the thickness of the tank walls is the easiest way to increase stability. We have designed our tanks so the wall thickness is equivalent to 1 percent of the tanks diameter.

We have, based on these variables exectued comprehensive simulations in Solid Works (Finite Element Method). These simulations justifies our tank design dimensions (refer Test Report).

3. Tank selection

We have based on the consulting with a specialist supplier, and the above factors selected tanks with the following spesifications:

T1,T2 and T3 (50 litre drain, and vacuum tanks)

- Diameter: 350 mm (Standard manufacturing diameter)
- Length: 520 mm
- Wall thickness (~1 percent of dia.): 4mm
- Material: 1020 Carbon Steel Sheet (SS)

- E-module: 205000 MPa [$\frac{N}{mm^2}$]
- Yield strength:283 MPa [$\frac{N}{mm^2}$]

T4 (100 litre holding tank)

- Diamter: 500 mm (Standard manufacturing diameter)
- Length: 250 mm
- Wall thickness (~1 percent of dia.): 5 mm
- E-module: 205000 MPa [$\frac{N}{mm^2}$]
- Yield strength:283 MPa [$\frac{N}{mm^2}$

Tank slope calcuation (ϕ)

To achieve a 1 degree slope:

$$Tan(1°)\ x\ distace\ between\ tank\ mounting\ brackets\ =\ Required\ height\ difference$$

This formula may be used as a standard when installing the tanks in order to achieve the goal of a 1° slope.

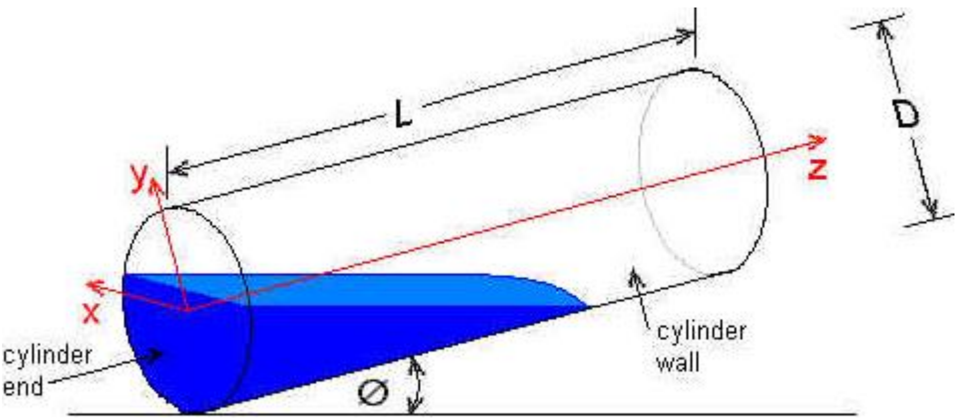

Figure 3: Tank illustration (http://www.lmnoeng.com/Volume/InclinedCyl.php)

3.3 Pumps

There are two pumps in the reservoir tank system:

- Feeding pump (*component 5, figure 1*) that transfers dehumidified silicon oil from T2 and T3 to T4.
- Oil drain pump (*component 8, figure 1*). The pumps purpose is to the empty drain tank T1 when necessary.

OEM Automatic (oem.no) supplies a suitable pump for both of these purposes.
The pump has a capacity of 0,75m^3/h (*12, 5 l/ min*) and a max. pressure of 1, 2 bars. This should make the pump ideal for the proposed purpose. This volumetric flow rate will drain a full waste tank (50/12,5 = 4) in ≈ 4 min.

Justification of our choice:

- High efficient with low power consumption: $12V \times 1{,}2A = 14{,}4W$
- ISO8846 classified (ignition protected)
- Non corroding material
- No maintenance necessary (no oil or lubrication)
- Centrifugal pump with low operating noise
- Small and space efficient pump (96,8mm x 69mm x 69mm, *LxHxW*)
- Relatively cheap: 2471 NOK ex. VAT

Figure 3: JABSCO 59510 Circulation pump (OEM.no)

3.4 Level indicators

PS requires two independent level indicating mechanisms, one manual (requirement 3.3.1) which can be visually inspected, and one electronic (requirement 3.3.2) that interfaces with system software.

3.4.1 Manual tank level indicator

Our manual level indicator uses the same principle as the one PS is currently using. The principle is simple and easily understood by looking at fig.4.

We will introduce some modifications and improvements to the level indicator. The new system will consist of pipes instead of hoses, and with better fittings/connections to ensure a completely sealed system (no air leak into the system).

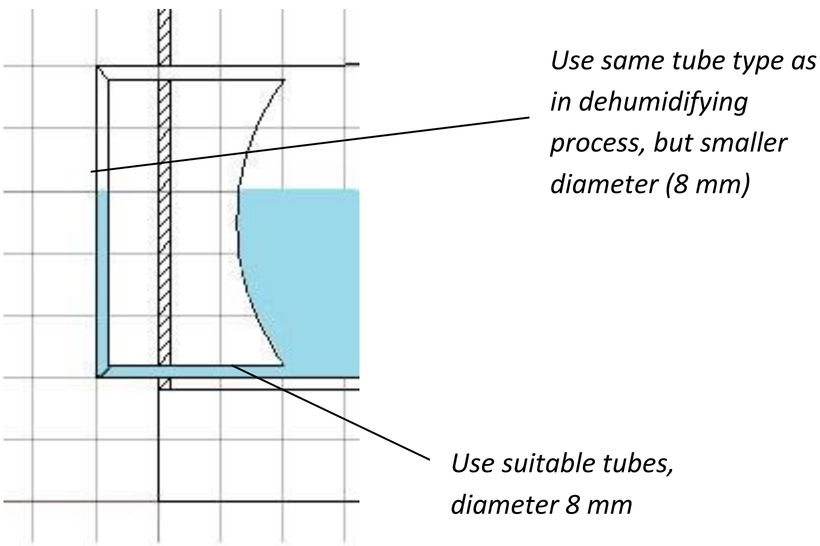

Figure 4: Simplified cross section (side) view of level indicator

3.4.2 Electronic tank level indicator

The electronic tank level sensor we propose to implement is a simple float-indicator type from *Temposonics (see fig)*. The level sensor operates in the following way:
A float is fitted on a guide rod; a magnet within the float affects a chain of reed contacts within the guiding rod. There are resistances with in the reed contacts, so it is similar to a simple potentiometer. The measured value can be evaluated as a resistance value or radiometric signal depending on input voltage. Based on these inputs a tank level measurement is made possible. For more detailed information see complete datasheet.

Justification of choice:

- The level indicator is recommended by an specialist from *Systemhydraulikk*
- Can operate in vacuum conditions
- Relatively simple construction
- Custom rod lengths can be special ordered
- Detailed datasheet, with wiring and mounting instructions.
- Small and compact construction

Figure 5: Temposonics EH, absolute, non-contact position sensor (systemhydraulikk.no)

Frame specifications

Bachelor Assignment spring 2015

Automatic Station Oil Filler Subsea Jumpers

AUTOMATIC OIL FILLING STATION

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1. Introduction

The framework forms the foundation of the whole system, and it is especially designed to meet both dimensional constraints and customer requirements. This document covers the frames technical specifications and our justification of design choices.

2. Dimensions

The total size of the framework is the direct result of our dimensional constraints, and customer requirements. Ref. requirement *3.1.1, 3.6, and 4.3.*

Final frame dimensions (based on the above-mentioned restrictions):

- Total frame width: 1100 mm
- Total frame length: 2480 mm
- Total frame height: 1000 mm

3. Components

The frame consist entirely of materials from *Norsk Stål (*expect PMMA Acryl front/back plate*);* all of the individual components refers to a "Norsk Stål" product number. All of these premade profiles and plates constitute a complete part list. This makes both the procurement and the assembly of the frame more convenient.

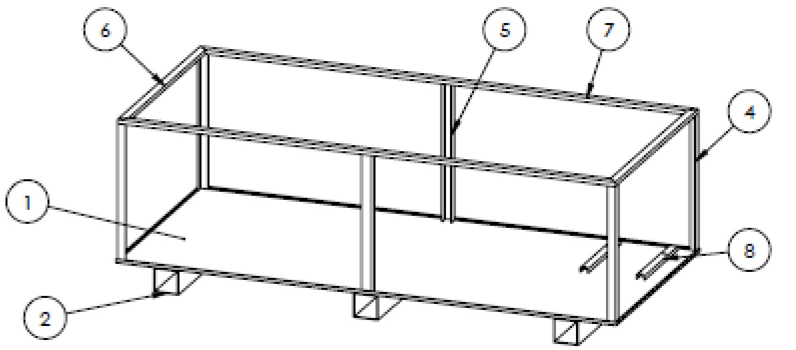


Figure 1: Framework sketch

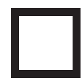
ITEM NO.	DESCRIPTION	PART NUMBER	QTY.
1	Foundation	671 71	1
2	Square profile leg	312818	3
3	Reinforcing rod	312734	6
4	Mounting angle	312627	4
5	Mounting channel	312642	2
6	Roof angle short	312638	2
7	Roof angle long	312638	2
8	Kaldformet kanal 40 x 20 x 2 x 440	312638	2

3.1 Detailed component description

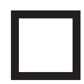
Item number (Refers to fig.1):

1. **Product type:** VV Plate Domex 240 YP
   Dimensions: 6, 0 x 1250 x 2500 MM

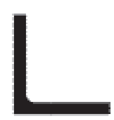
2. **Product type:** Square profile KF HUP
   Dimensions: 120 x 120 x 4 MM x 12 M



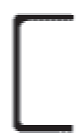
3. **Product type:** Squared precision steel pipes
   Dimensions: 15 x 15 x 1, 5 MM x 6, 1 M



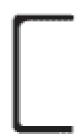
4. **Product type**: Cold formed angel steel
   Dimensions: 40 x 40 x 3 MM x 6 M



5. **Product type:** Cold formed channel
   Dimensions: 50 x 40 x 3 MM x 6 M



6. 7 / 8 **Product type:** Cold formed channel
   Dimension: 40 x 20 x 2, 0 MM x 6 M



3.2 Protective plates

There are mounted plates are on all sides of the frame. These plates encapsulate the system, and protect the surroundings from any major pressure leakages - or in a worst case scenario, an explosion. The front and back plates will be transparent PMMA plates, this to meet requirement 1.2.2 (visual inspection must be possible).

2 x side plates (mounted on each side):

- **Product type:** Perforated steel plates
- **Dimensions:** 0, 5 x 1000 x 2000 MM

Top plate (mounted on the top of the frame):

- **Product type:** Warm galvanized steel plate
- **Dimensions:** 0,6 x 1250 x 2500 MM

Front and back plates:

- **Product type:** PMMA molded acryl plates
- **Dimensions:** 10 x 3050 x 2030 MM

Justification of component choices:

- Pre- machined profiles and plates (reduce necessary machining) that is suitable for our needs
- All components can be welded together
- Can easily being cut to the desired lengths
- Holes and fitting can easily be customized and machined
- Materials can be procured from Norsk Stål
- Solid components with high strength
- High quality
- Experienced supplier

3.3 Material specifications

Components used in the framework are made out of **Carbon Steel sheet (SS)** with the following properties:

- Yield strength: ~ 280 MPa
- Tensile strength: ~ 425 MPa
- Elastic modulus: ~ 205000 MPa
- Mass density: ~ 7858 $\frac{kg}{m^3}$

A more comprehensively description of the materials can be found in the "Norsk Stål" product catalog (*ref. product catalogue*).

Front and back plates are made out of *Polymethyl methacrylate* (PMMA), which is a transparent polymer type. Most commonly referred to as acrylic or Plexiglas. These PMMA plates are delivered from Plastkompaniet.

Justification of material choice:

- Relatively cheap material
- Materials are possible to custom manufacture (Weld/cut/grind etc.)
- Materials can be procured from Norsk Stål
- High strength material properties
- A wide range of profiles/plates are pre- machined in this material
- PMMA plates: Transparent, lightweight, strong material.

4. Design

The component list is tailored to the frame construction. Only a small amount of custom manufacturing and machining is necessary.

The assembly of the frame only requires components to be cut to the right length (measurements from detailed frame drawings) and joined together as illustrated (by welding). Holes and fitting are machined after drawings/or customized on site. Fixture brackets to equipment's, such as the vacuum tank, accumulator and the Bredel hose pump are also customized on site, with the detailed system drawing as a guideline.

Justification of design choices:

- The square profile legs is chosen (and placed) to support the whole system in a satisfactory way (Ref: FEM analysis), and make it possible for easy access with lifting forks. The distance between them, and the distance from the ends makes sure that the legs are not in conflict with the lifting forks during a lifting operation.

- The framework is designed to be largely self-supporting, with the four angle steels (item no.4), and support mounting channel (Item no: 5), that support the overlaying mounting channels (item no. 6/7). This design feature makes the framework to a more solid construction

- Design choices regarding material and components are described above.

5. Testing and verification

The frame is carefully tested in *Solid works Simulation*, to verify and document that our proposed design is satisfactory. The results from these simulations confirm that our design, dimensions and materials meet all requirements. *See Test Report for detailed results.*

Pipes, Valves and Fittings

Bachelor Assignment spring 2015

AUTOMATIC OIL FILLING STATION

-

EIRIK S. MÆHRE
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KNUT OLA NYMOEN
HENNING HENRIKSEN

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4.1 Type 4

4.3 Supplier 4

1.0 Introduction

This document covers information regarding the choice of pipes and fittings throughout our system. It discusses why certain threads are most commonly used and what types of fittings that are used. A discussion and explanation of the size and type of piping is also given. Material usage and supplier is also a very important decision making factor and an overview of relevant considerations are given. Several hundred fittings and several meters of piping is used in the system design.

2.0 Fitting specification

2.1 Type

The types of fittings we have selected depends on what is available and what is appropriate for the required placement of pipes and other components. Tee fittings, nipples, unions, reducers and plugs are among some of which are used. Swagelok fittings are used to connect the piping system, with quick connect fittings connects to systems outside of the design.

2.2 Material

Whenever possible we have used different types of steel fittings, usually the cheapest one available. This material is durable, strong and most types of fittings are made of steel. It is often possible to find equal types of fittings in both steel and brass, but because of galvanic corrosion, we avoid mixing them. Steel is the primary material because of the abundant fitting types constructed with this material compared to brass.

2.3 Threads

The threads of the fittings are composed of NPT, BSP and ORFS. These threads are selected based on the available valve thread type, Swagelok thread availability and how suitable they are at maintaining a sealed connection.

2.4 Supplier

The primary choice of suppliers are suppliers available in Norway. TESS, which is a supplier Precision Subsea already use a lot and receive great discounts from are the main source. This accounts for all of the components in context with this document, which includes pipes and valves. If TESS do not supply the appropriate fitting we would use another supplier, though in our case this has only been necessary with the fittings that connects to the pipes. In this case we have used Swagelok as recommended by our employer.

3.0 Pipe specification

3.1 Type

Only one type of piping is used, but with a different diameter. We have ½” diameters and 1” diameters piping. The piping is circular with a wall thickness of 2 mm on both diameters. This is the lowest supplied wall thickness and this thickness can easily handle the operating pressure. The 1” diameter piping can withstand pressure of up to 210 bars while the ½” diameter piping can withstand pressure of up to 470 bar.

3.2 Material

Because of the Swagelok fitting standard requirements, we had to use stainless steel grade 316L. Even though this material is quite expensive compared to other materials, the total amount of material required is so small that the cost difference is insignificant.

3.3 Standard

The Swagelok fittings are only secure with the ASTM A213AW American standard which equals the EN10216-5 TC1 D4 European standard.

3.4 Supplier

As explained earlier we choose TESS as the supplier when possible, and they are able to provide the necessary piping’s.

4.0 Valve specification

4.1 Type

We need a total amount of 102 valves in the whole system. This number includes the pressure transmitters. As required by our employer, most of the valves (48 units) are solenoid valves capable of being opened or shut by a software. These valves are electronically controlled. Several manual valves are also included, both because of safety measurement and because Precision Subsea requires some manual interaction with the system before and after operation.

Safety valves are inserted close to the hose pump, accumulator and tanks because of required safety procedures.

Ball valves are used at possible extension ports, sealed of by plugs.

Electronic pressure transmitters are inserted at different points in the pipes in order to measure pressure at critical places.

In order to reduce pressure from the hose pump pressure side we have inserted several pressure reduction valves at this outline. The pressure will be reduced from 16 bar to 15 bar and from 16 bar to 2 bar. The final pressure reducer regulates flow and pressure in main line if necessary, it keeps the outflow constant at 16 bar.

4.3 Supplier

When possible we have used TESS, but since they do not deliver electronic pressure transmitter we have used Autek AS as the supplier. Autek owned by the same company that owns Precision Subsea, so that a low price will be possible. The tank safety valves are supplied by Slettebøe because they were 6 times cheaper than the ones TESS could deliver, even with the discount Precision Subsea receives from TESS.

Test report

- *SolidWorks simulation*

Bachelor Assignment spring 2015

AUTOMATIC OIL FILLING STATION

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1. Introduction

This document presents the results from our stress analysis in Solid Works simulation. These tests are executed to verify and document that our frame and tanks can handle the acting forces they are exposed to. The frame must handle the total weight of the system, while the tanks must be able to withstand the pressure difference between the atmospheric pressure and the internal pressure of the tanks. The simulation results clearly illustrate that safety factors and requirements are met in a satisfactory way.

2. Tank stress results

2.1 Vacuum tank

Tank properties:

- Diamter: 350 mm (Standard manufacturing diameter)
- Length: 520 mm
- Fillet radius: 5 mm
- Shell thickness (~1percent of diam.): 4mm
- Material: 1020 Carbon Steel Sheet (SS)
- E-module: 205000 MPa [$\frac{\mathrm{N}}{\mathrm{mm}^2}$]
- Yield strength:280 MPa [$\frac{\mathrm{N}}{\mathrm{mm}^2}$]

Loads and fixtures:

Applied external force: 100KPa (1Bar) of pressure. This external pressure simulates the atmospheric pressure. This pressure is simulated to act as seen below in fig.1 (*red arrows*).

Fixtures: The tanks are fixed to foundation by the two faces of the brackets (*green arrows*)

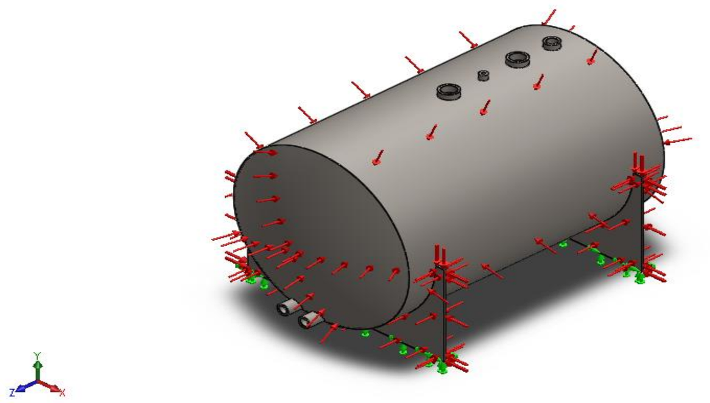

Figure 1: External load (100 kPa)

<u>Stress results (Von Mises Stress, MPa)</u>

Max stress: ~ 47 MPa

Safety factor: $\frac{Yield\ strength}{Max\ stress} = \frac{280}{47} = 5.9$ **Required safety factor**: > 2

The safety factor verifies that tank is more than capable to handle the lack of pressure equilibrium.

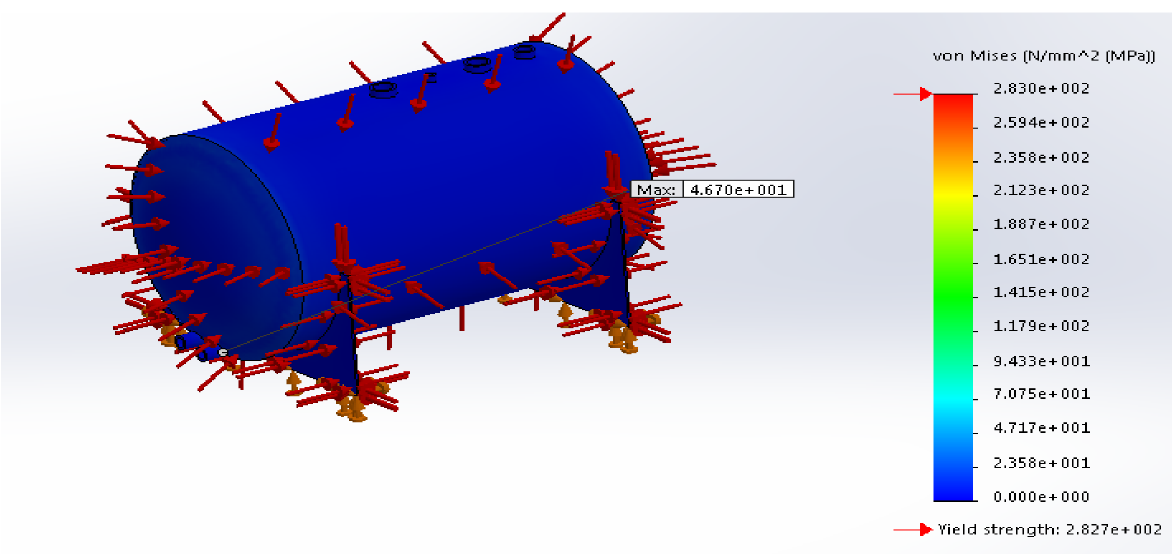

Figure 2: Max von Mises stress

Displacement results (mm)

Max displacement: 0.04 mm

The total displacement of the tank is insignificant; the result reflects the high safety factor.

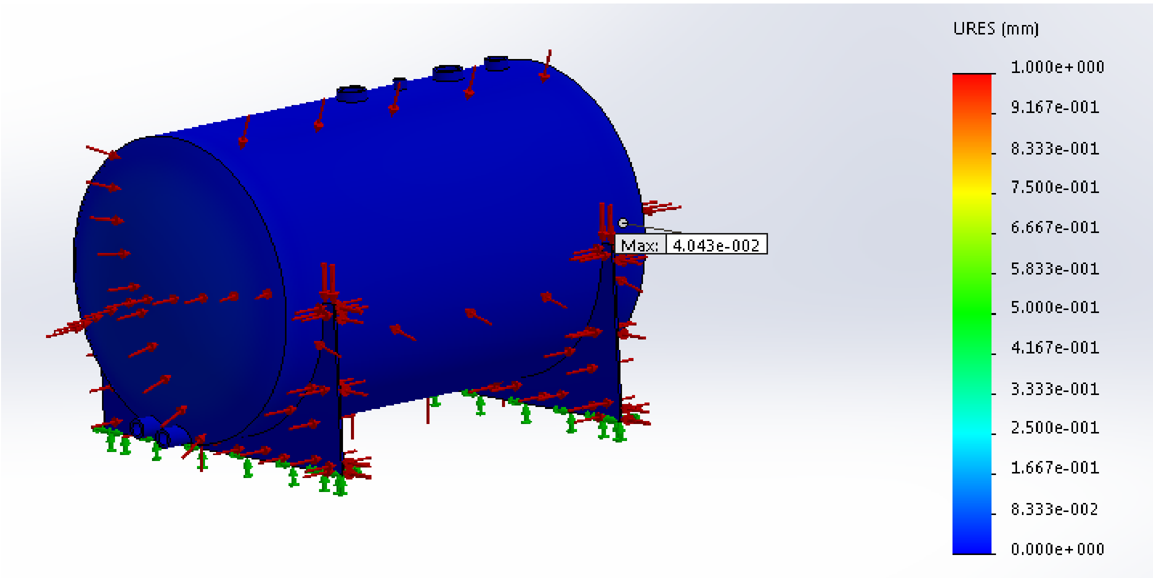

Figure 3: Displacement

2.2 Waste tank

Tank properties:

- Diamter: 500 mm (Standard manufacturing diameter)
- Length: 250 mm
- Fillet radius: 5 mm
- Shell thickness (~1percent of diam.): 4mm
- Material: 1020 Carbon Steel Sheet (SS)
- E-module: 205000 MPa [$\frac{N}{mm^2}$]
- Yield strength:280 MPa [$\frac{N}{mm^2}$]

Loads and fixtures:

Applied external force: 100KPa (1Bar) of pressure. This pressure is simulated to act as seen below in fig.4 (red arrows).

Fixtures: The tanks are fixed to foundation by the two faces of the brackets (green arrows)

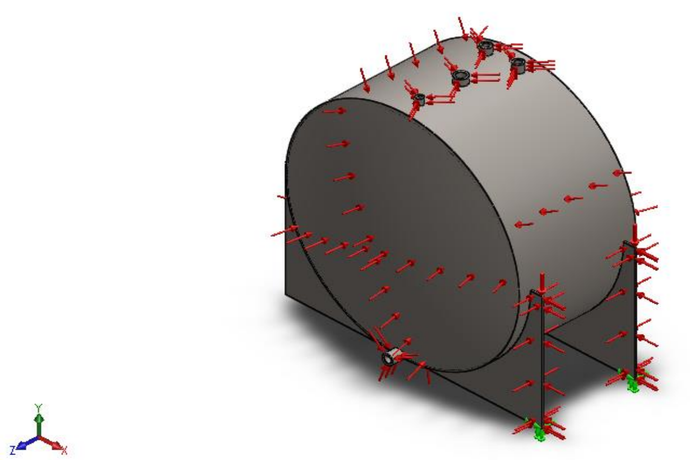

Figure 4: External load holding tank

Stress results (Von Mises Stress, MPa)

Max stress: ~59 MPa

Safety factor: $\frac{Yield\ strength}{Max\ stress} = \frac{280}{59} = 4.7$ **Required safety factor**: > 2

The safety factor verifies that the waste tank is more than capable to handle the lack of pressure equilibrium.

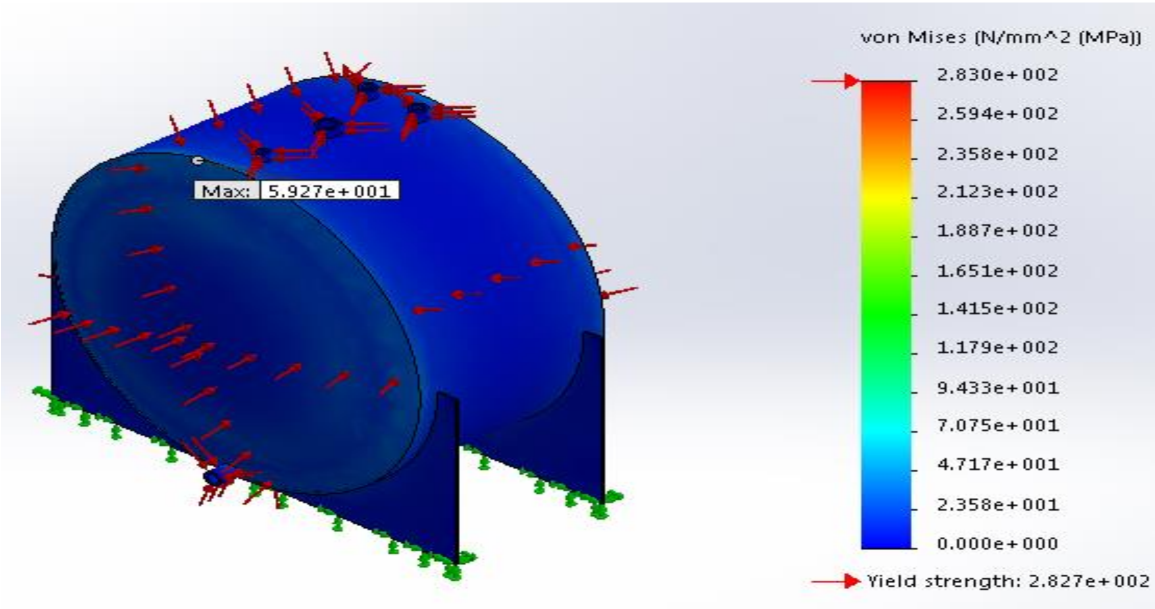

Figure 5: Max von Mises stress holding tank

<u>Displacement results (mm)</u>

Max displacement: 0.16 mm

The total displacement of the tank is insignificant. The result verifies that holding tank is suitable for our purpose.

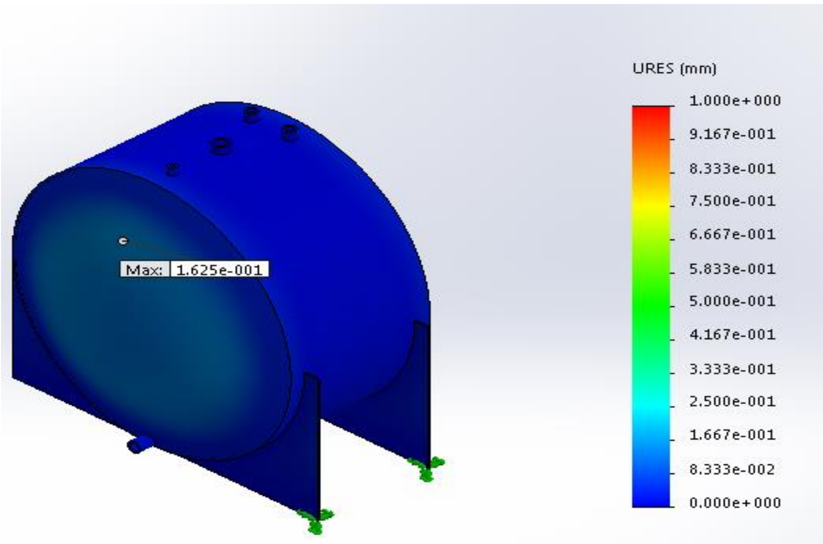

Figure 6: Displacement waste tank

2.3 Holding tank

- Diamter: 500 mm (Standard manufacturing diameter)
- Length: 510 mm
- Fillet radius: 5 mm
- Shell thickness (~1percent of diam.): 5 mm
- E-module: 205000 MPa [$\frac{N}{mm^2}$]
- Yield strength:283 MPa [$\frac{N}{mm^2}$

Loads and fixtures:

Applied external force: 100 kPa (1 bar) of pressure. This pressure is simulated to act as seen below in fig. 7 (*red arrows*).

Fixtures: The tanks are fixed to foundation by the two faces of the brackets (*green arrows*)

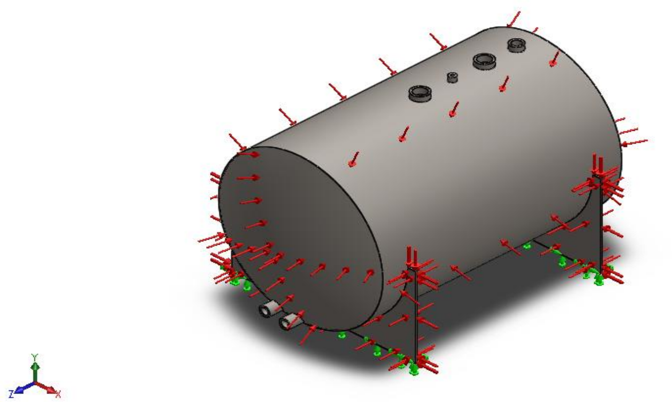

Figure 7: Holding tank

Stress results (Von Mises Stress, MPa)

Max stress: 101 MPa

Safety factor: $\frac{Yield\ strength}{Max\ stress} = \frac{280}{101} = 2.77$ **Required safety factor**: > 2

We can see that the safety factor is lower for the holding tank, then rest of the tanks. This underpins the theory described in the tank document. Higher length and diameter makes the tank more exposed to pressure instability. Despite this, the safety factor is > 2, so the tank is capable to handle the operating conditions.

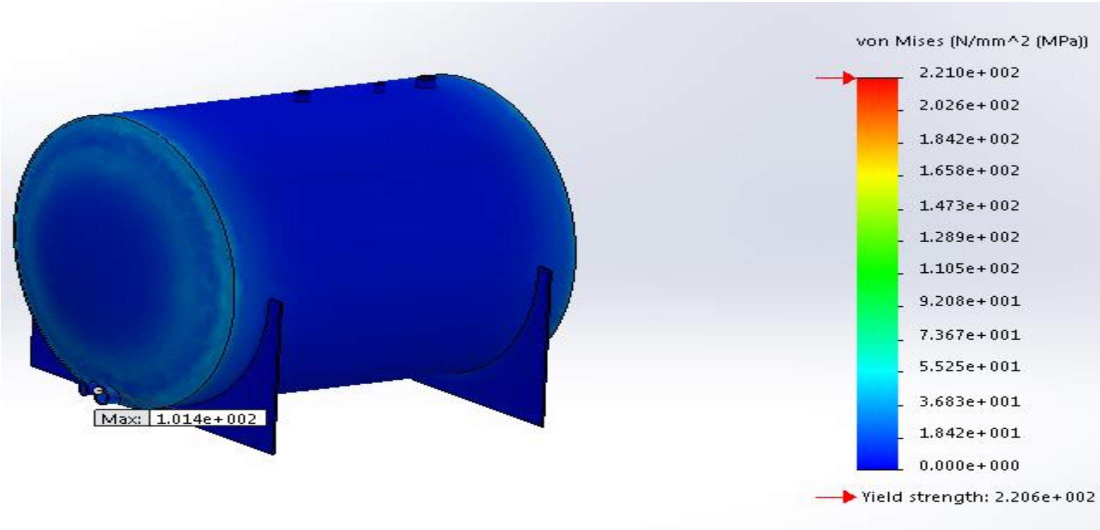

Figure 8: Max Von Mises stress holding tank

Displacement results (mm)

Max displacement: 0.17 mm

The total displacement of the tank is insignificant. The result verifies that holding tank is suitable for our purpose.

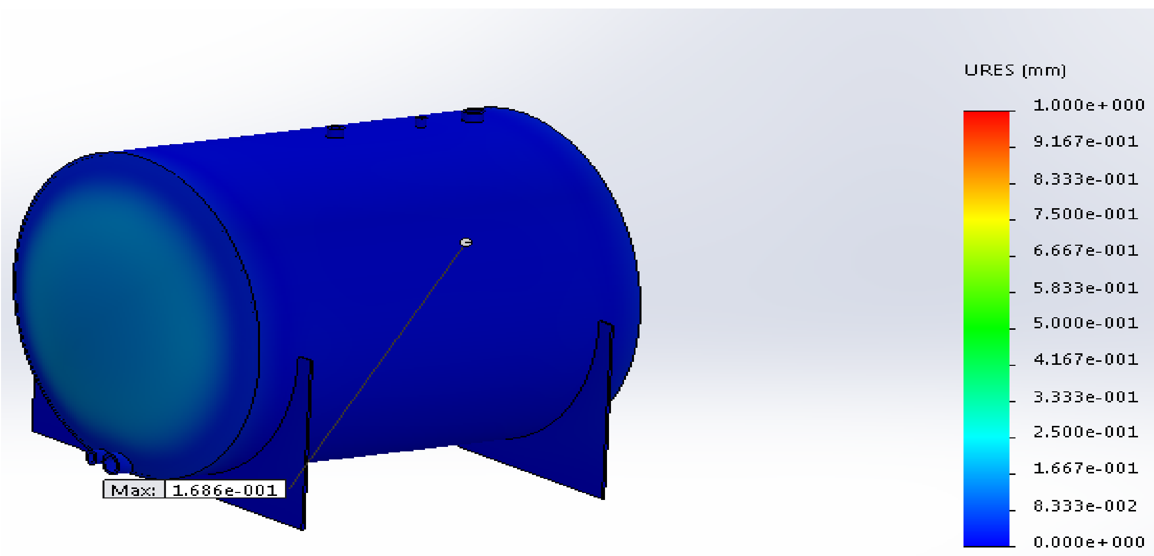

Figure 9: Displacement holding tank

3. Frame stress results

The frame is being exposed to forces from the total weight of the system, so it is crucial to verify that the frame can handle this applied force with a satisfactory safety factor. It is also highly important to see how the frame behaves during a lifting operation (Max. *Von Mises* stress and total displacement during a lift is particularly important).

Frame properties:

Total frame width: 1100 mm
Total frame length: 2480 mm
Total frame height: 1000 mm
Foundation plate thickness: 6 mm

Total frame weight: 204 kg (204 x 9.81 = 2001,3 N)

Yield strength: ~ 280 MPa
Tensile strength: ~ 425 MPa
Elastic modulus: ~ 205000 MPa
Mass density: ~ 7858 $\frac{kg}{m^3}$

Loads and fixtures:

Applied external force: The total external force acting on the frame is estimated to be approx. 7848N (800kg x 9, 81 m/s^2). The acting force is applied in newton and is assumed to be evenly spread over the whole foundation plate

The estimate is based on the following table:

Component	Approx. weight (kg)
Accumulator	10
Bredel hose pump	50
Circulation pump	2
Tanks (full)	460
Piping / tubes /valves / fittings	150
Vacuum pump	30
Misc.	90
Total	792

Fixtures: Are applied to the squared profile legs of the frame (see yellow arrows fig.10)

<u>Stress results (Von Mises Stress, MPa) in a *stationary situation*.</u>

Max stress: 48.8 MPa

Safety factor: $\frac{Yield\ strength}{Max\ stress} = \frac{280}{48,8} = 5.7$ **Required safety factor**: > 2

Safety factor is > 2. This verifies that the frame can handle the applied force in a satisfactory way.

Displacement insignificant < 0.8 mm

A thinner foundation plate < 6 mm, gave us an increased displacement, even though the safety factor was > 2. This fact justifies our choice of current plate thickness (*6 mm*).

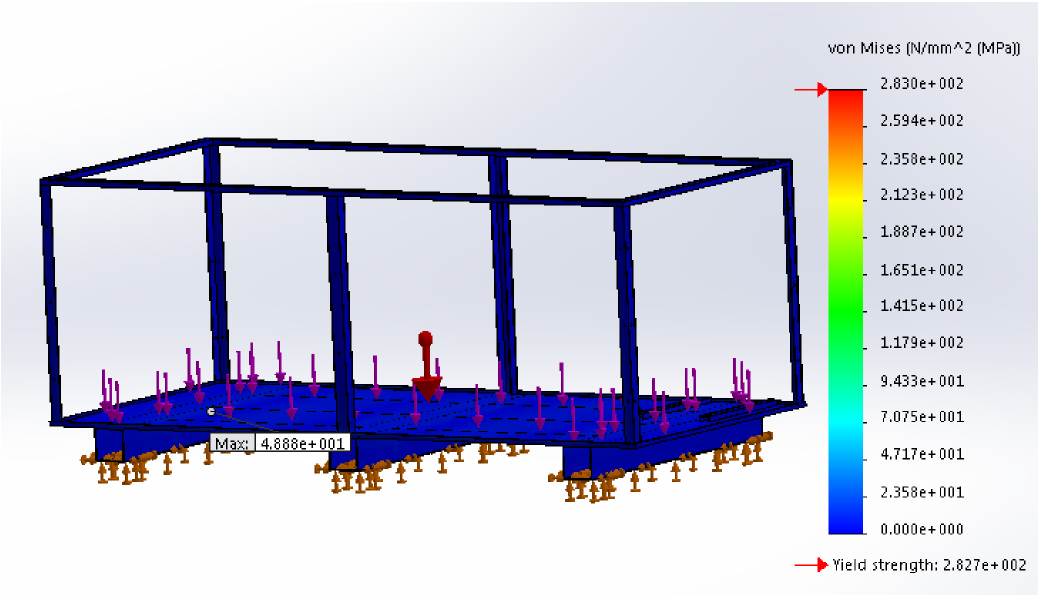

Figure 10: Von Mises stress in a stationary situation

__Stress results (Von Mises Stress, MPa) in a *lifting situation*.__

Fixtures: Are now applied to the simulated fork lifts (see yellow arrows figure below).

Applied external force: 7848 N (800kg x 9, 81m/s^2)

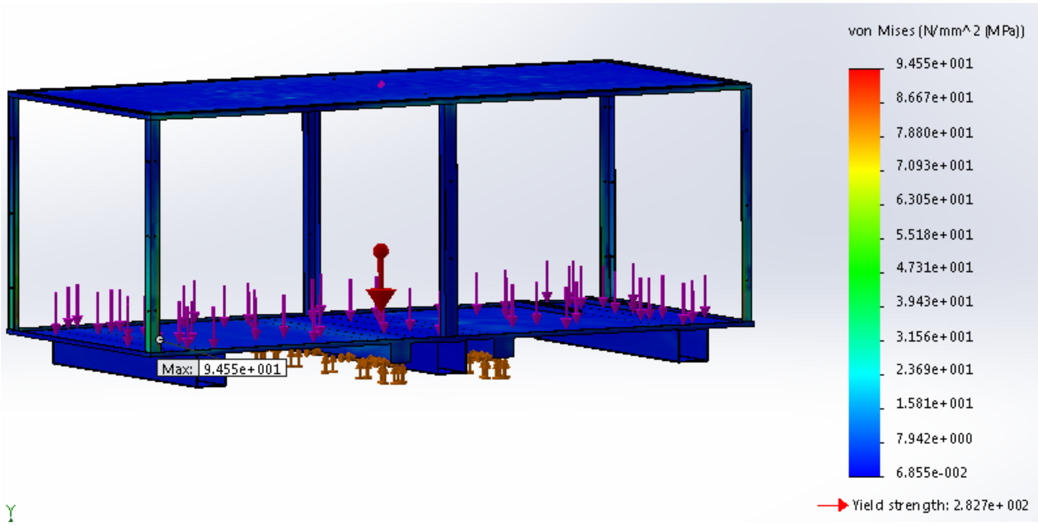

Figure 11: Max Von Mises stress in a lifting situation

Max stress: 94, 5 MPa

Safety factor: $\frac{Yield\ strength}{Max\ stress} = \frac{280}{94.5} = 2.96$

The results *verifies* that we will have a satisfactory safety factor during a lifting operation

<u>Displacement results (mm) in a *lifting situation*:</u>

Max displacement: 3, 12 mm

We can see that we will have a slight displacement in one of the angle steels during a lift. This displacement will be reduced when side and front plates are mounted. Thus, we can verify that the result is satisfactory.

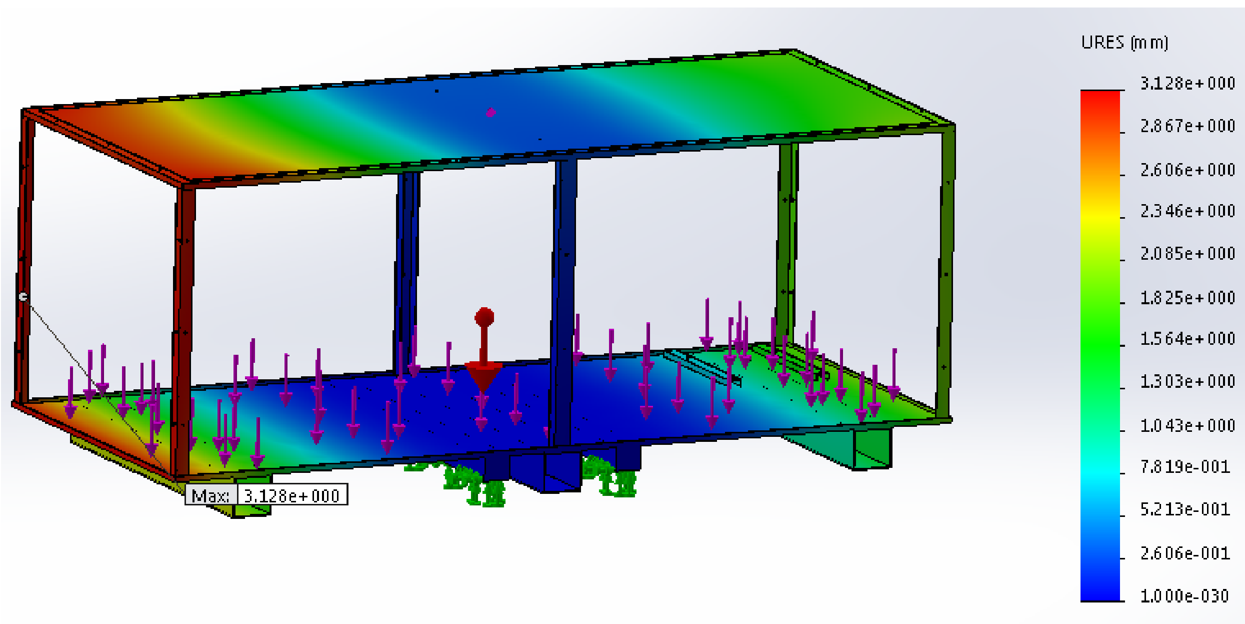

Figure 12: Displacement frame

Workmanship Specification

Bachelor Assignment spring 2015

Automatic Oil Filling Station

-

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1.0 Introduction

1.1 General Information

This document covers all workmanship procedures such as installation of instrumentation, tubing/piping, cabling, marking and labeling as well as basic corrosion prevention means.

1.2 Abbreviations

AOFS	-	Automatic Oil Filling Station
OD	-	Outer Diameter
ID	-	Inner Diameter

1.3 Scope

This purpose of this document is to describe functional and technical requirements related to installation of electrical equipment, instrumentation and piping.

This procedure is based upon NORSOK standard Z-010, Rev. 2, December 1997.

2.0 Workmanship Procedure

2.1 Instrument and Tubing

2.1.1 In-Line Instruments

All in-line instruments shall be installed in accordance with supplier recommendations.
Prior to final installation of control valve and other in-line instruments, process lines shall be properly cleaned as defined for the actual system.

2.1.2 Off-Line Instruments

Impulse tubing shall be as short as possible to avoid vapor/liquid pockets.
Instruments should be installed below tapping point for liquids and above tapping point for gas service where practical.

Impulse tubing which might entrap line fluid (liquid/gas) should be avoided. Impulse tubing shall have minimum 1:12 slope where specified on drawings.

2.1.3 Tubing Installation

Tubing ought to be put in trays where it is most practical. Tubing should be supported with tubing clamp approximately every 600 mm for tubing sizes less than 25 mm OD.

Tubing sizes above 25 mm OD shall as a minimum have support every 1,5 m. Tubing clamps should be made of noncorrosive material, stainless steel AISI 316 or flame retarding plastic.

Galvanic corrosion between tubing and tubing support system shall be avoided.
The tubing clamp shall, when installed, not allow for water/sea-water to be accumulated between tubing clamp and tubing, this is to avoid crevice corrosion.

Parallel runs of tubing on the same support shall be arranged such that it is possible to have access to every connection point. Installation into or through panels shall be by use of bulkhead unions or multi-cable transits.

Instrument tubing and cables may be installed on the same field tray.
All tubing, fittings which are not directly connected, shall be tightened by use of end-plug/cap.

The following sealing compounds shall be used as specified by product supplier:

- ❖ Loctite 401, Purchased at TESS: PN: KL1010083-20

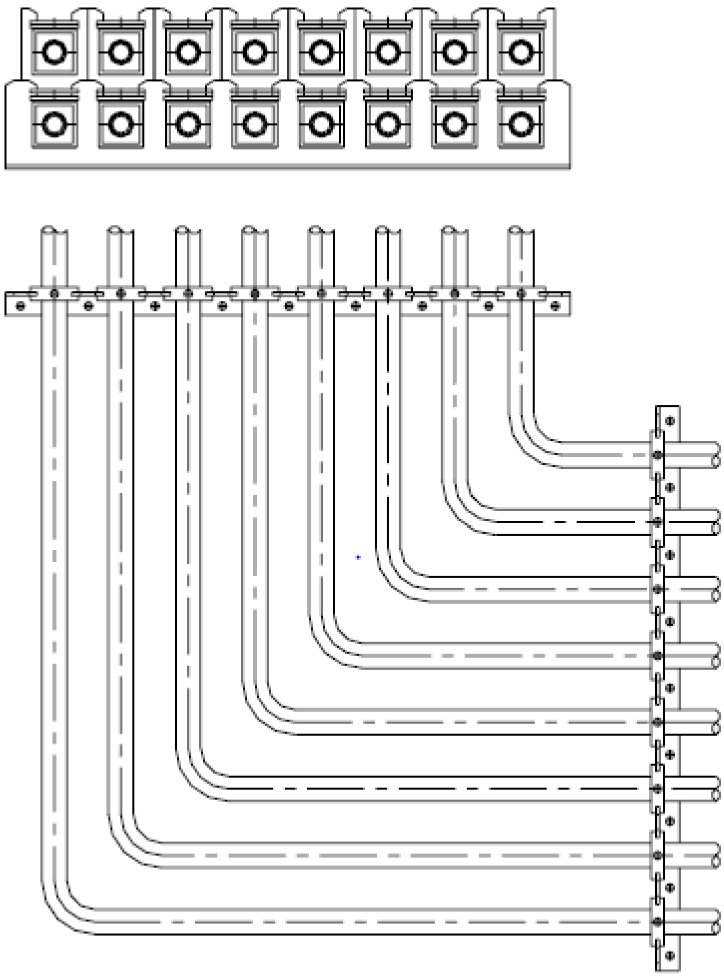

Figure 1: Typical Wall mounted tubing

2.2 Cabling

2.2.1 Cable Segregation

Signal cables shall be separated from low voltage power cables and high voltage cables by minimum 300 mm. When separation of the cable systems specified above is not possible or practical, a metal segregation barrier shall be installed. However, crossing at right angles is acceptable without further segregation.
IS and non IS instrument cables should be routed on the same cable ladder/trays, no segregation is required.

2.2.2 Cable Installation

All cables should be routed on cable ladders and trays. The filling of cables laid on cable trays, should not exceed the height of the trays side rail. 20% spare space for cables to be foreseen.

Once a cable has been cut, a protective cap/sealing shall be applied on the end. This is valid only when cable installation is done outdoor. All cable entries to equipment located outdoors and in wash down areas should be from below.

Sufficient cable spare length (e.g. by suitable routing) shall be provided for equipment which needs future adjustments or where equipment have to be dismounted for maintenance and calibration without disconnecting the cable. This is indicated on interconnection and wiring diagrams.

Single core cables for three-phase AC shall run in trefoil formation. Single core cables shall not be installed separately through openings surrounded by magnetic materials. Non-magnetic stainless steel separation walls and stay plates to be used in multicable transits utilised for single core cables.

2.2.3 Cable Bending Radius

The minimum permissible bending radius specified by supplier shall be adhered to.

Typical minimum bending radius:

- Signal cables : 6D (6 times outer diameter of cable)
- Power cables up to 1000V : 9D
- High voltage cables : According to suppliers requirements and recommendations

2.2.4 Cable Cleating and Strapping

Ultra violet resistant plastic straps shall be used for horizontal runs and for vertical runs and for horizontal runs in the vertical plane.

For strapping of fibre-optical and coaxial cables, supplier guidelines shall be adhered to.

The distance between cable straps shall not exceed:

- 600 mm for horizontal runs
- 300 mm for vertical runs and for horizontal runs in the vertical plane
- ten times the cable outer diameter from cable entry to the first strap (valid only for offshore installations)

2.2.5 Cable Glands

Mounting of cable gland in junction boxes shall normally be through free hole with back nut. Sealing washer to be used. If there is no space for back-nut, or the gland have “O-ring” as sealing, tapping holes shall be used.

For additional details for mounting of cable glands see suppliers mounting instructions.

Brass back plate or earthing lug to be used where metal glands are used in plastic boxes.

2.2.6 Cable Termination

All cable conductors except thermocouple cables shall be terminated by use of compression lugs or pin dependent upon the type of termination. The compression pin should be the type where the conductor strands are inserted through the whole pin and reach the bottom of the terminal.

In switchboards and distribution boards adequate space shall be provided for the use of a clip-on ampere-meter without causing undue stress on the cable conductors or connections.

The braid armour and the screen shall be unworn to the required length, twisted and fitted as required. This shall be done without any reduction of the cross sectional area.

Where the screen shall be left disconnected (applicable for field instrument), it shall be sealed and isolated with and isolating cap which allows for insulation testing without any disconnecting.

Each field cable conductor and earth wire should have a separate terminal.

2.3 Earthing/Bonding

Exposed conductive parts located in hazardous areas shall be bonded to the main structure. Separate bonding shall only be provided between the main structure and preassemblies, modules which are not welded or bolted.

Separate bonding shall be applied for equipment which is isolated from main structure. Enclosures of high voltage equipment located in hazardous areas shall be connected the PE and bonded to the main structure. Painting to be removed from all bonding points.

2.4 Brackets and Supports

Equipment brackets and supports should not be installed directly on removable equipment. Equipment brackets and supports should be fabricated in stainless steel or Painted Carbon Steel.

2.5 Bolting and other Fixing materials

Screws, bolts, nuts and washers shall be made of acid proof steel AISI 316 for sizes M16 and less. For sizes above M16 fastening materials of cadmium may be used.
Washers and lock washers to be used on all bolted connections, possibly washer and lock nut
If use of spring washers on painted surface, should a flat washer be used underneath.

Bolts, stud bolts exposed for temperature should be treated with suitable lubricant. Use suitable lubricant on acid proof bolts. With use of stud bolts, should washer be used at painted surfaces.

2.6 Marking and Labelling

2.6.1 Tagging

Tagging of major components and items are recommended to ease of maintenance and troubleshooting. This can be of locking wire and metal tags/signs.

2.6.2 Safety labels

Safety labels and warnings on items and equipment shall be used to prevent injury or damage.

2.6.3 Color and flow coding

Color coding of earth conductors and other electrical cabeling to ease of maintenance is preferred and recommended.

Flow coding on lines to show direction of flow as well as flowing medium is recommended.

2.7 Corrosion Prevention

To prevent corrosion, the following is recoomended:

- ❖ Water traps shall be avoided.
- ❖ Crevices should be avoided.
- ❖ Sharp edges and corners of carbon steel should be rounded by grinding to a radius of minimum 2 mm to obtain satisfactory adhesion for the painting.
- ❖ Stainless steel instruments, instrument supports and brackets mounted on carbon steel shall be galvanic isolated. For welded connections the weld plus 100 mm onto the stainless steel shall be painted.
- ❖ Stainless steel instruments, instrument supports and brackets, mounted on Aluminium, shall be galvanic isolated.

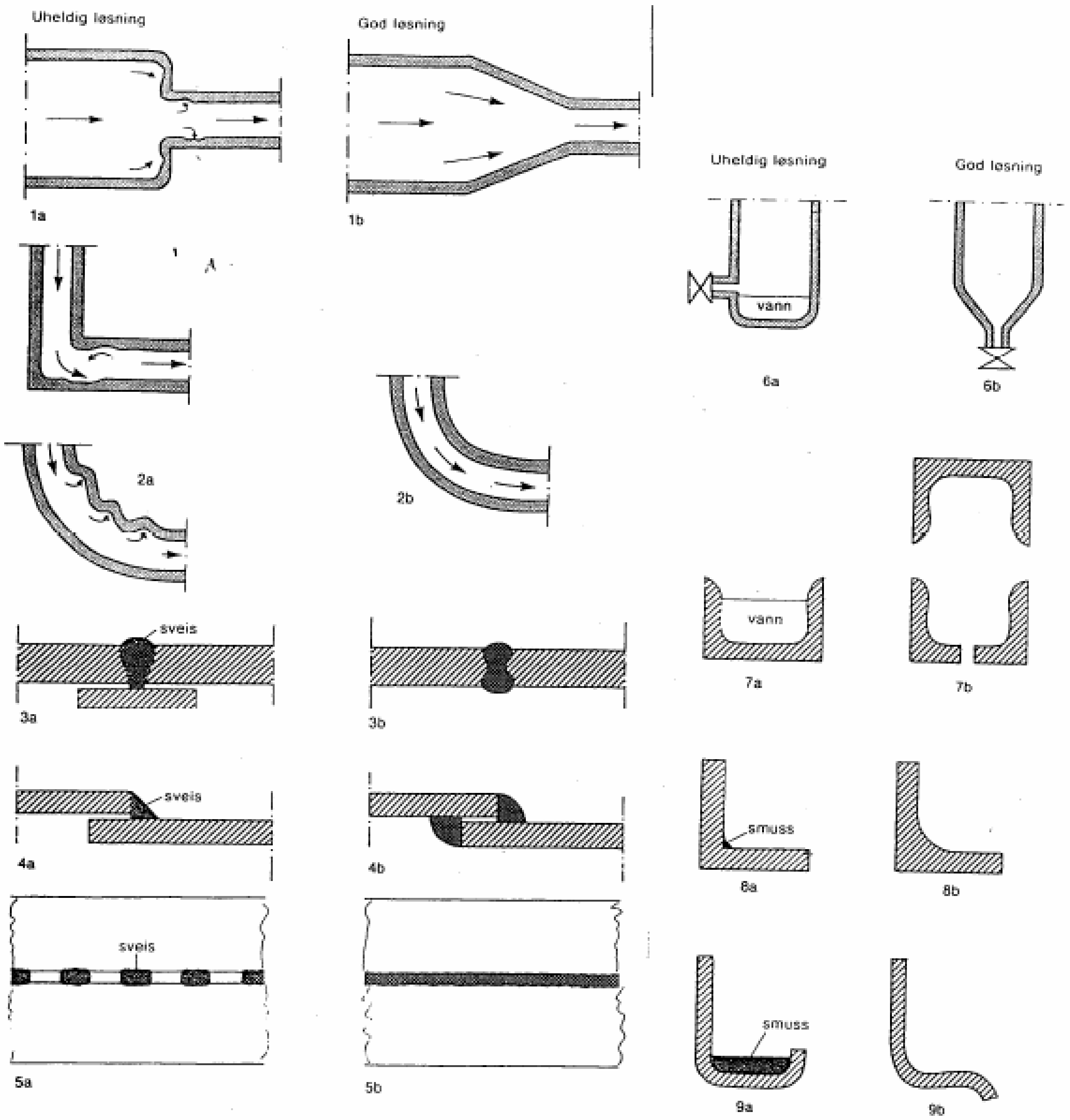

Fig. 5.1 Det er viktig å konstruere slik at ikke smuss og vann får anledning til å samle seg. Eksemplene 3, 4 og 5 viser ulike måter å utføre sveis på.
a Uheldige løsninger.
b Gode løsninger.
Kilde: E. Mattsson.

Figur 2: Corrosion Prevention

3.0 Torque Table

Refer to attachment 1 – Tingstad tiltrekningstabell for more information.

STUD BOLT LENGTH

Nominal Pipe Size (in.)	Stud Bolts for ANSI 150-lb			Stud Bolts for ANSI 300-lb			Stud Bolts for ANSI 600-lb			Stud Bolts for ANSI 900-lb			Stud Bolts for ANSI 1500-lb		
	Number of Bolts required	Size & Length of Stud Bolts (in.)	Wrench Size for Nuts (in.)	Number of Bolts required	Size & Length of Stud Bolts (in.)	Wrench Size for Nuts (in.)	Number of Bolts required	Size & Length of Stud Bolts (in.)	Wrench Size for Nuts (in.)	Number of Bolts required	Size & Length of Stud Bolts (in.)	Wrench Size for Nuts (in.)	Number of Bolts required	Size & Length of Stud Bolts (in.)	Wrench Size for Nuts (in.)
½	4	½ X 2½	7/8	4	½ X 2¾	7/8	4	½ X 3¼	7/8	4	¾ X 4¼	1¼	4	¾ X 4¼	1¼
¾	4	½ X 2½	7/8	4	5/8 X 3	1 1/16	4	5/8 X 3½	1 1/16	4	¾ X 4½	1¼	4	¾ X 4½	1¼
1	4	½ X 2¾	7/8	4	5/8 X 3¼	1 1/16	4	5/8 X 3¾	1 1/16	4	7/8 X 5	1 7/16	4	7/8 X 5	1 7/16
1¼	4	½ X 2¾	7/8	4	5/8 X 3¼	1 1/16	4	5/8 X 4	1 1/16	4	7/8 X 5	1 7/16	4	7/8 X 5	1 7/16
1½	4	½ X 3	7/8	4	¾ X 3¾	1¼	4	¾ X 4¼	1¼	4	1 X 5½	1 5/8	4	1 X 5½	1 5/8
2	4	5/8 X 3¼	1 1/16	8	5/8 X 3½	1 1/16	8	5/8 X 4¼	1 1/16	8	7/8 X 5¾	1 7/16	8	7/8 X 5¾	1 7/16
2½	4	5/8 X 3½	1 1/16	8	¾ X 4	1¼	8	¾ X 4¾	1¼	8	1 X 6¼	1 5/8	8	1 X 6¼	1 5/8
3	4	5/8 X 3¾	1 1/16	8	¾ X 4¼	1¼	8	¾ X 5	1¼	8	7/8 X 5¾	1 7/16	8	1 1/8 X 7	1 13/16
3½	8	5/8 X 3¾	1 1/16	8	¾ X 4½	1¼	8	7/8 X 5½	1 7/16	X	XXXXXX	XXX	X	XXXXXX	XXX
4	8	5/8 X 3¾	1 1/16	8	¾ X 4½	1¼	8	7/8 X 5¾	1 7/16	8	1 1/8 X 6¾	1 13/16	8	1¼ X 7¾	2
5	8	¾ X 4	1¼	8	¾ X 4¾	1¼	8	1 X 6½	1 5/8	8	1¼ X 7½	2	8	1½ X 9¾	2 3/8
6	8	¾ X 4	1¼	12	¾ X 5	1¼	12	1 X 6¾	1 5/8	12	1 1/8 X 7¾	1 13/16	12	1 3/8 X 10¼	2 3/16
8	8	¾ X 4½	1¼	12	7/8 X 5½	1 7/16	12	1 1/8 X 7¾	1 13/16	12	1 3/8 X 8¾	2 3/16	12	1 5/8 X 11½	2 9/16
10	12	7/8 X 4¾	1 7/16	16	1 X 6¼	1 5/8	16	1¼ X 8½	2	16	1 3/8 X 9¼	2 3/16	12	1 7/8 X 13¼	2 15/16
12	12	7/8 X 4¾	1 7/16	16	1 1/8 X 6¾	1 13/16	20	1¼ X 8¾	2	20	1 3/8 X 10	2 3/16	16	2 X 14¾	3 1/8

MATERIAL ACC. TO SB1 IN PIPING SPEC. 127376 03

Momenter for tørre studbolter og muttere:

Dim. Stud:	½"	5/8"	¾"	7/8"	1"
Moment:	75Nm	200Nm	350Nm	560Nm	850Nm

03

4.0 Attachments

Attachment 1 - Tingstad-Tiltrekkingsmomenter

Final design

Bachelor Assignment spring 2015

Automatic Station
Oil Filler Subsea Jumpers

AUTOMATIC OIL FILLING STATION

-

EIRIK S. MÆHRE
MARIUS MARTINSEN
KNUT OLA NYMOEN
HENNING HENRIKSEN

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2.0 AOFS Design 4

1.0 Introduction

This document shows some 3D model illustrations of the Automatic Oil Filling Station, AOFS, final design.

These pictures are for illustrational purposes only and are not to be copied and/or used without consent from Precision Subsea AS.

Subassembly illustrations are not included in this document, only frame and main assembly.

2.0 AOFS Design

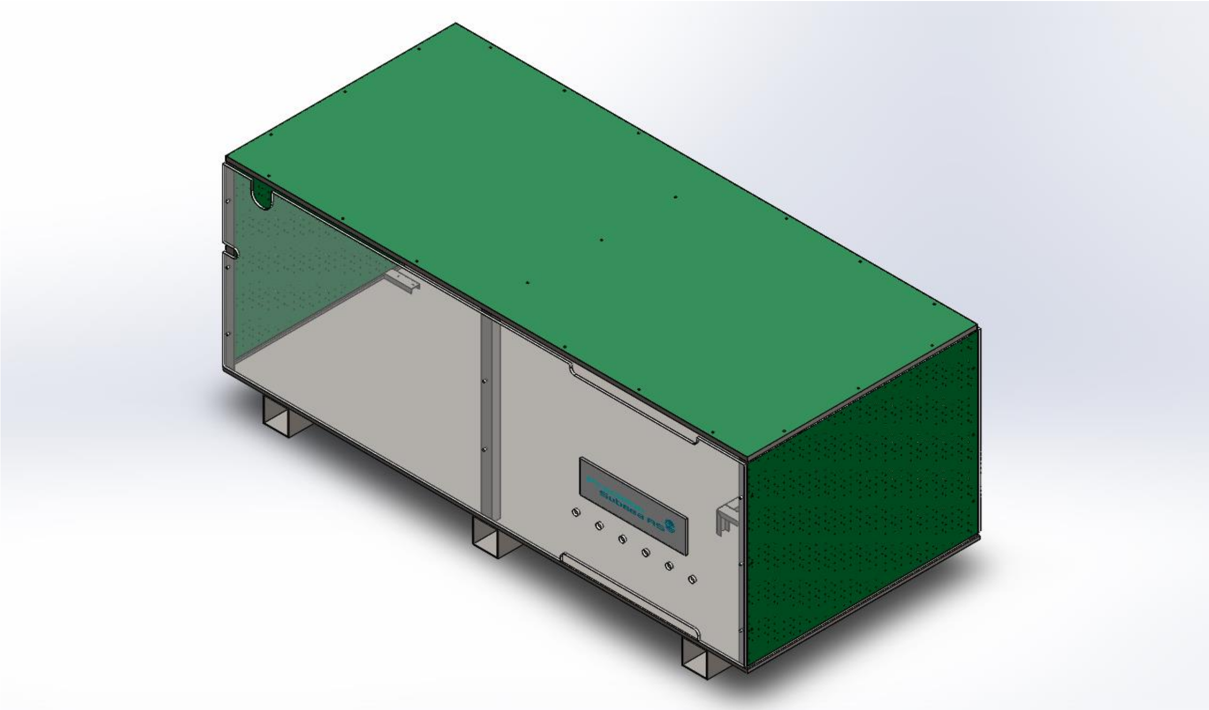

Figure 1: AOFS Frame

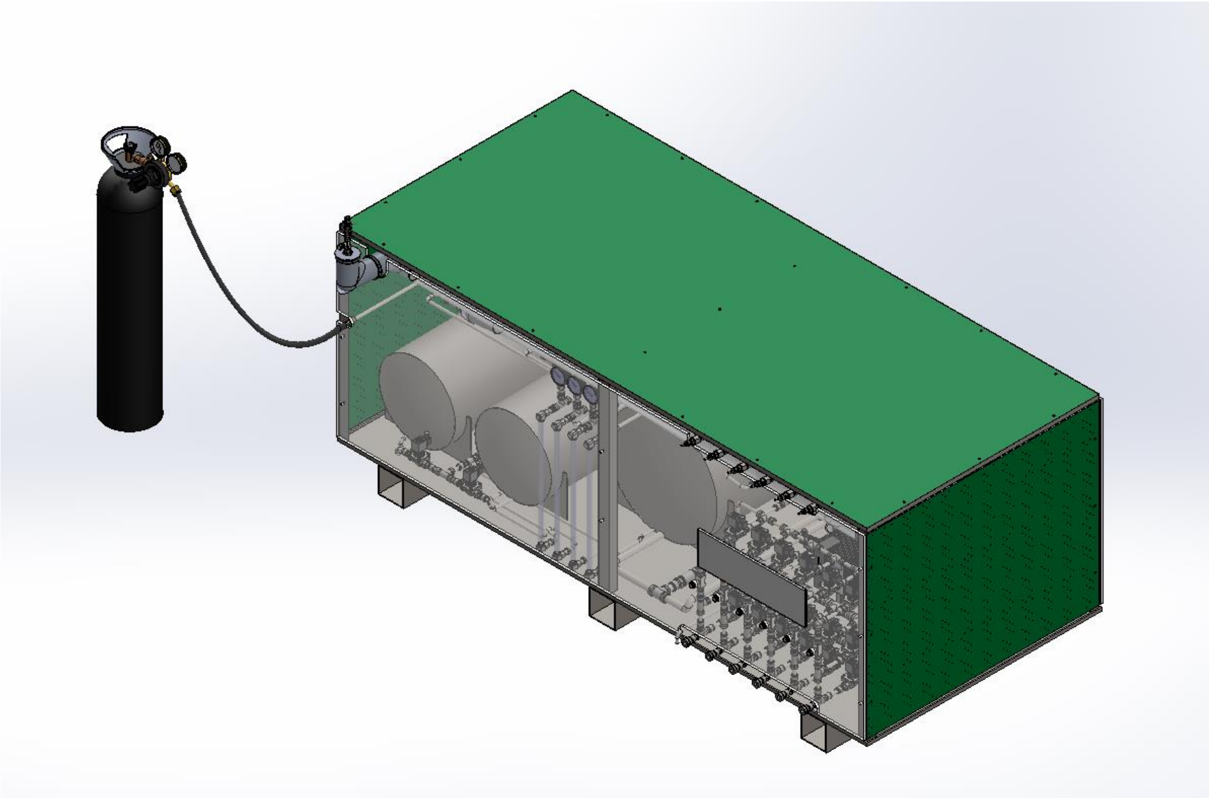

Figure 2: AOFS

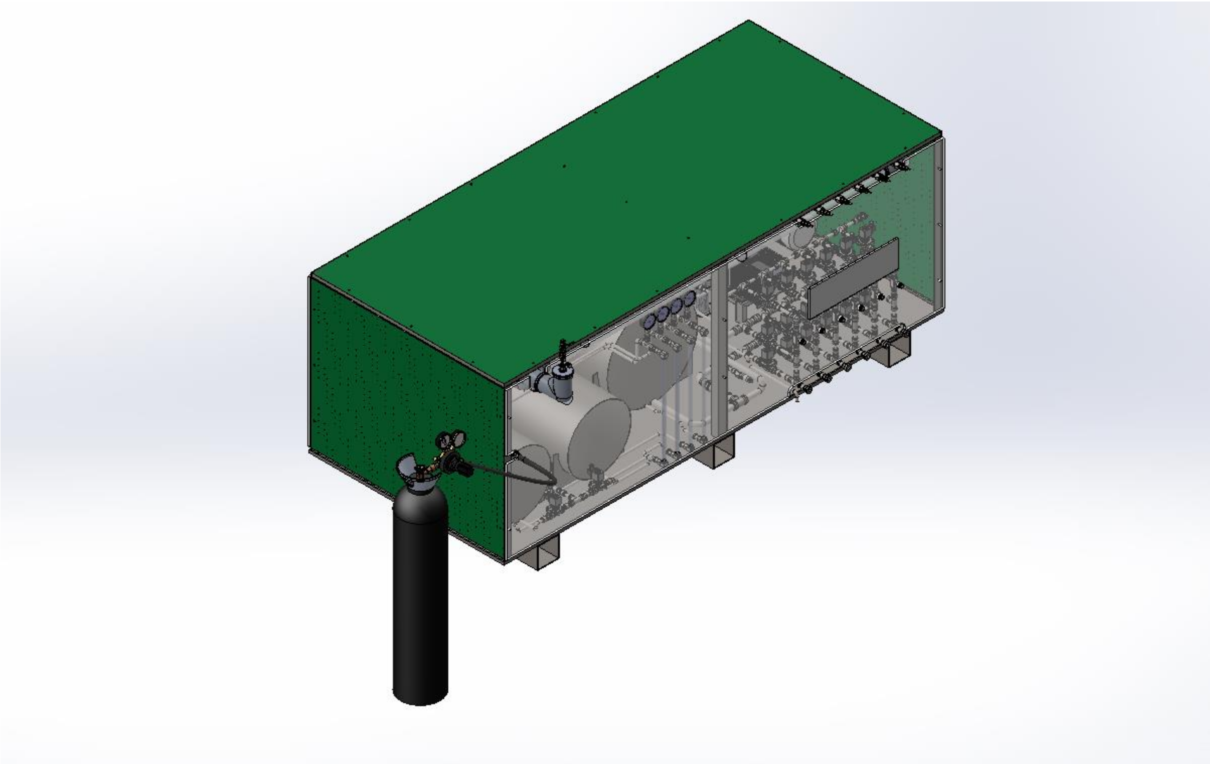

Figure 3: AOFS

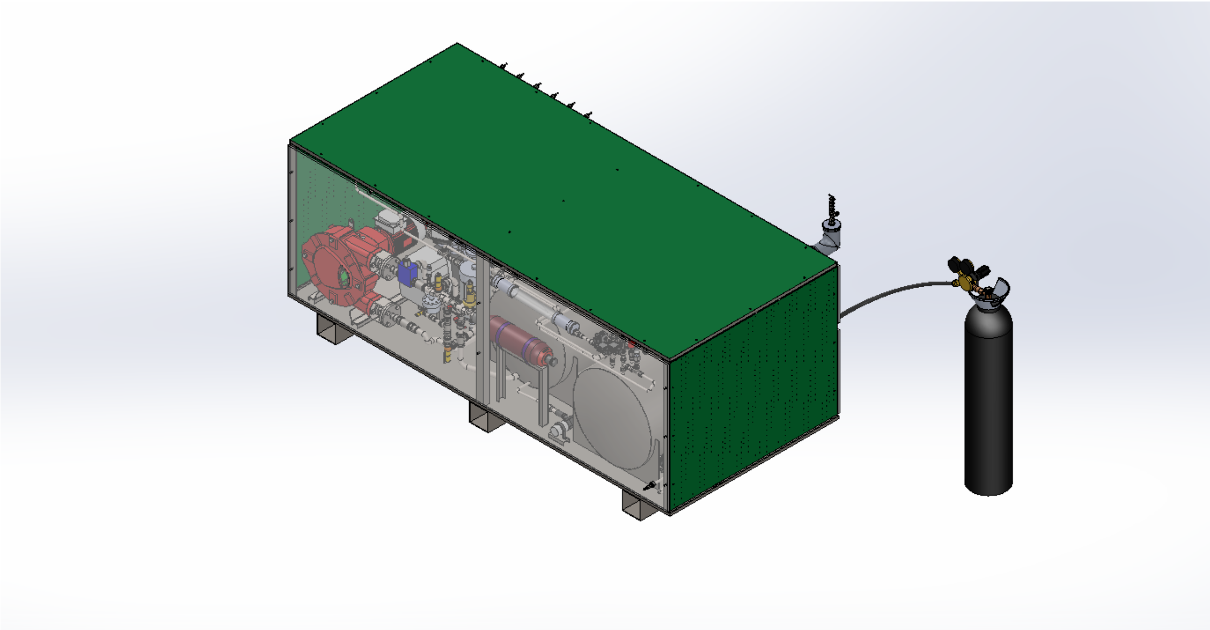

Figure 4: AOFS back