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Målesystem for hydrauliske stempelakkumulatorer.
Hydraulic Accumulator Measuring Unit(HAMU).

Utført i samarbeid med: FMC Technologies

Ekstern veileder: Odd Jan Kirkaune

Sammendrag: Ett målesystem som måler nivået av hydraulisk olje i en stempelakkumulator. Disse akkumulatorene er plassert på juletrær på havbunnen.

Stikkord:
- Subsea
- Målesystem
- Akkumulatortank

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I. Summary

This report is based on the challenges FMC Technologies has due to measuring the amount of hydraulic oil inside a piston accumulator tank on the bottom of the sea. It is favorably to know at any given time how much hydraulic oil is left in the tank; in time some of the oil will be lost to the environment due to its function.

There are several hydraulic accumulator tanks attached to a subsea Xmas tree, each operating on different system but perform the same main function, which is to send hydraulic oil to an actuator. The actuator uses the hydraulic oil as energy to open and close valves.

Today FMC Technologies does not have any satisfying solution regarding this problem; rather they use prior experience of how long it takes before an accumulator tank needs to be refilled.

In collaboration with FMC Technologies a solution to the problem has been developed for measuring the remaining hydraulic oil inside the tank, where a measuring system were put on the top of the accumulator tank protected by a housing. The critical issue for the system is an expected lifetime of 25 years.

Several solution regarding a measuring system where proposed. A scoreboard criterion where used to distinguish out the best solution according to the requirements given by FMC Technologies.

A detailed concept regarding the best solution where developed, which consist of a time-of-flight laser placed inside a housing which is attached to the top of the accumulator tank. The housing must be able to withstand water pressure down to 2750m (275 Bar). The bottom of the housing must be able to withstand internal pressure from the accumulator tank which is 345 Bar. The bottom of the housing also is a second barrier against the water pressure.

The report is a document which follows the process from a problem given by FMC Technologies to a concept idea which is generated step by step through this document.

II. Preface

In this thesis we will try to find a better solution for FMC Technologies, concerning the problem of knowing the remaining hydraulic oil in the accumulator tank, than the current method used by FMC Technologies today. Besides finding a proper measuring system that will fulfill the requirements given, the group will also design a proper housing for the measuring system, proper material selection due to strength and corrosion and perform the calculations needed for the design to withstand the pressure it will be exposed to.

III. Acknowledgement

There are some people that deserve an acknowledgement due to this project. Our external mentor at FMC Technologies Odd Jan Kirkaune has been our biggest support by guiding us through the project from the beginning to the end. He has also been a big contribution for technical support, ideas and suggestions regarding the problem along with our internal mentor Gunnar Flak at HIBU Kongsberg which has also contributed with ideas and guidance.

The group would also like to express our thankfulness to certain suppliers for giving valuable information and technical support about their products; Kim Grundstrøm (Acuity Laser Measurements), Kris Van Thillo (High Tech Metal Seals), Torill Finnerud (Proffpartner) and Suzanne Horrigan(L.J.Star).

IV. Abbreviations

FMC	Food Machine Corporation
SCM	Subsea Control Module
EMI	Electromagnetic Interference
SEM	Subsea Electronic Module
CPU	Central Processing Unit
I/O	Input/output
CAN	Controlled Area Network
HLP	Higher Layer Protocol
MTBF	Mean Time Between Failure
HAMU	Hydraulic Accumulator Measuring Unit
SSI	Simple Sensor Interface
RS	Recommended Standard
CiA	CAN in Automation
FEM	Finite Element Method
F.O.S	Factor of Safety

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1. Introduction

The bachelor thesis, in collaboration with FMC Technologies, was to develop a measuring unit that measures the level of hydraulic fluid in piston accumulator tanks.

The critical factors regarding this thesis is the design of the housing, this is where all the electronics are placed, how to attach the housing to the accumulator and to find a proper way to get a viewing into the accumulator for a measurement. We will have a selection of components with scoreboard regarding which materials and electronics that are most favorably. All of our components, except the electronics, will be exposed to pressure either external or external and internal. Therefore we have created a design in Solid Works which is a 3D-CAD software, to pressure test all of our components, to make sure they withstand the pressure. The design of the housing will incorporate economic, resistible to pressure and machine ability.

We have in previous submission proposed and discussed concepts for measuring and we will reduce these to one concept with the help of a scoreboard.

1.1 Goals

The main goal of the project is to develop a good design and concept of the measuring unit, the concept has to fulfill the requirements from FMC Technologies.

1.1.1 Secondary goals

We will consider these secondary goals to achieve our main goal.

- Dimension of housing
- Proper material selection
- Provide that every part withstand the pressure
- Try to maintain the 25 years lifetime expectancy
- Find a solution to attach the laser inside the housing
- Find a solution to attach the housing to the accumulator tank

1.2 Critical factors

- Try to maintain the 25 years lifetime expectancy
- Material
  - High corrosion resistance
  - Endure high pressure
- Design
  - Adapted so it can be mounted on the top of the accumulator
  - Allow the laser to propagate freely between housing and piston
- Communication
  - Must be able to communicate with SCM
  - Limited power accessibility

2. Background

2.1 Accumulators

There are two types of accumulator tanks used on Xmas trees, bladder and piston accumulators. Bladder accumulators are much cheaper and therefore more preferably used when there is no issue regarding remaining hydraulic fluid left in the tank (short distance to topside). But there are some disadvantages regarding the use of bladder accumulators. It is not possible to measure the remaining hydraulic fluid left and there are also a limitation regarding how much hydraulic fluid that can be extracted from the bladder accumulator during operation. Approximately the relationship between P0 and P2, Figure 1.a and 1.c cannot exceed 1:4.

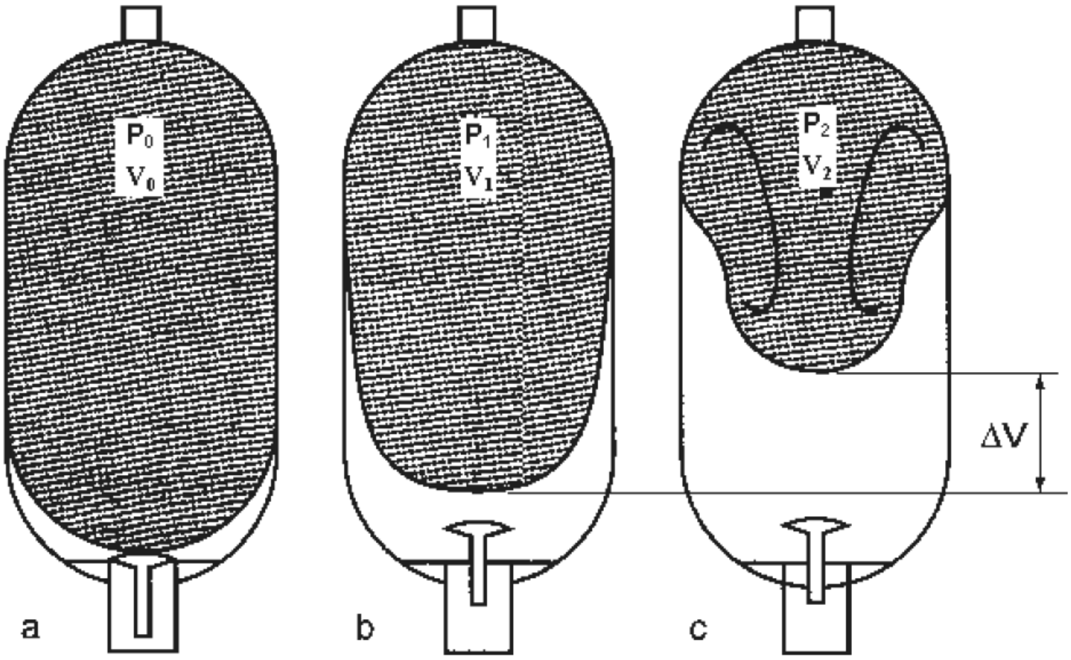

Figure 1 Bladder accumulator

There are no limitations for piston accumulators as it is for bladder accumulators, as mentioned above, and when there is a need of knowing remaining hydraulic fluid inside the tank there are only piston accumulators that can be used. Prior there have been several solutions due to determine remaining hydraulic fluid but they have all been inadequate solutions.

The piston accumulator tank used subsea, consists of a cylinder with two chambers separated by a floating piston. One chamber contains the hydraulic fluid and is connected to the hydraulic line, and the other chamber is filled with inert gas under pressure typically nitrogen which provides the compressive force on the hydraulic fluid (pressure in both chambers are always equal). Inert gas is used because oxygen and oil can form an explosive mixture under high pressure. There are many types of accumulator tanks, but they all have in common that they act as device for storing energy.

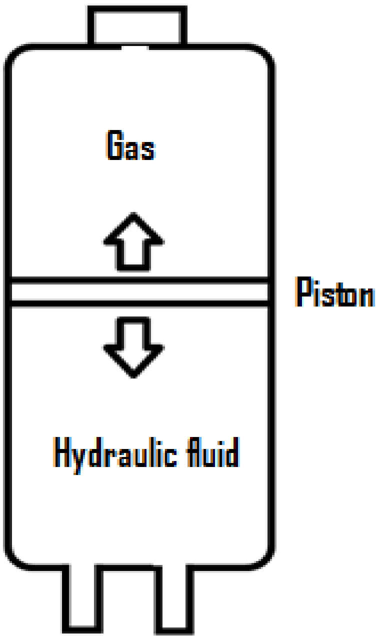

Figure 2 Piston accumulator

2.2 Durability

FMC Technologies has a requirement of 25 years of lifetime expectancy, to achieve this goal the material we use has to be durable and have a high corrosion resistance since there are no maintenance. The electronic components will be placed inside the housing where there will be 1atm pressure, 4^0C and it will be filled with dry N_2. Constant temperature and pressure, and dry nitrogen significantly decrease the corrosion rate on the electronic components.

2.2.1 Environment

In our assembly there can be no leakage of any environment-hazard substance. The only leakage that can occur is N_2 into the water, and since the air we breathe contains approximately 78% N_2 a leakage of this will not cause any hazards.

2.2.2 Financial

To achieve the 25 years lifetime, the material must have long time durability which significantly increases the production cost. We can see this as an investment since there will be much greater cost of maintaining the application.

2.3 Interface

2.3.1 Flange

A flange is used to attach the housing on to the accumulator tank, the connection between the flange and the accumulator tank will be EB-welded. EB-welding, or electronic beam welding, is a method used where material nearby the welding zone cannot be exposed to high temperatures due to lowering of strength in HAZ. Another advantage is that it can be used to weld different materials to each other and with different thickness. The welding seam will be bombard with a concentrated beam of electrons with an effect density of 10^7 W/cm^2. The flange will have eight threaded holes for the fitting of housing. We will then use pin bolts and nuts to fasten the cylinder to the flange. The flange used to attach cylinder to accumulator, is a FMC standard component.

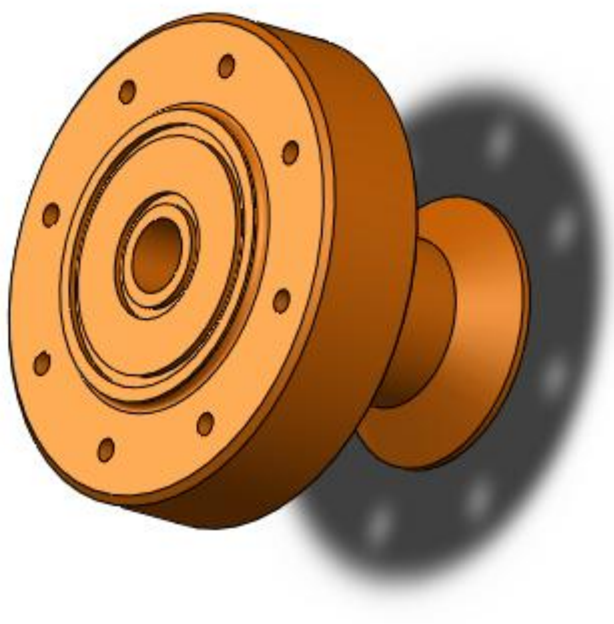

Figure 3 Flange

Bottom EB-welded to accumulator and top is fastened to cylinder with pin bolts and nuts

2.3.2 Communication

In our project, the goal is to make a distance measuring unit, and prove that it works with a simple serial port, like RS-232/422 interface. FMC uses RS-485/CAN-bus interface communication in subsea, which uses twisted pair wires. Twisted pair cabling is a type of wiring in which two conductors (the forward and return conductors of a single circuit), are twisted together for the purposes of canceling out electromagnetic interference (EMI) from external sources. This means that the signals can travel further than with serial wires. FMC will provide a serial to twisted pair adapter if the plan to use our idea.

We want to provide a little background on FMC Subsea Communication, so that people get a perspective on how our project fits in. The SCM is the brain of the Xmas three that sits on the bottom of the sea. It consists of a SEM, which includes CPU-, I/O- and Communication electronics, in addition to sensors and actuators that provides the SEM information and gives it the ability to perform different tasks. CAN-bus interfaces are one of the I/O functions implemented in the SEM. CAN-bus, is a message based protocol, designed specifically for automotive applications, but is now also used in other areas such as industrial automation and medical equipment

SEM has many Nodes, and each one has an assigned ID related to its function and physical location in the system. Each Master/Slave Node in the Subsea Control Module is typically an I/O Board with CAN Controllers inside the SEM. More than one Master/Slave Nodes may exist at one CAN-bus, but only one Master/Slave Node shall have Master functions activated at the time. Other Master/Slave Nodes shall be Passive or shall operate like Slave Nodes. Slave Nodes will typically be, except for Master/Slave Nodes, Internal and External Sensors and Actuators. The Master/Slave and Slave Nodes must include four implementation layers described in the following chapters:

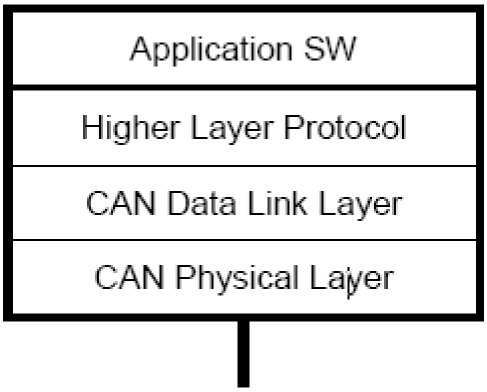

Figure 4 Master node

The HLP is a library of functions used for controlling the CAN-bus nodes. HLP is used between the CAN data link layer and the application software. A master Node may have several slave Nodes, external and internal ones. They communicate to each other through a multiplexer. Our Acuity AR1000 laser will become one of these external slave nodes, and will then communicate with the SCM through the FMC RS-485/CAN-bus interface. The SCM is part of a Subsea Control System, which typically consist of the following components:

- Subsea Control Module with Subsea Electronic Module
- Internal sensors and actuators inside the SCM
- External sensors and actuators

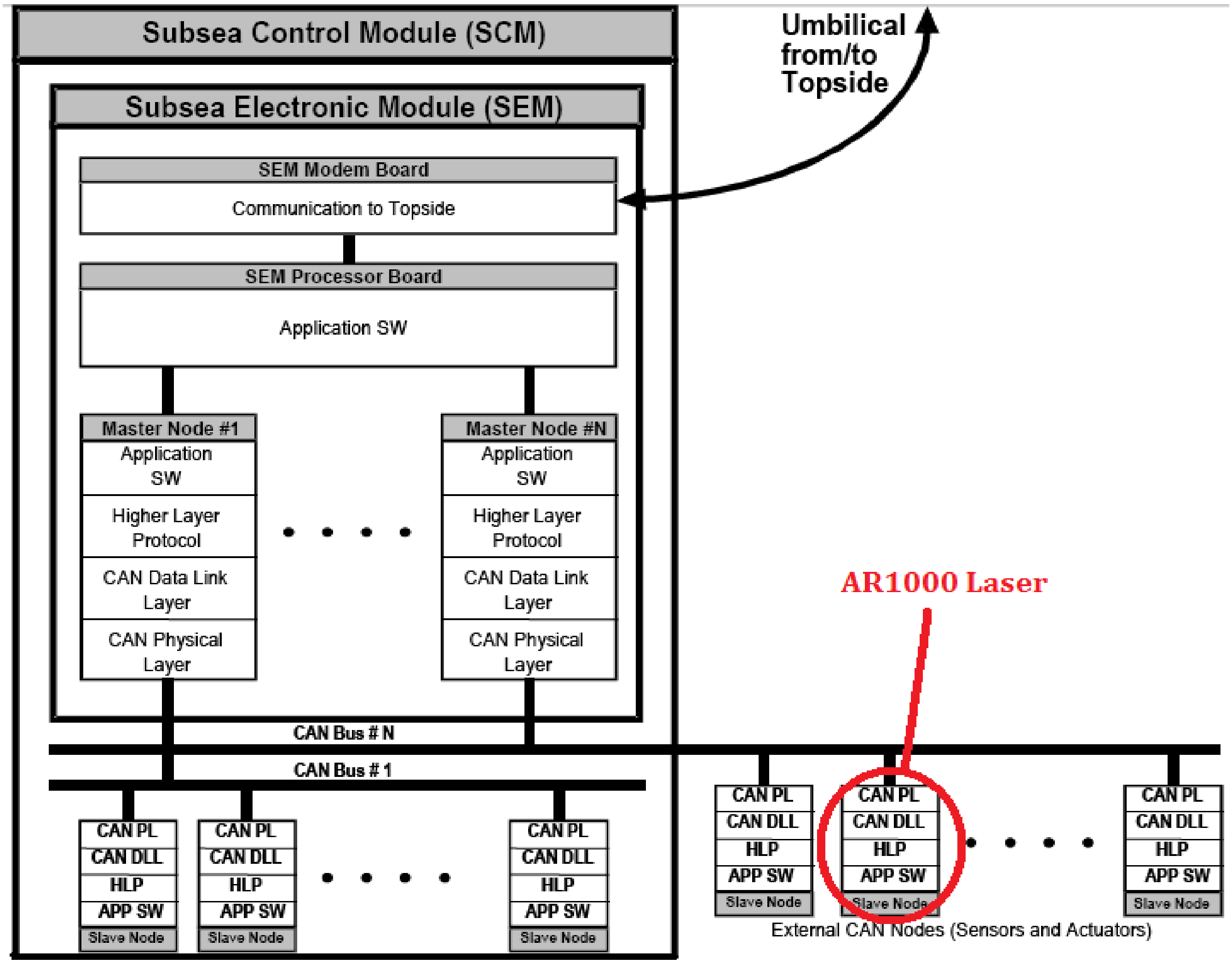

Figure 5 Subsea Control System

3. Concept generation

3.1 Pre study measuring system

During pre study stage there were several different solutions suggested. Those that were considered as possible and solvable will be further analyzed with a scoreboard matrix.

The solution will be a device that is able to measure the distance between a point and a surface, where the point is the top of an accumulator tank and the surface the piston. If the distance from top to piston is known the remaining hydraulic fluid is easy to calculate.

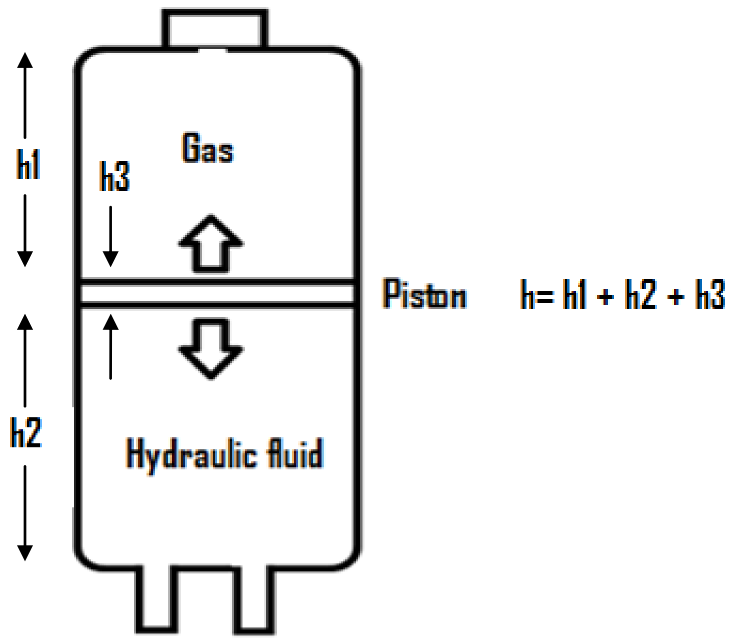

Figure 6 Piston accumulator tank

From Figure 5, the remaining hydraulic fluid is approximately given by

$$V = \pi r^2 h2$$

Where h2 is given by:

$$h2 = h - h1 - h3$$

Diode reading:

The main principle for diode reading is to measure the change in the frequency (frequency modulation). The system will be placed at the top of the accumulator tank and a sending diode will send a laser beam through a prism which will scatter the beam into two beams. The prism will be placed in a position so that one of the beams will be sent to a receiver diode and the other beam will penetrate into the tank through a hole and hit the surface of the piston. This will then be scattered into many beams, and some of these will be reflected back almost in the same direction as they were sent from. These beams will strike a mirror which will reflect it to the receiver diode. By frequency modulation between the frequencies from these two beams we can calculate the distance down to the piston.

Radar:

The radar uses the same principle as diode reading (frequency modulation), where a signal is sent into the accumulator tank. When the signal hit the surface a small part of the signal will be reflected back to the radar through an antenna.

Magnet sending unit:

With this solution there will be a pipe parallel to the accumulator tank connected to the bottom and top of the accumulator tank. Inside the pipe there will be a magnet floater, and the principle is that when the tank has equal amount of hydraulic fluid and gas then the magnet floater will be in the middle of the pipe. As the amount of hydraulic fluid decreases the magnet floater will decrease its height in the pipe giving an indication of amount of hydraulic fluid left in the tank.

3.2 Selection part one

For narrowing down to one solution we will use a scoreboard to determine the best solution. Even though the solution will be counted as the best solution in the scoreboard it is not given that this is the final and best solution as a measuring system, but it will bring us one step closer to determine a final solution for the problem.

3.2.1 Scoreboard criteria

We reached these criteria's during a discussion within our group and with our external mentor:

Cost: Always an important factor in any aspect. Grade 8.

Accuracy: From conversations with our external mentor, the accuracy does not have to be extreme. Grade 7.

Durability: The system would have to be able to operate without maintenance for 25 years. Grade 10.

Maintenance: No maintenance, because this is more expensive then replacing the system. Grade 0.

Communication: Since this information is not available in any other form, the information will have to be sent topside to be read. Grade 9.

Size: For environments with high pressure it is preferably with smallest possible size. Grade 5.

Design: The design is not important, since it will be out of sight, although it should be functional. Grade 3.

3.2.2 Scoreboard matrix

		Solutions					
Criteria	Value (1-10)	Diode Reading		Radar		Magnet Sending Unit	
		Points (1-5)	Total	Points (1-5)	Total	Points (1-5)	Total
Cost	8	4	32	1	8	5	40
Accuracy	7	5	35	5	35	3	21
Durability	10	5	50	5	50	2	20
Maintenance	0	0	0	0	0	0	0
Communication	9	4	36	5	45	4	36
Size	5	5	25	1	5	5	25
Design	3	3	9	4	12	3	9
Total			187		155		151

Table 1 Scoreboard of different solutions

From the scoreboard matrix in Table 2, "Diode Reading" scored most points. Thus it is the best solution. The next stage will be to evaluate how to make this solution better and if there are any alternative solutions which will be beneficial to use.

3.3 Selection part two

Our solution builds on the principle of frequency modulation. In the process of gathering information on how to build an electronic system that were able to use frequency modulation to measure the distance from the top to piston, we also discovered a principle with time of flight. Time of flight is a variety of methods of measuring the time it takes for an object, particle or acoustic, electromagnetic or other waves to travel a distance through a medium, enables us to calculate the distance the wave have travelled.

There are now two different principles that have to be taken in consideration before we determine a final solution (frequency modulation and time-of-flight). The biggest concern in relation to this project is trying to maintain a lifetime expectancy of 25 years. We searched the web for a variety of different companies that delivers completed measuring lasers with both the principles. The main reason for this is because these companies have a MTBF calculated for their products. MTBF is the predicted elapsed time between inherent failures of a system during operation. A system failure is failures that would put the system out of service and into a state of repair. Under these definition failures that can be left or maintained in an unrepaired condition is not considered a system failure.

In proportion to building our own system from scratch and buying a completed measuring system from a distributor, the conclusion were that a distributor would have a much higher insight regarding these principles. Building a system from scratch would be much more time consuming regarding high enough accuracy and there would be impossible to make any lifetime expectancy since this involve testing the system for a longer period of time. To ensure we overcome the requirements given by FMC the diode reading system were repudiated by a complete laser system. Another benefit for the group internally was freeing time for building a prototype.

After searching for various lasers with various benefits/disadvantages from various suppliers we came down to six lasers that would fit our application. Another scoreboard was created to determine the best choice of solution. The scoreboard has the same values as the previously scoreboard since the criteria's have not changed, but there have also been added new criteria`s.

3.3.1 Scoreboard criteria

Cost: Always an important factor in any aspect. Grade 8.

Accuracy: From conversations with our external mentor, the accuracy does not have to be extreme. Grade 7.

Durability: The system would have to be able to operate without maintenance for 25 years. Grade 10.

Communication: Since this information is not available in any other form, the information will have to be sent topside to be read. Grade 9.

Maintenance: No maintenance, because this is more expensive then replacing the system. Grade 0.

Environment: Describes the toughness of the laser, more preferably with lasers with high MTBF and are made for though environments. Gives indication of higher lifetime expectancy. Grade 10

Size of lens: For environments with high pressure it is preferably with smallest possible size. Grade 5.

Design: The design is not important, since it will be out of sight, although it should be functional. Grade 3.

3.3.2 Scoreboard matrix

		Solutions					
Criteria	Value (1-10)	Ar200		AR1000		AR4000	
		Points (1-5)	Total	Points (1-5)	Total	Points (1-5)	Total
Cost	8	4	32	2	16	4	32
Accuracy	7	5	35	5	35	3	21
Durability	10	5	50	5	50	2	20
Communication	5	2	10	5	35	4	20
Maintenance	0	0	0	0	0	0	0
Environment	10	4	40	5	50	4	40
Size of lens	8	1	8	3	24	5	40
Design	3	2	6	4	12	2	6
Total			**181**		**222**		**179**

		Solutions					
Criteria	Value (1-10)	ST263 DistoGAGE		Astech LDM 301 A		Astech LDM 41 A	
		Points (1-5)	Total	Points (1-5)	Total	Points (1-5)	Total
Cost	8	3	24	1	8	1	8
Accuracy	7	5	35	5	35	5	35
Durability	10	4	40	5	50	5	50
Communication	5	3	15	5	35	5	35
Maintenance	0	0	0	0	0	0	0
Environment	10	4	40	3	30	3	30
Size lens	8	5	40	1	8	3	24
Design	3	3	9	4	12	4	12
Total			**201**		**178**		**194**

Table 2 Scoreboard of different solutions

The size of lens had to be added because a large lens makes the housing larger in diameter, so this was an important aspect because we want to make the housing as small as possible. A large lens indicates that the laser needs a large reflecting surface for measuring. For further notice it is suggested to try and collimate the size of the lens by making the penetration hole between the housing and the accumulator tank smaller then the size of the lens. This is another reason for building a prototype because we will be unable to determine how much we can collimate the lens without testing. Environment criteria were also added prior to earlier scoreboard because a laser built for tougher environment is more robust.

3.3.3 Final solution of measuring system

From the scoreboard matrix the AR1000 laser is the best solution and will therefore be considered as the final solution for the measuring system. When a final measuring system have been chosen it is now possible to make the mechanical design of the housing, since the housing has to be adapted to the size of the laser.

3.4 Mechanical design

The idea is to make the environments as good as possible for the measuring system by protecting it from all devices which will contribute to shorten its lifetime. In other words the housing is the component which will have to withstand corrosion from the seawater, pressure from the sea column and separate the system from the accumulator tank.

3.4.1 Criteria for mechanical design

List of criteria that are considered as important aspect, regarding design of the housing for our measuring system.

Price: Always considered, but quality is more important.

No leakage to the system: This is the most important criteria because seawater leaking into the measuring system will destroy it instantaneously.

Mean time between failure: impossible to guarantee a lifetime of 25 year, but very important criteria, due to high replacement cost.

Durability: High resistance against corrosion and mechanical wear.

Parts: The assembly should consist of as few parts as possible because it increases the durability.

Physical size: The size of the housing should be as small as possible. Small parts withstand pressure better.

Ease of manufacture: Making the parts less complex lowers the manufacture costs.

3.5 Material selection

3.5.1 Introduction

Choosing proper material for the housing is one of the important challenges for our construction, the parts are static therefore we do not need to consider the factor of wear resistance due to motion. The most important factor is the surroundings with an external pressure up to 275 bars, and some places, as a second barrier, an internal pressure of 345 bar.

As we know FMC Technologies has a wide experience from subsea installations, and has a great knowledge of which materials that can be used in these environments. We will in chapter 3.5.3 comment different materials that can be used for our assembly.

3.5.2 Challenges

The main concern is the seawater surrounding the housing; the seawater is highly corrosive due to dissolved salts, ions. Therefore the material of the housing needs to have a high corrosion resistance. To protect the subsea installations from corrosion it is common to use a sacrificial anode on the installation, the anodes are generally cast aluminum alloys or in some cases zinc and magnesium alloys.

Another challenge is the hydrostatic pressure the housing has to withstand; this comes from the weight of the seawater, in other words the sea column. As mentioned earlier the external pressure will be 275 bar.

We also have to consider the viewing we need to have into the accumulator, this material needs to withstand an internal pressure of 345 bar and be transparent.

3.5.3 Assortments of materials

Inconel 625:

Inconel 625 is a nickel-chromium-molybdenum alloy that is non-magnetic, corrosion- and oxidation-resistant under a wide range of temperature and pressures; this metal has good strength and toughness from cryogenic to 1100 C^0. It also resists scaling and oxidation at high temperatures.

The material can be hard to machine and shape with traditional methods due to rapid work hardening, but is outstanding when it comes to weldability and brazeability.

17-4 PH:

The 17-4 PH is a martensitic precipitation-hardening stainless steel with Cu and Nb/Cb additions, and has a high strength, high hardness and adequate corrosion resistance. The corrosion resistance in 17-4 PH is better than any of the standard hardenable stainless steels. When the alloy is exposed to stagnant seawater for any length of time, it is subjected to crevice or pitting attacks.

The alloy is hard and is therefore hard to shape and should be limited to mild operation, but this depends on the hardness of the material.

22Cr Duplex :

This material consist of 22% chromium, 3% molybdenum, 5-6% nickel and is a nitrogen alloyed austenitic-ferritic stainless steel, and it has a high corrosion resistance as well as high strength and impact toughness. The chromium, molybdenum and nitrogen create a good resistance to crevice and pitting corrosion even in very oxidizing and acidic solutions. The yield strength is about twice as austenitic stainless steel, this means that you can save weight and material in design due to the high yield strength making it more cost efficient. The material is suitable for the temperature range of -45 C^0 to 315 C^0, it may be considered outside this range with precaution.

The material is easy to machine and possesses a good weldability.

3.5.4 Selection of material

To choose a proper material for the housing we have to consider the corrosion resistance of the material, this is very important since the housing will have no maintenance during preferably 25 years. The other factor is the pressure; this means that the hardness, strength and toughness all affects our choice.

With the help and experience from FMC Technologies we have chosen 22Cr duplex, this material has a high strength and impact toughness, and it has a high corrosion resistance. In addition, the 22Cr duplex has high yield strength and therefore more cost efficient due to saving weight and material in the design.

4. The HAMU

4.1 Introduction

We have now decided which concept we will use, and by selecting this solution we can separate it down to sub concepts. The whole assembly consists of both mechanical and electronic problem that needs to be solved, and by breaking it down to sub concepts it is easier to detect the problems that might occur. We will now list the sub concepts and complement them further on in this chapter:

- Material selection
- Attachment of housing to accumulator
- Transmit laser beam into the accumulator
- Fitting the laser to housing

4.1.1 Principle

On Figure 7 the final assembly of the HAMU is shown. The housing will be a one atmospheric chamber to protect the electronic. To transmit the laser beam into the accumulator and reflect off the piston for a measuring, we need to have a clear view into the accumulator. This is one of the problem that needs to be solved, and we will describe the solution in following chapters. We will also describe the process and solutions to the sub concepts mentioned in chapter 4.1 further on. In real process, temperature and pressure is also necessary to know at any given time, this is already solved by FMC and is therefore no concern regarding our project but should be mentioned.

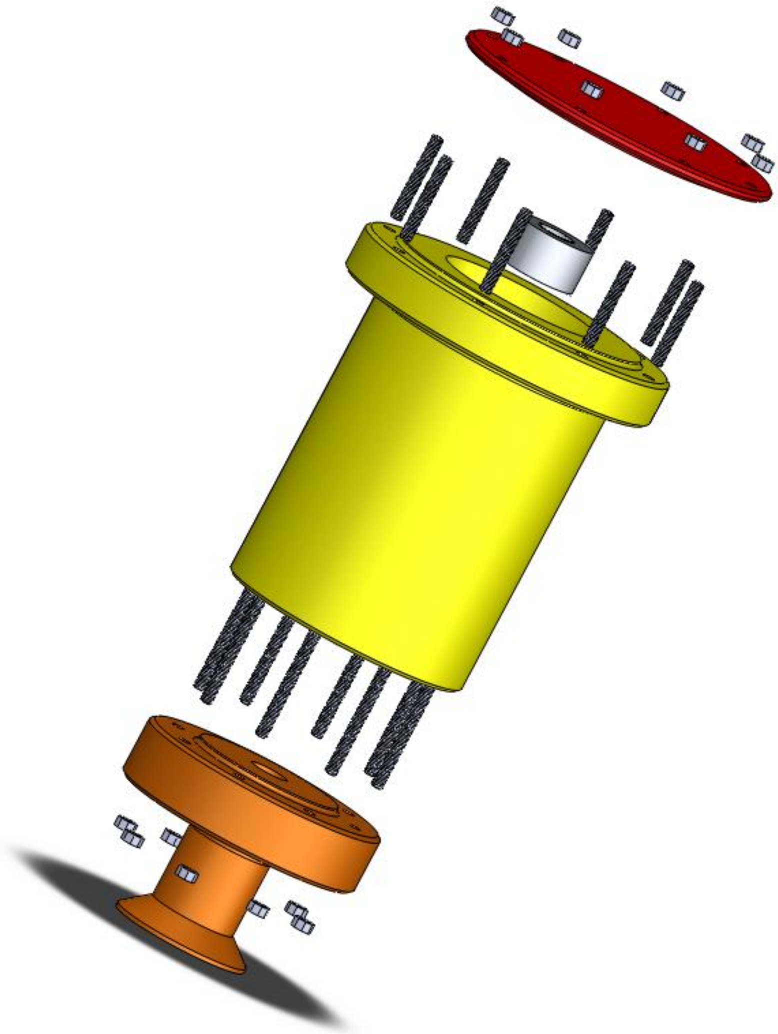

Figure 7 Final assembly

4.2 Ar1000 laser

4.2.1 General description

The AR1000 laser uses time of flight of light to measure distance. The laser beam is projected from the lasers aperture and shines on the targets surface, where it creates a small spot. The laser light will be scattered in all directions. A collecting lens is located in the sensor to the side of the laser aperture. It collects a small portion of the reflected light, which is focused on a photo detector which converts it to an electric signal. The signal is amplified and symbolizes a shift in phase. This phase is compared to a reference signal to determine the amount of shift and hence a change in distance.

Figure 8 AR1000 laser

4.2.2 Key specifications

Key specifications are considered those that are related too FMC requirements.

Accuracy: Average of ±3mm FMC requires ±5mm.

Signal refresh rate: FMC wants refresh rate to be once per second, the AR1000 laser is programmable so this can be determined by the user.

Span: AR1000 laser is capable of measuring distances up to 150m, height of accumulator tanks lies between 1 – 2m.

Output: The electronic interface has to be CAN-bus with CAN-open 2.0B orRS485 with modbus protocols. AR1000 laser has RS232 full duplex as standard output, but RS485 as an optional output. A converter from RS232 to RS485 is necessary for communication, this converter can be put inside the housing between the laser and the glass to metal seal penetrator.

MTBF: Approximately 100 000 hours for AR1000 laser, gives an expected lifetime for over 11 years, by making the environments better for the laser due to constant temperature, pressure and surrounded with dry nitrogen this will be increased event further since the MTBF is calculated for rougher operating conditions.

4.2.3 Laser housing

The housing of the laser is not built for sea measurements and therefore the housing will not be able to withstand the environments on the seabed. Since there will be designed a new housing for the AR1000 laser which is capable of withstanding these environments the originally housing serves no purpose, in fact it will only make the new housing larger than necessary. Since there is beneficial to have components under high pressure as small as possible we will remove the originally housing to save space.

Below is a simplified 2D drawing of the AR1000 laser with its originally housing and a 2D drawing of the space required without the housing.

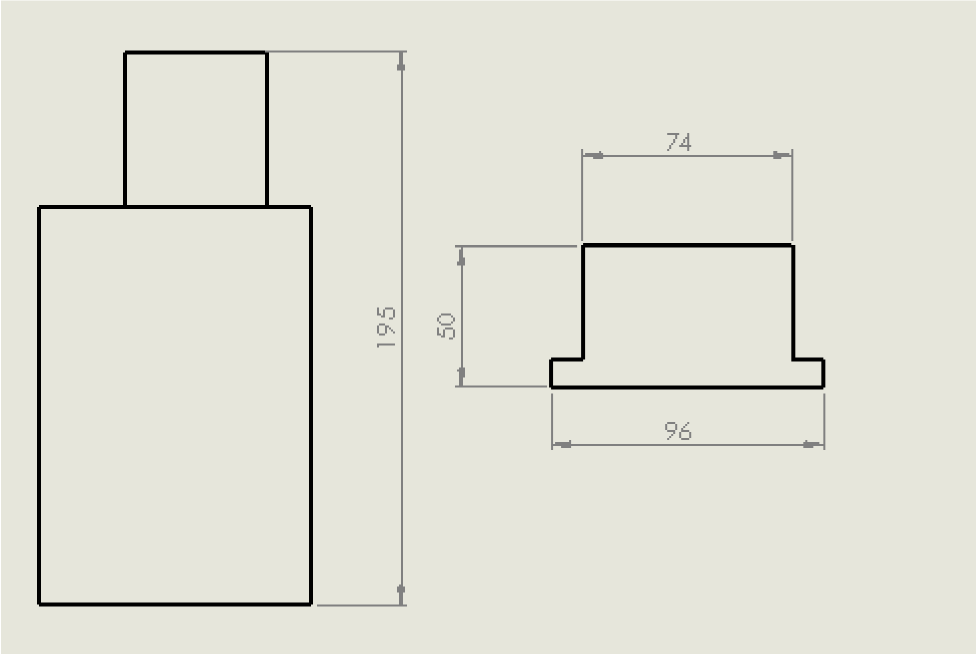

Figure 9 AR1000 laser with originally housing

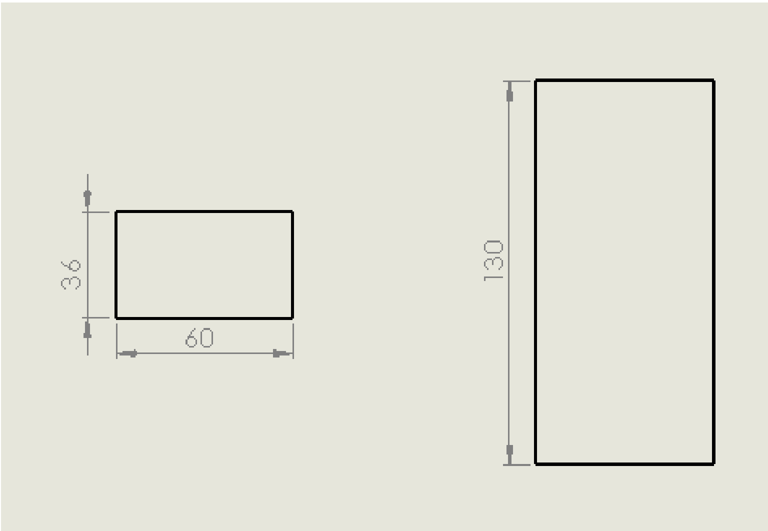

Figure 10 Ar1000 laser without housing

Since the originally housing severs no purpose, and from the 2D drawings we can conclude that there is quite a difference in space occupied with and without the housing. The conclusion of stripping the laser from its originally housing is determined. The space occupied by the laser without the housing is about half the size the laser would occupy with its originally housing.

4.2.4 Communication

The AR1000 supports many types of communicational outputs. There are the serial outputs RS-232 full duplex and the optional RS-422, as well as the simple analog output that measures the laser range between 4-20 mA. One can also use the optional Profibus RS-422, DP-V0 and the Simple Sensor Interface protocol.

We decided to use the RS232 as the output/input communication for several reasons, firstly because our external mentor recommended it, but we also concluded after research that RS-232 fit our specifications best.

RS-232 is a standard for serial binary single ended data and control signals. This is a simple and common use of transmitting electrical signals with two wires, one wire carries the voltage signal, and the other carries the reference voltage, which is usually ground. We are using full duplex, meaning that RS-232 can both send and receive signals. This means that we need to use three wires for the communication with the laser, one for transmitting data, one for receiving data, and the last for a reference signal (ground).

RS-232 is limited by a short range, which is undesirable on the sea floor. FMC technologies will either use a RS-232 to RS-485 converter or a RS-232 to CAN-bus converter. These are small converters that make the voltage signals travel further with a different serial standard.

For our prototype, we only use the RS-232 serial standard for communication, as the range is short. The software Microsoft Hyperterminal will be the protocol used. FMC Technologies used various protocols for the RS-485/CAN-bus standards, but the most used are CiA for CAN-bus and Modbus for RS-485.

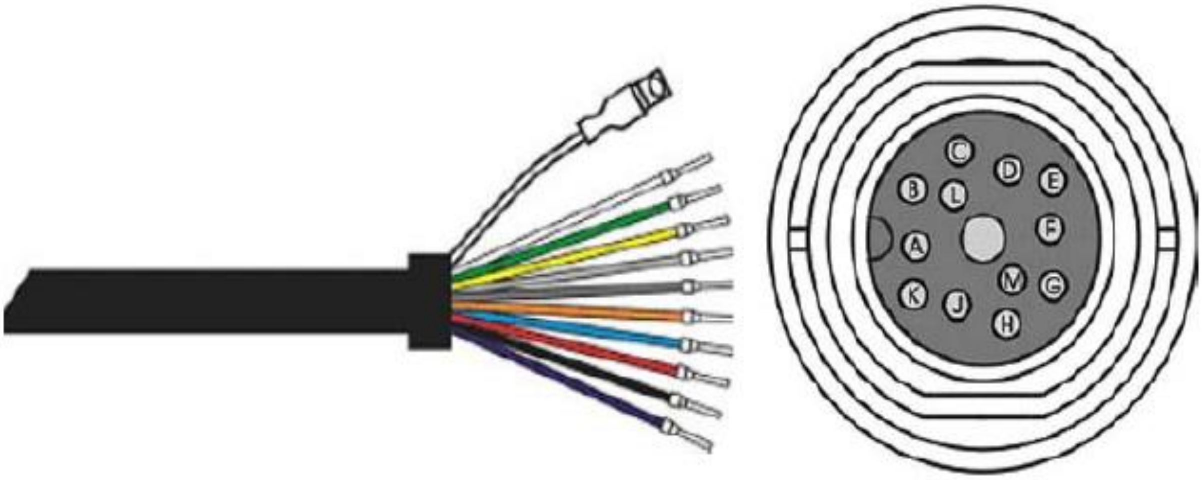

Figure 11 AR1000 laser interface cable that supports different output standards

Wire	Pin	Function in All Modes
Brown	C	External Trigger Input (3V to 24 V)
Red	D	Analog output (4-20 mA current loop)
Orange	G	Supply Voltage +15V (10- 30 VDC)
White	H	Alarm Output
Grey	J	Ground (serial)
Blue	L	Ground (Power supply common return)
Clear		Shield

The serial communications wires can be used for RS232 or RS422.

Function in Selected Serial Mode			
Wire	**Pin**	**RS232 models**	**RS422 models**
Yellow	B	RxD – Receive Data	RX– : Receive Data –
Green	A	TxD – Transmit Data	RX+ : Receive Data +
Black	E		TX- : Transmit Data -
Violet	F		TX+ : Transmit Data +
Grey	J	Ground (serial)	

Table 3 Describes interface cables for AR1000 laser

.

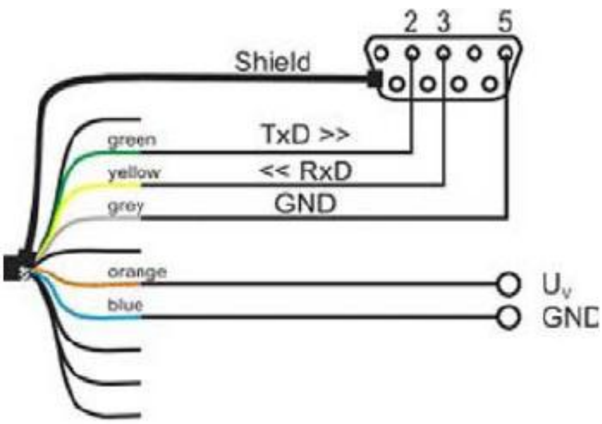

Figure 12 RS-232 Serial Connection

The RS-232 connection uses a D-subminiature connector with 9 pins as shown in the picture above, often called DE-9 or DB-9. This is an electrical connector that used to be widely used in computers, but is now being replaced by USB connectors in most computers. This connector will then be connected to the RS-485/CAN-bus serial converter, which sends the signals to the SCM.

4.3 Housing

Primary the housing consist of two parts, a cylinder and a top lock. The top lock is necessary to be able to fit the laser and its components inside the cylinder. The housing is intended to be as symmetrical and uniform as possible, where there have been taken in consideration ease of manufacturing due to machining.

The flange is the connection between the housing and accumulator tank. This is a standard flange FMC uses subsea as an interface. To make the entire assembly uniform (with flange) parts of the dimensions derives from the flange, the others derives from FEM testing and dimension measured according to the laser.

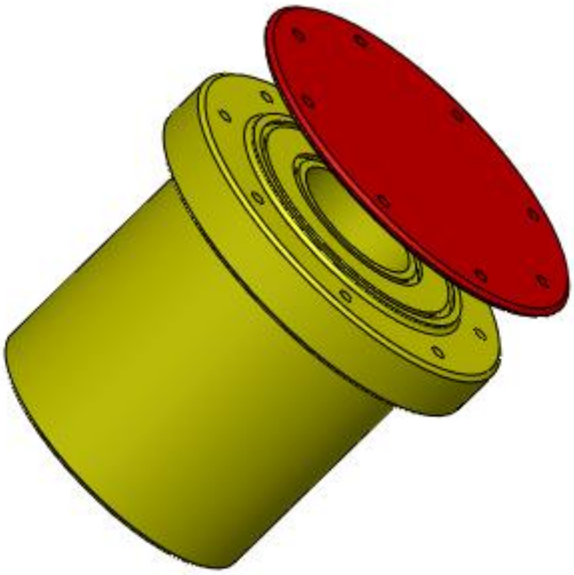

Figure 13 Assembly of housing

The housing is connected to the flange same way the top lock is connected to the cylinder, by using 8 pin bolts and nuts to fasten the parts. The interface between cylinder and flange and between cylinder and top lock will be sealed with special gaskets which will be described in detail later in this chapter.

All parts will consist of the same material 22 CR Duplex, there is not any need for using different materials which serves different functions when all parts are exposed to the same forces and are under static pressure.

4.3.1 Chamber

The chamber inside the housing will be a one atmosphere chamber which is necessary to create a good environment for the electronic components. To achieve this the housing needs to be completely sealed from its environments which are accomplished either by using gaskets or by welding. To increase the lifetime of the electronic components which is an essential factor, the chamber needs to be dried. FMC has a standard method by filling the chamber with dry nitrogen and when the chamber is completely dried up the chamber will be sealed.

4.3.2 Cylinder

The bottom of the cylinder is identical to the flange for the two surfaces to meet and to be connected, likewise for the top of the cylinder and the top lock. To make the part as much uniform as possible and easy to manufacture we used the same outer diameter throughout the cylinder except at the top since the outer diameter of the top lock is given by the space required to fit the laser. The outer diameter could have been reduced due to unnecessary high F.O.S except for the top and bottom of the cylinder which has to be equal to the opposite surfaces. Reducing this area would make the cylinder much less uniform and more expensive to machine due to a more complex part. Not preferably since there is no restriction due to weight limitations except beyond common sense. Also taken in consideration is that the cylinder would be casted into one uniform cylinder equal largest outer diameter of the cylinder and then machined to desired shape.

The inner dimensions of the cylinder are all given by the space required to fit the laser inside. One of the drawbacks with the AR1000 laser is that the lens of the laser is not in center of one of the sides but a distance of 37mm to one edge and 22mm to the other edge. Since the lens is not in center we need to make an offset to the shorter edge for the lens to be centered, an offset of 15mm has to be added. Not preferably since the inner diameter has to be 15mm larger then if the lens where in center, but some of this space will be used for a RS232 – RS485 converter which is necessary for the laser to communicate with SCM.

The laser will be fitted correctly inside the cylinder by using a bracket and screws. The bracket is designed to fit the laser and will be welded to the top lock.

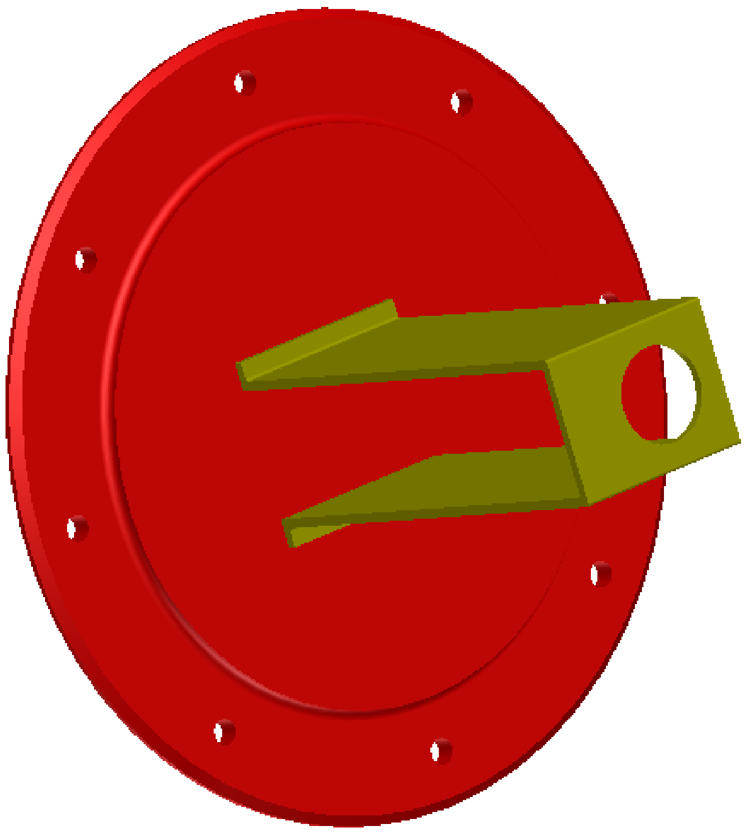

Figure 14 Bracket

For the laser beam to propagate freely from the cylinder through the flange and into the accumulator tank a hole all through the flange and into the accumulator tank is necessary and a metaglass for sight which can resist high pressure has to be EB welded in the housing. The glass is necessary to maintain a one atmosphere chamber, since this is a first barrier against internal pressure from the accumulator tank and a second barrier against the external pressure from the water column.

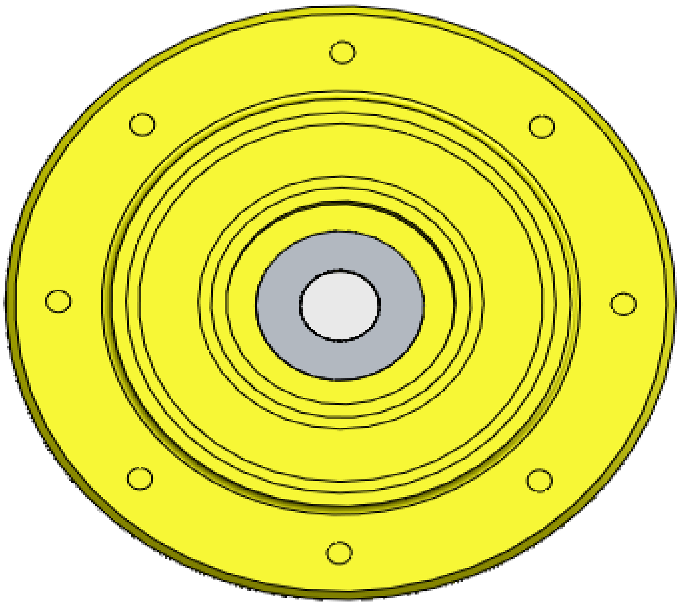

Figure 15 Cylinder with metaglass

4.3.3 Metaglass

Metaglass is a mechanical toughened glass and exceeds the pressure and impact resistance of conventional toughened glass. Metaglass can be used in environments with up to 1000 bar, depending on material and design. The metaglass can be supplied with either a metal ring for welding or just the glass. The metal ring can be supplied with variety of materials such as Stainless Steel and Hastelloy, and the glass is a Borosilicate or a Soda Lime alternative.

The method used in sealing the metal ring to the glass is a fusion between melting glass and a metal ring. When cooling of glass it solidifies and the metal ring attempts to contract due to the difference in the linear coefficient of expansion between the glass and the metal. This results in a uniform compressive stress throughout the glass.

Figure 16 Metaglass

Unlike thermally toughened glass, which is only skin toughened, the metaglass is mechanical toughened and the entire cross section is under compression. This means that if a scratch, uneven stresses or erosion occurs, this will not affect the strength or integrity of the glass.

4.3.4 Top

The top lock has as a main function to seal the housing, and is necessary because of the space needed for the electronic components to be put inside the cylinder. Its dimensions derive from FEM testing by changing its thickness until a acceptable F.O.S is reached and the diameter is given for the space needed inside the cylinder.

The top lock will also be the interface for the glass/metal seal penetrator which is necessary to avoid leakage and is the connection between the AR1000 laser and the SCM. This is a standard method for FMC and the glass/metal seal penetrator has to be EB welded in the top for sealing.

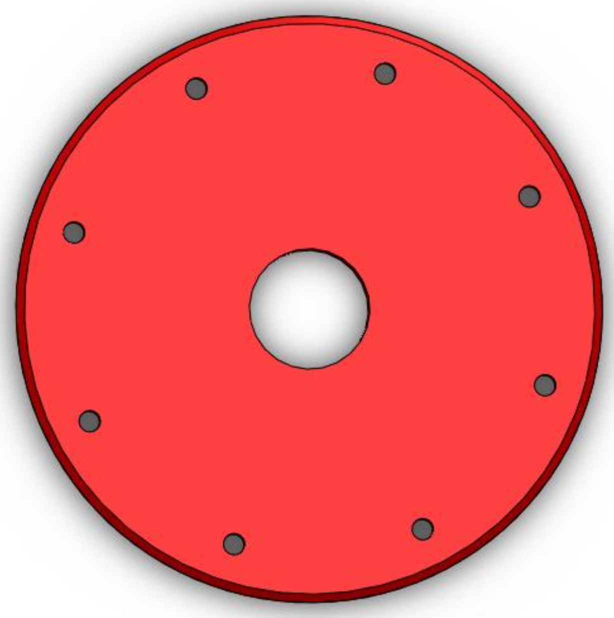

Figure 17 Top hole for placement of glass/metal seal penetrator

4.3.5 Glass/metal seal penetrator

The glass metal/seal penetrator is a must for all instruments in a one atmosphere chamber. Normally the pins are fed through pins insulated with a glass pipe which in turn are isolated from the penetrator body.

The pins are made from a metal with thermal expansion compatible to glass. In the termination end the pin has a solder cup for electric wire and the pin is gold plated. On the jumper side the pin with the solder cup has an insulation collar.

A crack in the glass of the penetrator will in most cases causes a drop in insulation resistance. Water will easily enter the crack, but a silicone oil molecule is 2000 to 20000 times bigger than water molecules and will stay outside the crack. Water in such a crack is held back with capillary forces and will be very hard to extract.

Abstracted from report given by Odd Jan Kirkaune, FMC Technologies.

The glass/metal seal penetrator is used to prevent any form of leakage which in most cases would be devastating. Material compatibility is an important factor when welding the penetrator to the top.

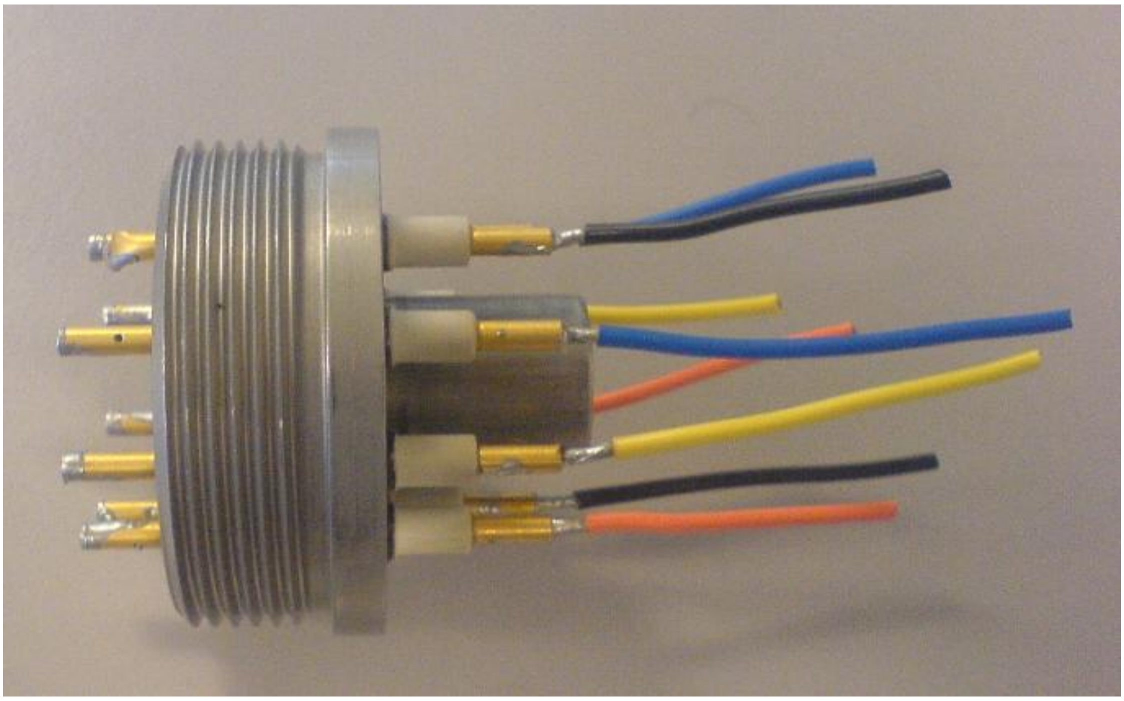

Figure 18 Glass/metal seal penetrator

4.3.6 Bolts and nuts

The material and quality of bolts and nuts were given in collaboration with FMC Technologies; the quality of bolts and nuts is a standard for subsea equipment. We started our design with four pin bolts with M16 size, but after a design review we decided to change it to eight pin bolts with M8. The decision was taken because of adjustments to the housing; the holes were too large to fit the housing. The pressure test with eight pin bolt holes was sufficient enough to satisfy the requirements from FMC Technologies.

The bolts are L7M which is a low temperature carbon steel grade with internal hexagon, since this quality is no standard from supplier these bolts will have to be machined on request and therefore there is no specified length. In other words, the length of the bolts can be chosen from the design. The L7M grade must meet the requirements of 100 000 psi tensile strength, 80 000 psi yield strength and Brinell hardness of 212-237 HB.

A4-80 is the grade of the nuts, A4 stands for the steel grade and 80 stands for property class which means that A4-80 is a high strength steel. This is acid proof austenitic steel, and to improve the resistance to corrosion it is Mo alloyed.

4.3.7 Sealing

By discussing within the group and with our external mentor we came to a conclusion that using C-rings from HTMS would be a good option for sealing the 1 atmospheric chamber. C-rings is a resilient metal seal which is based on sealing by a relative high specific contact load at the sealing line which is generated by compression of the seal to a certain groove depth and a certain resiliency, in this case compression generated when tightening the nuts.

In general metal seals are designed for the purpose of providing the required tightness when subjected to extreme temperatures, pressure and media. There are two different types of C-rings, C-ring for internal pressure and external pressure. C-rings are beneficial because they require low bolting load and have good spring back.

For our purpose there will be used two C-rings (back to back), where one ring protects the chamber from external pressure and the other one from internal pressure in case of an accident. Meaning that for sealing there will be two grooves with one C-ring in each groove, the outer c-ring will have its mouth facing outwards and the inner C-ring will have its mouth facing towards the 1 atmospheric chamber (hence back to back). The material for C-ring sealing for external pressure is Alloy 625 with silver plating, and the C-ring for internal pressure is Alloy 718 with silver plating. The C-ring will be tested by measuring the leakage rate over the sealing by sucking vacuum between an O-ring and a C-ring and then blowing Helium from the outside, if no Helium passes through the seal is completely tight.

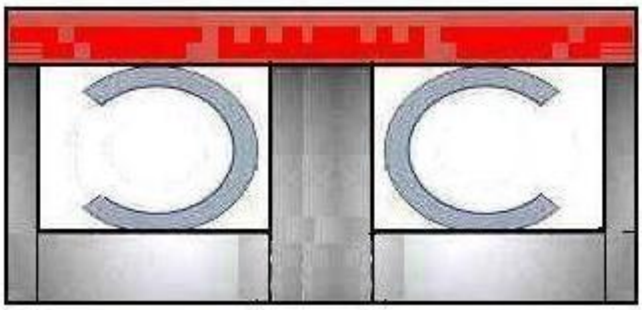

Figure 19 C-rings back to back

4.4 Strength calculation

4.4.1 Introduction

The strength calculations will be executed by first designing the housing in Solid Works and calculate the strength in Solid Works Simulation. Solid Works Simulation calculates the strength based on the principle of FEM. The main scope is to see if the design is able to withstand the hydrostatic pressure it will be subjected to.

We will see if the parts individually and as an assembly will be able to meet the F.O.S given by FMC which is 1.25. In addition to calculate the F.O.S we will also calculate the stress displacement. The F.O.S and stress displacement are two calculations which are both linked to each other, meaning if you know the F.O.S you also know the stress but they give a different point of view.

An important aspect is that you have to be aware that no calculation are 100 % reliable, this due to many factors such as material defects etc., meaning that the application has to be tested physically by FMC test procedures before the design can be validated. Although the design cannot be validated by these calculations they will give an insight whether the application will pass the test procedures or not.

4.4.2 Assembly

The assembly is considered the flange, cylinder and the top together. This strength calculation is executed as a part combined with the three parts together in an assembly. All the parts have been strength calculated individually also, for more information se appendixes about FEM report.

A problem regarding using the Solid Works Simulation is placing restraints and load correctly, different restraints and applying the load different may give large differences in the result. For an instance it is considered that load which are not perpendicular to each other and works either with and angle or in opposite direction of another applied load will give a higher F.O.S then if you only applied the forces working in one direction. It were drawn a conclusion in collaboration with a teacher who teaches in Solid Works that applying all the forces at once is correct because this is what happens in its natural environment.

In an assembly it is very important that the restraints are correct according to how they will be restrained in reality. Placing a part onto another part is a form for restraint because it will result in locking the part for an instance in one direction. Forces applied can also result in a form of restraint which has to be taken in consideration. Building up a system of correct restraints can sometimes be difficult and confusing, also it is required a certain amount of restraints before Solid Works Simulation is able to run an analyze. This can be somewhat experimental since situations where all restraints are place correctly and still the analyze is not able to run can occur. This is of course due to a logical reason and can therefore be solved correctly.

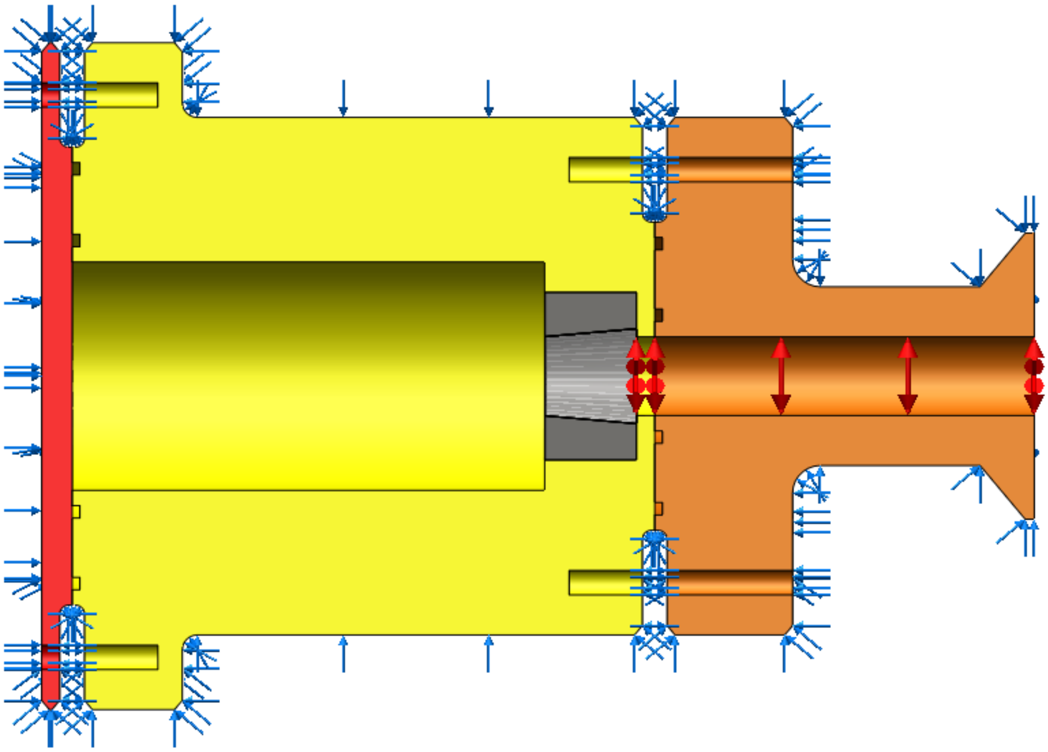

Figure 20 Shows displacement of pressure on the assembly.

Blue color = 275 bare (water column) and red color = 345 bar (internal pressure from accumulator tank)

By cutting the assembly in two it gives a better insight in the displacement of loads applied since one of the loads is applied inside the flange and cylinder. The assembly is not split in two pieces during analyze only for showing the load displacements. Both loads are hydrostatic pressure with uniform distribution.

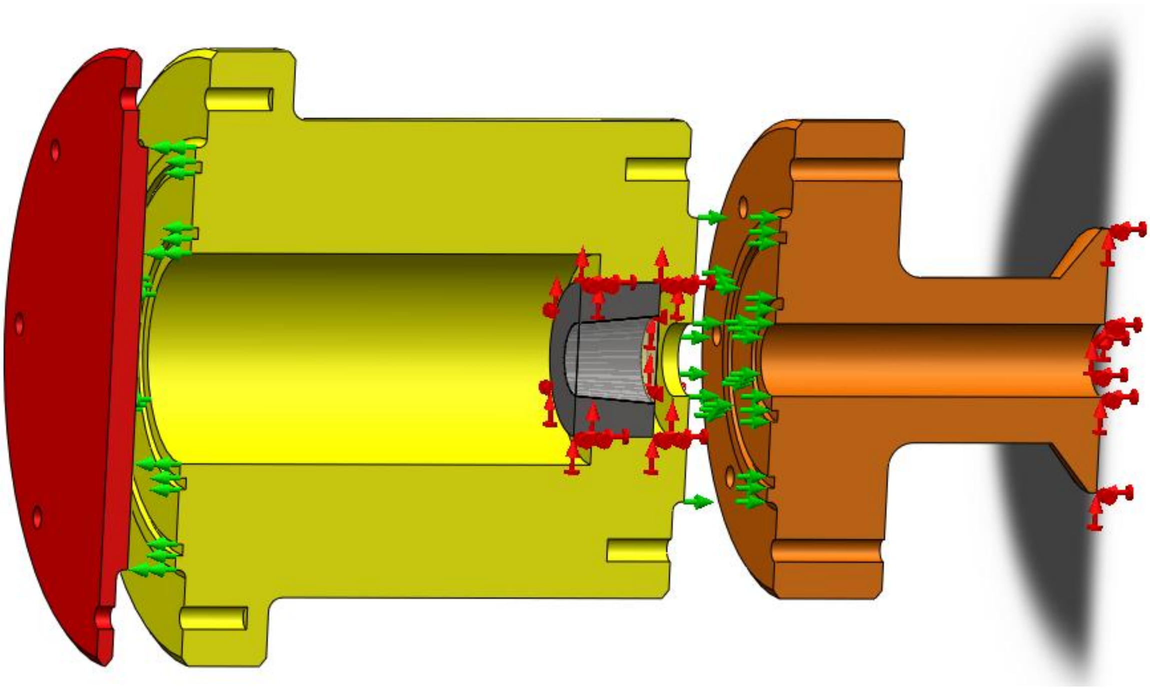

Figure 21 Shows displacements of restraints.

Red color = fixed geometry and green color = roller/hinge geometry

Since the metaglass will be welded into the cylinder and the bottom of the flange welded onto the accumulator tank both of these parts need to have fixed geometry. Fixed geometry allows no movement of any kind in any direction as if they were the same part which is the same as if they were welded. For the interface between the flange and cylinder and the interface between cylinder and top roller/hinge geometry were used. The roller/hinge geometry serves the same purpose as if you placed for an instance the cylinder on the top of the flange. You would only be able to move the cylinder to the sides (roll it around) not be able to move it downwards due to the flange and upwards due to gravity.

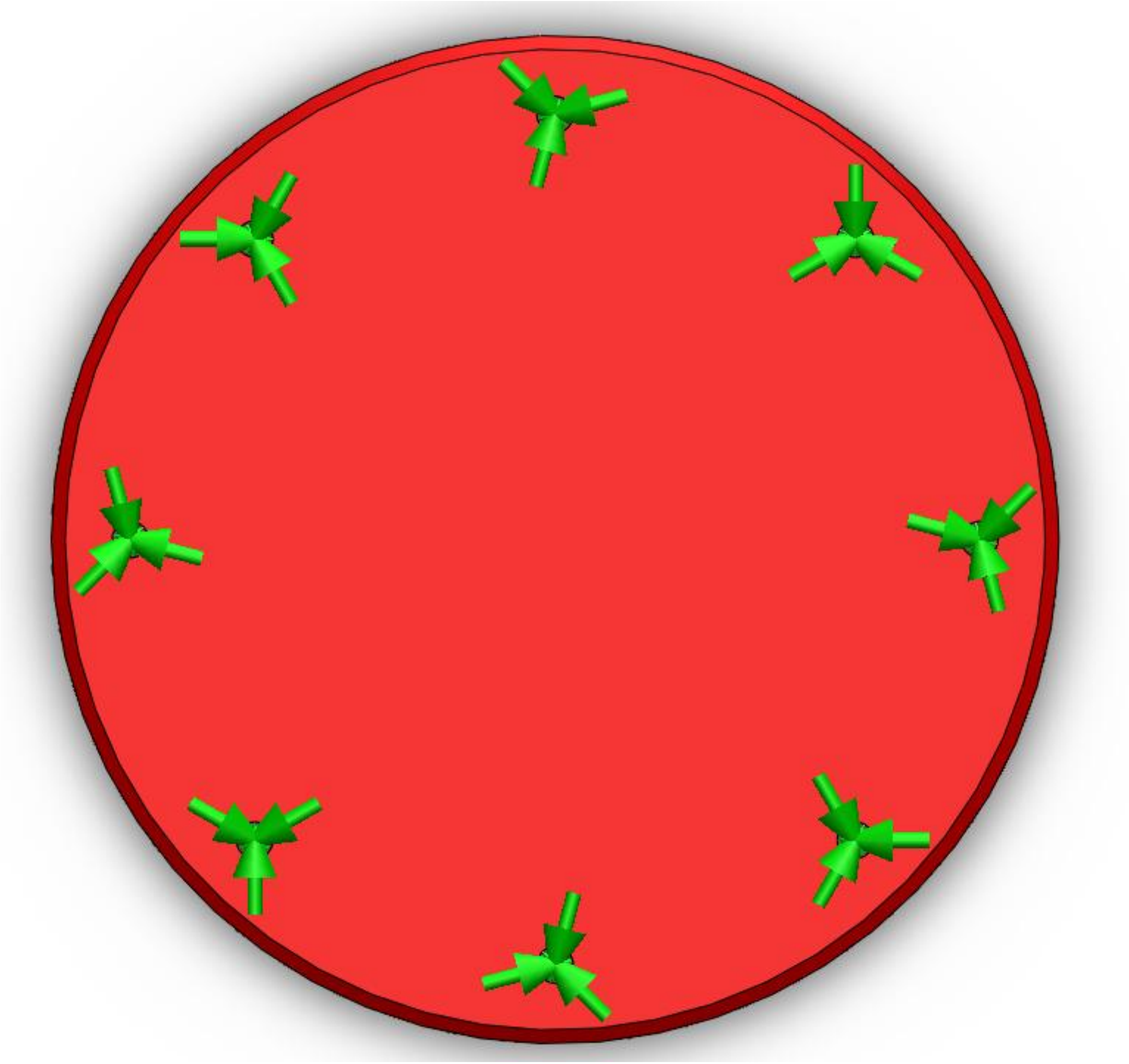

Figure 22 Shows displacement of how the bolts and nuts restraints the top

This restraint is used for all holes, but only showed for the top lock to give a better view of how the restraint affects the movement. This is an advanced fixture where only radial translation is allowed for cylindrical faces, because all the parts have a cylindrical shape. This restraint is a one dimension restraint which does not allow the part to move in any direction in the selected dimension.

Before calculating the F.O.S and stress displacement it is necessary to create a mesh. Mesh is number of meshes to be used to build up the part; hence finer mesh gives more accurate answer and coarser more inaccurate. On larger faces a coarse mesh is good enough but on more deferred places such as corners and fillets a finer mesh is necessary for a more accurate result. To ensure an accurate result a mesh control where placed on all critical areas.

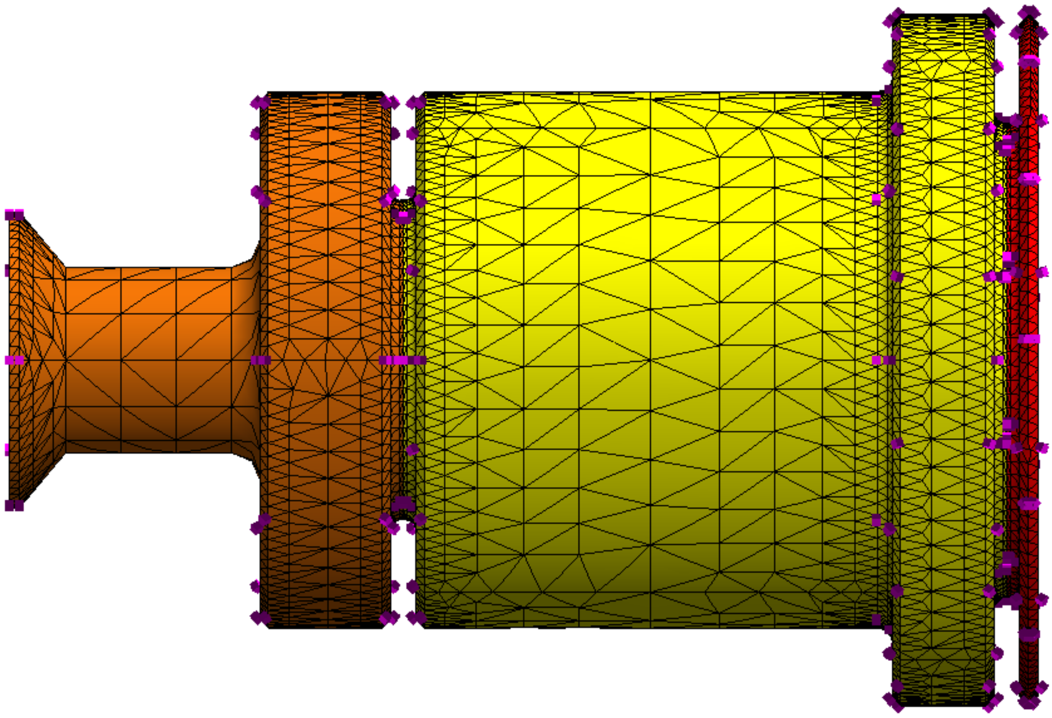

Figure 23 The mesh, purple boxes indicates mesh control (finer mesh)

Result and discussion:

In figure 24 the final displacement of F.O.S is given. The minimum F.O.S for the entire housing is estimated to be 1.58 which is above the required F.O.S from FMC. The outer measurements in the HAMU are not specified in any way by FMC, but we have tried to keep it as close as possible the outer diameter of the flange which is given by FMC. Keeping us close to the outer diameter of the flange ensures that the housing will not create any problem regarding space. Having the total height of the housing as low as possible have also been a primary concern, even though we have not received any space or weight limitations from FMC.

The final measures of the housing went through an experimental phase before they were decided. We ended up in a design where we used the outer diameter of the flange as a starting point, but due to the space required for fitting the laser inside the cylinder we needed to expand the outer diameter of the cylinder at the interface between the top and the cylinder.

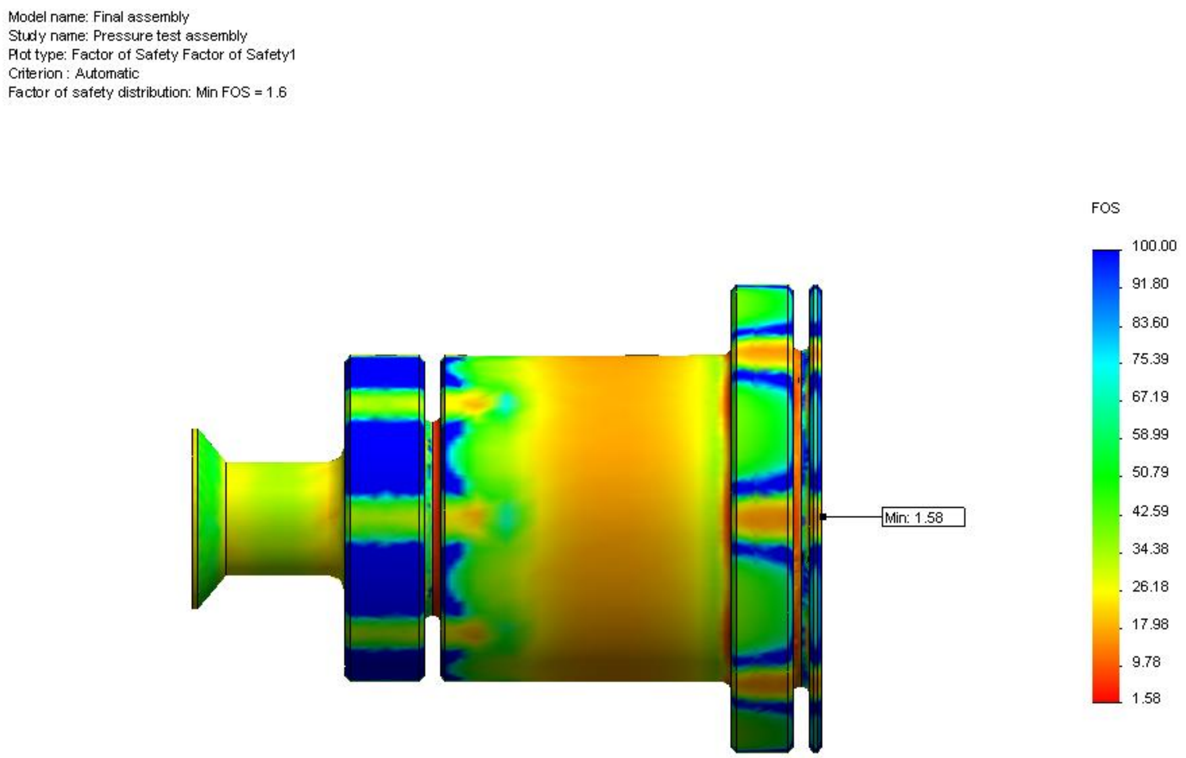

Figure 24 F.O.S displacement by color

Figure 25 shows the stress displacement based on the principle of Von Mises Stress. The figure is also an animated view of how the housing would deform if the load applied is large enough. The highest stress applied is about 323.4MPa at the top, which is concurrent with the lowest F.O.S at the top.

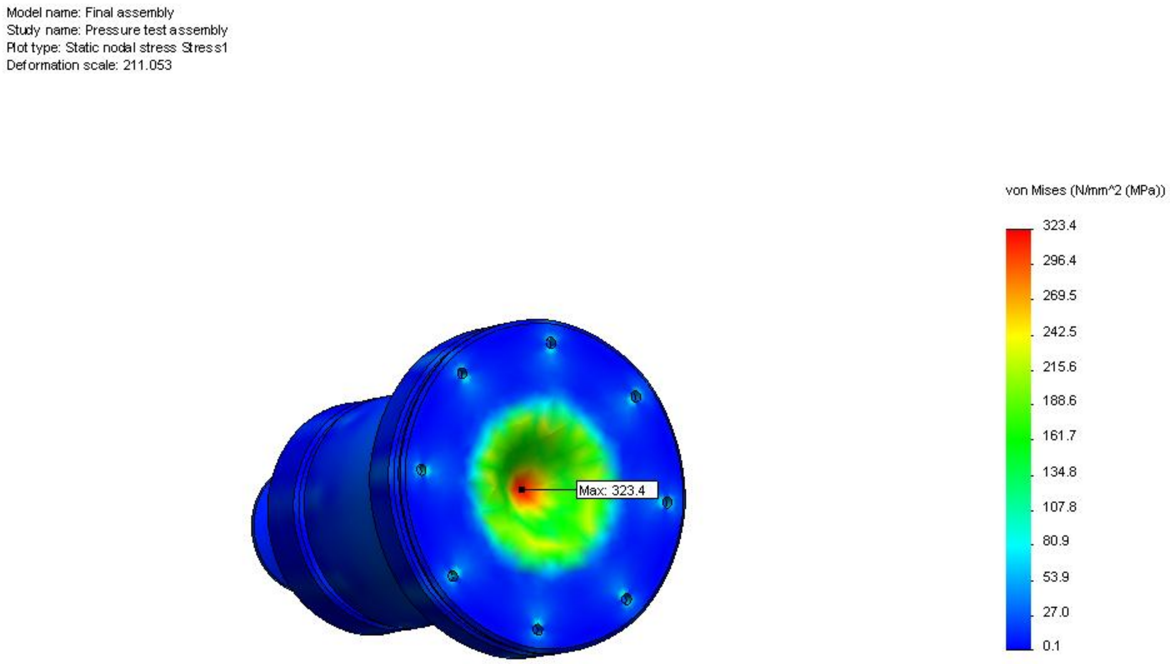

Figure 25 Stress displacement by color

Although we have the displacement of F.O.S we also want to get an indication of how large the displacement will be when the load is applied. Even though the displacement is only elastic, in time this can be converted to plastic deformation due to wear. So a low displacement indicates a long service life. A displacement plot is shown in figure 26.

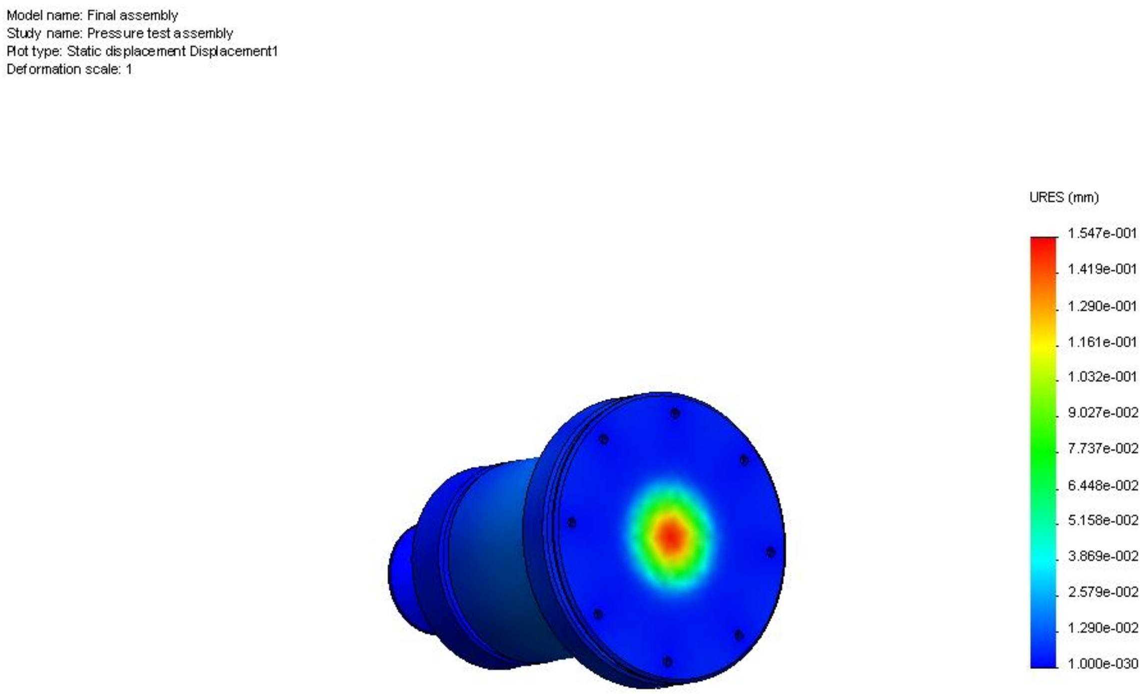

Figure 26 Displacement plot

The largest displacement will occur in center of the top as expected since this is the same zone of highest stress displacement. Largest displacement occurs in this zone because the cylinder is hollow in this zone, this results in a zone where there is no support from the cylinder. From the figure we obtain a maximum displacement of 0.155mm which is considered acceptable.

In case FMC would like to reduce the weight of the design, a design insight plot may be plotted. Figure 27 shows a design insight plot, where the translucent portions of the design carry the applied load less efficiently than the solid portions. These translucent areas may be removed with more confident pursuit of a reduced weight design.

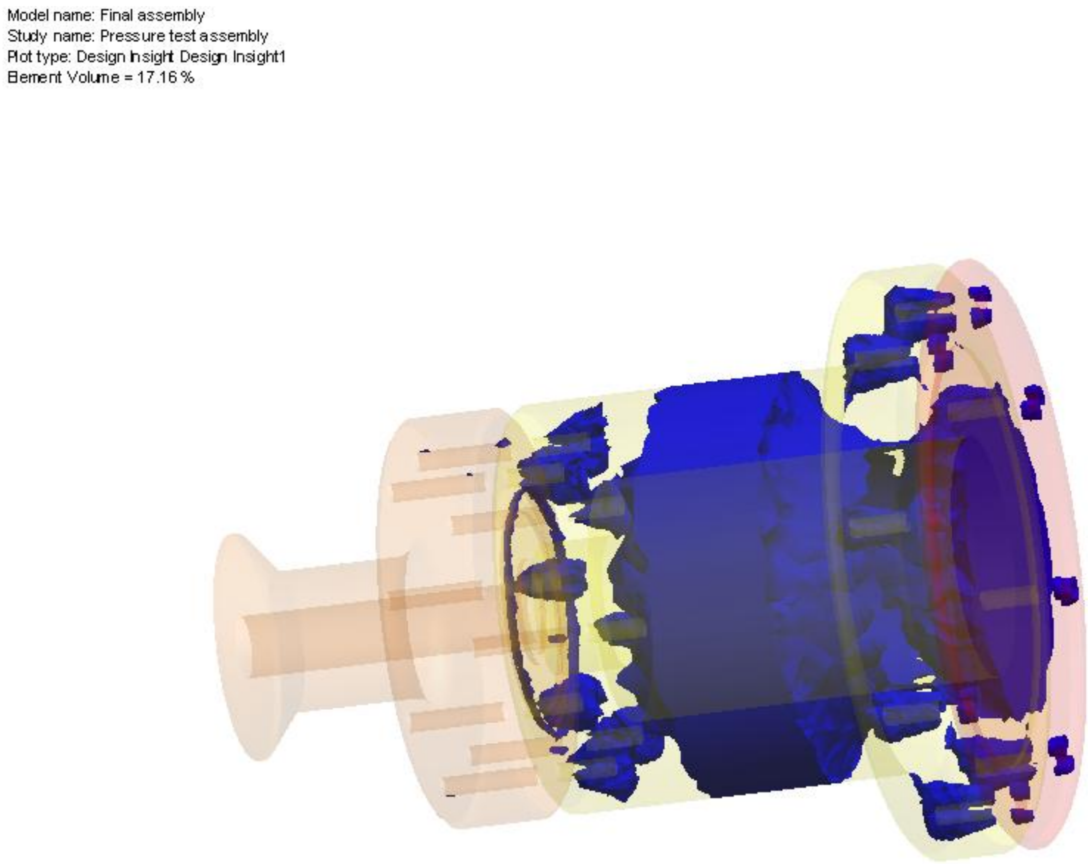

Figure 27 Design insight plot

4.5 Prototype

4.5.1 Introduction

Our external mentor at FMC suggested that it would be beneficial to build a prototype of the measuring system to use at the final presentation. The prototype would be able to show that the measuring system would work in real life as well as in theory.

Another important aspect due to building a prototype is that we could test and analyze that the laser would be able to measure when the lens were collimated. Since the hole through the flange where the laser transmits the beam and receives the reflected beams, is smaller than the size of the aperture and the collecting lens this could be a problem. The hole diameter through the flange is 25.9mm while the aperture and the collector lens is about 30mm.

This chapter will describe how the prototype is built, which materials are used and how we communicate with laser. This prototype is the kind which is only made with the intention of showing how we are able to measure the height from the top of the accumulator and down to the piston. The material used is intended to give the audience a better insight of how the system works and are not made for withstanding the environmental issues regarding the seabed.

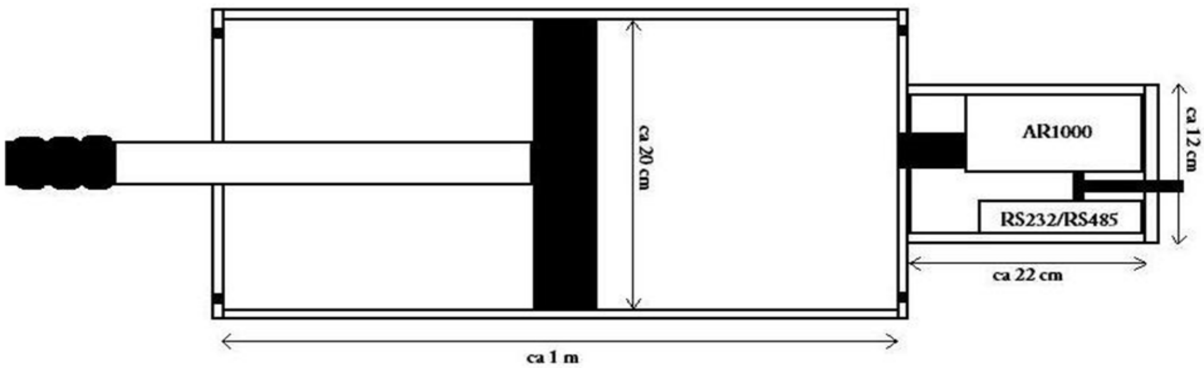

Figure 28 Principle sketch of prototype

4.5.2 Material selection

Since the scope for this prototype is to make something that shows the audience how the measuring system works, we wanted to create the housing and the accumulator tank in a way which enables the viewers to see what is happening inside the system. Best way in resolving this matter is to make the entire prototype in a transparent material. By using a transparent material the audience will see how the laser beam propagates from the housing into the accumulator tank.

By discussing within the group and with our external mentor acrylic plastic where considered a good option. Even though acrylic plastic is considered an expensive material it serves other functions which are very important. It is completely transparent and is very easy to machine which will be a cost reduction.

In collaboration with FMC we found a supplier for the acrylic plastic which FMC already uses, enables us to receive discount on our products. Astrup A/S which is located in Oslo were also very quick to response our inquiry. Since they already had a price agreement with FMC we considered them as the best supplier.

Following product were considered necessary to build the prototype:

- Tube made of acrylic plastic, 1m x 200mm diameter.
- Tube made of acrylic plastic, 0.5m x 120mm diameter.
- Plate made of acrylic plastic, 1m x 1m.
- Cylindrical block made of acrylic plastic, 200mm x 120mm diameter.

4.5.3 Construction

The longest tube is intended to be used as the accumulator tank, originally they have heights of 1 – 2 m, and this tube has a height 1m so it will be in real dimension and not scaled down, even though it will be the smallest possible accumulator tank. For the cylinder we used the shorter tube but cut it down to 200mm in height to make the relation due to the originally parts more precise.

The plate where used to make a bottom and top for the accumulator tank and a top lock for the housing by cutting them into specified dimensions. The remains of the plate where used as a rack for the accumulator tank.

The plastic to be used as the flange needed some additional machining other than cutting. The flange which were delivered from Astrup A/S as a uniform cylinder needed to be machined so it would look more like the originally flange, but in a less complex version. We made a simplified version of the flange and a 2D drawing and sent it to Koberg A/S for machining.

In the prototype we fastened the laser to the flange instead of the bottom of the housing because there is no interface between the flange and the housing. This is not needed since this is a simplified version of the housing and therefore we will glue the parts together rather than screw them except from the laser which we fasten by four screws on the top of the flange and place the housing over.

The piston where made by cutting a piece of wood into a circle of 185mm in diameter. A rod where then attached to it, enables us to move the piston up and down inside the tank for different measurements. The piece of wood was painted black, this due to testing the piston for worst case scenario of reflection, since a darker surface absorbs more of the beam which enables less reflection. Completely dark would result in no reflection at all. A bicycle tube where used to staple around the piston allowing moving smoothly, acting as a seal between the two rooms inside the accumulator tank.

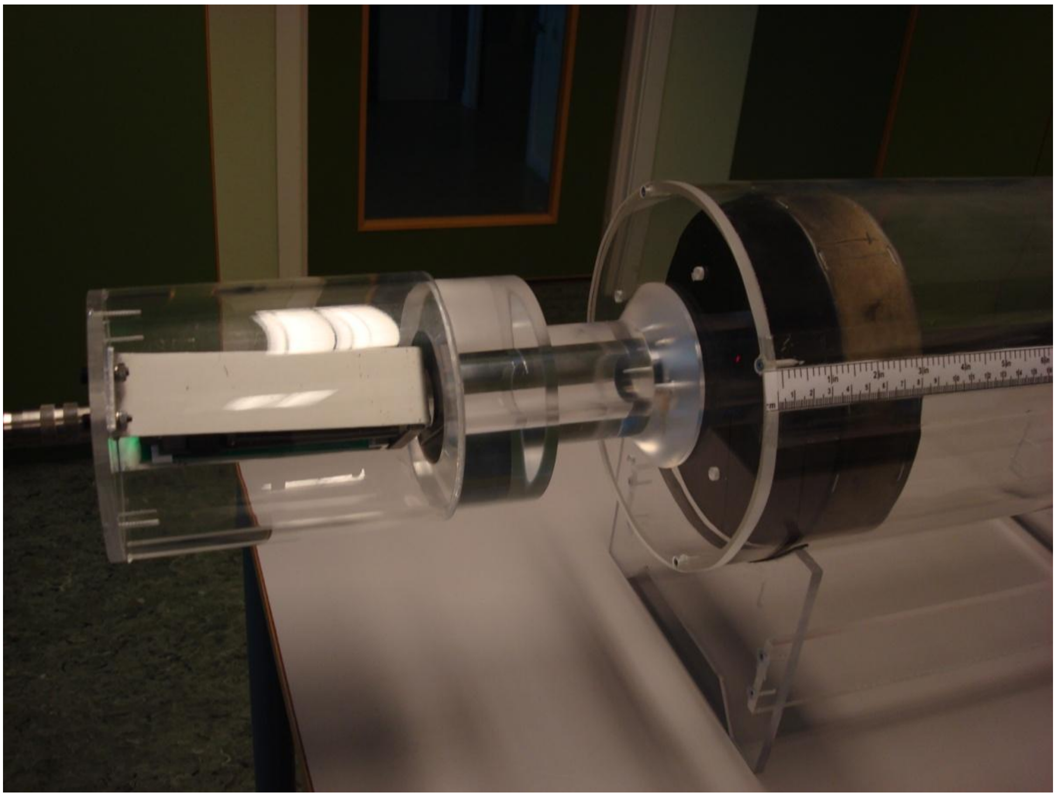

Figure 29 Laser beam through flange and on to the piston

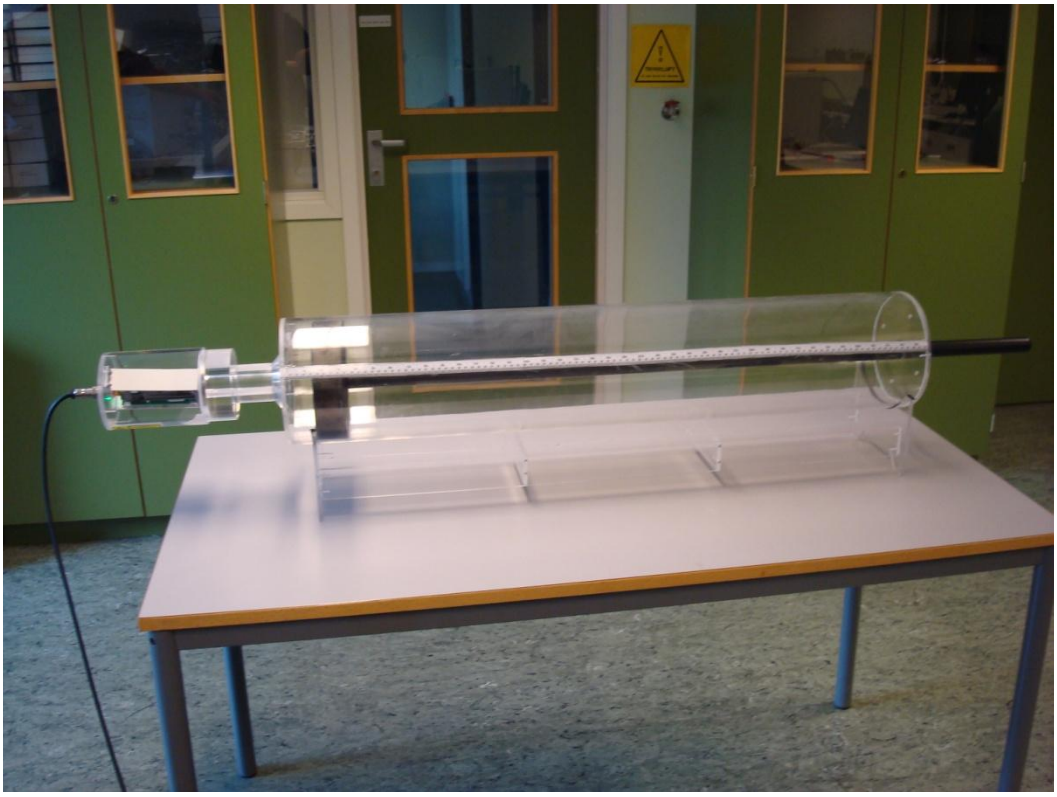

Figure 30 Fully assembled prototype

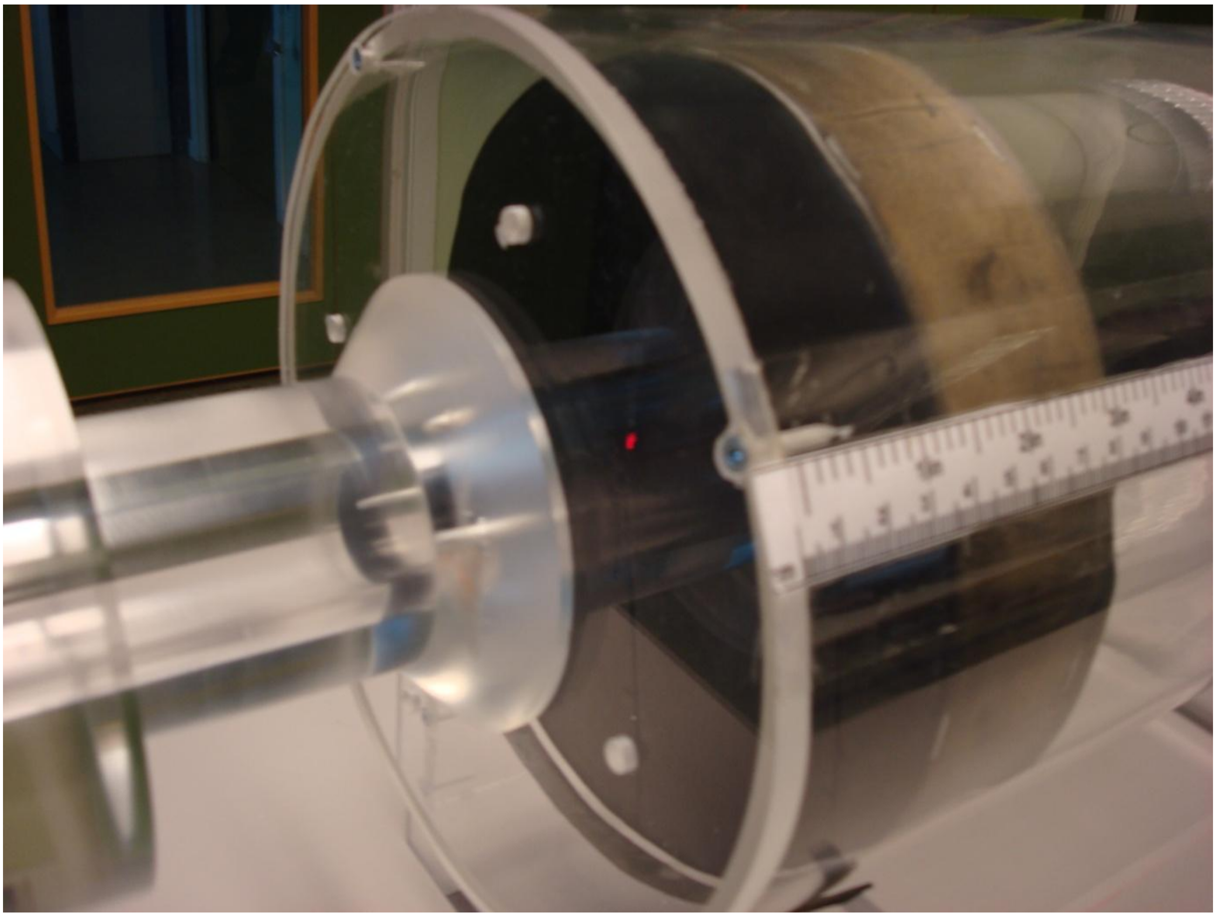

Figure 31 Laser beam

4.5.4 Communication

The Acuity AR1000 laser came with user's manual and a 12-pin connector (Binder series 423) that plugs into the laser at one end, and needs power and signal cables connected at the other end:

There were three different ways of connecting the laser for measuring; RS-422, RS-232 and analogue output. We decided to go with the RS-232 serial connection, because it fitted our application best. It converts the analogue signal to meters in either decimals or hexadecimals. The RS-422 is basically the same, but it works better for long-distance remote measuring. The 12-pin connector uses 6 wires for connection, three ground wires, one for power (10-30V) and the last two as signal cables (transmitting and Receiving). All other wires are not used for this connection and they will be soldered to a female 9-pin DB-9 connector.

We got hold of a male-to-male DB-9 cable that we cut in two, and figured out the wire colors for which wire went where. We then started soldering the 12-pin connector to the DB-9 cable. The green wire (Transmit) to pin 2, the yellow wire(Receive) to pin 3, the grey wire(GND) to pin 5 and the safety chassis ground to the shield wire.

For power, we used a laptop-computer 20 volt power supply which we soldered to the Orange (Uv) and Blue (GND) wires.

After connecting all wires properly to the connector, the wires where then connected to the laser, computer and power supply. The Windows program used for communication with the AR1000 is called Microsoft HyperTerminal, which computers with operating systems like Vista and 7 does not have, but a demo can be download from the web that works, and the computers on the HiBU microcontroller-lab still have Windows XP that includes Microsoft HyperTerminal.

After days of troubleshooting with the user manual and customer support, we were still not able to communicate with the laser. It would not turn on, and HyperTerminal could not turn it on either. On the third day, we had a meeting with our internal mentor, Gunnar Flak, and he pointed out that the outgoing signal cable from the computer should have -10 volts. We measured our cable, and it turned out that the wiring diagram in the manual did not fit our cable, it was the opposite. The signal cables were crossed, so the green cable (transmit) should go to pin 3, and the yellow cable (receive) should go to pin 2.

Immediately after we switched the wires and connected the laser, the laser turned on, and HyperTerminal transmitted the distance measured.

4.5.6 Testing

When we got the Acuity AR1000-laser from our mentor at FMC, we had to test it to make sure it worked properly. For this we used our prototype that simulates an accumulator tank in Plexiglas. The prototype itself was not completely assembled yet, but all that was needed was the accumulator tank. We connected the laser to a computer with the program Windows HyperTerminal, and the test could begin.

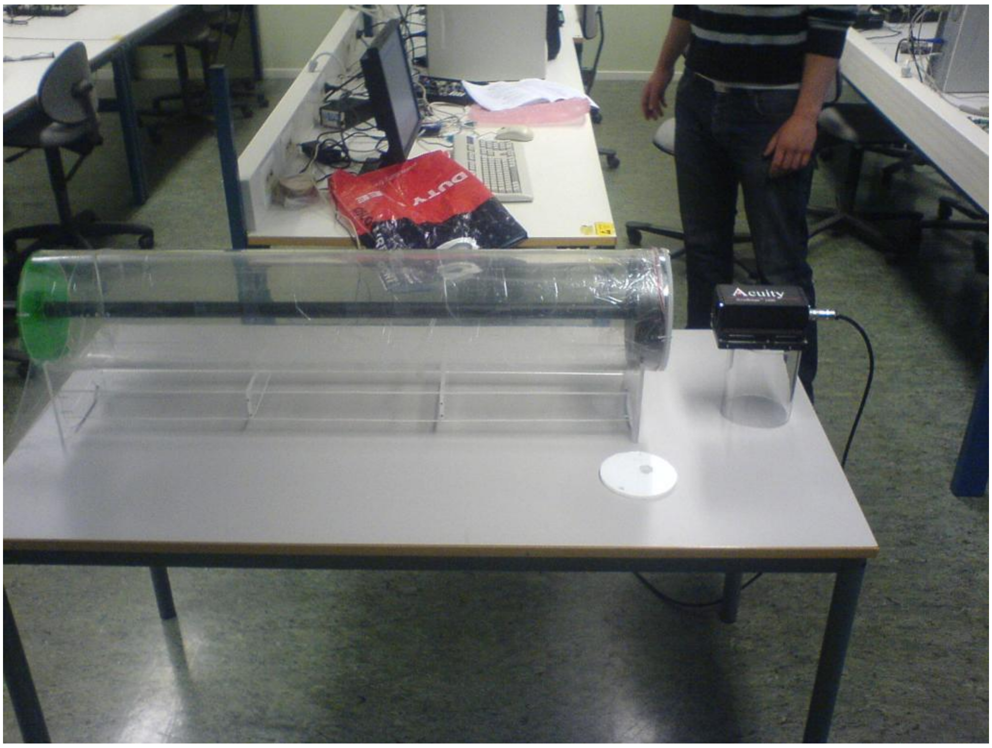

Figure 32 Accumulator test.

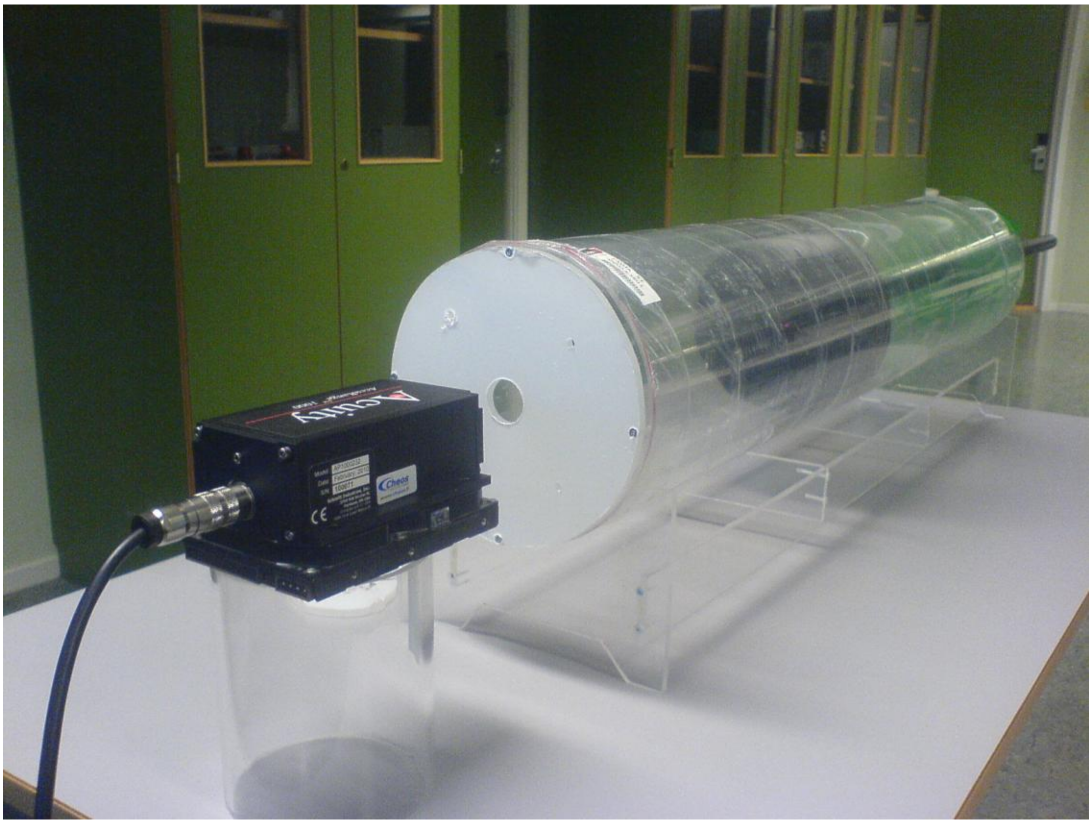

Figure 33 Accumulator test

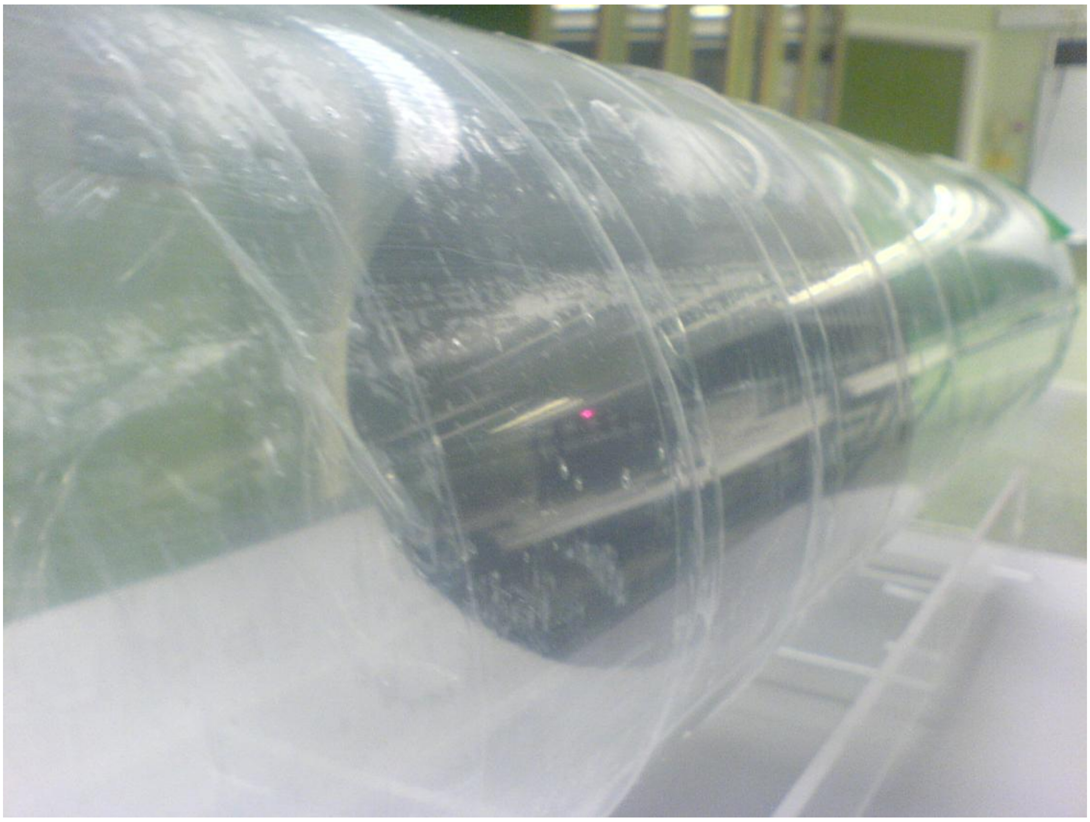

Figure 34 Laser pointed towards the accumulator piston

The different distances for the accumulator was measured up with a folding ruler and noted. The laser was then turned on with the command LF, and the measuring was started with DT. The distances measured and the laser outputs matched perfectly, and with even more accurate decimals than necessary. The test was performed many times, and with different distances. As the laser specifications specified, the laser will read an accurate distance from 0.1 to 30 meters. These specifications works nicely in our applications, as the biggest accumulator is approximately 2 meters in length, and the laser will be installed at least 10 cm about the accumulator top, because of the flange.

We also tested the SO command, which sets the currently distance measured as offset. This means that we can mark the distance the laser is installed from the accumulator top as offset. Another similar command is OF, that manually sets the offset by typing OF, and then the distance you want as offset. These commands are a nice feature, and worked precisely. We also tested other unrelated commands, such as changing the readout from decimals to hexadecimals, and changing the Baud rate. Another nice feature command is the ST command, which can adjust the time the laser displays the distance measured.

Figure 35 Piston is at the top of the accumulator.

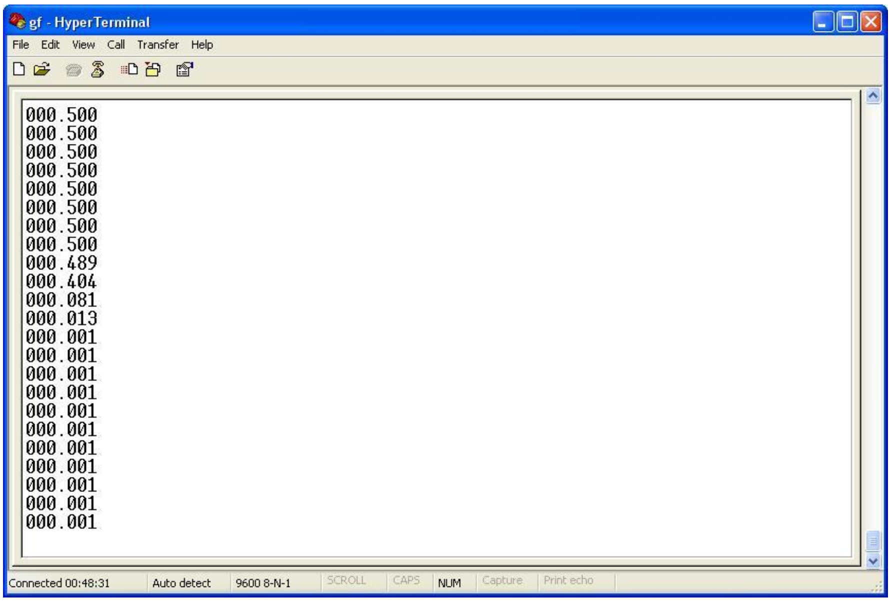

Table 4 Laser readout

The laser readout is virtually zero, when the AR1000 is set to its offset by typing SO in HyperTerminal.

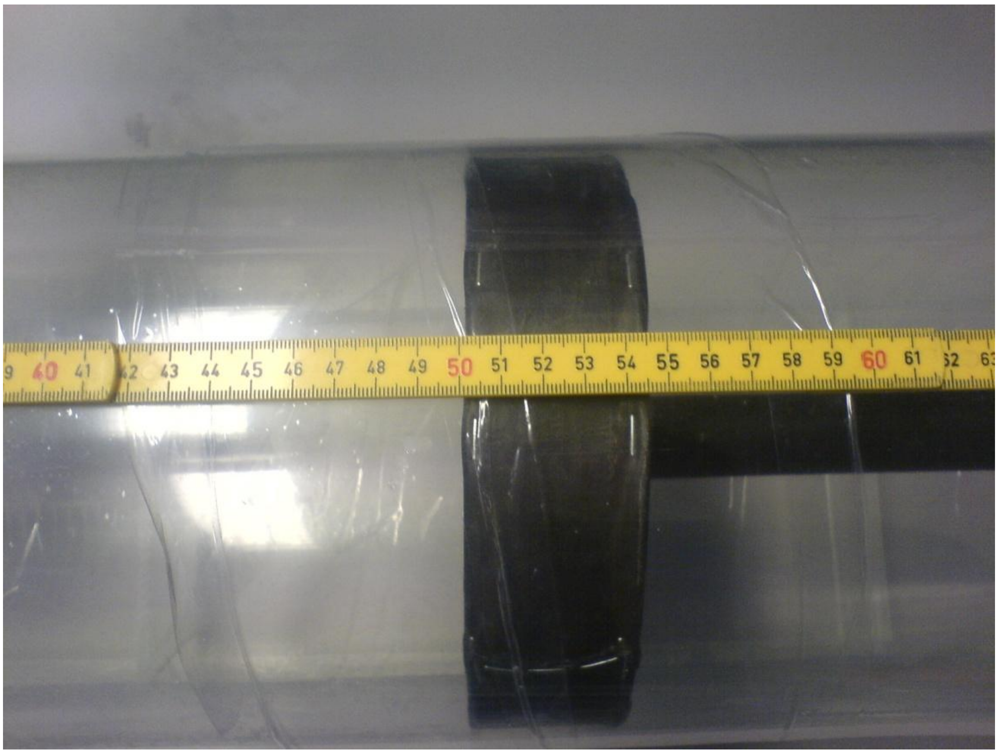

Figure 36 The piston is in the middle of the accumulator.

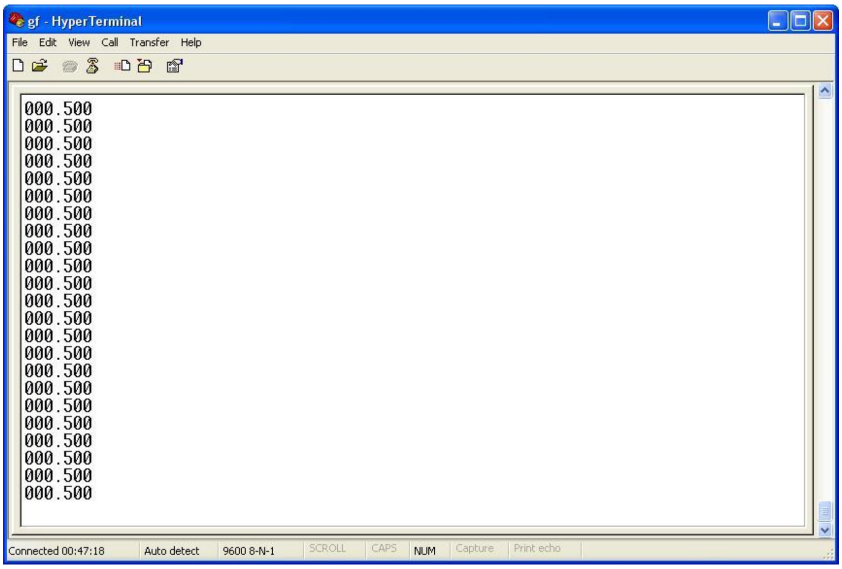

Table 5 Laser readout

The laser readout is 0.5, which is 50 cm.

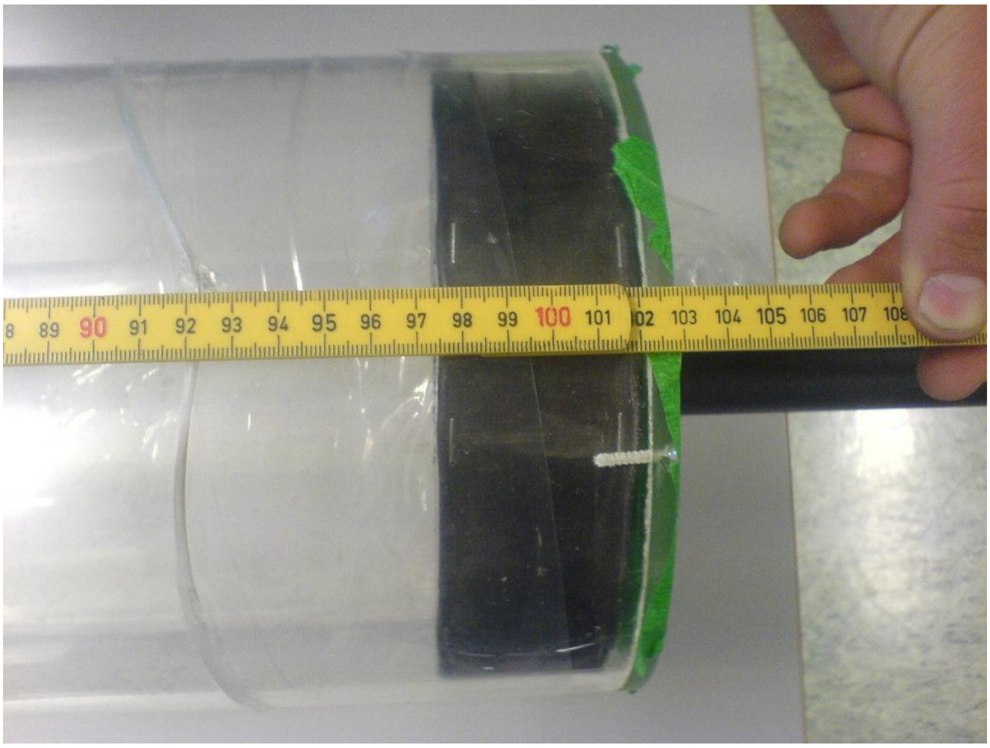

Figure 37 Our prototype tank is 102cm, and the piston is 2 inches thick.

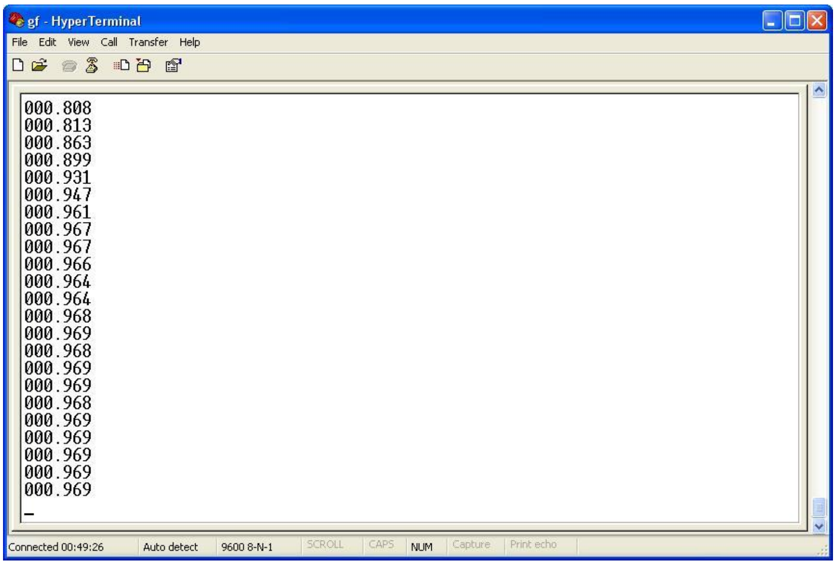

Table 6 Laser readout

The laser readout is approximately 0.97 meters, which matches up to the length of the accumulator tank minus the piston thickness.

A command that FMC might find usable is the AS command. This command can configure certain commands you want automatically started when the laser is turned on. If you type in ASDT, the laser will automatically start to track the distance when power is applied.

This is the complete command list, which can be displayed by typing ID:

```
ID[Enter]....................show this list
DT[Enter]....................distance tracking
DS[Enter]....................distance tracking 7m
DW[Enter]....................distance tracking with cooperetive target (10Hz)
DX[Enter]....................distance tracking with cooperetive target (50Hz)
DF[Enter]....................distance measurement with external trigger
DM[Enter]....................distance measurement
TP[Enter]....................internal temperature [C]
SA[Enter] / SAx[Enter].......display/set average value [1..20]
SD[Enter] / SDd[Enter].......display/set display format [d/h]
ST[Enter] / STx[Enter].......display/set measure time [0..25]
SF[Enter] / SFx.x[Enter].....display/set scale factor
SE[Enter] / SEx[Enter].......display/set error mode [0/1/2]
                             0..Iout=const., ALARM=const.
                             1..Iout: 3mA @RE>RB, 21mA @RE<RB, ALARM: OFF@AH>0,  ON@AH<0
                             2..Iout: 21mA @RE>RB, 3mA @RE<RB, ALARM:  ON@AH>0, OFF@AH<0
AC[Enter] / ACx.x[Enter].....display/set ALARM center
AH[Enter] / AHx.x[Enter].....display/set ALARM hysterese
AW[Enter] / AWx.x[Enter].....display/set ALARM width
RB[Enter] / RBx.x[Enter].....display/set distance of Iout=4mA
RE[Enter] / REx.x[Enter].....display/set distance of Iout=20mA
RM[Enter] / RMx y.y z[Enter]..remove measurement
TD[Enter] / TDx y[Enter].....display/set trigger delay [0..9999ms] trigger level [0/1]
TM[Enter] / TMx y[Enter].....display/set trigger mode [0/1] trigger level [0/1]
BR[Enter] / BRx[Enter].......display/set baud rate [2400..38400]
AS[Enter] / ASd[Enter].......display/set autostart command [DT/DS/DW/DX/DF/DM/TP/LO/ID]
OF[Enter] / OFx.x[Enter].....display/set distance offset
SO[Enter]....................set current distance to offset (offset = - distance)
LO[Enter]....................laser on
LF[Enter]....................laser off
PA[Enter]....................display settings
PR[Enter]....................reset settings
```

Table 7 Command list

One specific problem as mentioned and that was the metaglass and flange diameter. This diameter was smaller than the laser and reflector diameter combined. This was because the external mentor wanted as small hole as possible. For subsea, with the high atmospheric pressure, the smaller the cavity with 1 atmospheric pressure, the better.

The laser and reflector diameter was measured to 30 millimeters, and the flange hole that is between the laser and accumulator tank was 25.9 millimeters. We then had to test if the laser could still measure distances through this hole. We drilled a 25 mm hole in a piece of wood, and put it in front of the laser. With the laser properly set in front, the reflector had no problem receiving the laser signal that was sent back. We figured this because the laser signal was sent directly back, and not in an angle. This fits our application, as the accumulator piston is flat. For our final presentation, we will add a permanent measuring tape to the accumulator tank, for convenient testing.

We are now familiar with the different commands, and know that the laser works flawlessly, and can now move on to installing the laser in the prototype. The laser meets the requirement specifications.

5. Conclusion

This project was given by Odd Jan Kirkaune at FMC Technologies, who also has been our external mentor. The goal was to find a new solution of measuring the level of hydraulic fluid in piston accumulators at the seabed. As earlier solutions were insufficient, bladder accumulator were used instead. Since piston accumulators are much more reliable than bladder accumulator it was desirable to find a new solution to this problem.

The first phase was to find several measuring methods that could be adaptable for subsea installations. We then used a scoreboard matrix to choose the best solution for our project, for this we set up a number of requirements in collaboration with FMC Technologies. After choosing our concept, several sub concepts had to be taken into consideration; such as material selection, and if we were going to use the principle of flight time or frequency modulation.

Our design is a cylinder with a top bolted in place with two C-rings back to back for secure sealing; this means that inside the cylinder there will be a one atmospheric pressure to protect the electronic inside. In addition there will be N_2 inserted into the cylinder to prevent corrosion, and a glass/metal seal penetrator on the top for sealing the power supply and electronic outputs such as the output signal from our laser. Inside the cylinder the laser and a converter from RS232 to RS485 or Can Bus will be placed.

For the laser to have a clear path for sending the laser beam into the piston accumulator, we needed a material that could withstand high pressure and in the same time be transparent. A solution to this problem was to use a glass called Metaglass that are EB-welded in the bottom of the cylinder; this is a glass that withstands high pressure due to the mechanical tempering of the glass and also gives a free sight. We also needed an opening down in the accumulator, and the solution we decided to use was a flange that is welded onto the accumulator. This flange is then bolted to the cylinder with two C-rings back to back for secure sealing.

To select a proper material for our construction we had to consider the environment, and for all subsea construction corrosion is a very important factor. By choosing a material with high hardness and high yield strength, material can be saved by reducing wall thickness and thereby reducing material cost. We therefore wanted to use 22Cr Duplex for HAMU.

The group has worked well together and during discussions we have always come to an agreement, and all problems have been solved in plenary. We all have different qualities, and therefore we have tried to use these on proper areas. We have put a lot of us in this project, and believe that this is a good and usable solution.

6. Sources

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7. Appendixes

Name	Description	Folder Name
A in R	Solid Works report	Solid Works report
B	Solid Works pictures of parts	Solid Works pictures
C	2D drawings and part specification	2D drawings
D in R	FEM report	FEM report
E	22Cr duplex steel	22Cr Duplex steel
F	Metaglass	Metaglass
G in R	C-ring	C-rings
H in R	Bolts and nuts	Bolts and nuts
I in R	AR1000 laser	AR1000
J in R	RS-485	RS485
K in R	CAN Bus Protocol for FMC CAN Bus systems.	Spec CAN Bus protocol
L	Minutes of meeting	Minutes of meeting
M in R	Review of meetings	Review of meetings
N	E-mail	Mail
O	Economic	Economic
P	Gantt-chart	Gantt-Chart
Q in R	Hour list	Hour-list
R	CD	

Appendix A in R

Appendix B

Appendix C

FMC CORPORATION PETROLEUM EQUIPMENT GROUP O-C-T	REVISIONS			ENGINEERING STANDARDS	NUMBER 1028
	A 0031390	G	N		PAGE 1 OF 2
	B 1055990	H	O	FLANGES 1" NOMINAL	ISSUE DATE: 06-15-93
	C	J	P		DRAWN BY: STRICKLER
	D	K	Q		CHECKED BY: MASON
	E	L	R		REVIEWED BY: BUCHTA
	F	M	S		APPROVED BY: WILLIAMS

(1) OPTIONAL: FOR 10K AND BELOW USE 1/2 " API LP SEE STD 0520. (B)
ABOVE 10K USE 1 1/8 " AUTOCLAVE CONNECTION.

(2) DATUM AT THRU BORE TO BE CONFIRMED BY ENGINEER.

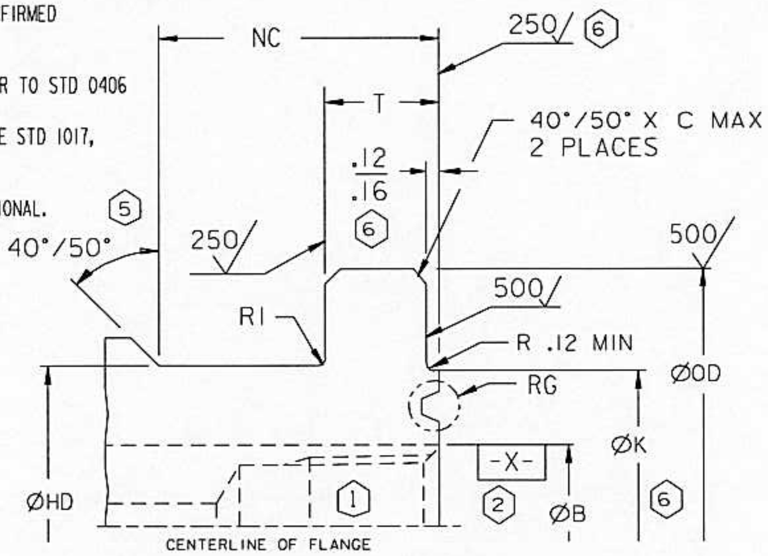
(3) FOR BOLT HOLE DIMENSIONS REFER TO STD 0406

(4) FOR RING GROOVE DIMENSIONS SEE STD 1017, STD 1018 AND STD 1030.

(5) BEVEL ANGLE LESS THAN 40° OPTIONAL.

(6) APPLICABLE ONLY ON FLANGES WITH BX RING GROOVES

(7) FOR REFERENCE ONLY



	STD LINE	PRESSURE	BORE SIZE B	OUTSIDE DIA OF FLANGE OD	THICKNESS OF FLANGE T	HUB DIAMETER HD	BACKFACE NUT CLEARANCE NC	RAISED FACE DIAMETER K	BACKFACE RADIUS R1	RING GROOVE RG
	AA	2,500	1.00 / 1.02	6.31 / 6.18	1.69 / 1.62	2.31 / 2.25	3.8	—	.14 / .10	R-18
(7)	AB	12,000	1.00 / 1.02	6.81 / 6.69	2.12 / 2.00	1.88 / 1.82	4.5	—	.14 / .10	R-82
	AC	12,500	1.00 / 1.02	6.81 / 6.69	1.69 / 1.62	2.38 / 2.31	4.2	4.047 / 3.985	.40 / .36	BX-150
	AD	18,000	1.00 / 1.02	7.18 / 7.06	1.75 / 1.69	2.44 / 2.38	4.2	3.188 / 3.125	.40 / .36	BX-SPCL
	AE	24,000	1.00 / 1.02	7.18 / 7.06	3.00 / 2.94	2.38 / 2.34	5.5	3.174 / 3.112	.40 / .36	BX-SPCL
	AF	30,000	1.00 / 1.02	9.06 / 8.94	3.00 / 2.94	2.38 / 2.34	5.8	3.174 / 3.112	.40 / .36	BX-SPCL

FMC CORPORATION PETROLEUM EQUIPMENT GROUP O-C-T	REVISIONS			ENGINEERING STANDARDS	NUMBER 1028
	A 0031390	G	N	FLANGES 1" NOMINAL	PAGE 2 OF 2
	B 1055990	H	O		ISSUE DATE: 06-15-93
	C	J	P		DRAWN BY: STRICKLER
	D	K	Q		CHECKED BY: MASON
	E	L	R		REVIEWED BY: BUCHTA
	F	M	S		APPROVED BY: WILLIAMS

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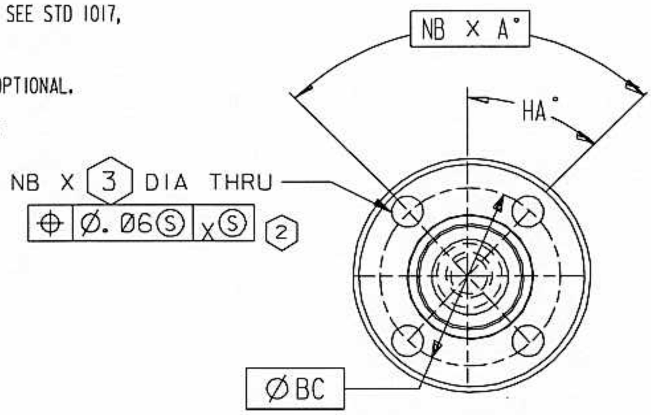
(4) FOR RING GROOVE DIMENSIONS SEE STD 1017, STD 1018 AND STD 1030.

(5) BEVEL ANGLE LESS THAN 40° OPTIONAL.

(6) APPLICABLE ONLY ON FLANGES WITH BX RING GROOVES

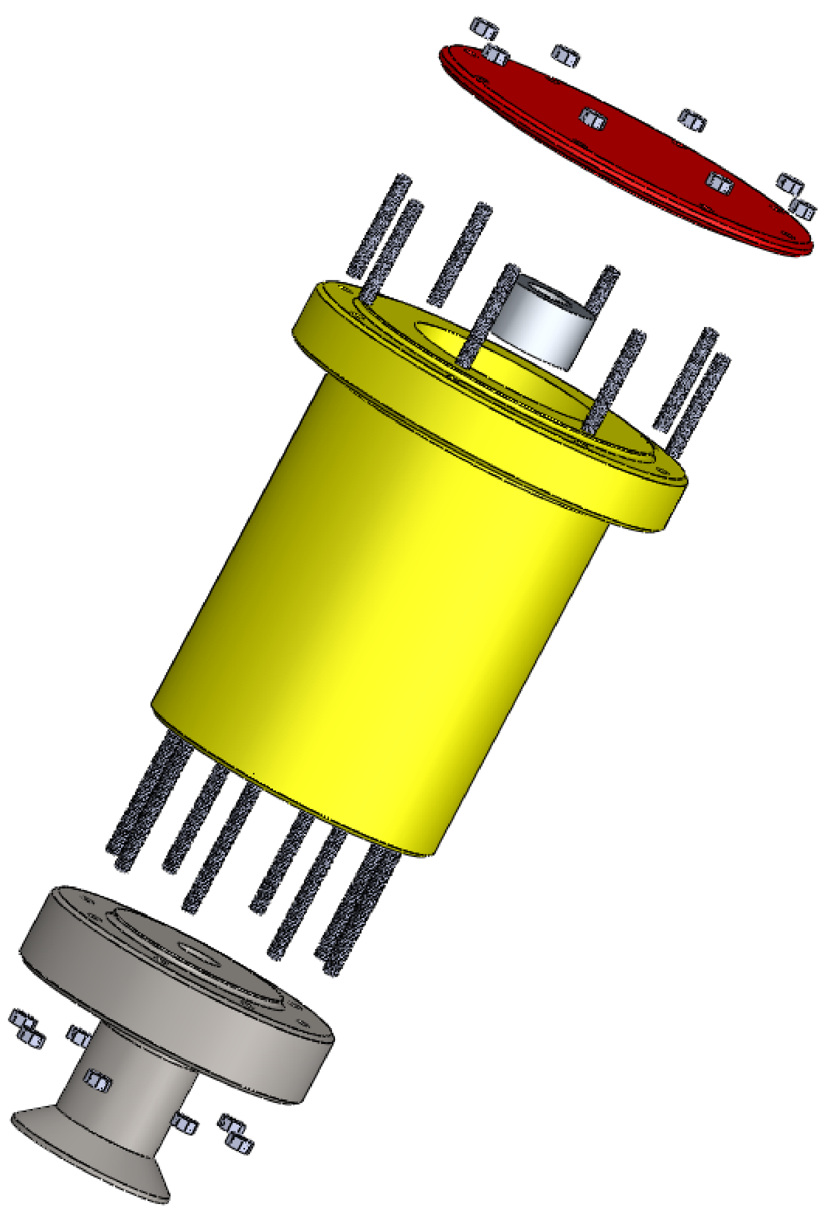
(7) FOR REFERENCE ONLY

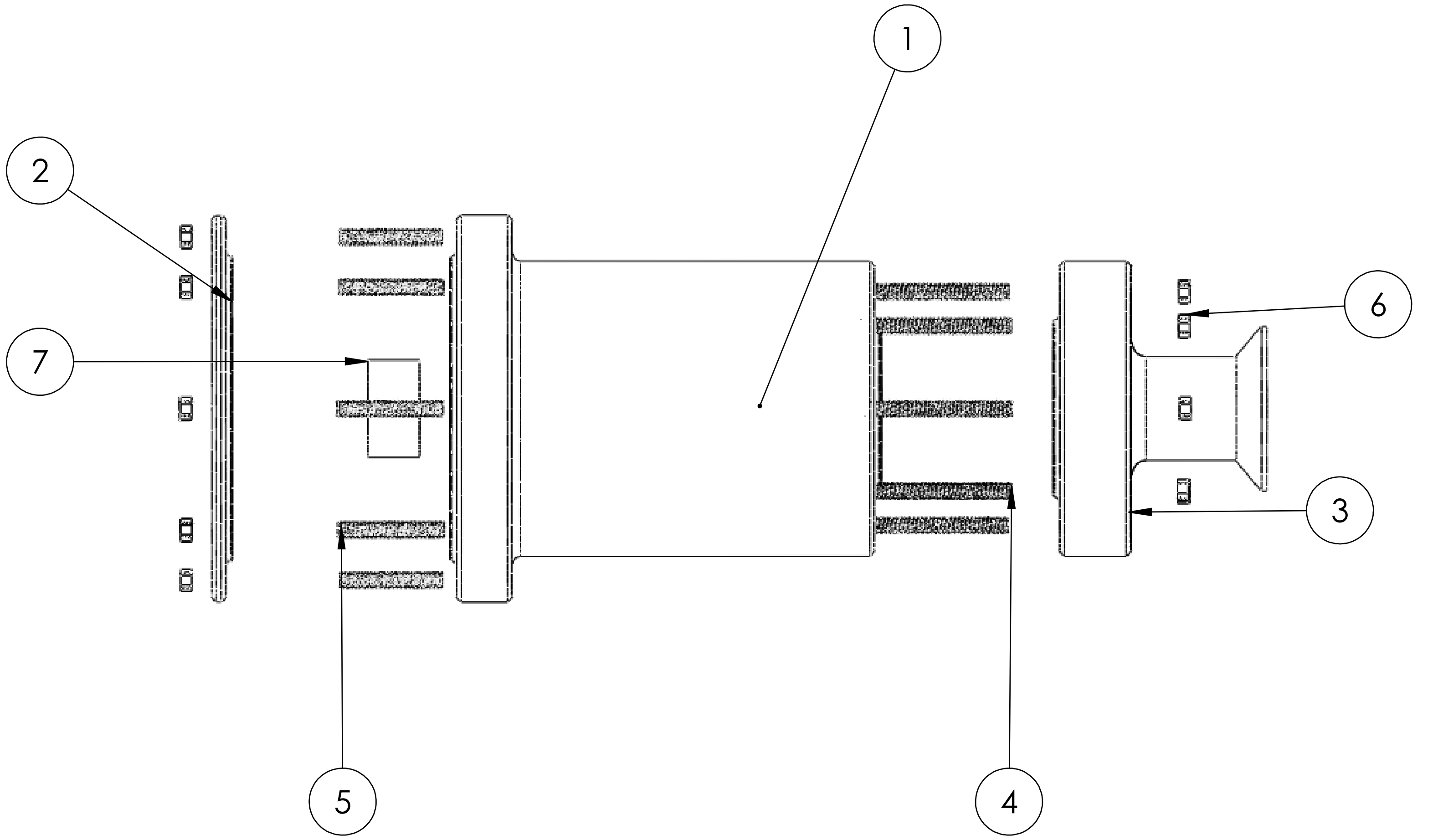


(7)

STD LINE	PRESSURE	BOLT DIAMETER		NUMBER OF BOLTS NB	BOLT CIRCLE BC	BASIC ANGLE A	HALF ANGLE HA	CHAMFER C
AA	2,500	.875	FOR BOLT HOLES, SEE NOTE 3	4	4.25	90°	45°	.12
AB	12,000	1.000		4	4.62	90°	45°	.12
AC	12,500	1.000		4	4.62	90°	45°	.12
AD	18,000	1.000		4	5.00	90°	45°	.06
AE	24,000	1.000		4	5.00	90°	45°	.06
AF	30,000	1.125		4	6.75	90°	45°	.06

ITEM NO.	PART NUMBER	MATERIAL	QTY.
1	Housing	CR22 Duplex	1
2	Top	CR22 Duplex	1
3	Flange		1
4	Bolt flange-housing	L7M	8
5	Bolt top-housing	L7M	8
6	Nut	A4-80	16
7	Metaglass		1





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

MATERIAL:

DWG NO.

Assembly

A3

WEIGHT:

SCALE:1:5

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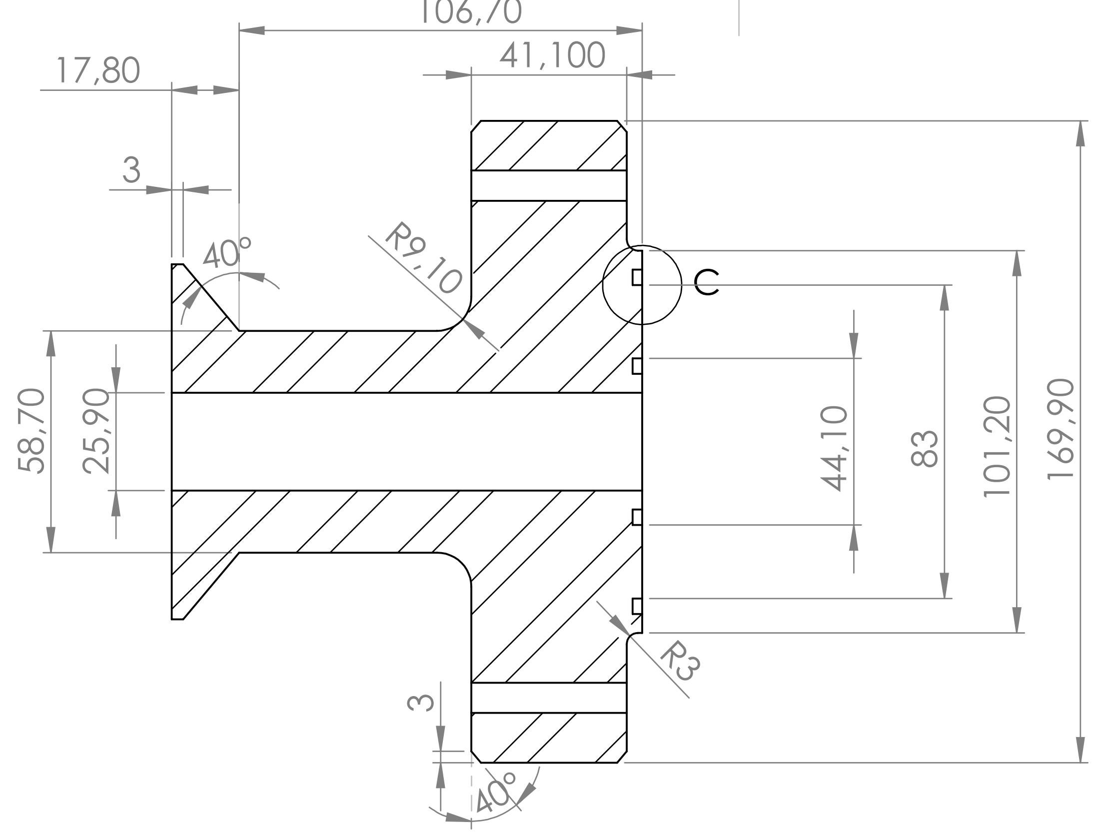

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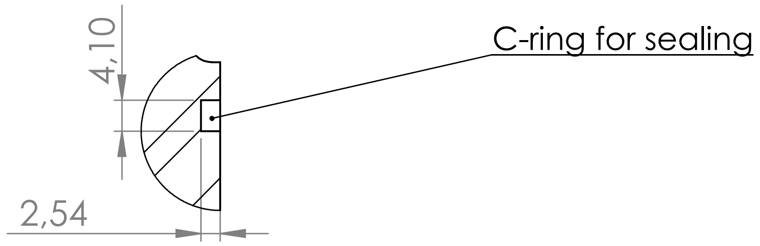

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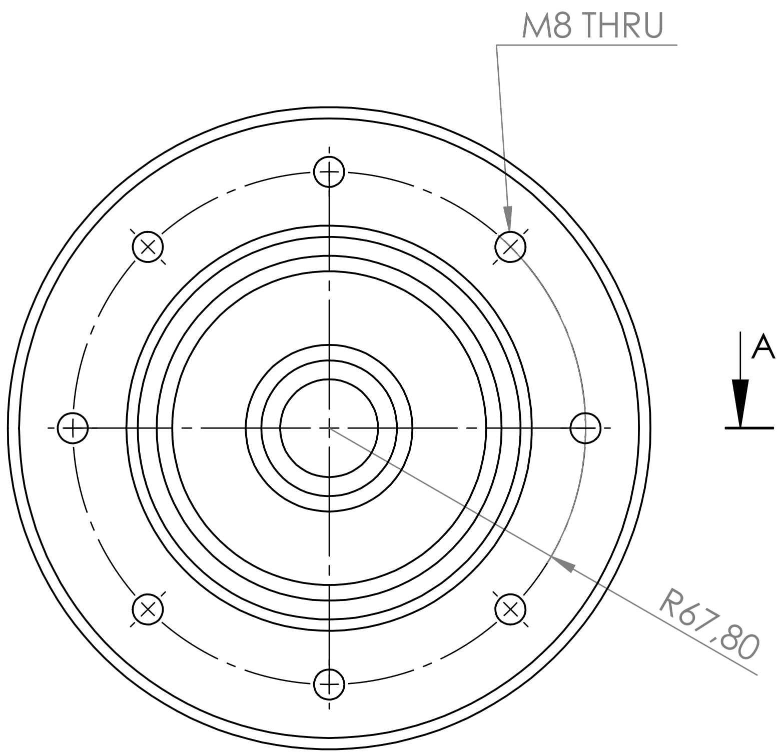
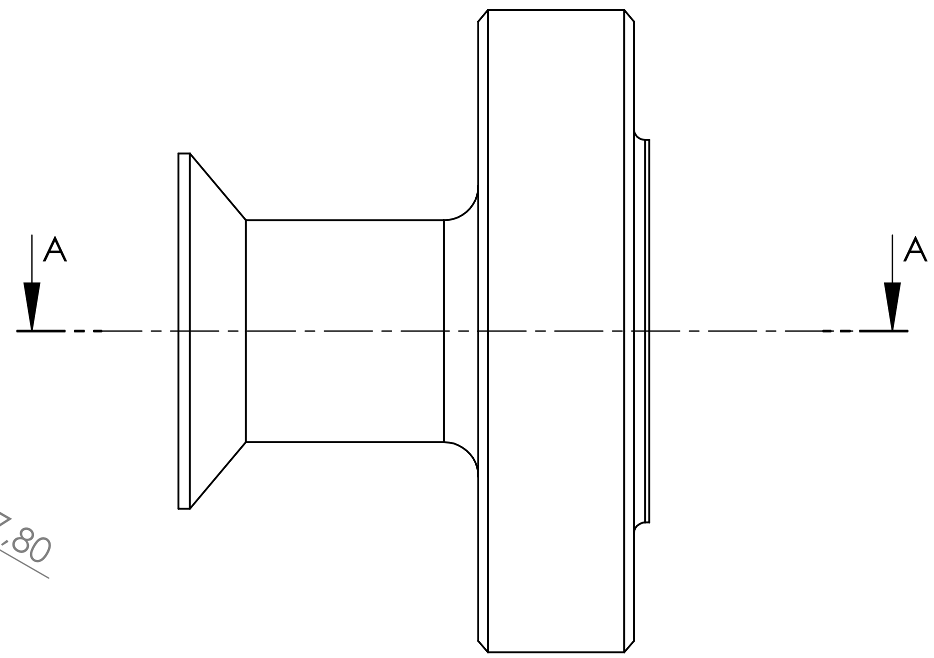
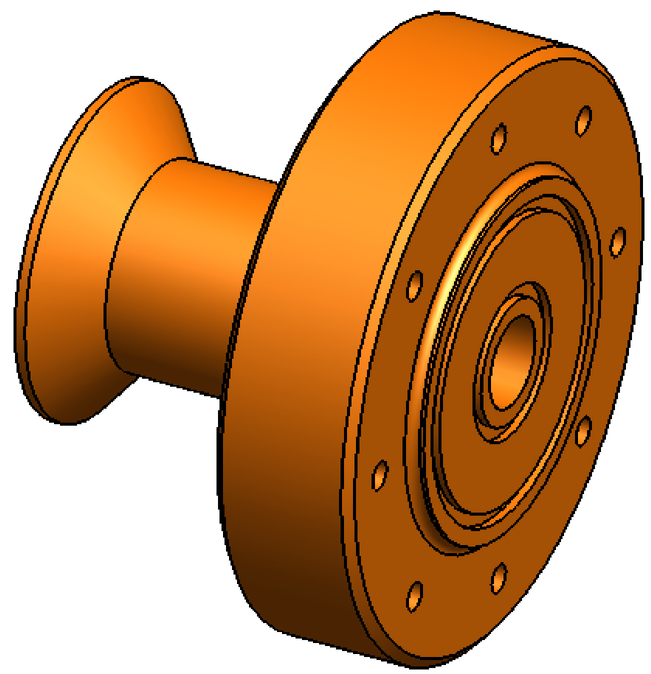






UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

MATERIAL:

WEIGHT:

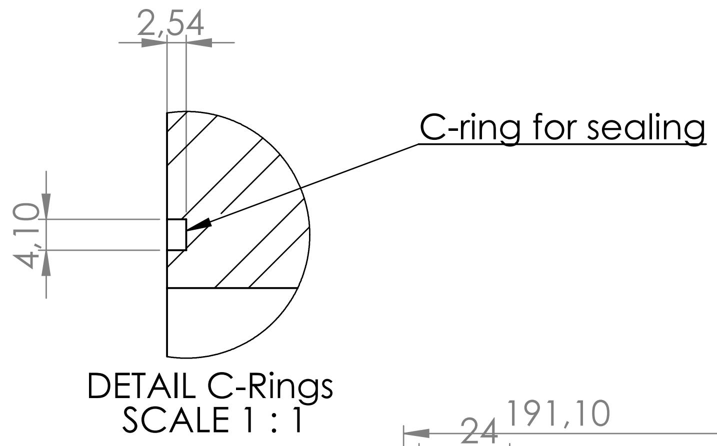
DWG NO.

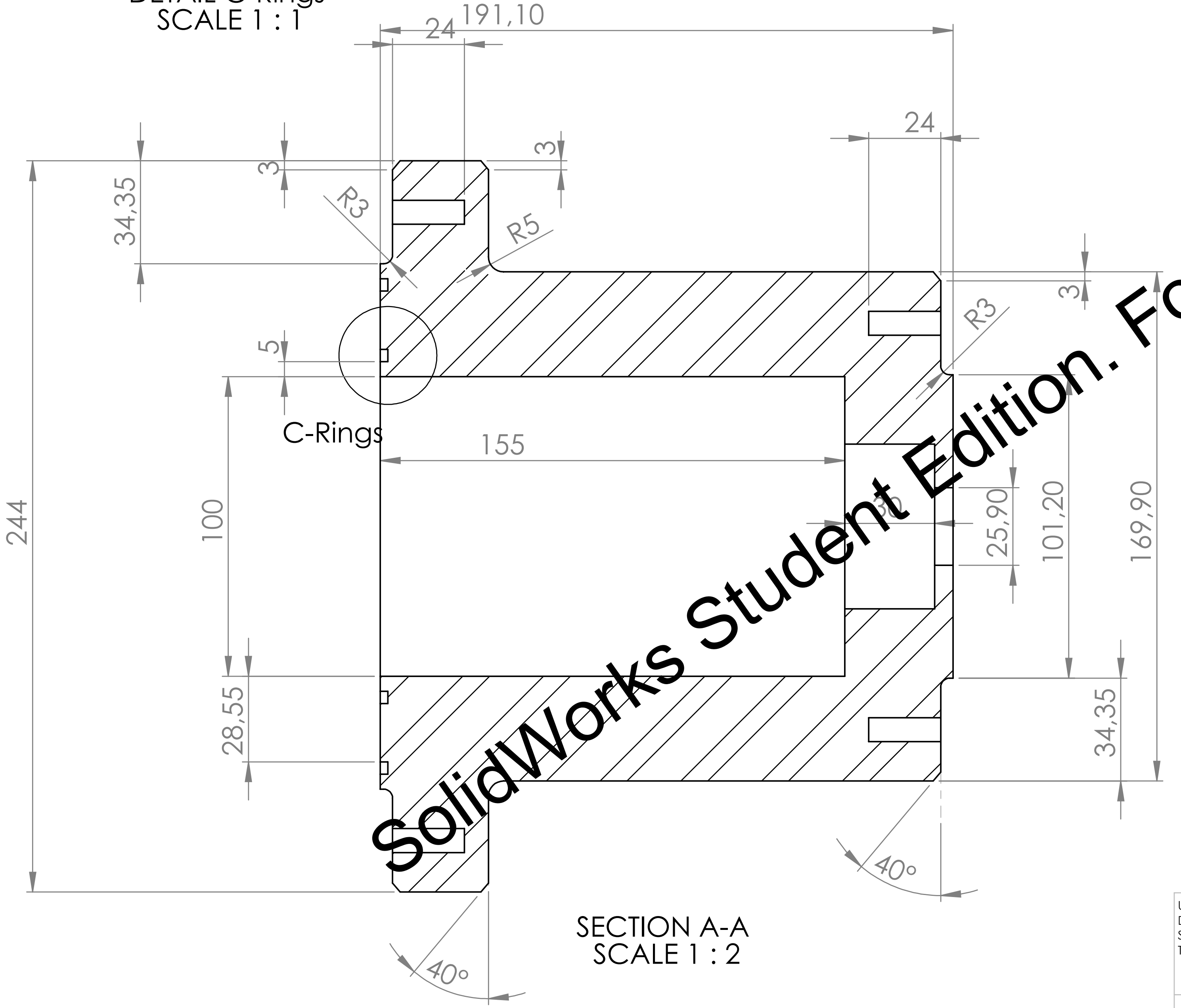
Flange

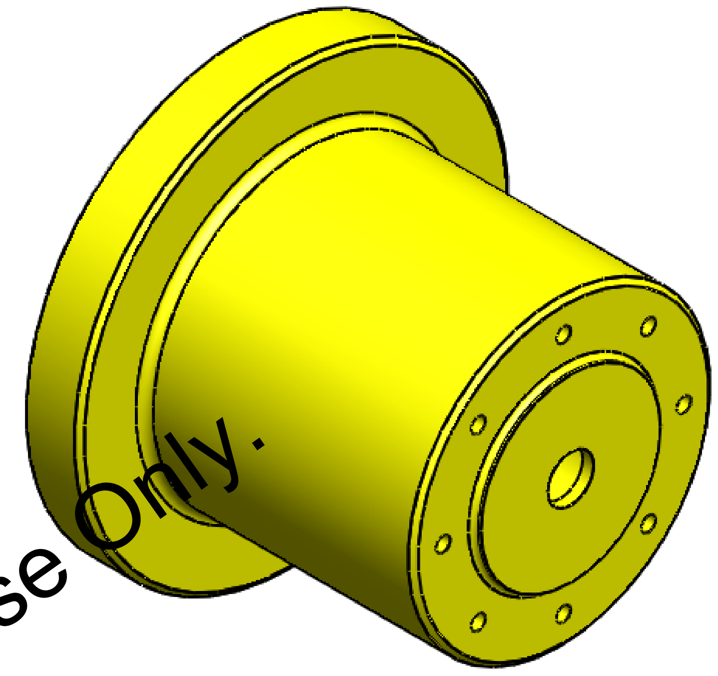
A3

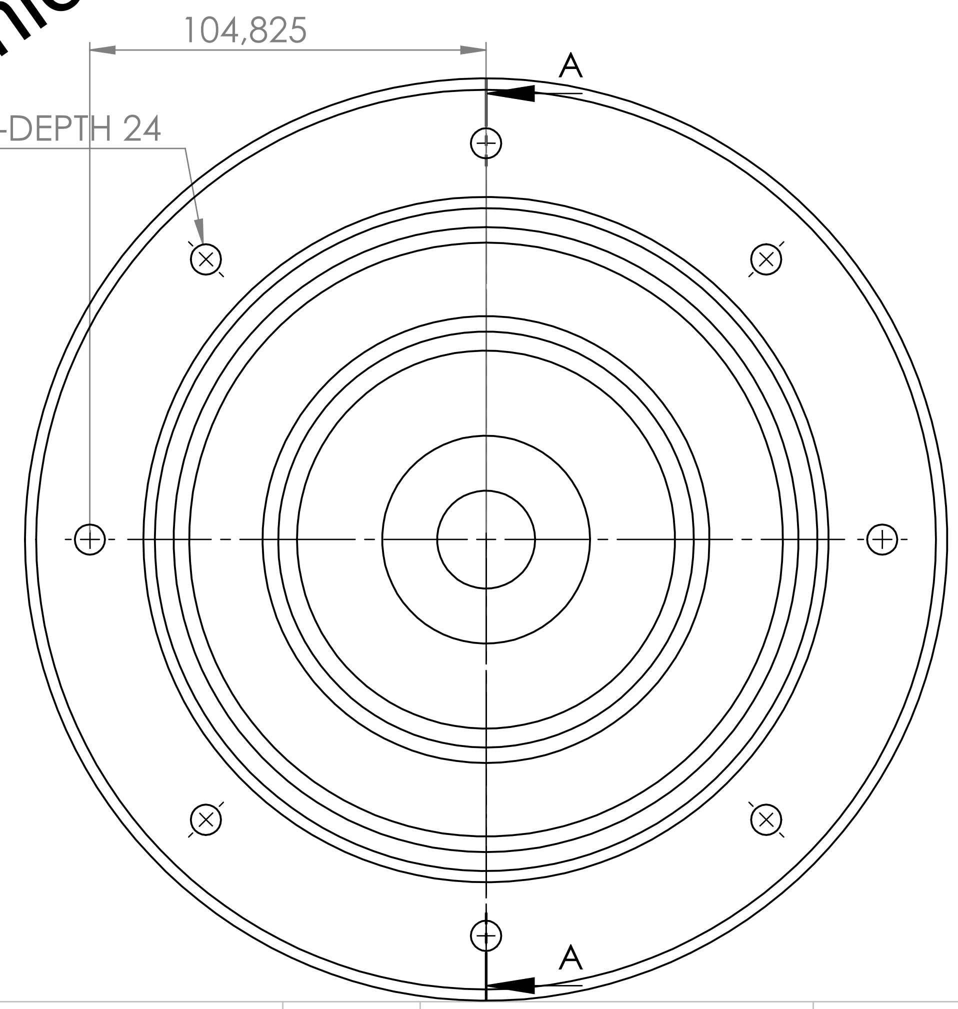
SCALE:1:2

SHEET 1 OF 1





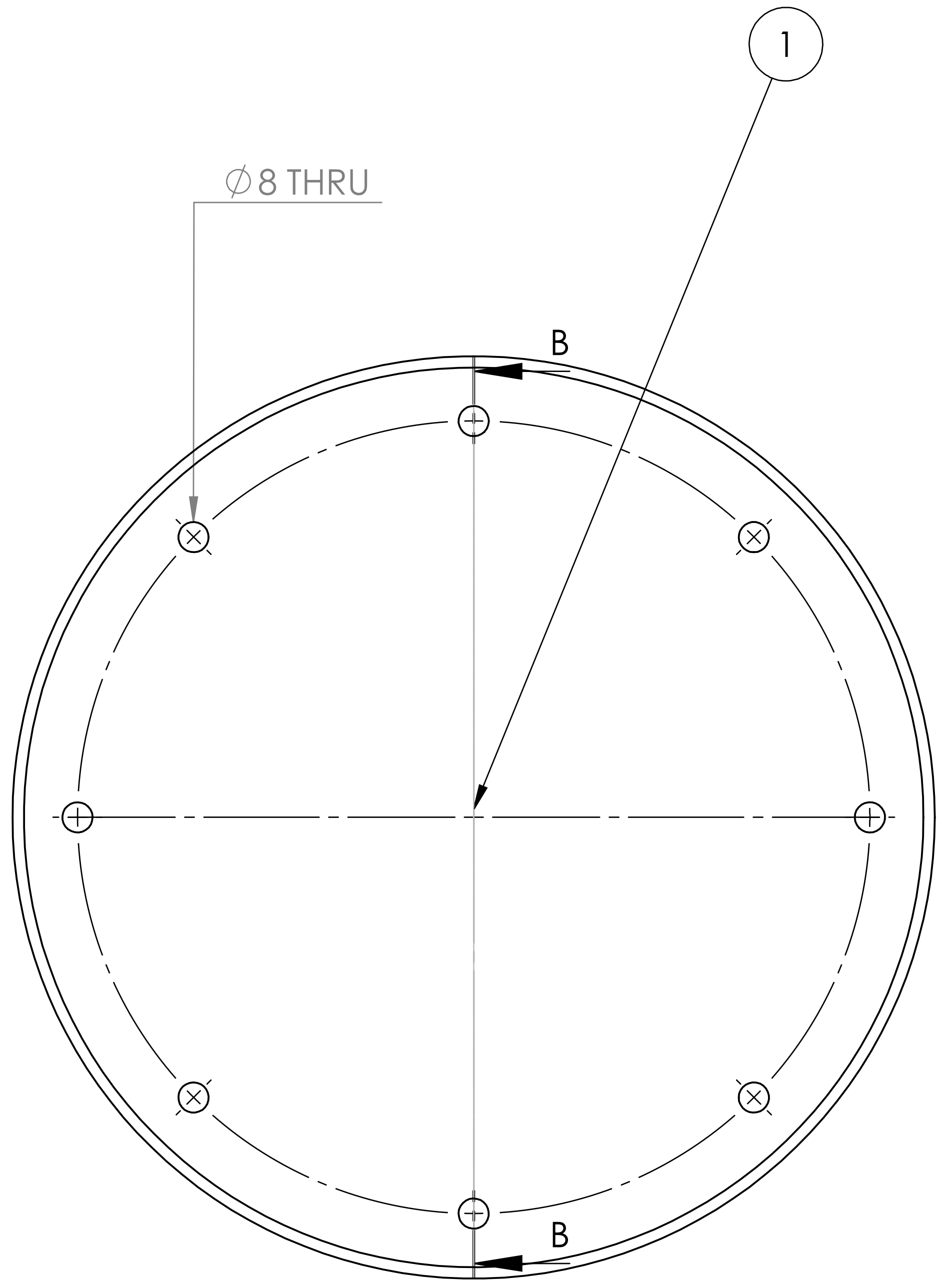


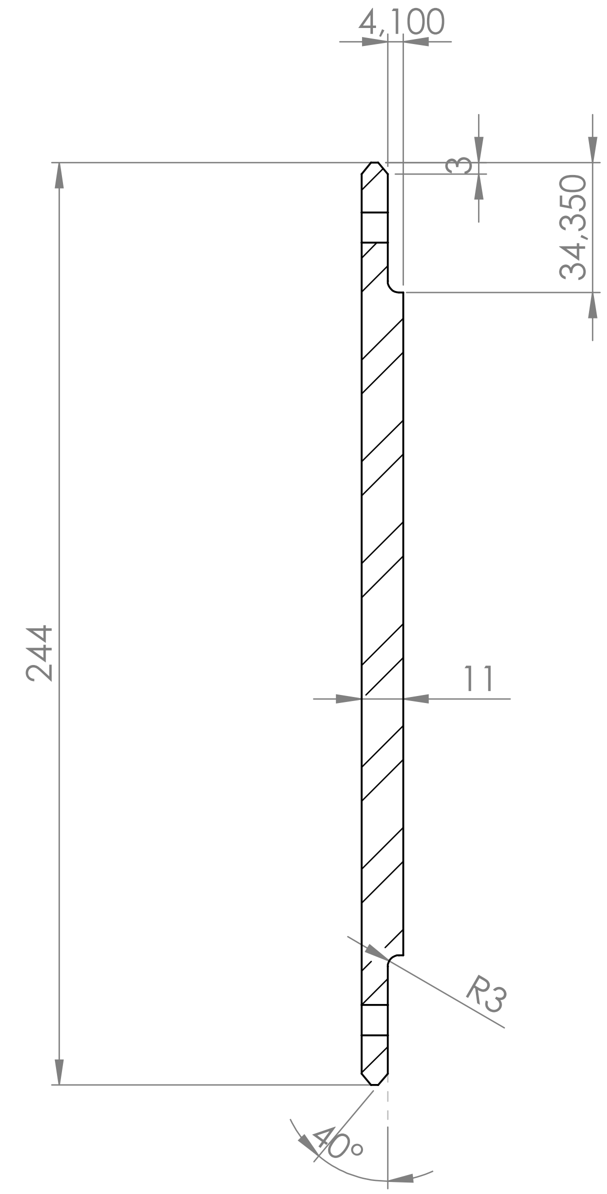


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION

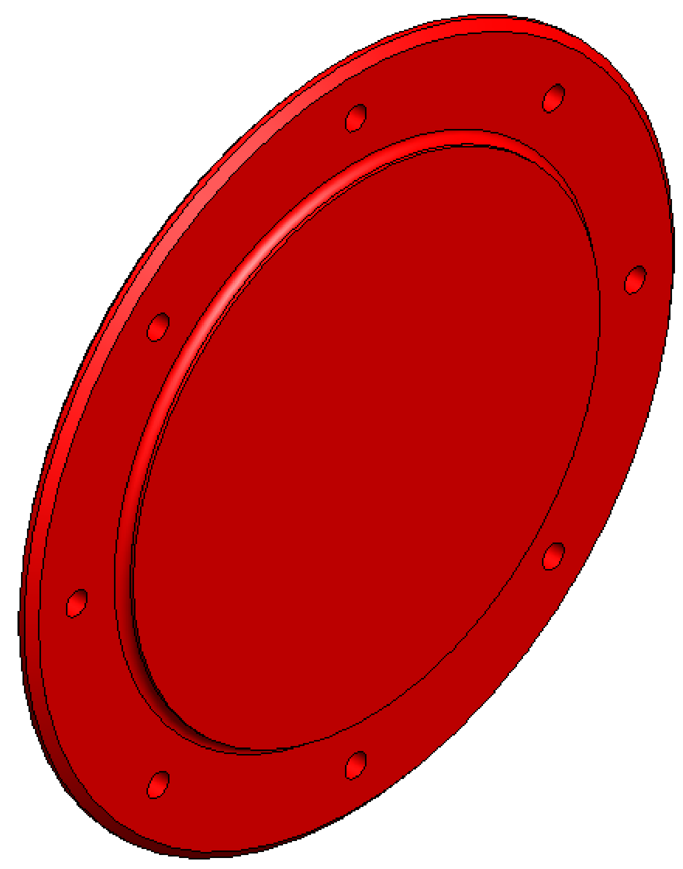
	NAME	SIGNATURE	DATE		TITLE:
DRAWN					
CHK'D					
APPV'D					
MFG					
Q.A				MATERIAL: CR22 Duplex	DWG NO. Housing — A3
				WEIGHT:	SCALE:1:5 — SHEET 1 OF 1

1	Hole for metal/glass seal penetrator





SECTION B-B
SCALE 1 : 2



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION	
	NAME	SIGNATURE	DATE	TITLE:	
DRAWN					
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL: CR22 Duplex	DWG NO. Top	A3
			WEIGHT:	SCALE:1:5	SHEET 1 OF 1

Appendix D in R

Appendix E

Industeel URANUS® 45N 22Cr 3Mo Duplex Stainless Steel with PREN = 33 or 34

Categories: Metal; Ferrous Metal; Duplex; Stainless Steel; T S30000 Series Stainless Steel

Material Notes:

Description: URANUS® 45N (UR 45N) is a nitrogen alloyed (= 0.15%) austenitic-ferritic stainless steel (22.05 type) with improved structure stability and high general, localized and stress corrosion resistance properties. UR 45N with 22% Cr and 3% Mo additions, performs much better than 316L grade in almost all corrosive media,. The yield strength is about twice that of austenitic stainless steels. This allows the designer to save weight and makes the alloy more cost competitive when compared to 316 L grade. Typical operation temperatures are -50°C/+ 280°C (-58°F/+536°F). Lower temperatures uses could to be considered require additional precautions, in particular for welded structures. UR 45N is a multi-purposes material which can be used in various corrosive media. Typical applications are Pulp and Paper industry, Oil and Gas industry, Pollution control equipments, Chemical industry and Chemical tankers.

Iron content calculated as remainder.

Information provided by manufacturer.

Key Words: EURONORM 1.4462 - X2 Cr Ni Mo 22.5.3, AFNOR Z3 CND 22.05 AZ, DIN X2 Cr Ni Mo 22-05, W. Nr 1.4462 ; VdTÜV Blatt 418, ASTM A240 - UNS S31803

Vendors: No vendors are listed for this material. Please click here if you are a supplier and would like information on how to add your listing to this material.

Physical Properties	Metric	English	Comments
Density	7.80 g/cc	0.282 lb/in^3	

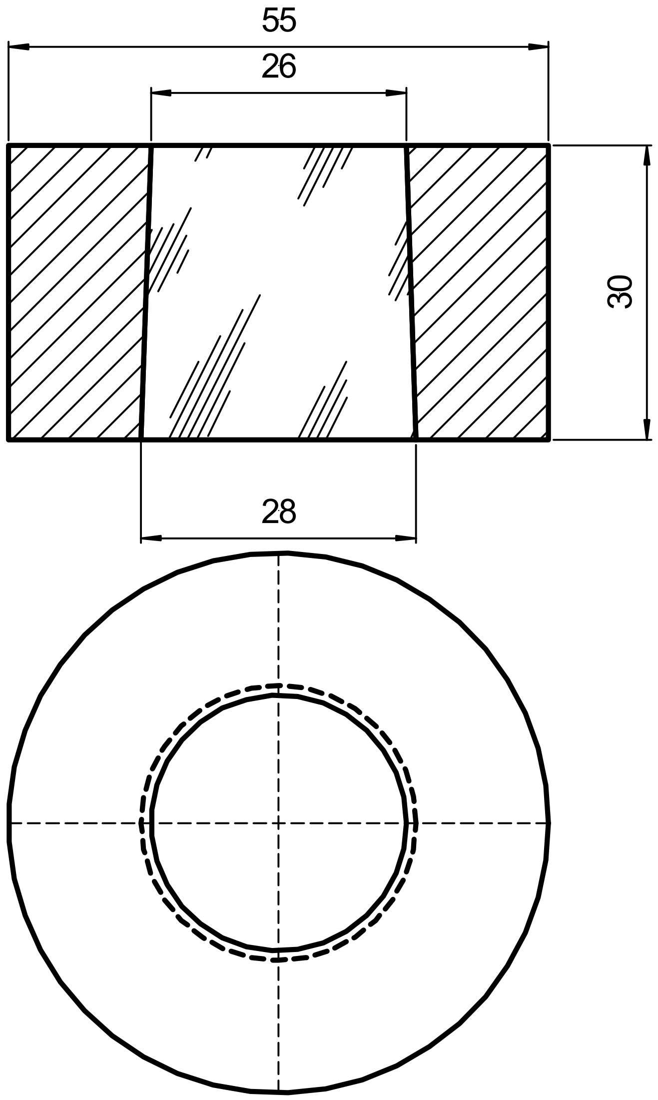
Mechanical Properties	Metric	English	Comments
Hardness, Brinell	210 - 240	210 - 240	Typical
Hardness, Rockwell C	15.0 - 20.0	15.0 - 20.0	Typical
Tensile Strength, Ultimate	>= 680 MPa	>= 98600 psi	
Tensile Strength, Yield	>= 460 MPa	>= 66700 psi	Y.S. 0.2%
	>= 490 MPa	>= 71100 psi	Y.S. 1%
Elongation at Break	>= 25.0 %	>= 25.0 %	
Modulus of Elasticity	200 GPa	29000 ksi	
Poissons Ratio	0.333	0.333	Calculated
Charpy Impact	>= 120 J	>= 88.5 ft-lb	
	150 J	111 ft-lb	Typical
	>= 75.0 J @Temperature -50.0 °C	>= 55.3 ft-lb @Temperature -58.0 °F	
	90.0 J @Temperature -50.0 °C	66.4 ft-lb @Temperature -58.0 °F	Typical
Shear Modulus	75.0 GPa	10900 ksi	20°C

Electrical Properties	Metric	English	Comments
Electrical Resistivity	0.0000800 ohm-cm @Temperature 20.0 °C	0.0000800 ohm-cm @Temperature 68.0 °F	

Thermal Properties	Metric	English	Comments
CTE, linear	13.5 µm/m-°C @Temperature 20.0 - 100 °C	7.50 µin/in-°F @Temperature 68.0 - 212 °F	
	14.0 µm/m-°C @Temperature 20.0 - 200 °C	7.78 µin/in-°F @Temperature 68.0 - 392 °F	
	14.5 µm/m-°C @Temperature 20.0 - 300 °C	8.06 µin/in-°F @Temperature 68.0 - 572 °F	
Specific Heat Capacity	0.450 J/g-°C @Temperature 20.0 °C	0.108 BTU/lb-°F @Temperature 68.0 °F	
Thermal Conductivity	17.0 W/m-K @Temperature 20.0 °C	118 BTU-in/hr-ft^2-°F @Temperature 68.0 °F	

Component Elements Properties	Metric	English	Comments
Carbon, C	0.020 %	0.020 %	
Chromium, Cr	22.0 %	22.0 %	
Iron, Fe	69.518 - 69.52 %	69.518 - 69.52 %	
Molybdenum, Mo	3.0 %	3.0 %	
Nickel, Ni	5.30 %	5.30 %	
Nitrogen, N	0.16 %	0.16 %	
Sulfur, S	<= 0.0020 %	<= 0.0020 %	

Appendix F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26
30
28

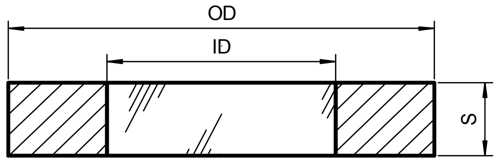
METAGLAS SIGHT GLASS DISC

RING MATERIAL: Duplex Stainless Steel (1.4462)

GLASS: Borosilicate Glass (DIN 7080)

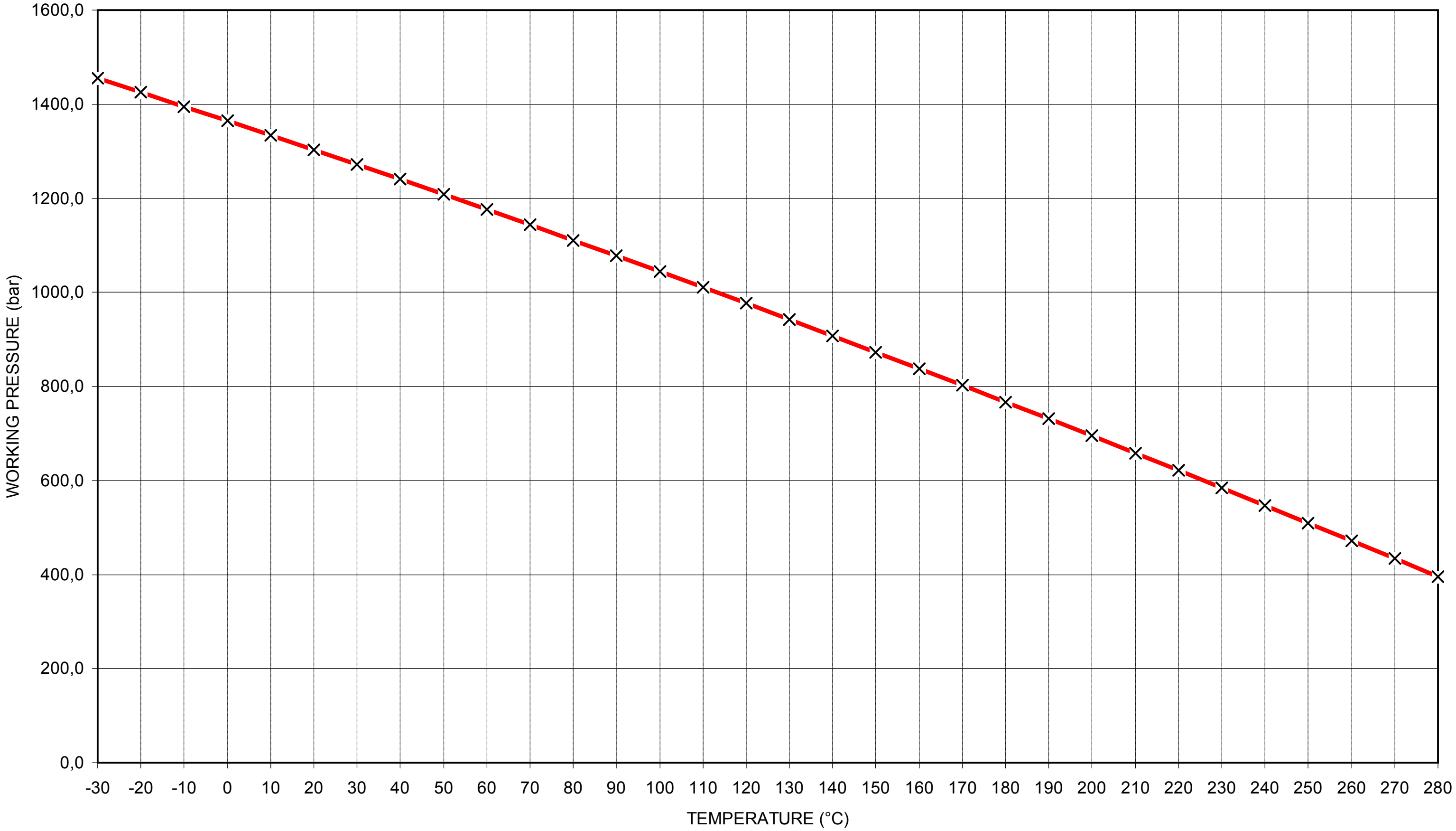
DIMENSIONS

OD	ID	Thickness	
50	25	30	(mm)
1,97	0,98	1,18	(inch)



No. 79

TEMPERATURE (°C)	TEMPERATURE (°F)	MAX. WORKING PRESSURE (bar)	MAX. WORKING PRESSURE (psi)
-30	-22	1455	21096
-20	-4	1425	20665
-10	14	1395	20229
0	32	1365	19788
10	50	1334	19344
20	68	1303	18894
30	86	1272	18440
40	104	1240	17982
50	122	1208	17519
60	140	1176	17052
70	158	1144	16581
80	176	1111	16105
90	194	1078	15625
100	212	1044	15141
110	230	1011	14653
120	248	977	14160
130	266	942	13663
140	284	908	13163
150	302	873	12658
160	320	838	12149
170	338	802	11636
180	356	767	11119
190	374	731	10598
200	392	695	10073
210	410	658	9544
220	428	621	9012
230	446	585	8475
240	464	547	7935
250	482	510	7392
260	500	472	6844
270	518	434	6293
280	536	396	5738



CHANGE	DESCRIPTION OF CHANGE	DATE	NAME

MANUFACTURED BY:

METAGLAS® SIGHT GLASS DISC

	DATE	NAME
DESIGNED	16.10.2008	Schuller
CHECKED		

Stress Calculations for Metal Fused Sight Glass Discs

Fused metal sight glass discs are used in many sectors of the chemical and pharmaceutical industries. They provide an alternative to the thermally stressed sight glass discs made to DIN 7080.
Thermally stressed discs fail suddenly once a crack appears, whereas the fused metal glasses, when damaged, suffer surface cracks but not total failure.

As opposed to thermally stressed sight glass discs, the fused metal glasses are subject to compression stresses resulting from the difference in thermal expansion coefficients of the metal and glass. The difference in operational properties between the thermal and mechanical stressing sight glass discs can be explained by the residual stress which results from the manufacturing process; in the case of the thermally stressed sight glass discs, the heated blank is quenched by air applied to the outer surface which shrinks and simultaneously shocks the still hot and soft core area. During further cooling the surface area is subject to compression stress and the core sector under tensile stress. The resulting equilibrium is illustrated in figure 1 (left hand section, curve b).

In the production of metal fused sight glasses, the steel ring and glass are heated up to the necessary melting temperature where the glass flows onto the steel ring. During the cooling of the composite mass, when a point is reached below the so called inversion temperature the glass comes under compression stress due to the different yet suited expansion coefficients of steel and glass; the level of this stress is proportional to the impeded heat expansion. At the same time the steel ring comes under tensile stress. The mechanically stressed sight glass disc comes under a homogeneous compression stress which applies homogeneously across the whole cross section (shown in diagram 1, right hand section curve b where the horizontal lines signify the stressed area). Due to the effect of bending loads on the beginning of a crack in the case of the thermally stressed disc the crack comes under tensile stress whilst in the case of the mechanically stressed disc the crack will be under compressive stress (load stress curve in each case represented by a; load and residual stress resultant curves in each case represented by c, yellow stress area*). That means that in the case of the thermally stressed disc the limiting value Klc for sudden "overcritical" crack formation is exceeded, inother words, the disc will shatter.

In the case of the mechanically stressed disc, the crack formation resulting from the localised exceeding of the breaking strength factor Klc will enter an area limited by the compression stress, with the result that the breaking mechanics – load factor Kj becomes smaller again than the breaking strength factor Klc – and the crack development is halted. Every effort to extend the crack requires renewed energy supply in form of pressure increase. A sudden bursting of the disc is thus unlikely so long as the compression stress condition is maintained.
In the production of fused metal sight glasses, steel ring and glass are heated together to the temperature where the glass liquefies and begins to flow onto the steel ring. This is followed by a relatively quick cooling of the parts which ensures the retention
by the ring material of its mechanical strength. The glass is compressed as it solidifies by the steel ring. The cooled sight glass discs are then ground and polished on both faces to produce a clean glass.
After the cooling process the geometry of the structural parts is demonstrated in figure 2.

The metal surround, because of its greater thermal expansion coefficient, compresses the glass disc not just radially; it is responsible for setting up forces at right angles to the glass surface around the joint area. The result is that around this border area the glass is subjected to compression stress and the metal to tensile stress.
The stress condition can be recognised in shape distortion of the visible surface. The change in thickness around the joint area causes a slight convex form which even grinding of the surface will not entirely remove. The "new surface" created by the manufacturing process inevitably follows the effective forces acting upon it.

FEM – investigations (4) into fused metal sight glass discs show that the compressive stress is not unconnected with the radius and spacing coordinates at right angles to the glass surface.
Figure 3 shows the typical course of radial stress in the glass surface, indicated as compression stress by the minus sign.
From the centre of the glass a relatively large area of constant stress can be recognised. Close to the glass edge i.e. one or two millimetres from the separation area bordering the steel, the stress is shown to be at a distinct minimum. Further toward the steel rim, the compression stress rises at a steep gradient again, and indeed over the value at the centre of the glass.

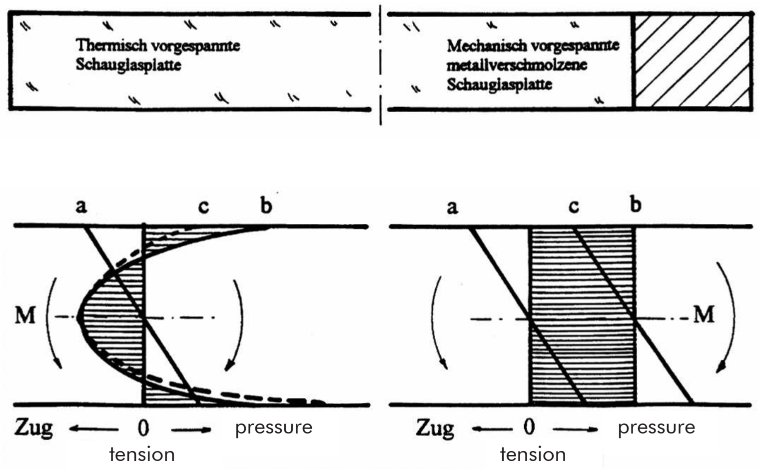


Figure 1

Schematic representation of stress distribution in direction of thickness for thermal (left) and mechanical (right) stressing of a sight glass disc

a bending stress progression resulting for one sided compression application,

b residual stress progression created by the manufacturing process,

c overlap of load stress and residual stress progression

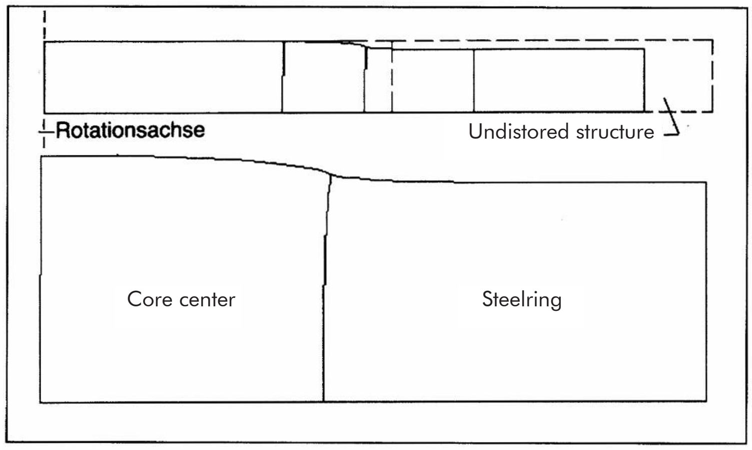


Figure 2

Distorted and undistorted structure

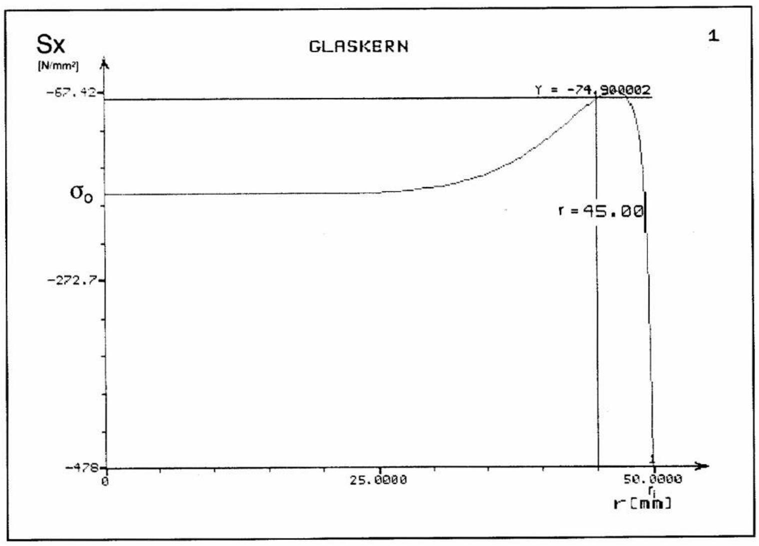


Figure 3

Curve of Sx stress relative to glass centre (on glass surface)

Figure 4

Radial Stress distribution at the transition of steel ring and glass core

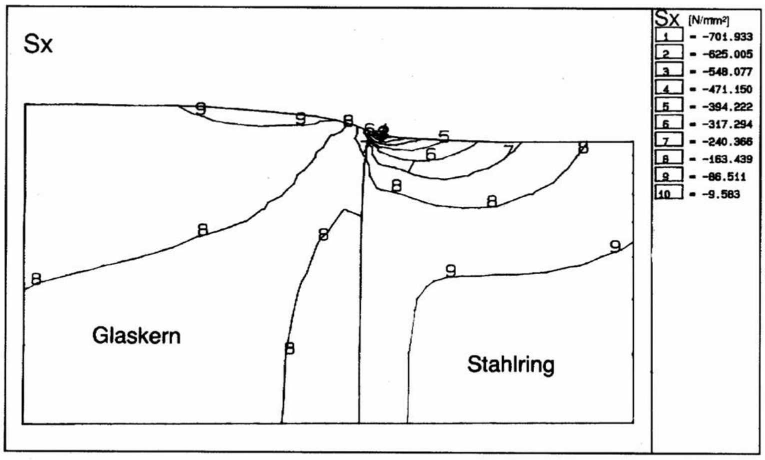


Figure 5

Radial Stress distribution in glass core (section from fig.4)

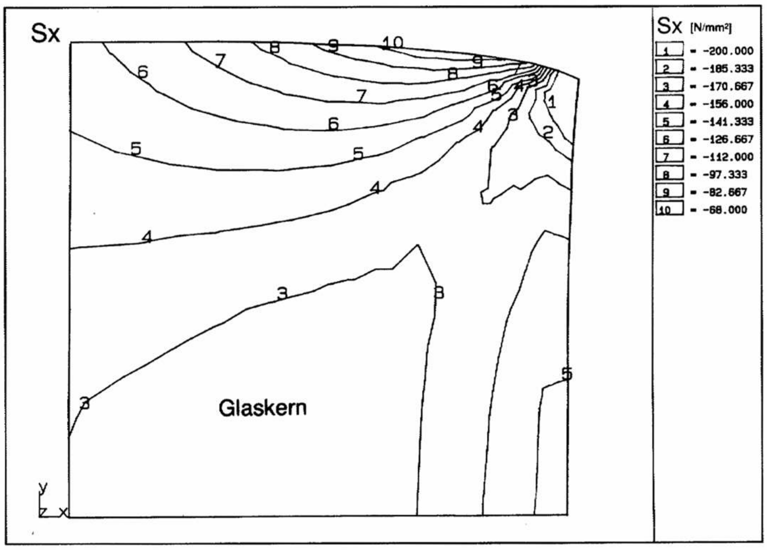


Figure 4 shows the lines of equal radial stress at the transition from glass to steel.

Figure 5 is an enlarged section of the stress diagram from fig 4.

From fig 5 it is possible to recognise the concentration of stress near the glass - metal joint. These stress peaks are concentrated in a very specific area of the steel – glass transition (Fig 6).

If this zone is subjected to further stress e.g. temperature shock, mechanical loading, it can, in some cases lead to crack formation or even in the glass or even flaking off splinters. These however remain limited to a range of a few millimetres, as the further tendency to cracking is prevented by the adjacent compression stress.

The formation of stress cracks can be minimised by “fire polishing” a concave glass surface tin the critical stress zone.

Fig. 8 and Fig. 9 show glasses slightly damaged.
No risc for further use.

If the surface glass breaks up into larger flakes, as shown in Fig.10, the sight glass should be exchanged, although even here there is yet no risk to safety.

Fig.11 shows a glass which has been attacked by chemical corrosion and has lost more than 50% of its bulk.
Therefor must be exchanged (hight risc)

Figure 6

Zones of critical stresses

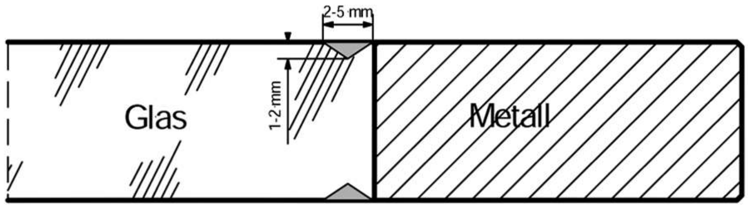


Figure 7
"fire polished glass surface"

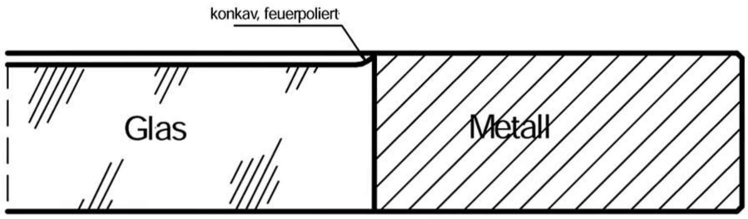


Figure 8
Circular (conentric) cracks

Figure 9

Circular cracks and break away at the edge

Fig. 8

Fig. 9

Figure 10
the surface glass breaks up into larger flakes

Figure 11
shows a glass which has been attacked by chemical corrosion

Fig. 10

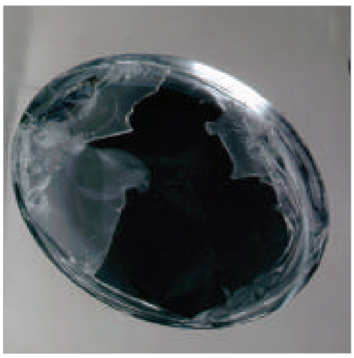
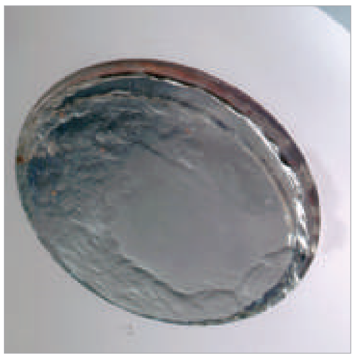


Fig. 11



Load bearing capacity

Normal sight glasses which are secured by flanged components between gaskets (DIN 28120) must be treated as lying freely when bending occurs under one sided pressure, even when subjected to high compression forces. On the other hand glasses in pressure glass systems can be considered as clamped around the edge, so long as the pressure ring itself is not significantly distorted under load.

If the loading of a sight glass e.g. up to the level of its compression stress, (distortion in the linear elastic zone), is permitted and provided glass dimensions and stressing are the same, then if the assumption in the previous paragraph is fully valid, the load on the pressure glass system can be increased by a factor 0.303/0.188 = 1.6. The constants 0.303 and 0.188 originate in the calculation fundamentals for disc bending under even loading of free lying and tightly clamped discs.

Under the above assumptions, fused metal sight glass discs can be loaded up to the point of decline of their calculated compression stress values (that means near to their bursting pressure) with the following pressure (above atmospheric) from one side:

$$p = -\frac{\tau_G \cdot s^2}{0{,}188 \cdot 4 r_1^2}$$

When calculating the maximum permissible operating pressure a safety factor of 8 is used.

Calculation of stress in glass and steel

For the calculation of tangential and radial stresses in glass, tg and pg as well as critical tangential stresses in steel ts1 at r1, the Adam's calculation fundamentals(1)(2) must be used

$$\tau_G = \rho_G = \frac{(\alpha_G - \alpha_S)\ (T_i \quad T)}{\dfrac{-2 \cdot \mu_G + 1}{E_G} + \dfrac{-2 \cdot \mu_S \dfrac{r_1^2}{r_2^2} + \left(1 + \dfrac{r_1^2}{r_2^2}\right)}{E_M \cdot \left(1 - \dfrac{r_1^2}{r_2^2}\right)}}$$

und

$$\tau_{S1} = -\tau_G \cdot \frac{1 + \dfrac{r_1^2}{r_2^2}}{1 - \dfrac{r_1^2}{r_2^2}}$$

E [N/mm2]	modulus of elasticity
μ	Poisson ratio
α 20/300 [K-1]	coefficient of thermal linear expansion
Ti	inversion temperature
r1	inner radius of metal ring
r2	outer radius of metal ring
T	operating temperature

Summary

Mechanically stressed sight glasses provide an increase in safety when compared with thermally stressed sight glasses. The appearance of concentric surface cracks in the zone around the glass edge is not due to manufacturing faults but the result of the different relationship of glass and metal to heat. The expansion coefficient of steel at temperatures under 400 °C is greater than that of glass by a factor of 2 to 3. This results in the metal shrinkage being greater than that of glass. This shrinkage is not only radial but axial which leads to tensile stresses in the surface of the glass at the transition of glass and metal. Since glass can take high compression stresses but only low tensile stresses, stress cracks can appear on the glass surface.

These hairline cracks remain restricted to a narrow zone in the glass metal area and cause only little reduction in the toughness of the sight glass. Exchange of the glasses only becomes necessary when the transparency of the glass is affected by splinters flaking away, or if V shaped sliver break out of the glass, reducing its thickness markedly.

Since, in practice, other factors affect the glass, such as chemical erosion by hot lyes, condensate or acidic solutions, it is vital that the glass is checked to determine a suitable down period for each individual vessel so that – subject to equal operational sequences and conditions - a glass exchange routine can be realised.

References

[1] Adam: Theoretische Grundlagen der Druckglaseinschmelzung, Feinwerktechnik 56 Heft 2 (1952)
[2] Untersuchungsbericht der Fa. Schott; Bericht über die Untersuchung an einem stahlgefaßten Schauglas in Druckglastechnik vom 23.3.1982
[3] DIN 7079: 1996-02 Runde, metallverschmolzene Schauglasplatten für Druckbelastung
[4] Schwellenbach, Paul: Spannungsberechnungen und Ermittlung der Inversionstemperaturen an metallverschmolzenen Schauglasplatten in Zentrales Ingenieurwesen - Techn. Überwachung der Bayer AG - Jahresbericht 1989
[5] Stallmann, Klaus: Sicherheitsgewinn durch Einsatz metallverschmolzener Schauglasplatten in Chem.-Ing.-Tech. 60 (1988) Nr.2, S 132-137

Appendix G in R

Appendix H in R

Appendix I in R

Appendix J in R

Appendix K in R

Appendix L

MINUTES OF MEETING

Project: SE10-10
Contract: FMC Technologies
Report: 1

Subject

Hovedoppgave

Meeting date:	20. Oktober 2009	Printed:	29.10.09	Location:	HIBU - Kongsberg

Written by:	SE10-10	Sign:	Date: 29.10.09

ITEM	MINUTES	ACTION	DUE
	10/09-09 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 1130-1300		
1	Møte med FMC	Alle	--
	Vi var interessert i prosjektet, og ordnet møte med Odd-Jan Kirkaune. Vi fikk en kort introduksjon på hva prosjektet handlet om. Vi ble enige om å ta prosjektet.		
	17/09-09 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0815-1430		
2	Prøver å sette oss mer inn i prosjektet, finne ut hvordan systemet fungerer.	Alle	--
3	Skriver ned spørsmål til Odd-Jan.	Alle	24/09
	24/09-09 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 1130-1300		
4	Møte med FMC	Alle	--
5	Odd-Jan besvarer våre spørsmål, og vi får et bedre innblikk i prosjektet.	Alle	--

6	**1/10-09 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0815-1430** Vi setter oss inn i hva som skal gjøres frem til jul. Vi har noen spørsmål angående prosjektideen som må vises til Olaf.	Alle	8/10
7	**8/10-09 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0815-1430** Begynner med prosjektide. Vi fordeler de forskjellige avsnittene på hverandre.	Alle	18/10
8	**15/10-09 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0815-1430** Gjør oss ferdige med prosjektideen.	Alle	18/10
9	**22/10-09 – Anders Eriksen, Alexander Sjøberg og Marius Østerud. 0815-1200** Starter på forstudien.	AE,AS,MØ	1/11
10	Magnus er borte, og får egne oppgaver.	MB	1/11
11	**29/10-09 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0815-1200** Gjort oss ferdige med forstudie.	Alle	1/11
12	**05/11-09 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud, Marius Østerud. 1130-1300** Møte med FMC	Alle	16/12
13	**16/12-09 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0815-1300** Hatt første møte med intern veileder. Fått tilbakemelding på forstudie. Fått informasjon på diverse ting. Funnet internettside.	Alle	16/12
14	Kravspek er nesten ferdig, mangler kun vedlegg		4/1
15	**17/12-09 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 1130-1300** Møte med FMC	Alle	-
16	**28/12-09 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0815-1500** Alle vedlegg til kravspek er ferdig Jobber med prosjektplan	AS AE,MB,MØ	4/1 11/1

17	**07/01-10 –Magnus Bjerkerud og Marius Østerud. 0815-1300.** Begynner arbeid med presentasjon 1	MØ,MS	11/1
18	**08/01-10 – Anders Eriksen, Alexander Sjøberg og Magnus Bjerkerud. 0815-1400** Prosjektplan er ferdig	AE,AS,MB	-
19	Sender foresprøsel vedrørende når presentasjon 1 skal framføres. Sender mail til ekstern veileder og foreslår 14/1-10	AE,AS,MB	-
20	**20/01-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0815-1200** Ferdig med egen webside, som skal benyttes som informasjonskanal,	Alle	21.01
21	**20/01-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0815-1200** Presentasjon 1 har blitt satt til mandag 25.01.10	Alle	15.01
22	**25/01-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0930-1000** Gjennomført presentasjon med med ekstern veileder, intern veileder og sensor	Alle	25.01
23	**03/02-10 – Anders Eriksen, Magnus Bjerkerud, Marius Østerud og Alexander Sjøberg. 08.00-1130** Gruppen har funnet en mulig laser(flight time), som del av løsningsforslag på prosjektet. Dette skal diskuteres på neste møte med ekstern veileder	Alle	-
24	**03/02-10 – Anders Eriksen, Magnus Bjerkerud og Marius Østerud. 08.00-1130** Forbereder oss til møtet i morgen, skriver ned spørsmål	AE,MB,MØ	04.02

25	**04/02-10 – Anders Eriksen, Alexander Sjøberg og Marius Østerud. 1130-1400** Møte med FMC, vi diskuterer modifikasjonen på laseren, og hvilken materiale housingen vil bestå av. Diskuterer også hva som skal være tilgjengelig på hjemmesiden.	AE,MØ,AS	-
26	**10/02-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0930-1400** Starter med valg av design og komponenter.	Alle	22.02
27	**11/02-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud. 0930-1500** Møte med Odd-Jan. Diskuterer egen strømforsyning og hvor overgangen mellom grensesnittene på RS-232 og RS-485 skal ligge.	AE,AS,MB	-
28	**17/02-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0930-1400** Fortsetter med valg av design og komponenter.	Alle	22.02
29	**18/02-10 – Anders Eriksen, Alexander Sjøberg og Marius Østerud. 1130-1300** Møte med Odd-Jan. Vi finner ut en ny ordning på og feste housingen til akkumulatoren som er bedre enn butec koblinger. Vi diskuterer en annen type laser som kan være relevant.	AE,AS,MØ	-
30	**24/02-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0900-1400** Starter med designet av housingen og flensen i Solidworks.	Alle	26.03

	25/02-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0900-1400		
31	Fortsetter med designet av housingen og flensen i Solidworks. Diskuterer ulike løsninger.	Alle	26.03
	3/03-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0900-1300		
32	Magnus og Marius starter med presentasjon 2.	MB,MØ	24.03
33	Marius starter å designe prototype.	MØ	26.04
34	Anders og Alex fortsetter med designet av housingen og flensen i Solidworks.	AE,AS	26.03
	4/03-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0900-1400		
35	Møte med Odd-Jan. Diskuterer leverandør av koblingspenetrator, størrelsen på prototype og om metaglasset vil holde under trykk.	Alle	-
	10/03-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0900-1400		
36	Magnus og Marius fortsetter med presentasjon 2 og prototypen.	MB,MØ	24.03
37	Anders og Alex fortsetter med designet av housingen og flensen i Solidworks.	AE,AS	26.03
	11/03-10 – Anders Eriksen, Magnus Bjerkerud og Marius Østerud. 0900-1400		
38	Møte med Odd-Jan, vi diskuterer leverandører av materiale til prototype, og dimensjoner/boltstørrelser til housing.	AE,MØ,MB	-
39	Diskuterer grensesnittet mellom laser og PC (RS-232/RS-485/RS-422).	AE,MØ,MB	-

	17/03-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0900-1500		
40	Alex og Anders forsetter med designet av housingen.	AE,AS	26.03
41	Magnus og Marius jobber fortsetter med presentasjon 2.	MB,MØ	24.03
42	Marius finner materialer til prototype.	MØ	26.04
	18/03-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0900-1500		
43	Magnus og Marius drar på møtet med Odd-Jan for å få svar på noen spm, og for å kikke på laseren som har kommet.	MB,MØ	-
44	Marius og Magnus oppdaterer dokumenter og websiden.	MB,MØ	-
45	Alex og Anders forsetter med designet av housingen.	AE,AS	26.03
	23/03-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0900-1500		
46	Gruppen forbereder seg til presentasjon 2.	Alle	24.03
	24/03-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0900-1600		
47	Gruppen fremfører presentasjon 2. Olaf poengterer at vi må dokumentere valg av laser og andre valg bedre. Mentorene og Olaf virker fornøyd med resten.	Alle	-
	12/04-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0800-1500		
48	Anders og Alexander begynner med trykktesting av housingen og flensen.	AE,AS	15.04
49	Marius og Magnus starter med å koble sammen ledningene som skal koble sammen laseren med programmet Hyperterminal på Pc'en.	MB,MØ	26.04
	13/04-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0800-1500		
50	Anders og Alexander fortsetter med trykktesting av housingen og flensen.	AE,AS	15.04

51	Marius og Magnus fortsetter med å koble sammen ledningene som skal koble sammen laseren med programmet Hyperterminal på Pc'en. De velger også ut hva som skal bestilles av plastikk til prototypen.	MB,MØ	26.04
52	Marius utfyller rapporten som viser til valg av laser.	MØ	-
	14/04-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0800-1600		
53	Anders og Alexander fullfører trykktestingen.	AS,AE	15.04
54	Magnus og Marius fullfører sammenkoblingen av ledningene som gir strøm og signaler til laseren, laseren fungerer.	MB,MØ	26.04
55	Marius og Magnus bestiller pleksiglass delene som skal brukes til prototypen av Astrup A/S.	MB,MØ	26.04
	19/04-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0800-1600		
56	Anders og Alexander lager maskineringstegning til c-ring.	AE,AS	-
57	Marius og Magnus setter seg inn i kommandoene i programmet til laseren. Testing av laser.	MB,MØ	26.04
	22/04-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0800-1400		
58	Møte på FMC med Odd Jan	AE,AS, MØ,MB	-
	26/04-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0800-1200		
59	Maskineringstegning til flens for prototype sendes Odd Jan for bestilling	AE, AS	-
60	Tilpasse øvrig deler til prototype gjøres ferdig	MØ,MB	-
	11/05-10 – Anders Eriksen, Alexander Sjøberg, Magnus Bjerkerud og Marius Østerud. 0900-1200		
61	Usikkerhet på om laseren kan måle igjennom et hull på 25mm, Marius og Magnus må teste om det er mulig. Fortsetter på prototypen.	MØ,MB	-

62	Anders og Alexander starter på innlevering 3. **18/05-10 – Anders Eriksen, Alexander Sjøberg og Marius Østerud. 0900-1200**	AE, AS	28.05
63	Fortsetter på innlevering 3. Anders skriver FEM rapport, Marius skriver kommunikasjonsrapport og Alex skriver om nuts and bolts.	AS,AE, MØ	28.05

Appendix M in R

Appendix N

Re: Acuity Contact Inquiry: Worldwide

Fra: **Kim Grundström** (kim.grundstrom@cheos.fi)
Sendt: 14. april 2010 13:03:39
Til: Anders Eriksen (anders_1000000@hotmail.com)
Hello Anders,

Are you sure the power connection is correctly wired? The red laser beam should turn on when applying
the power to the unit? Is the power supply still giving 20 V when it is connected to the AR1000, e.g. is there
enough of current available as well? Not more than 150 - 200 mA is needed.
If there is no red beam output no measurements can be done.

It seems that there is no power connected to the unit.....

Have you tried a straight RS-232 connection without the USB conversion in between?

This is odd, there is never any problem with this sensor....

Best regards,
Kim

----- Original Message -----
From: Anders Eriksen
To: kim.grundstrom@cheos.fi
Sent: Wednesday, April 14, 2010 1:20 PM
Subject: RE: Acuity Contact Inquiry: Worldwide

Hello

We received the laser(AR1000), and have tried to test it with basic rs-232 and microsoft hyperterminal.
We have problems with making it work, the laser will not turn on (we do not see a red laser emitted).

The powersupply used is giving 20 volts, and we installed it using the diagram in the manual (blue to ground, and orange to Vdc)
We even tried it with the basic analog setting (power, and using the red wire to measure mA). We get a constant readout of 4mA, not matter where we point the laser.

We tried different computers, with the basic DB-9 connector (using connector 2(green),3 and 5(gray), and wiring together 7 to 8 and 1,4 and 6), and a usb to db-9 converter, but we cannot seem to get a connection with Hyperterminal (We tried several commands described in the manual, but no response).
We used the standard settings with 9600 baud, ect....

We really don't know where to go from here.

Do you have any suggestions? Troubleshooting?

regards

Anders.

FW: SV: Bestilling

Fra: **Magnus Bjerkerud** (magnusbjerkerud@hotmail.com)
Sendt: 14. april 2010 13:21:20
Til: anders_1000000@hotmail.com

Subject: SV: Bestilling
Date: Wed, 14 Apr 2010 13:04:27 +0200
From: Kai.Remen@astrup.no
To: magnusbjerkerud@hotmail.com
CC: oddjan.kirkaune@fks.fmcti.com

Takk for bestillinen

Ordrebekreftelse er sendt FMC Kongsberg Subsea ved Odd Jan Kirkaune.

Mvh
Kai Remen

Fra: Magnus Bjerkerud [mailto:magnusbjerkerud@hotmail.com]
Sendt: 14. april 2010 11:40
Til: Kai Remen; Odd Jan Kirkaune
Emne: Bestilling

Hei.

Da bestiller vi herved følgende:

1. Plexiglass rør: 200mm(utvendig diameter) * 1m(lengde)

PMMA RØR EX 200X190MM, kr 1245,- pr m - 25% + kappetillegg kr 1,- pr mm dia.

kr 1245,- + kr 200,- = kr 1445,-

2. Plexiglass rør: 120mm(utvendig diameter) * 0.5m (lengde)

PMMA RØR EX 120X110MM, kr 826,- pr m - 25% + kappetillegg kr 1,- pr mm dia.

kr 413,- + kr 120,- = kr 533,-

3. Plate: 6mm * 1000mm * 1220mm

PMMA PL ST KLAR 0000 6x1000x1220 mm,   kr 765,- pr kvm - 25%

kr 765,- * 1.22kvm = kr 934,- (Denne kapper vi selv)

4. Blokk/bolt av transparent plast: 120mm diameter * 200mm lengde

Massiv blokk/bolt i PMMA støpt koster for: ø 120 mm kr   7745,- pr m

200 mm lengde mot kappekostnad kr 150,-

kr 7745,- * 0.2m + kr 150,- = kr 1699,-

Total pris: kr 4611,- (Uten prisavtalen med FMC)

Regningen kan sendes til FMC Kongsberg ved Odd Jan Kirkaune,
regner med at prisavtalen med FMC da gjelder?

Mvh. Magnus.

Fra: **Van Thillo Kris** (kris.htms@pandora.be)
Sendt: 14. april 2010 21:32:06
Til: Anders Eriksen (anders_1000000@hotmail.com)
1 vedlegg
CI & CE s...JPG (59,0 kB)

Hi Anders,

Please find hereby our proposal.

For the seal which have to seal the outside pressure and sea water, we propose a CE-seal in Alloy 625 with a silver plating.

And for the inside pressure seal for Nitrogen, we propose a CI-seal in Alloy 718 with a silver plating.

Please find attached the drawing of the groove dimensions and the seal part numbers.

When you advise us the quantity, we will make a price offer.

Please advise if you have some questions.

Best regards,

Kris.

---------------------- **Original Message** ----------------------

From: Anders Eriksen <anders_1000000@hotmail.com>
To: <kris.htms@pandora.be>
Date: Wed, 14 Apr 2010 18:51:20 +0200
Subject: **RE: Cylinder seals**

Hi.

-according to NACE? what does it means?
-There are dry nitrogen inside.
-temp are 4 degree celsius

Best regards
Anders Eriksen

Date: Wed, 14 Apr 2010 18:01:33 +0200
From: kris.htms@pandora.be
Subject: Cylinder seals
To: anders_1000000@hotmail.com

Hi Anders,

Thank you for the drawings and dimensions.

Before I will make a proposal and give the groove dimensions, we would like to ask you the following:

-Is there a need for material according to NACE?
-Which medium is there inside ?
-Temperatures?
-Please advise the quantity needed? For the price calculation.

Than you in advance.

Best regards,

Kris.

P Save a tree...please don't print this e-mail *unless you really need to*

----------------------- **Original Message** -----------------------

From: Anders Eriksen <anders_1000000@hotmail.com>
To: <kris.htms@pandora.be>
Date: Tue, 13 Apr 2010 11:57:14 +0200
Subject: **RE:**

Here are the drawings, i hope you are able to understand them.
4 drawings, two sets of c-rings between a first face and the oppositing face.

Best Regards
Anders Eriksen

Date: Mon, 12 Apr 2010 09:57:41 +0200
From: kris.htms@pandora.be
Subject: FWD: RE:
To: anders_1000000@hotmail.com

Hi Anders,

Thank you for the feedback.

We will wait for the drawings.

Best regards,

Kris.

---------------------- **Forwarded Message** ----------------------

From: Anders Eriksen <anders_1000000@hotmail.com>
To: <kris.htms@pandora.be>
Date: Mon, 12 Apr 2010 09:52:24 +0200
Subject: **RE:**

Hello.

I doesnt have access to my drawings today, so i will mail you another set tomorrow, i need two sets of c-ring one for the bottom and one for the
top of the sylinder. there are to be back to back, so that they will protect for leakage
both ways(internal and external).

- The pressure inside the system is 1atm, and the external pressure, due to the column of the seawater are up to 275 bars.
- The material need to be able to withstand corrosion from seawater for 25 years
- there will be used 8 bolts with materialgrade L7M quality and the nut is to be A4-80 grade. The torque to be used will be determined from the need to press the c-ring down until its complety tightened.
- temperatur is constant about 4 degree celsius

Best regards
Anders Eriksen

Date: Tue, 23 Mar 2010 20:04:08 +0100
From: kris.htms@pandora.be
Subject: re: FW:
To: anders_1000000@hotmail.com

Hi Anders,

Thank you for the drawing.

Could you advise me about the following:
-Pressure inside the system.

-Is there a need for material according to NACE?
-How many bolts do you have and what is the size, quality and torque used?
-Which medium is there inside the housing and which outside?
-Temperatures?
-Please advise the quantity needed?

Thank you in advance.

Best regards,

Kris.

P Save a tree...please don't print this e-mail *unless you really need to*

---------------------- **Original Message** ----------------------

From: Anders Eriksen <anders_1000000@hotmail.com>
To: <kris.htms@pandora.be>
Date: Fri, 19 Mar 2010 00:30:55 +0100
Subject: **FW:**

Hello.

I put the drawing in a word document.
I hope this will help you in determining which c-ring i need to use, due to the dimensions.
The measurements are all inn mm.

Best regards
Anders Eriksen

Få nye Windows Live™ Messenger. Last ned her.

Få nye Windows Live™ Messenger. Last ned her.

From:	Suzanne Horrigan <shorrigan@ljstar.com>	**Sent:**	Tue 04/05/10 18:11
To:	"alexander_sjoberg@epost.no" <alexander_sjoberg@epost.no>	**Priority:**	Normal
Subject:	RE: Metaglas Sight Glass Discs	**Type:**	Attachments
Attachments:	angebot 1010631 star.pdf 70.1 kb Prospekt März 2006 Metaglas Englisch2.pdf - Adobe Acrobat.pdf 1134.3 kb		

Hello,

Below is the price for the metaglas disc you requested and attached is the drawing, pressure / temp chart and stress calculations.

Qty: 1 ea.
Metaglas Disc
Size: 55mm (OD) x 26/28mm (View) x 30mm (Thick)
Material: Duplex Stainless Steel (1.4462)
Design Pressure: 620 bar @ 200C
Price: $285.00 Net Each
Delivery: 6 Weeks

If you have any questions or need additional information please feel free to contact me.

Suzanne Horrigan, *Administrative Assistant*
LJ Star Incorporated
PO Box 1116 | Twinsburg OH 44087
330.405-3040 | 330.405-3070
shorrigan@ljstar.com | http://www.ljstar.com

From: Alexander Sjøberg [mailto:alexander_sjoberg@epost.no]
Sent: Monday, May 03, 2010 3:47 AM
To: TechInfo
Subject: Metaglas Sight Glass Discs

Hello,

We are doing our bachelor thesis withinin engineering in collaboration with FMC Technologies, and for our construction we need a Metaglas Sight Glass Disc. Viewing diameter is 25,9mm and it has to withstand a pressure of 620 bar. Can you please send us a technical drawing of the dimension we need? We also need some specifications of the

Metaglas if you have that, like tensile strength, yield strength and so on.

Kind regards

Alexander Sjøberg

From:	"Torill Finnerud" <torill.finnerud@proffpartner.no>	**Sent:**	Wed 17/03/10 12:50
To:	<alexander_sjoberg@epost.no>	**Priority:**	Normal
Subject:	SV: SV: M15 bolter	**Type:**	Embeded HTML/Text

Ok… Alle L7 kvaliteter blir brukt offshore…

Materiale A4-80 (syrefast) M12
Lender:
20-25-30-35-40-45-50mm (med helgjenget lengde)
60-70-80-90-100-110-120-130-140-150mm (delgjenget)

Disse er de lengdene som er greie å få tak i, stort sett.

I grade L7 materialer kan du få den lengden du vil. Dette er et materiale som ikke finnes i bolter normalt, så de må lages.
Hvis du kan bruke grade 8.8 (det er det vanlige bolter er lage av… noen kaller det carbon bolter) er de i samme lengder som A4-80 + opp til ca. 200mm (hver 10mm oppover)

Hvis dette er et prosjekt dere planlegger for subseabruk for eksempel er det mange tilleggskrav til en bolt, så det forbauser meg hvis dere kan bruke en standard bolt.
Hvis det er offshore/subseabolt er det som regel krav om en spesiell produksjonmåte (testing av råmaterial) max hårdhet, Mpi testing av ferdiglaget skrue. Batchmerking-batch traceabillity sertifikater i "bøtter og spann" osv…
Hvis det er tilfelle, så kan dere også velge lengde, for da må skruene lages okke som.

Med vennlig hilsen / Regards
ProffPartner AS
Torill Finnerud
Tlf: + 47 982 97964
http:\\www.proffpartner.no

Fra: Alexander Sjøberg [mailto:alexander_sjoberg@epost.no]
Sendt: 17. mars 2010 12:35
Til: Torill Finnerud
Emne: Re: SV: M15 bolter

Da tror jeg faktisk vi vil gå ned til M12. Den ene kvaliteten er A4-80, den andre er jeg ikke helt sikker på da. Er det noen av de(L7, L7S, L7M) som blir brukt mest offshore? Hvis ikke går vi ut ifra at det er L7M.

On Wed 17/03/10 12:09 , "Torill Finnerud" torill.finnerud@proffpartner.no sent:
Hmmm…..

M15 er igrunn aldri brukt (eller ytterst skjeldent) Det er mulig å lage skruer med M15, men dette vil bli ekstremt dyrt, da de fleste ikke har verktøy til M15.

Litt lettere er det med M12,M14 eller M16
M12 og M16 er de letteste… så hvis du kan vippe opp til M16, er det en stor kostnadsmessig besparelse.

Materialgraden: L7E…. har jeg aldri hørt om….. Kanskje du mener L7 eller L7S eller L7M
Og når du sier 80-kvalitet ? mener du da… grade 8.8 eller A4-80 (syrefast) ?

Bolten du er ute etter heter iso4762, eller din 912 (denne er med innv. 6kt spor) sylindrisk hode.

Hvis du har litt mer presis på materialgraden, kan jeg gi deg lengder som er standard.

Med vennlig hilsen / Regards
ProffPartner AS
Torill Finnerud
Tlf: + 47 982 97964
http:\\www.proffpartner.no

Fra: Alexander Sjøberg [mailto:alexander_sjoberg@epost.no]
Sendt: 17. mars 2010 11:53
Til: Torill Finnerud
Emne: M15 bolter

Hei Torill,

Nå har vi kommet en god vei, og kommet frem til at vi skal bruke M15 bolter med L7E eller 80-kvalitet. Bolten skal være innvendig sekskant. Har du noe spesifikasjoner på dette med tanke på lengder?

Med vennlig hilsen

Alexander Sjøberg

Appendix O

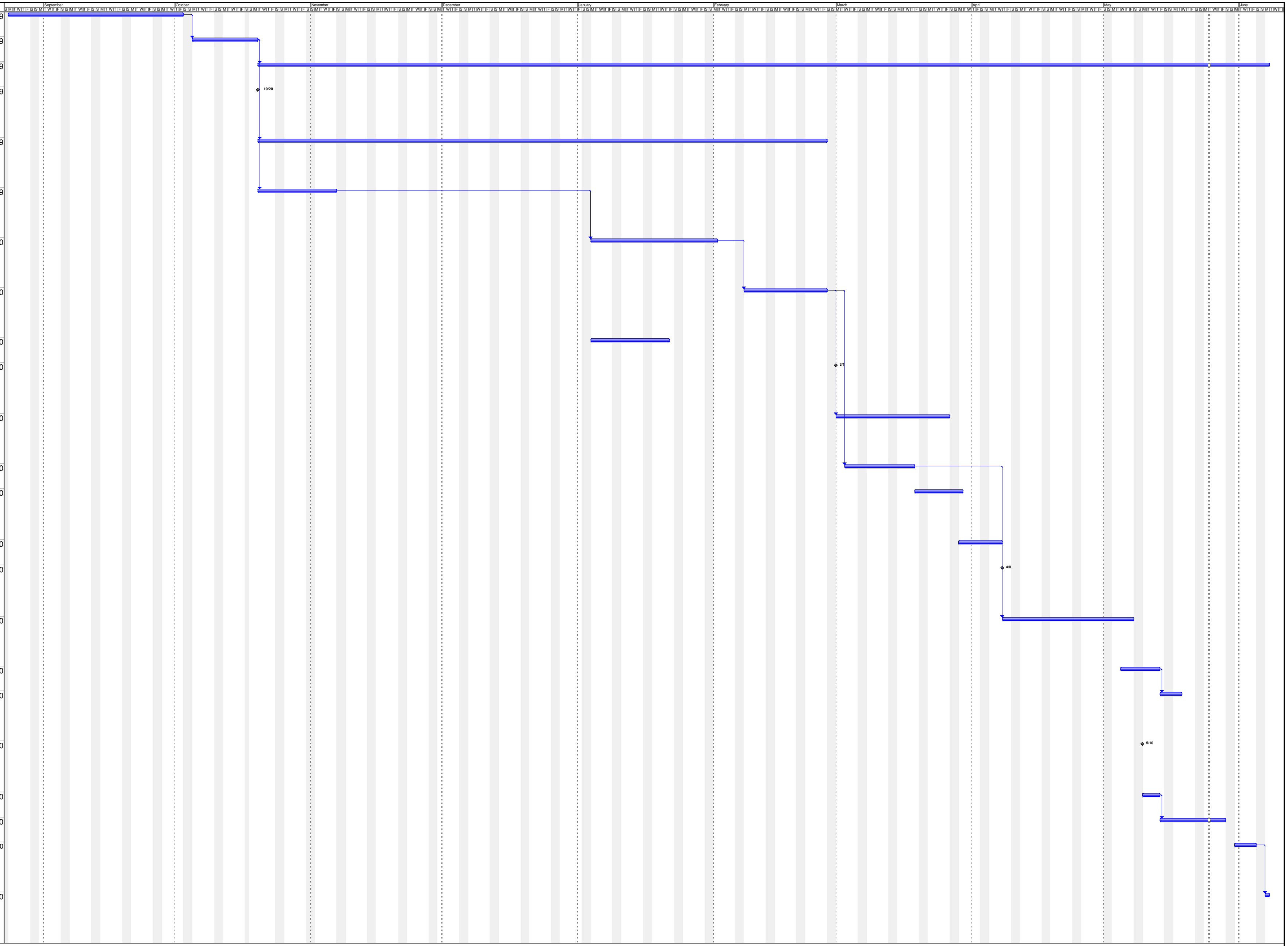
Economic

In the start of our project we were given an economical limit of 15 000 NOK, but when we decided to buy a complete laser we were permitted to exceed the budget. This budget was to build a prototype and not a full assembly of metal.

Internal costs	
Laser	13000,-
PMMA plast til prototype	2024,80,-
PMMA maskinering flens	2100,-
Various parts for prototype assembly	200,-
Cable	50,-
Final documentation	2000,-
Total	19374,80,-

Appendix P

ID	Task Name	Duration	Start
1	Apply for projects	30 days	Mon 8/24/09
2	Project idea	12 days	Mon 10/5/09
3	Main project	165 days	Tue 10/20/09
4	**Milestone 1: Webpage, plan and prestudy:**	0 days	Tue 10/20/09
5	1.1 Plan and prestudy	94 days	Tue 10/20/09
6	1.1.1 Choose concept	14 days	Tue 10/20/09
7	1.1.2 Selection of components	21 days	Mon 1/4/10
8	1.1.3 Construction and design selection	15 days	Mon 2/8/10
9	1.2 Webpage	14 days	Mon 1/4/10
10	**Milestone 2: Analyze of design and material selection:**	0 days	Mon 3/1/10
11	2.1. Pressure test of housing with FEM	20 days	Mon 3/1/10
12	2.2 Electronic design	12 days	Wed 3/3/10
13	**Påskeferie og eksamensforberedels**	7 days	Fri 3/19/10
14	**Eksamener**	8 days	Mon 3/29/10
15	**Milestone 3: Prototype and testing**	0 days	Thu 4/8/10
16	3.1 Building prototype	22 days	Thu 4/8/10
17	3.2 Testing	7 days	Wed 5/5/10
18	3.2.1 Analyze and review of testing	3 days	Fri 5/14/10
19	**Milestone 4: Deliver final report**	0 days	Mon 5/10/10
20	4.1 Report draft	4 days	Mon 5/10/10
21	4.2 Final report	11 days	Fri 5/14/10
22	4.3 Preparation for presentation	5 days	Mon 5/31/10
23	**Presentation of post-graduate thesis**	1 day	Mon 6/7/10



Project: Project1
Date: Tue 5/25/10

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Appendix Q in R

Appendix R