LockDog Contingency Tool 20T
For HCS 12” Installation Tool

Degree project in the Bachelor of Science in Engineering Programme

Mechanical Engineering

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Gothenburg, Sweden, 2012 Examiner: Gert Persson Report No. 73/2012

PREFACE

This degree project has been done at Aker Solution in Gothenburg spring 2012 as a part of the mechanical engineer program with specialization mechanical design, 180HP at Chalmers University of Technology.

We want to thank Martin Stegberg, our mentor and all engineers at the Tie-in Department at Aker Solutions for all the help we got. We also want to thank our mentor Gert Persson at Department of Material and Manufacturing technology at Chalmers University of Technology.

A special thanks goes to Gustaf Wallerstedt, Martin Stegberg and Runar Helgesen for giving us the opportunity to carry out the project at Aker Solution and helping us with the equipment and work-area at your company.

Ort: Göteborg Datum: 13-06-2012

Jonas Pettersson Erik Hoglid

SUMMARY

Aker Solutions is a global leading company in the offshore industry with its headquarters in Oslo, Norway. Aker Solution has recently opened its first office in Sweden, Gothenburg.

When a subsea installation with oil- and gas pipes is done, an installation tool is used. The installation tool is connected to an interface/connecting system with two bolts. The installation tool together with the pipe will thereafter be lowered down to the subsea plant where it will be connected to the structure.
When the pipe and the pipe interface have landed at the subsea installation platform, the installation tool is removed. This is done by moving two levers connected to each bolt, unlocking the installation tool. This is carried out by an underwater robot (ROV-Remote Operated Vehicle).
These ROV are used in the entire installation process and will do all the work at the subsea plant. For tasks it can't do by its two arms it uses tools.

Due to the pipe flexibility, an angle between the installation tool and the subsea structure can occur. Tensions will then arise between the bolt and the pipe connection system. In some cases tension gets so high that the ROV won't be able to unlock the two bolts and disconnect the installation tool, making further installation impossible.

Aker Solution gave us the assignment to develop a contingency tool. This tool will be used when the ROV fails to disconnect the installation tool.

The project started with collecting information about ROV (underwater robots) and the steps in the installations process. Then 16 different concepts of possible contingency tools were developed. A Pugh matrix was evaluated and together with Martin Stegberg at Aker Solutions one final concept was chosen that had all requirements to meet the design criteria.

Further development of the final concept was made with help of the CAD-program SolidWorks. A complete 3D- prototype was developed. FEM-analyses, drawings for manufacturing and operation maintenance manual were also made.

All documents and drawings for manufacturing have been handled over to Aker Solutions.

SAMMANFATTNING

Aker Solutions är ett världsledande företag inom offshorebranschen med sitt huvudkontor i Oslo, Norge. Aker Solutions har kontor i Göteborg där drivs bland annat projekt inom rörinstallationer för undervattens plattformar.

Vid installation av en olje/gasledning på havsbottnen används ett installationsverktyg för att sänka ner ledningen så dess ände hamnar på önskad plats. Kopplingen mellan installationsverktyget och ändröret är konstruerat med två bultar som är kopplade till varsin hävarm, dessa låser ändröret till installationsverktyget. Sammankoppling och frånkoppling av installationsverktyget från ändröret utförs av undervattensrobotar. Undervattensrobotarna används också för att sammankoppla ledningens ändrör till övrig struktur på botten. För det sistnämnda använder robotarna verktyg.

Eftersom ledningen är flexibel kan det uppkomma en vinkel mellan installationsverktyget och övrig struktur vid installationen. Om vinkeln blir stor uppkommer spänningar mellan bultarna och ändröret. I värsta fall kan vinkeln och därmed spänningen bli så stor att undervattensroboten inte längre klarar att dra ur bultarna och därmed koppla loss installationsverktyget. Det scenariot måste till varje pris undvikas.

Därför har Aker Solutions, som utvecklar och monterar dessa ledningar, givit oss i uppgift att utveckla ett extra verktyg som undervattensrobotarna kan använda i de fall då bultarna i installationsverktyget inte går att lossa.

Första delen av projektet bestod i att samla information om undervattensroboten och hur installationsprocessen går till. I andra delen av projektet skissades det på olika lösningar på extra verktyget. Detta resulterade i 16 olika koncept, dessa utvärderades med hjälp av en utvärderingsmatris samt med Martin Stegberg på Aker Solutions. Till slut valdes ett koncept som uppfyllde de kraven som var satta för extraverktyget och som var tillförlitligast.

Vidareutveckling av konceptet gjordes med hjälp av CAD-programmet SolidWorks. En fullständig 3D-prototyp modellerades fram. Denna användes sedan för FEM-analys, ritningsunderlag för tillverkning samt en operationsmanual som beskriver hur extraverktyget fungerar och skall användas.

Alla dokument och ritningsunderlag har lämnats över till Aker Solutions. Ett beslut om verktyget skall produceras ligger nu hos Aker Solution.

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DESIGNATIONS

HCS-Horizontal Connection System. *A horizontal connection system for subsea sites that connects cables and pipes to subsea sites.*

ROV-Remote Operated Vehicle. *A submarine which can be driven remotely from a ship.*

FEM- Finite element method. *FEM is used to do studies of the material and simulate stresses that occur at different kind of loads.*

CAD-Computer-Aided Design. *A technique to draw 3D-models.*

SolidWorks-CAD program. *A program to make 3D-models.*

UTH-Umbilical Termination Head. *A control box that together with an umbilical cable can control subsea sites.*

IT- (first end) Installation tool. *A tool which is used to lower and install cables.*

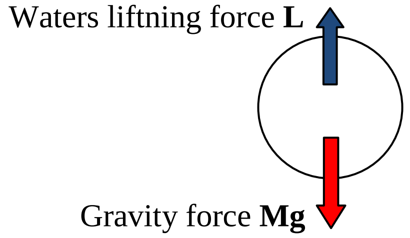
CT-Contingency tool. *A tool which is used when a normal procedure not going as planned.*

LDCT-LockDog contingency tool. *Name of the final concept.*

OMM-Operation and Maintenance Manual. *A guide for ROV operators and maintenance for a product.*

Envelope-Dimension requirements.

Weight in Water- Is the weight for an object minus waters lifting capacity.



Actual force F in water will be:

$V = Volume\ [m^3]$
$\rho = Dencity\ [kg/m^3]$
$F = Mg - V \cdot \rho\ \cdot g\ [N]$

1 INTRODUCTION

1.1 Background

HCS system is a subsea installation system to connect different platforms with each other. Aker Solution has a problem with the installation process for HCS, first end installation tool.

The problem is when the first end installation tool is going to disconnect with the HCS. Two lock pins who keep the installation tool connected to the HCS have had a tendency in some circumstances to wedge themselves. Demands from Aker Solutions customers are that it needs to be a total safety system with an emergency solution to lose the lock pins if they get wedge.

1.2 Purpose

The purpose is to develop a contingency tool for the HCS installation process.

Develop a contingency tool with a 3D-module, drawings for manufacturing and an OMM.

1.3 Delimitations

- Only HCS 12" with umbilical cable system will be handled.
- Only the release of 1:st end installation tool will be handled, calculated and designed.
- Minor analytical calculations and FEM-analyses are done in SolidWorks.
- No new 1:st end installation tool are developed.
- No economics consideration is made.

1.4 Precision of question formulation

- What is the installation tool release problem for ROV today?
- Is it possible to use an existing ROV tool as a contingency tool?
- Is it possible to modify the installation tool for an interface to connect a contingency tool?
- Is it possible to design a contingency tool which is reliable?

2 THEORETICAL FRAME OF REFERANCE

This chapter, information about the main parts in an HCS installation process, also information about programs and eliminations methods.

2.1 ROV

ROV is a vehicle used for jobs under water; usually at places there a diver can’t work due to the extreme conditions. ROV stands for Remote Operated Vehicle and as the name describes you can drive/fly it from a distance, normally from a ship.
There are two types of ROV, one is for exploring, this is light, small and don’t have so many functions as an installation ROV. That is because it needs to get in small places and if it hits something it will not destroy anything. ROV use several propellers and floating tanks working together to control it and steer it to the place you want it.
An installation ROV, like the Triton XLX 150 on the other hand has lots of functions. It has hydraulic pressure and two arms. One of the arms is 5- articulated and used to hold on to stuff and lift heavy equipment and materials. The other arm which is a 7- articulated is used to do more precision operations.
Aker Solution is using ROV for all their install operations under water. Depth down to 3000m makes it impossible for divers to work and therefor an ROV is used.
Aker Solution use ROV for tasks like guiding equipment down to the bottom, change seals and install new pipes, an example is a HCS installation.
If the ROV doesn’t manage to do certain operation with its both arms it can use extra tools. All tools are made to work under water and can be plugged in with the ROV hydraulic/electric systems.

Figure 2.1-ROV-Triton XLX 150

Table 2.1-ROV parts

Number	Description
1	7- articulated arm
2	5- articulated arm

2.2 ROV tools

Standard tool

Subsea installations are mainly done by the ROVs seven articulated arm. In some cases the ROV use tools to carry out certain operations. All ROV-tools are collected in a bag that is submerged together with ROV from the boat. In Table 2.2 is some ROV tools shown.

Table 2.2-ROV tools

			
Torque tool	Hydraulic impact wrench	Hydraulic grinder	Bolt puller

Contingency tool

Contingency tool are often special made for contingency procedures, therefor only designed to just fulfill a specific task. If something happen with the normal installation a back-up tool (Contingency tool) are available to solve the problem.

2.3 HCS

This chapter will give some information about all the main part used in a HCS.

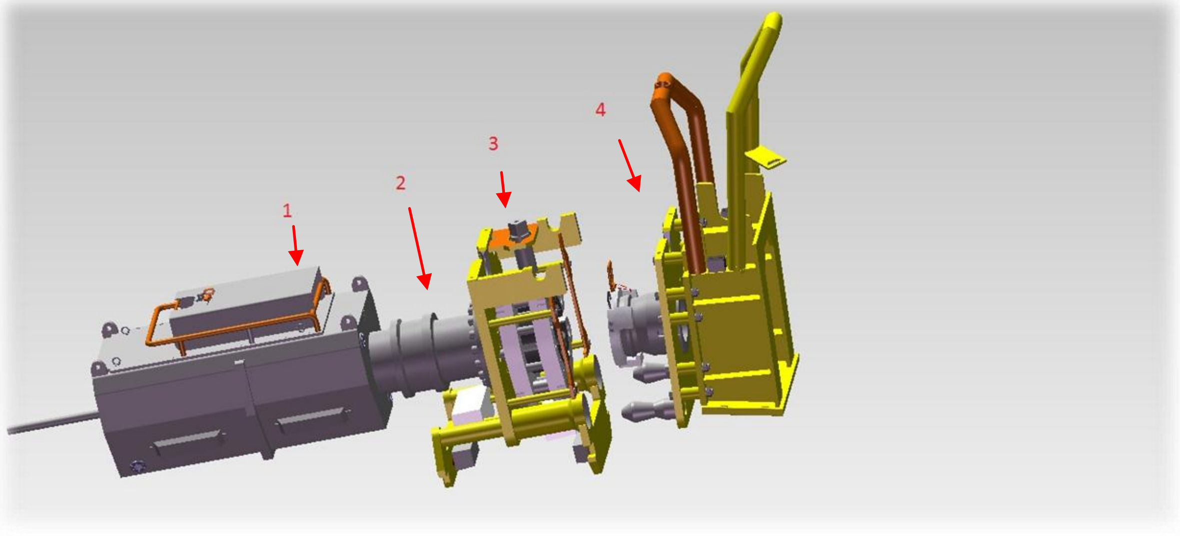


Figure 2.2-HCS with a umbinical control unit

Table 2.3-HCS-main parts

Number	Description
1	Umbilical control unit (doesn't exist if an oil or gas cable is used)
2	Cable
3	HCS part which is connected to a cable
4	HCS manifold

2.4 Installation tool

An installation tool (Figure 2.3) is used to immersing the cable to HCS manifold. Steel wires from the boat are used to lower the IT together with the cable. Aker Solutions have used two different connecting systems to connect and disconnect the installation tool from the HCS.

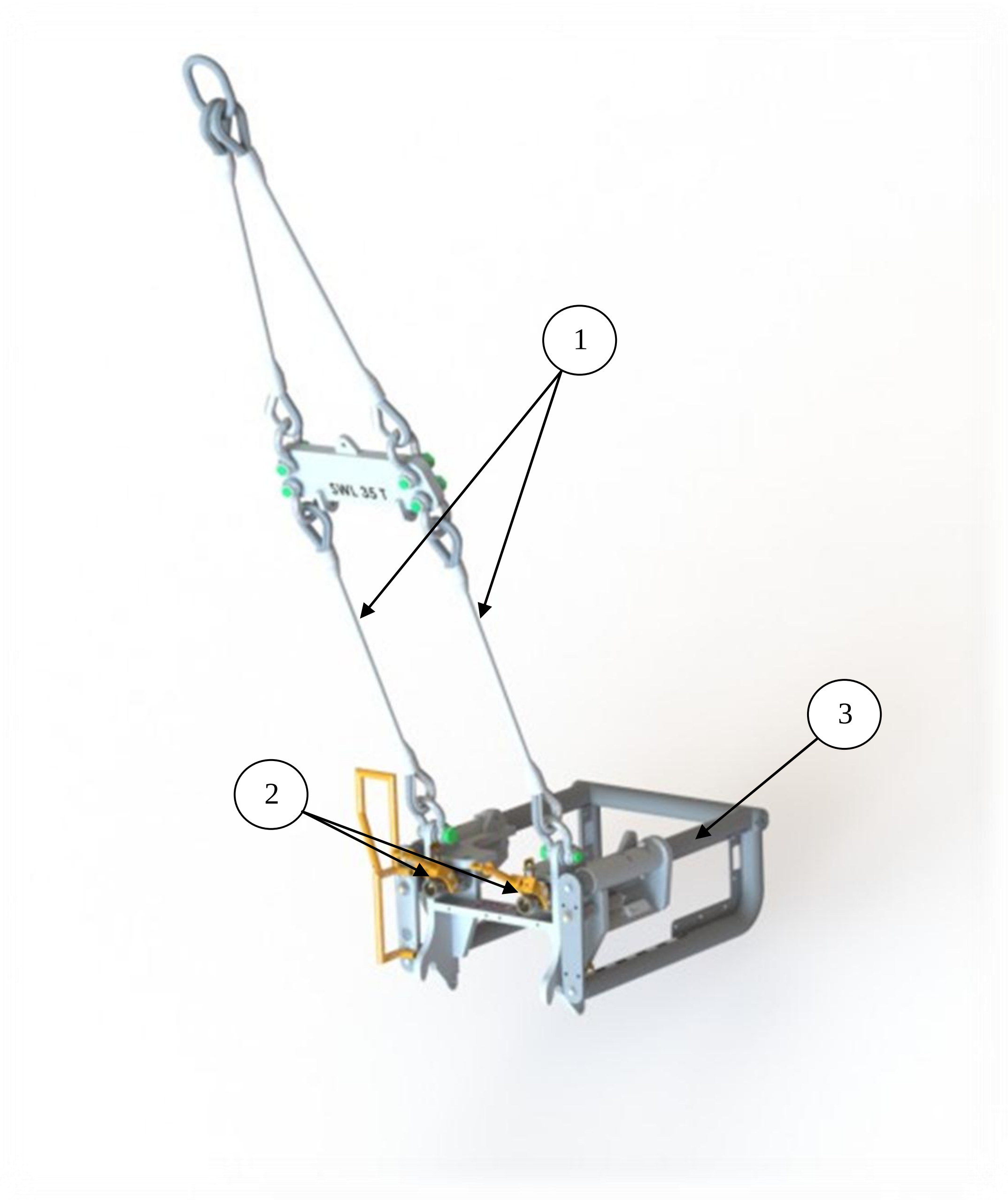


Figure 2.3-Installation tool

Table 2.4-Parts in the Installation tool

Number	Description
1	Steel wires
2	Lever or Screw bolt system
3	Guide structure

2.5 Installation process

To connect umbilical cables under water a HCS connecting system are used. An umbilical cable is unwound from the boat together with the installation tool. Under the whole installation process an ROV is used to control the installation. When the IT and umbilical cable has landed at the connecting site. ROV release the IT. When the work is completed the IT will be brought back up to the ship. (Figure 2.4)

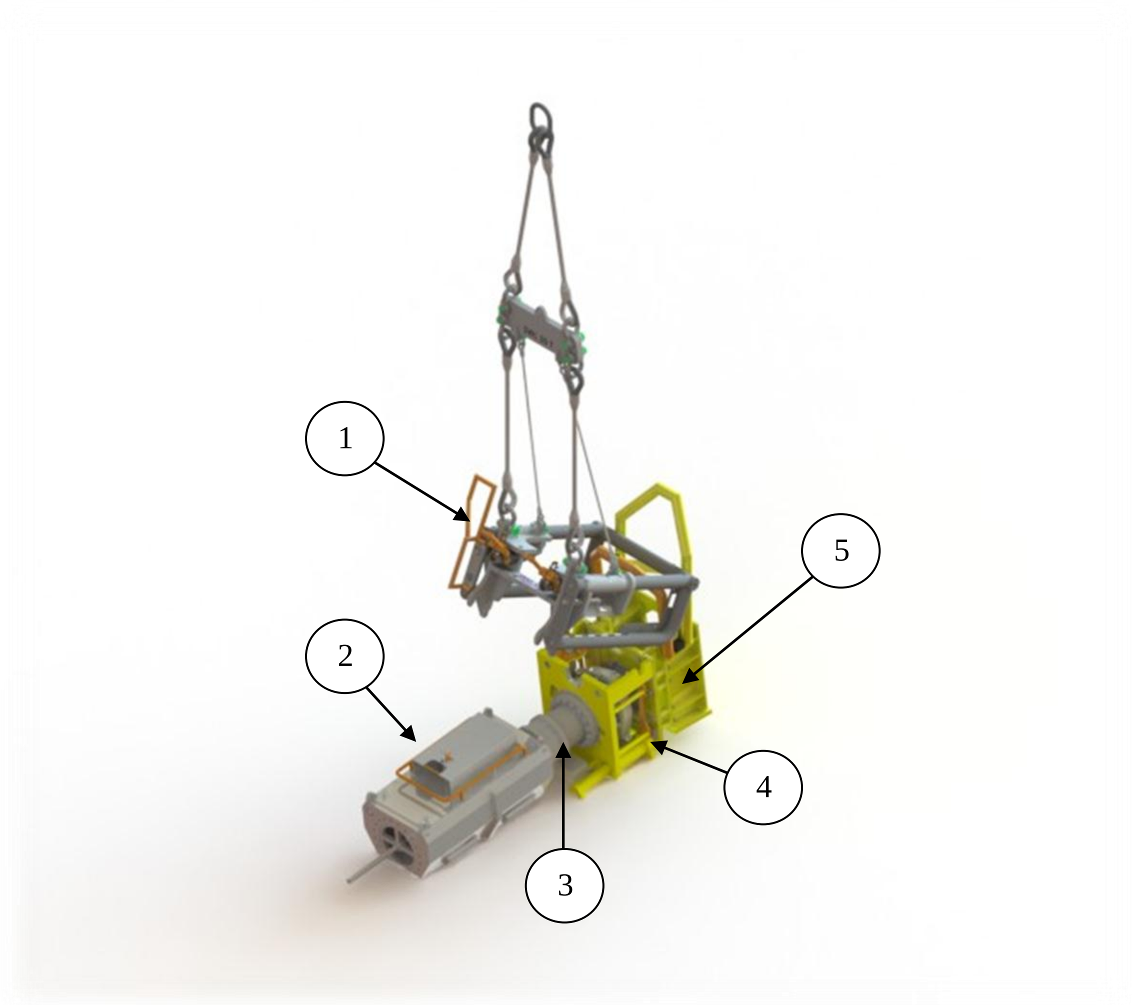


Figure 2.4-Installation process

Table 2.5-HCS with a IT

Number	Description
1	Installation tool
2	Umbilical control box.
3	Pipe
4	One part of the HCS, which is lower down with the IT
5	The other part of the HCS which is mounted on some type of structure.

Screw bolt system

Under the installation bolted joints are used to connect the installation tool with HCS, see Figure 2.5. HCS and IT is connected to each other through two bolts which are screwed into two holes on the HCS. Due to the nature of the flexible cables, particularly when umbilical cables are used, stresses can occur between HCS and installations tool. Force and shear stress spreads to the two bolts and when the ROV try to unscrew the two bolts friction between the joint prevent the ROV to unscrew them. Another problem with this system is that the threads can easily be damaged and the blister wears out. This system is still relevant as a locking solution if a CT is developed which can bring the bolt out if it get wedge. But at the moment it is replaced to a lever system because of the systems unreliability.

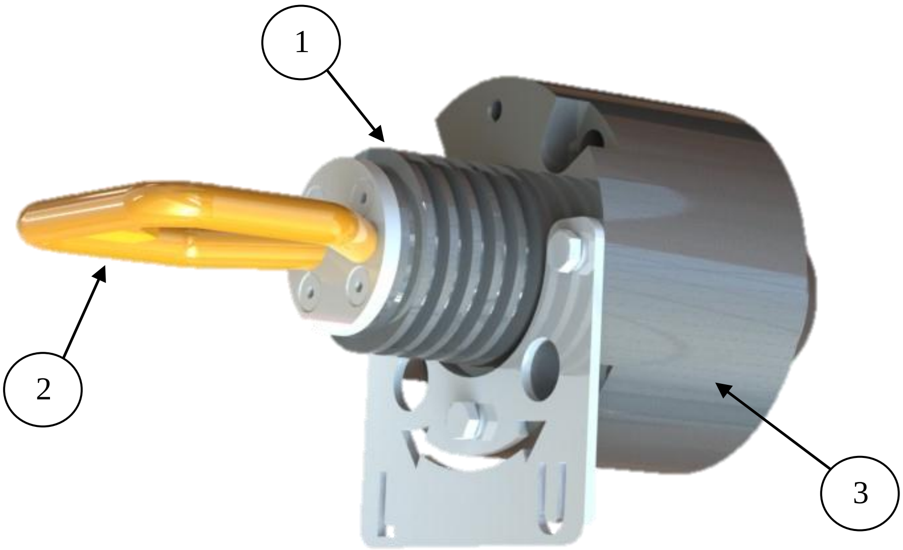


Figure 2.5-Screw bolt

Table 2.6-Parts, Screw bolt

Number	Description
1	Bolt with threads
2	ROV-Handle
3	Outer structure with is mounted on the IT. See Figure 2.3 number 1.

Lever system

This is a new system replacing the screw bolt system. An arm is used as a lever which gives the ROV more power to move the lock pin. The different parts are described in Figure 2.6.

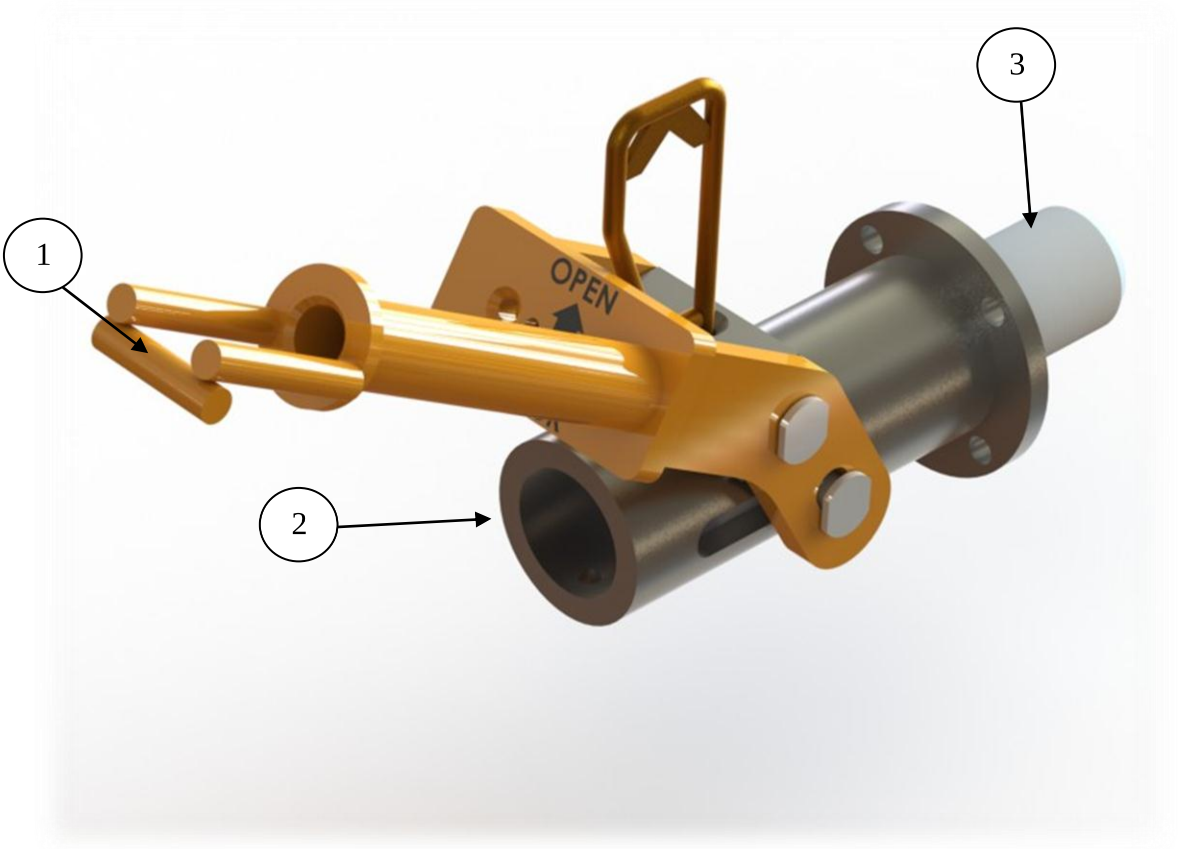


Figure 2.6-Lever system

Table 2.7-Parts, Lever system

Number	Description
1	Lever with ROV-handle
2	Guide pin which is also mounded on the IT. See Figure 2.3.
3	Lock pin

2.6 CAD/FEM

To make 3D-models a CAD-program is used. CAD stands for Computer-aided Design [1]. A CAD-program is used to make technical drawings which are used for constructions.

New CAD-programs like SolidWorks and Pro/Engineer has the opportunity to do several kinds of simulations to confirm the design.
An example is to detect interference between components which is useful to detect problems you might not see due to the modules structure.

Another example of simulations is FEM (Finite element method) [10]. FEM is used to do studies of the material and simulate stresses that occur at different kind of loads. Basic simulations can be made in a CAD-program to get a overview if the model will manage the stresses.

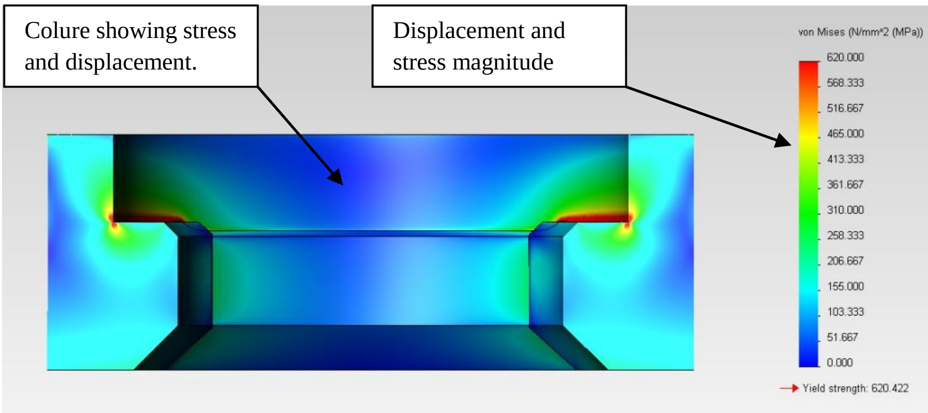


Figure 2.7-A FEM-Simulation in Solidworks showing von Mises

After a FEM-simulation, information about displacement and stresses like von Mises will be displayed in the program. The simulated module will change colure from blue=low stress/no displacement to red=high stress/much displacement see Figure 2.7 for von Mises and Figure 2.8 for displacement simulation.

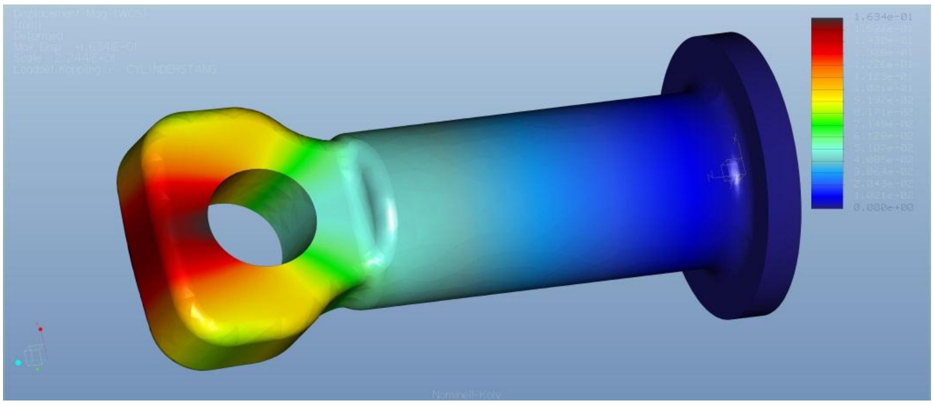


Figure 2.8-A FEM-Simulation in SolidWorks showing displacement

2.7 Pugh-matrix

Pugh matrix is an evaluation matrix. It is an effective method to evaluate a variety of concept.

This method is frequently used in engineering to evaluate and find the best solutions of a number of concepts or ideas. It can also be used to rank investments options, vendor options and product options.

The method is a list of values in rows and a column that allows an analyst to systematically identify, analyses and rate the performance between sets of values and information [2].

The reference design is list in the column Datum see Appendix A. All criteria that the design needs to fulfill are listed. After all design criteria are listed, every criteria's gets a number (-1),(0) or (1). (-1) means that the reference design not fulfils the criteria. (0) means that the criteria do not exist on the reference design. (+1) means that the reference design fulfils the criteria. After that all design concepts gets an own column with a number.

All design concepts is then weighted against the reference design and all criteria are weighted separately. If it is better than the reference design (+1), if it is worst (-1), if the criteria not exist (0).

When all is done, summery the (+1), (0), (-1) on all concepts and on the reference design. All concepts that have better number than the reference design pass the selection. Whether any concept stands out, it may be worthwhile to explore these concepts more.

3 METHOD

In this chapter the work process will be described as a guide line how the work is organized and the order tasks will be carried out.

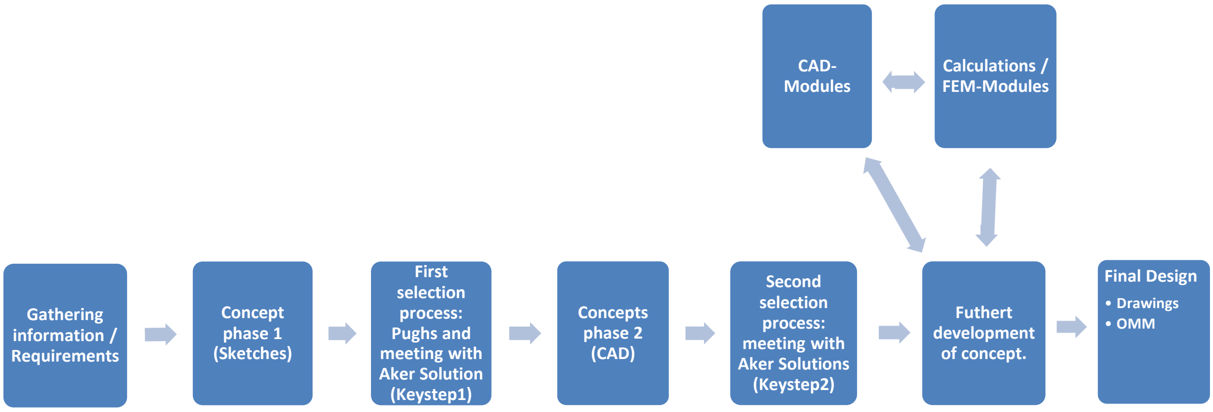


Figure 3.1–Work process

The work process will be carried out in the order as shown in Figure 3.1. All concept selections will be done together with Aker Solution and our mentor Martin Stegberg.

It starts with gathering information about Aker Solution and about the main problem. Then basic sketches will be made. In the first selection process, a Pugh matrix was made and together with Martin Stegberg three concept groups are chosen for further development.

Next step is the second concept phase; CAD-models will be made in SolidWorks to easier see problems and benefits for either concept. Another benefit in a CAD-program is that it easy to do minor changes and the possibility to do motion studies.

Second selection process, will all the CAD-modules be compared against each other and if they meet all the design criteria and standards. One concept will be selected for further development.

Further development of one concept is to design a final product which stand up to all criteria and as many desire as possible. In this process calculations are made together with FEM-analysis to get a guideline of necessary material and dimensions.

When the last concept stage are finished and approved by Aker Solution an OMM and drawings for manufacturing will be made. The final calculation to approve the design and to ensure that it will bear the load will be done by Aker Solution.

4 DESIGN CRITERIA

Installation tool

- The dimension on the lock pin will not be changed. (diameter 80mm)
- The release system needs to be detachable from the IT.
- IT needs to be able to connect a contingency tool in a contingency situation.
- Enough space for the ROV to fulfill the operation and space to connect and operate the contingency tool.
- All tools needs to be able to be operated by an ROV.

Contingency tool

- The contingency tool need to have a weight under 50 kg (weight in water).
- The tool needs to be able to handle dragging force up to 20 metric tons (200 kN) and push force up to 10 metric tons (100 kN).

ROV

- Lift and pull force when the ROV is attached is 250kg (2.5kN).
- Lift and pull force in water nonattached is 50kg (0.5kN).
- The ROV arm torque is 170Nm.
- Hydraulic pressure 270 bar

5 DESIGN BASIS

Contingency tool

Contingency tool needs to fit the requirements of envelop as shown in Figure 5.1 and Table 5.1.

CT need to have a weight under 50 kg (weight in water).

Working hydraulic pressure, 270 bar.

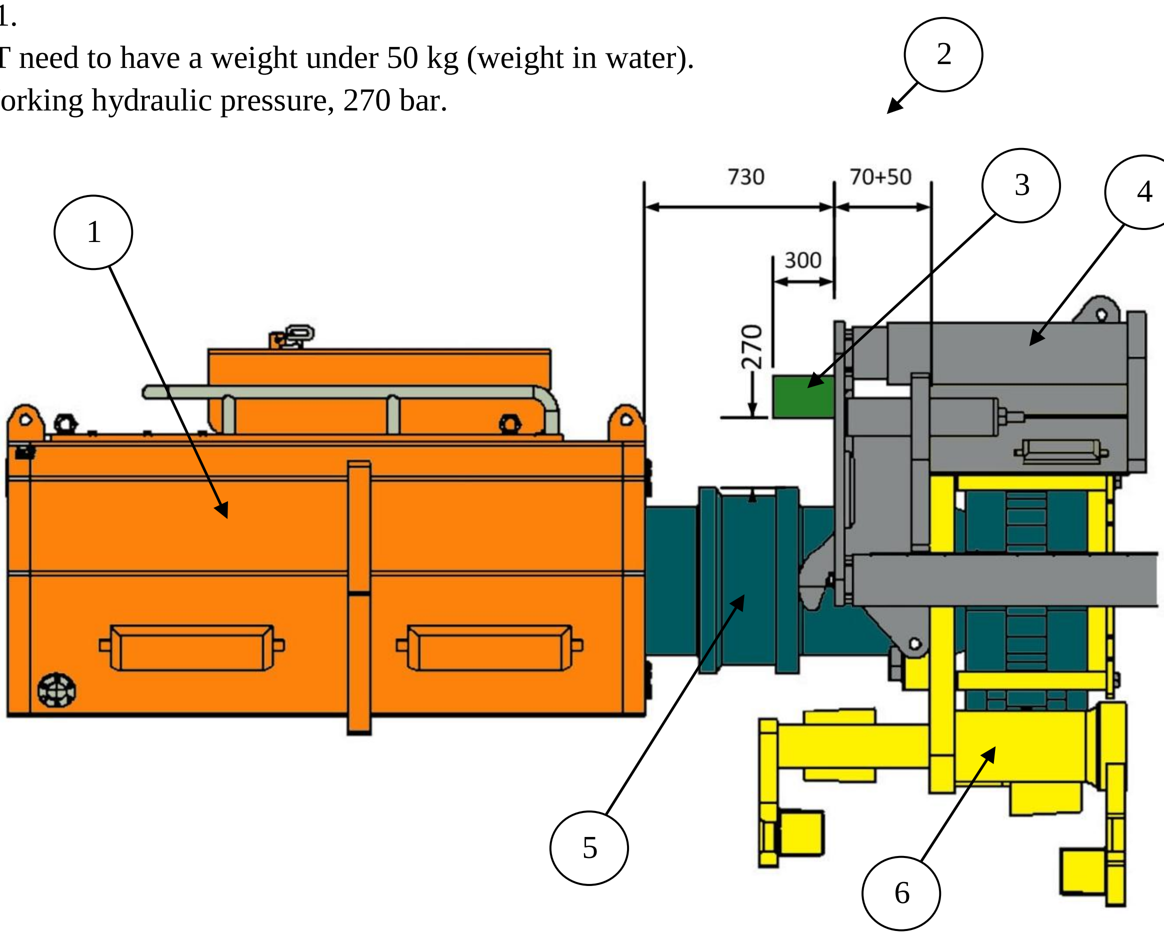


Figure 5.1-Envalope, messure in mm

Table 5.1-Parts in the envalope

Number	Description
1	UTH: (Control box)
2	Installation wall (70mm) and HCS wall (50mm)
3	Length for the lever system
4	Installation tool
5	Pipe between UTH and HCS
6	HCS

ROV

All information is based on ROV Triton XLX 150 [7].

Table 5.2-ROV Triton XLX 150

ROV Triton XLX 150	
"Flying" ROV has a lifting capacity of::	50kg (0.5kN).
Retained ROV has a lifting capacity of:	250kg (2.5 kN)
ROV arm torque is:	170Nm
Hydraulic pressure:	270bar
Number of bidirectional auxiliary hydraulic manifolds:	12

6 CONCEPT

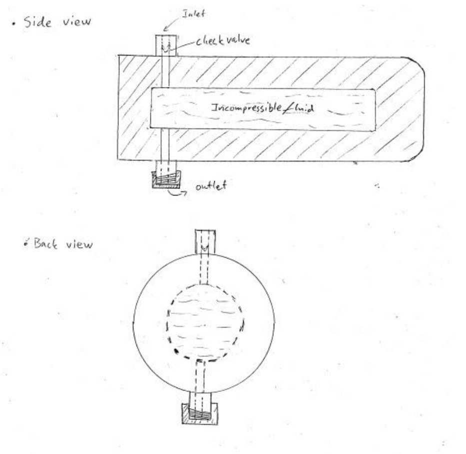
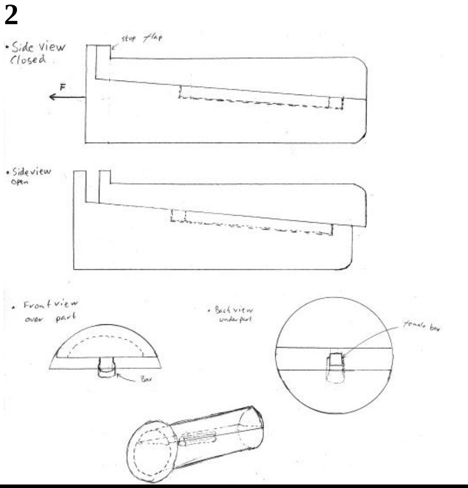
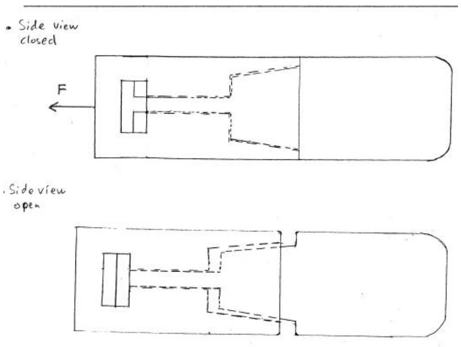
Here describes the two concept faces that end with a final concept.

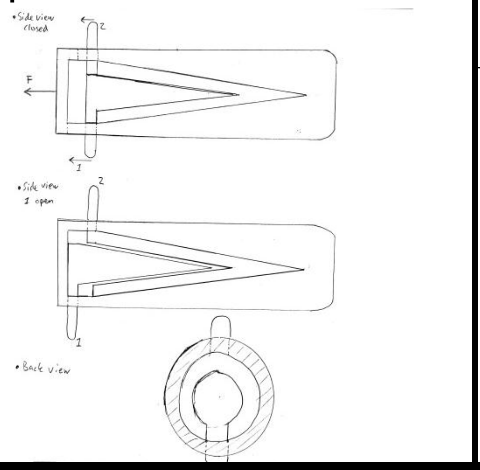
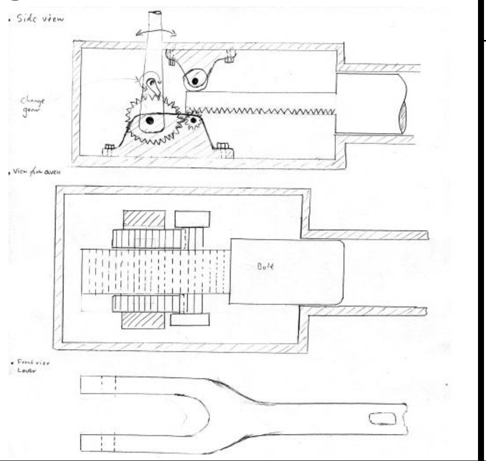
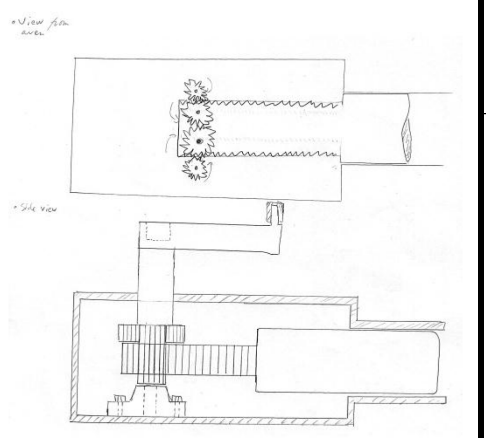
6.1 Concept phase 1

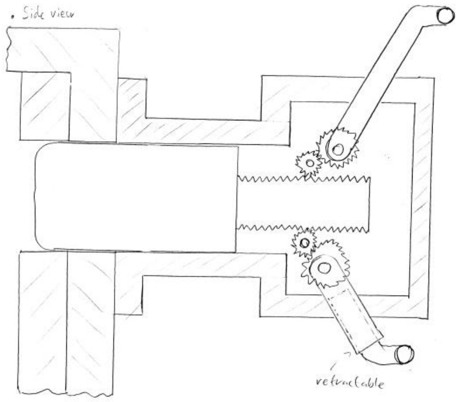
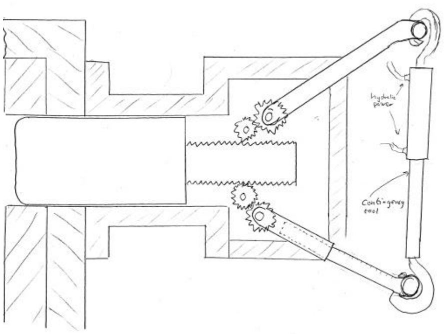
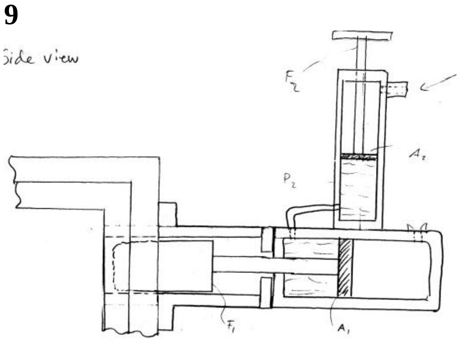
Concept phase 1 started with brainstorming ideas based on the information from theoretical frame of reference. To have a similar appearance a design sheet for all the sketches was made. Description, benefits and drawbacks for each concept was discussed in each sheet.
The design sheet can be seen in appendix B together with all the sketches.

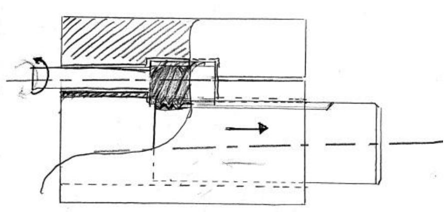
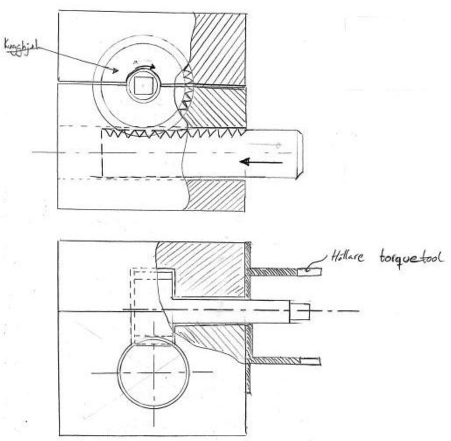
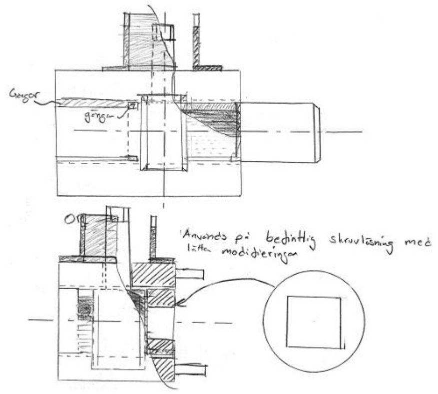
The different concepts are presented in Table 6.1.

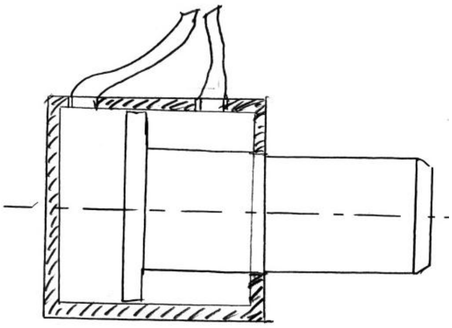
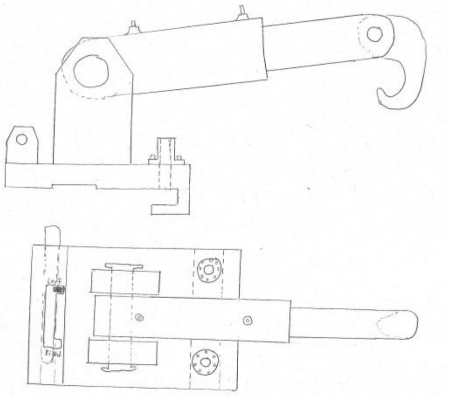
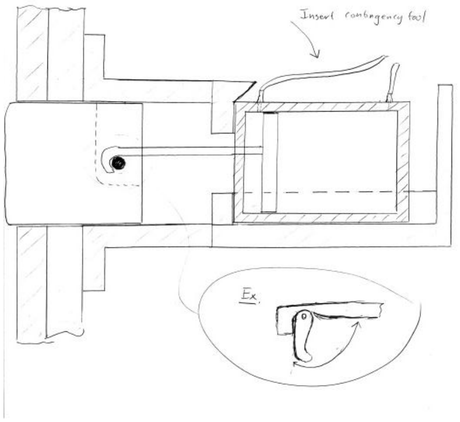
Table 6.1-Concept Phase 1

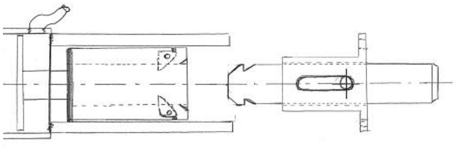
Concept	Description	Advantages	Disadvantages
1 	When lock pin is wedge the liquid is drain to reduce the circumference.	Reduced power on the bolt. Additional solvents opportunity without a CT.	Difficult to achieve the same material properties as a homogeneous bolt.
2 	When the lock pin is wedge the bolt can be split and the circumference will be reduced.	Reduced permits. Reduced area to pull. Additional solvents opportunity without a CT.	Difficult to achieve the same material properties.
3 	The lock pin can be separated forming a thinner shell that can flex and release the pressure	Reduced power on the bolt. Additional solvents opportunity without CT.	Edge formed by fragmentation. Maybe get stuck in the extraction.

Concept	Description	Advantages	Disadvantages
4 	Utilization of the bolt material properties to flex the lock pin.	Reduced area. Additional solvents opportunity without a CT. One to two different cleats to drop the pressure.	Maybe defects in material properties.
5 	Lever to pump out the bolt with a ratio of gears.	Lever for increased torque.	Many parts. The gear can be worn out.
6 	Gears are coupled to a winch that ROV rotates to transfer the torque trough rack on the lock pin.	Can use planetary gears as a contingency tool. Easy to use. Easy to handle.	The gear can be worn out.

Concept	Description	Advantages	Disadvantages
7 	Lever uses to disconnect the IT. Power transfer thought two gears to the lock pin. The lower lever is only used for the contingency tool.	Easy to connect the contingency tool. Easy for ROV to operate.	The gear can be worn out. Many parts
8 	Extra hydraulic cylinder that can be connected on the concept 7 to give extra power to release the lock pin.	Hydraulic power. Easy to operate for ROV.	Can be difficult to connect to IT.
9 	Piston with small area but with a long rod transmits incompressible liquid through a hose to a cylinder with a larger area.	Easy to connect contingency tool. Easy to handle.	Leakage of the incompressible fluid reduces the efficiency

Concept	Description	Advantages	Disadvantages
10 	A worm wheel engages with a toothed bolt.	Very high pull force on the bolt.	Slow operation in a normal operation.
11 	A gear that is in engagement with a toothed bolt.	Simple design. Fast operation if it's not wedge.	High ratio and in this case gives this tool very low power. Needing a torque tool.
12 	Two types of worm wheel, one of them is the lock pin connected to the tool and mounted on the IT. It uses threads to move the lock pin out. The second one is a contingency tool to mount on the screw bolt if it gets sucked.	Worm wheel gives high power ratio. May be so high that a torque tool won't be necessary. Easy to mount on the screw bolt.	Threads can be weak. As a CT it will require a long square connection for the screw bolt.

Concept	Description	Advantages	Disadvantages
13 	A mounted cylinder on the IT. Hydraulic power is used to remove the lock pin to its position.	No CT needed. Everything is mounted on the IT.	Slow operation in a non-emergency situation.
14 	Using hydraulic cylinder that gives more power to release the lock pin.	Can be used on both sides. Easy to manage hydraulic power	Heavy and large construction.
15 	A hydraulic cylinder is design with a hook. Connects to the lock pin.	Easy to connect for ROV. Easy construction.	Challenge to design the hook so it manages the stress.

Concept	Description	Advantages	Disadvantages
16 	The hydraulic contingency tool (left side). It's connected to the lock pin (right side) in a contingency situation.	Hydraulic pressure is used, keeping moving parts down. Low modification on existing tool.	The connection between the CT and lock pin will experience high stresses.

6.2 First selection process

A Pugh matrix was done to distinguish bad concepts (sketch phase) from good ones see Appendix A. Some concepts (sketch phase) were similar and therefore all sketches were divided into four concept groups for easier selection process. Concept group one was eliminated. All remaining concept groups were divided in subgroups for concept phase 2 see Figure 6.1.

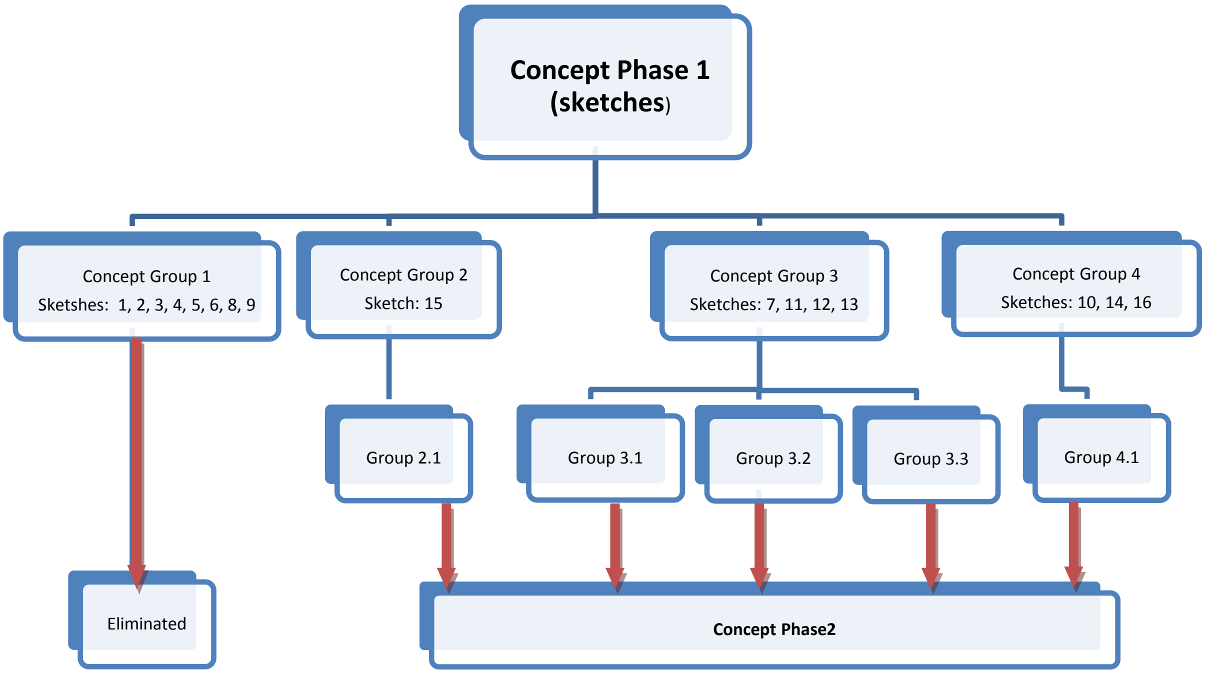


Figure 6.1- Concept Phase 1 chart

Concept Group 1

Concept group 1 had the focus to a new design on the bolt.

This concept group was made before all the design criteria were collected from Aker Solutions. Aker Solutions does not want any changes on these bolts, therefor this concept group was eliminated.

Concept Group 2

Concept group 2 consists of concept (sketch) 15 that uses a hydraulic arm to move the lever. This concept was already nearly a working solution and would work on the IT today, therefore further development wasn't necessary. Group 2.1 pass to Concept Phase 2.

Concept Group 3

Concept group 3 consists of concepts (sketches) that are designed with a mechanical solution. We together with Martin Stegberg have decided that three subgroups 3.1, 3.2 and 3.3 will be developed as shown in group 3.1-3.3.

Group 3.1

A horizontal operating lock pin works through a horizontal motion to lock and unlock the lock pin see Figure 6.2. This concept idea is to have a solution with is mounted directly on the IT which means that a CT will not be necessary. Group 3.1 passed to Concept Phase 2.

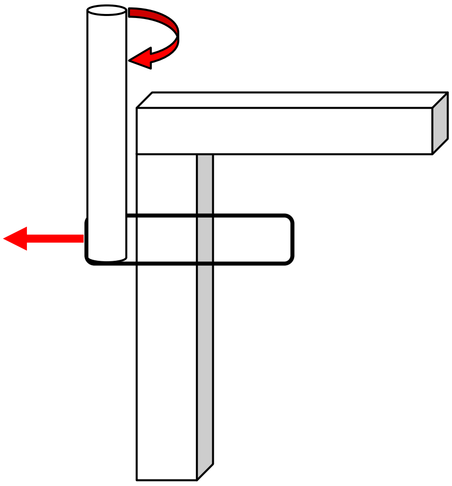


Figure 6.2- Vertical rotation to horizontal moment

Group 3.2

This idea is to get a vertical rotation to a horizontal rotation see Figure 6.3. The horizontal rotation will make the screw bolt to spin out from its locked position using a torque tool. Group 3.2 passed to Concept Phase 2.

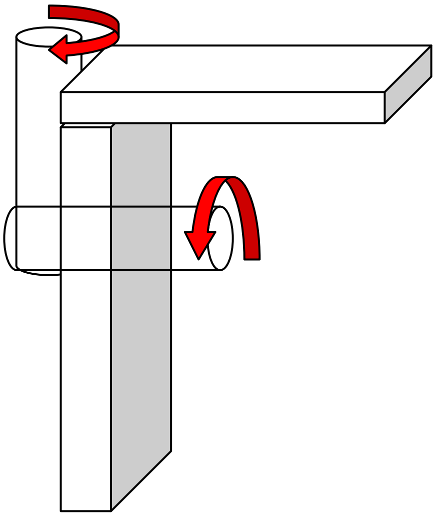


Figure 6.3-Horizontal to vertical rotation

Group 3.3

The horizontal rotation is moved up using different mechanical components see Figure 6.4. Group 3.3 passed to Concept Phase 2.

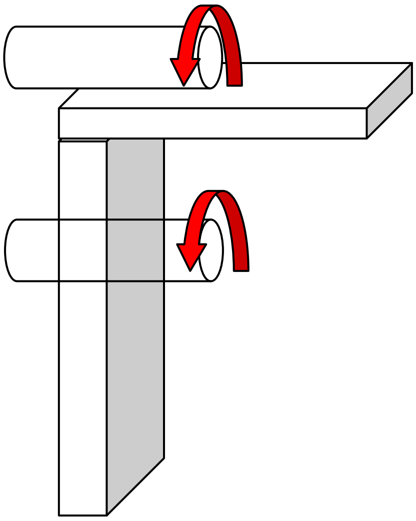


Figure 6.4-Horizontal to horizontal rotation

Concept Group 4

Hydraulic pressure will be used to operate the CT see Figure 6.5. A solution using a hydraulic piston will be developed. Group 4.1 passed to Concept Phase 2.

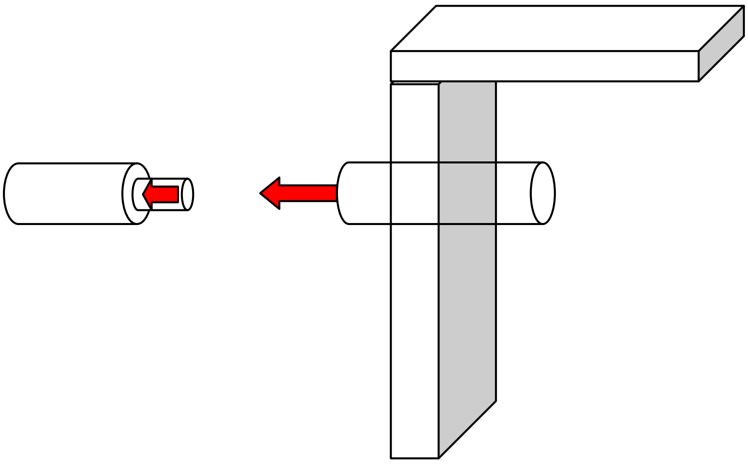


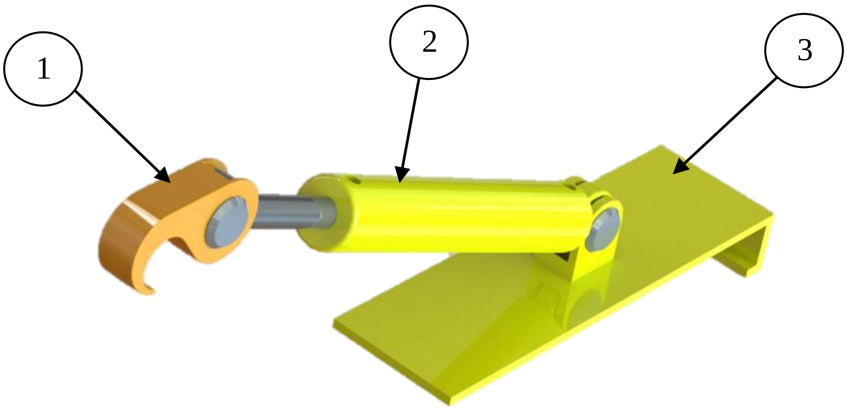
Figure 6.5-Hydraulic solution

6.3 Concept phase 2

Remaining groups after concept phase 1 is: Group 2.1, 3.1, 3.2, 3.3 and 4.1 see Figure 6.1. The best parts from all ideas in each group were picked and combined to a new design. When the new design was developed, 3D CAD-models was made in each group. It will gives a better view of concepts and thereby easier to evaluate. Description, benefits and drawbacks for each group was discussed and sees in each groups table.

Table 6.2-Group: 2.1

Group: 2.1- Hydraulic arm

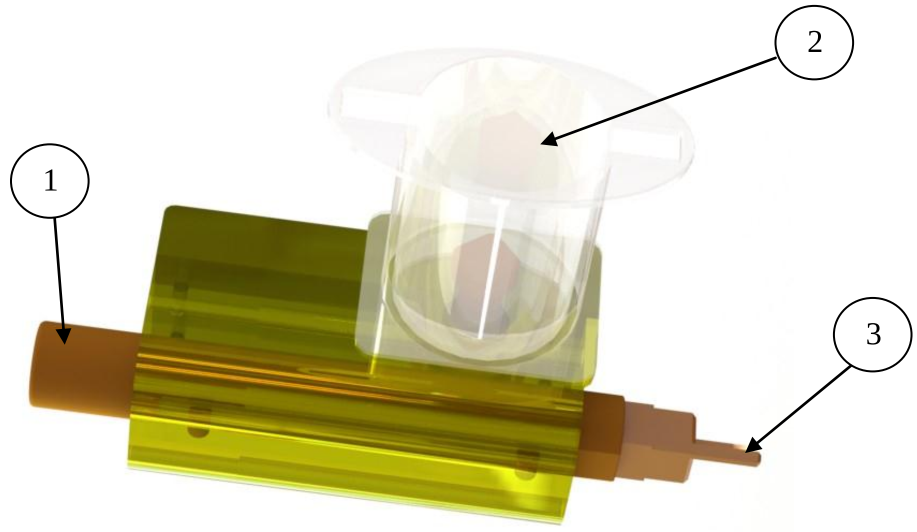


Number	Description
1	Hook
2	Hydraulic cylinder
3	Interface to IT

Description of concept	Advantages	Disadvantages
The concept operates on the lever system and connects on top of the installation tool and the hydraulic arm connects to the lever with a hook.	Easy to operate for ROV	Need to modify installation tool for connection.
	Few parts	Need buoyancy block because of the weight.
	Easy to connect on installation tool.	

Table 6.3-Group: 3.1

Group: 3.1- Vertical rotation to horizontal movement



Number	Description
1	Lock pin (racked)
2	Standard holder for torque tool
3	ROV-handle

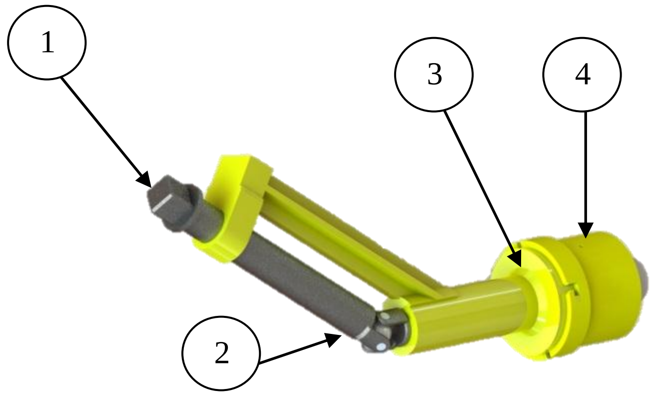
Description of concept	Advantages	Disadvantages
This concept is directly mounted on the IT. The rotation is transmitted through a gear which is coupled to a rack which moves the lock pin on the IT. The ROV can connect a torque tool to gain more torque than from the ROV arm.	Moving the vertical rotation to horizontal movement.	After connection a torque tool is needed to operate the tool.
	Manages the envelope	Complicated design
	Easy to connect a torque tool	Using gears

Group: 3.2- Horizontal to vertical rotation

In group 3.2 two solutions A and B were developed.

Table 6.4-Solution A

Solution A- Propshaft

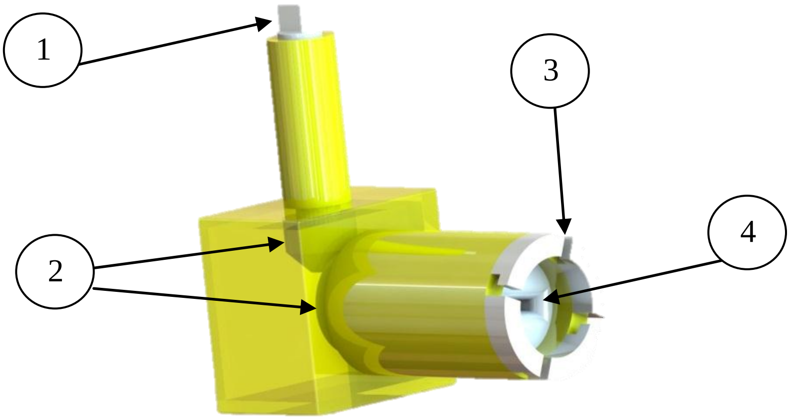


Number	Description
1	Standard connection for torque tool
2	Propshaft
3	Interface to IT
4	Interface to CT

Description of concept	Advantages	Disadvantages
This concept can only be connected to the screw bolt system on the IT. After connected to the IT a torque tool connects to a standard holder for torque tools. The CT transmits the torque through a propshaft that is articulated in a fixture. The rotation led through a shaft to the screw bolt by a connection between the shaft and bolt.	Moving the rotation from horizontal rotation angle to withstand the envelope	After the CT is connected a torque is required to operate
	Few parts	A big propshaft is required to handle the force
	Easy to operate for ROV	The CT to heavy and needs buoyancy blocks

Table 6.5-Solution B

Solution B- Helical gears

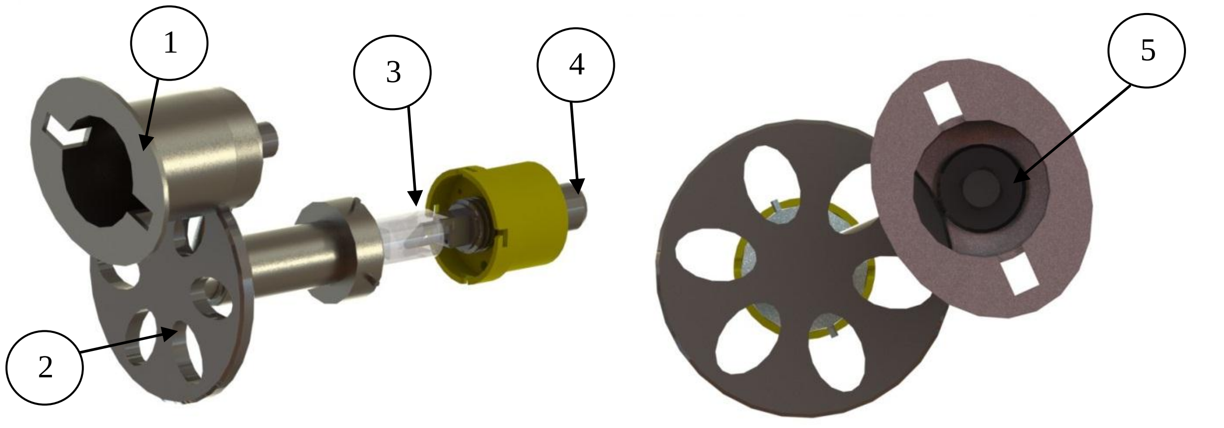


Number	Description
1	Standard connection for torque tool
2	Helical gears
3	Interface to IT
4	Interface to screw bolt

Description of concept	Advantages	Disadvantages
This concept can only be connected to the screw bolt system on the IT. The concept transmits torque throw helical gears. A torque tool connects to the CT with a standard torque tool connecter. The rotation transmits through a shaft to the helical gears that transmits the rotation to the screw bolt through the connection on the shaft.	Moving the rotation from the horizontal rotation to vertical rotating	After the CT is connected a torque is required to operate
	Few parts	Difficult to calculate helical gears
	Easy to operate for ROV	The CT to heavy and needs buoyancy blocks
		Gears are undesirable at subsea

Table 6.6-Group: 3.3

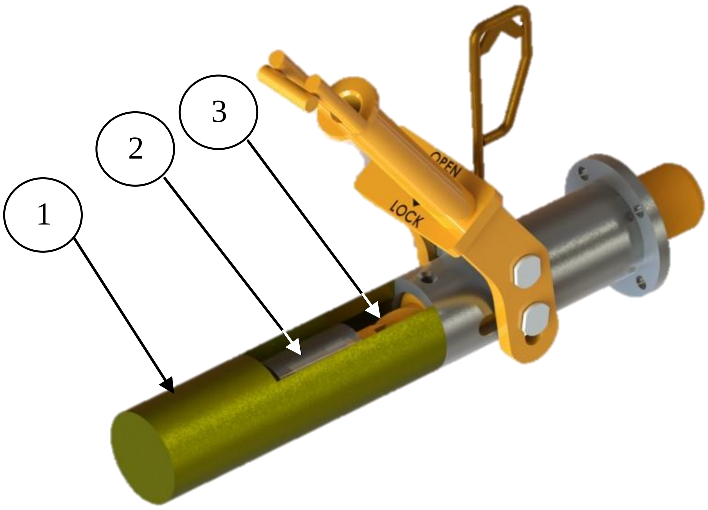
Group: 3.3- Horizontal to horizontal rotation



Number	Description
1	Standard holder for torque tool
2	Gear wheel
3	Connection to IT
4	Interface to CT
5	Gear wheel

Description of concept	Advantages	Disadvantages
This concept can only be connected to the screw bolt system on IT. Two gears move the rotation up on the upper part of IT, that’s give ROV more space to operate with. The lower gear is connected to the screw bolt through a shaft what connect and transmit the torque from the torque tool. The torque tool connects to CT with a standard torque tool connecter.	Moving the rotation from lower to upper part	After connection, a torque tool is needed to operate the contingency tool
	Easy for ROV to operate	Gear is undesirable at subsea
	Easy to dimension and design	Concept is heavy
	Easy to connect CT to IT	

Table 6.7-Group: 4.1

Group: 4.1-Hydraulic pulling solution	
	
Number	**Description**
1	Hydraulic cylinder
2	Rod
3	Lock pin connection to rod

Description of concept	**Advantages**	**Disadvantages**
This concept use hydraulic power to release the lock pin. A connection between the rod and the lock pin will connect the two parts. Hydraulic pressure transfers from ROV to the cylinder.	No mechanical parts	May be hard to spot hydraulic leeks on cylinder
	Using hydraulic pressure to move the lock pin, this means that no mechanical gear is used	Difficult to make it work in both directions. Push and Pull
	Few parts	
	No extra standard tool is required	

6.4 Second selection process

From these five groups one concept group was chosen for further development, see Figure 6.6. Together in a meeting with Martin Stegberg were all groups discussed and the result will be listed below.

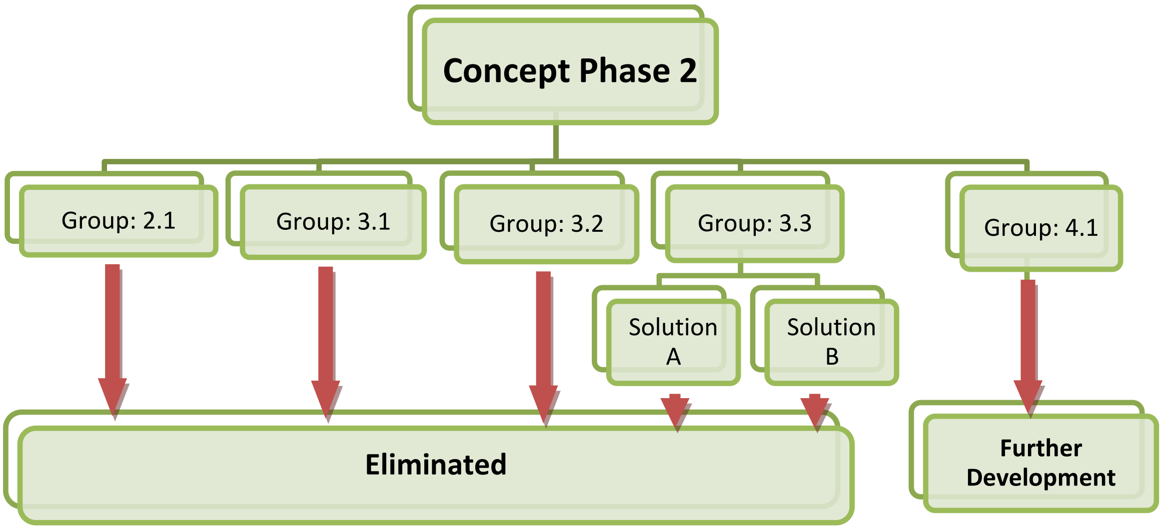


Figure 6.6- Concept Phase 2

Group 2.1

Concept fulfills the requirement for a subsea tool and design basis if a buoyancy block is attached to the tool. To connect this concept, major changes on the IT structure is necessary. This results in major calculation and FEM-analyses for the IT structure.
It was decided to be a backup concept if the other concepts would not work in consideration with Aker Solutions.

Group 3.1

This concept include components that not has a sufficient reliability for subsea conditions. No further development was made.

Group 3.2

Group 3.2 with the two different solutions A and B was removed as a potential solution, due to the difficulties to make a construction which would manage the design basis. Also it would be difficult to make a construction which has a sufficient reliability when a mechanical component is used.

Group 3.3

This concept include components that has not a sufficient reliability for subsea conditions. No further development was made.

Group 4.1

This concept group has lots of benefits and fulfills the requirements for subsea tools and hydraulic cylinders have been used in several other ROV tools.

Group 4.1 was then chosen for further development.

7 FURTHER DEVELOPMENT OF CONCEPT

Group 4.1 is a hydraulic solution that operates on the IT with a lever system see Figure 7.1. The 3D-model that was developed in concept phase 2 was used as a basis for further development and to a final concept.

Figure 7.1- Group 4.1

The big challenge was to minimize the CT as much as possible. A smaller CT is easier for the ROV to maneuver. A table with cylinder criteria was developed, see Table 7.1.

Table 7.1- Cylinder criteria

Criteria	Value
Stroke Length	80 mm
Hydraulic Pressure	680 bar
Max length	240 mm
Pull force	20 metric ton

The company Malmorstad [12] could produce a cylinder that achieve our cylinder criteria and with even better max length to 200 mm.
Data from Malmorstad were used to make an envelope for the hydraulic cylinder, see Figure 7.2

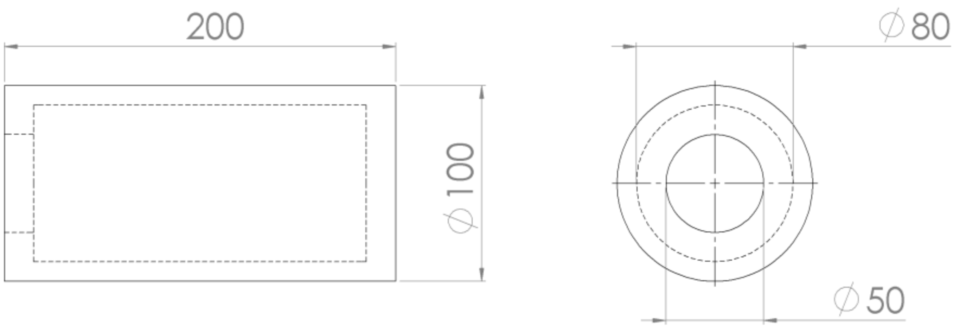


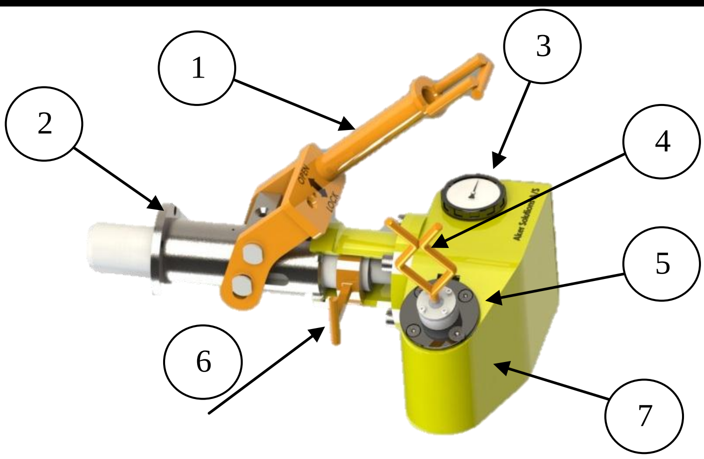
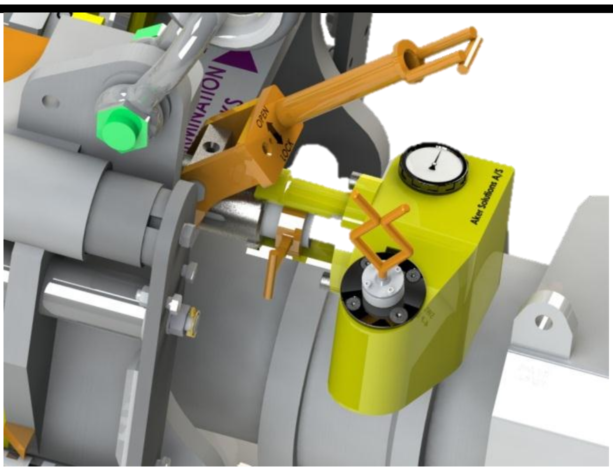
Figure 7.2-Envelope of the hydraulic cylinder

CT with splint system

A basic structure was made for further development. The final design needs two connecting systems; one that connect the CT to the IT, one that connect the rod to the lock pin. To make the operation for the ROV maneuverable, few motions as possible is to prefer. When designing the connecting systems it was important to manage the tension in structure and fit the envelope of HCS.

To connect CT to IT an outer bayonet coupling is used. Rod and lock pin is connected through a splint. To operate the CT a control box is needed, see Table 7.2. This protects the main components: mini booster, pressure reducer, pressure gauge, receptacle, and hydraulic pipes.

Table 7.2 – Concept with splint

<table>
<tr><th>Figure</th><th>Description</th></tr>
<tr><td>
</td><td><table>
<tr><th>Number</th><th>Description</th></tr>
<tr><td>1</td><td>Lever system</td></tr>
<tr><td>2</td><td>Interface to IT</td></tr>
<tr><td>3</td><td>Pressure gauge</td></tr>
<tr><td>4</td><td>Fishtail</td></tr>
<tr><td>5</td><td>Receptacle</td></tr>
<tr><td>6</td><td>Splint</td></tr>
<tr><td>7</td><td>Control box</td></tr>
</table></td></tr>
<tr><td></td><td>Concept installed together with the installation tool</td></tr>
</table>

This concept resolves in three main motions for ROV to operate CT these motions is described inTable 7.3.

Table 7.3-Motions

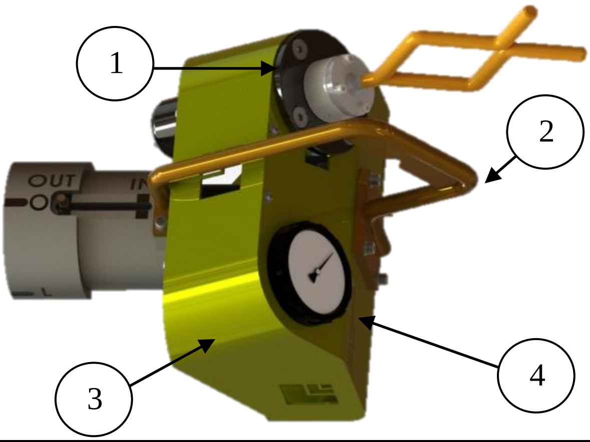
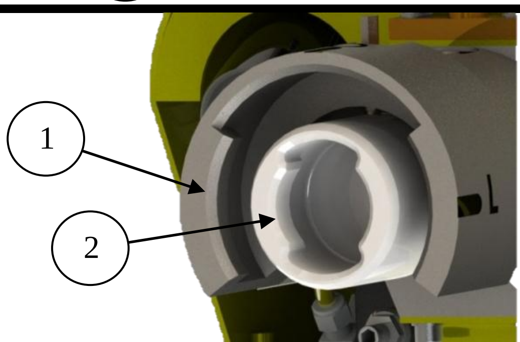
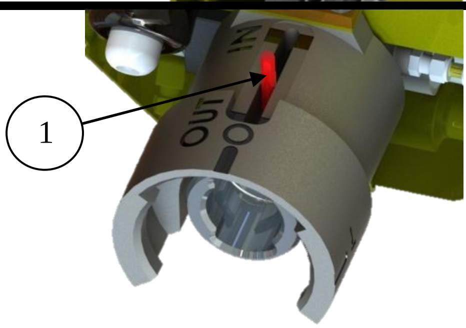
Motion	Description
1	Connect the CT to the IT with rotating CT 90^{o} clockwise
2	Connect the splint to the rod and the lock pin
3	Operate the CT

A virtual installation with the whole structure was simulated in SolidWorks. The simulation found it very difficult with the rotation in order to connect the CT to IT without impacting the surrounding structure. Another problem was that the rod could rotate freely. This means that the rod could rotate in an undesirable situation where it is impossible to connect CT on IT. These problems were discussed with Martin Stegberg for further development.

CT with two bayonet couplings

Further development of the concept was made and a final design emerged. The rod was designed with same bayonet coupling as the cylinder, see Table 7.4.This design decreased movements for ROV. To stop the rotation of the rod, a guide pin was developed. It holds the rod in right position.

Table 7.4-CT with two bayonet copulings

Figure	Number	Description
	1	Receptacle
	2	ROV handel
	3	Control box
	4	Pressure gauge
	1	Outer bayonet coupling
	2	Inner bayonet coupling
	1	Guide pin

This solutions resolve in two main motions for ROV to operate CT see Table 7.5.

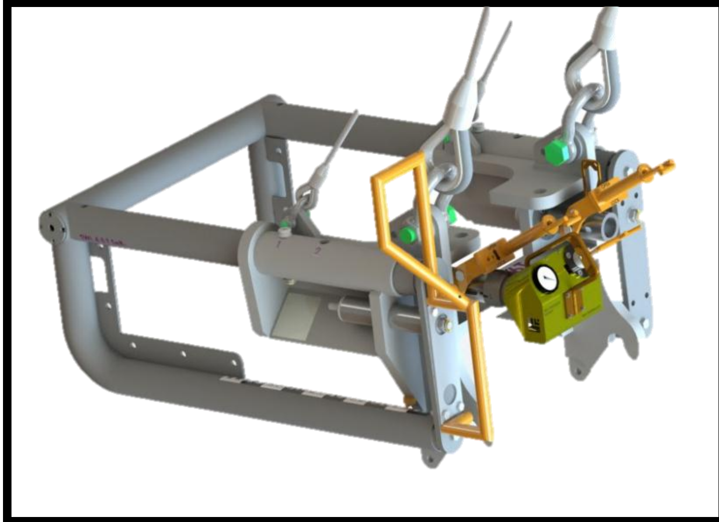
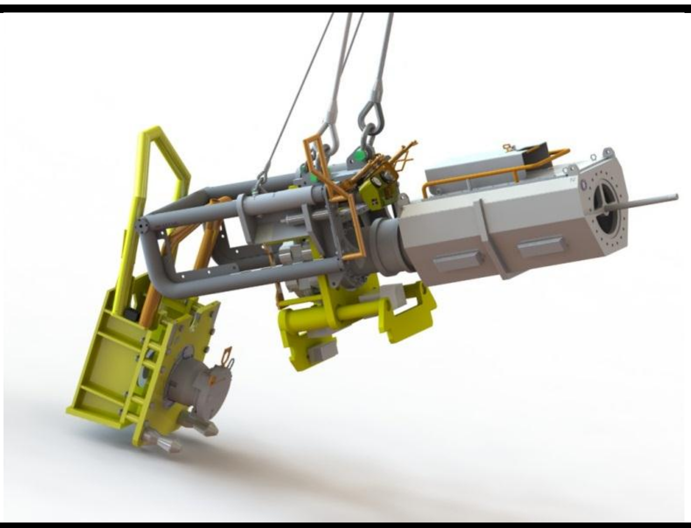
Table 7.5-Motions

Motion	Description
1	Connection between; CT to the IT, rod to the lock pin is done though a 90^{o} clockwise rotation.
2	Operate the CT

Installed CT

Table 7.6 shows final concept connected to IT and HCS.

Table 7.6-Connected contingency tool

Figure	Description
	CT (Contingency tool) connected to the IT (installation tool)
	Installation tool with the contingency tool connected to the HCS
	A closer view on the contingency tool when it is connected to the installation tool.

8 THE FINAL DESIGN

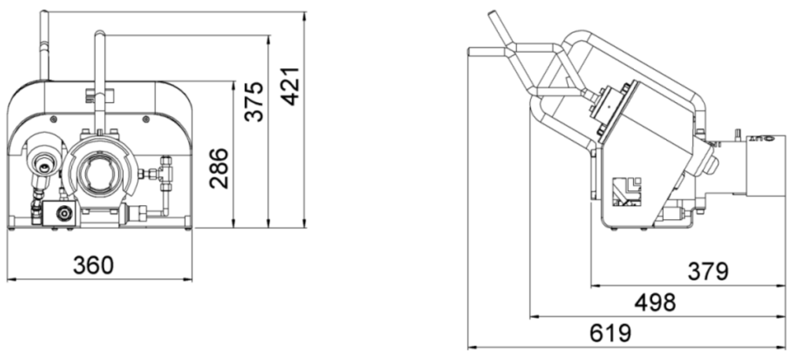
Together with Aker Solution the final design was named LockDog Contingency Tool (LDCT). All technical information and details of the parts in the final concept is described in this chapter. Further technical information for the LDCT is described in OMM see appendix D.

8.1 Design Specifications

Table 8.1 describes the technical information and envelope about the LDCT. LDCT is designed so it meets the design basis which was set at the beginning of the project. Some technical specifications are from Malmorstad [12] and miniBooster [3] which representing certain parts in the final design.

Table 8.1-Tecnichal specifications

Measurement	Value
Operational force capacity	Pull 20 metric tonnes (680 bar) Push 10 metric tonnes (200 bar)
Max. allowable water depth	3 000 m (10 000 ft)
Operation temperature range	0 to + 50 ^{o}C
Input pressure	170-207 bar (2465 - 3000 psi)
Input flow	0-14 l/min (0 – 3.7 gal/min)
Maximum working Pressure retract (after booster)	680 bar (9860 psi)
Maximum working Pressure extend	200 bar (2900 psi)
Design Pressure hydraulic system	207 bar (3000 psi)
Check Valves	In Dual Port Hot Stab / In Dual Port Receptacle
Hoses/ piping	For subsea usage
Stroke length	80 mm
Weight in air	39 kg
Weight in water	35 kg



8.2 Assembly and parts

Figure 8.1 shows an assembly view with all parts (Table 8.2) that the LDCT include. All parts are presented later in this chapter.

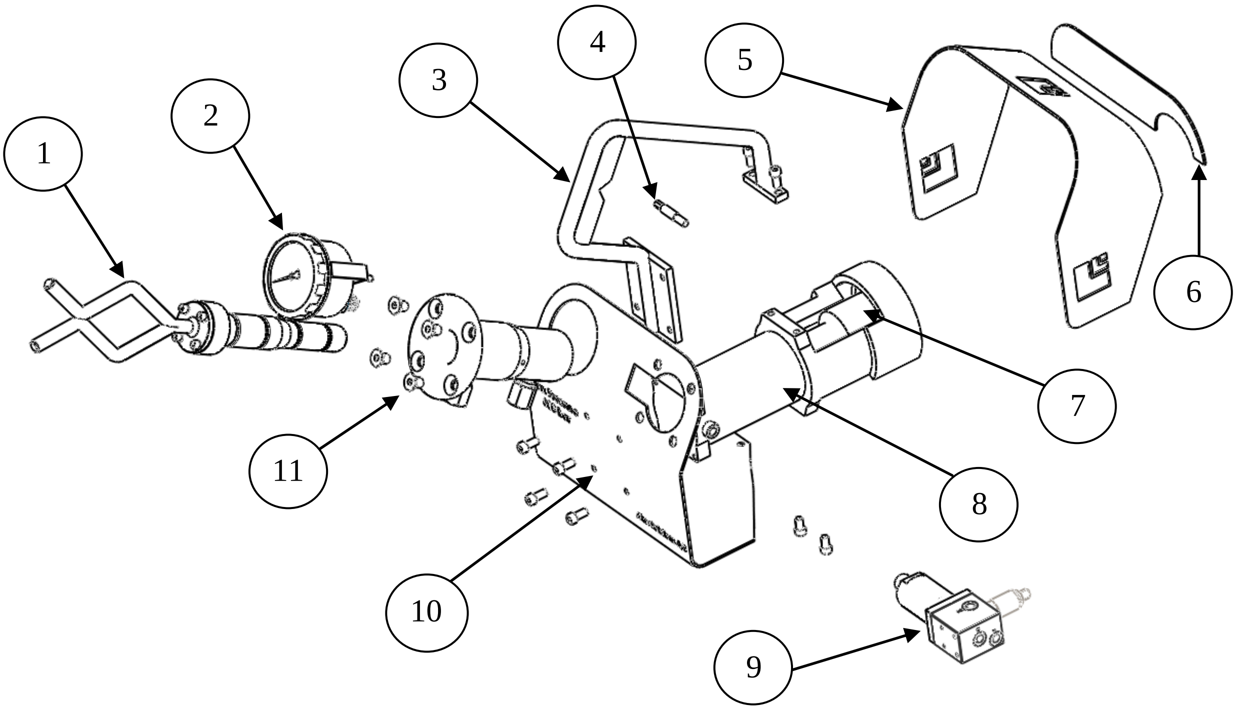


Figure 8.1- Assembly view

Table 8.2-Parts in the LDCT

Number	Description
1	Fishtail
2	Pressure gauge
3	ROV-handle
4	Pin guide
5	Control box – top part
6	Control box – back part
7	Rod
8	Cylinder
9	Pressure booster HC2 with CV2 pressure reducer
10	Control box – front part
11	Receptacle for ROV-hydraulic connection interface

Cylinder and rod

The cylinder and rod is the main part on LDCT, see Figure 8.2 and Table 8.3. Because of the narrow dimensions on the envelope for HCS, the cylinder with its outer bayonet coupling is made in one piece. This design is engineered with the corporation with the company Malmorstad [12] to fulfill the design basis and the material strength. The rod has also a bayonet coupling to connect on the lock pin.

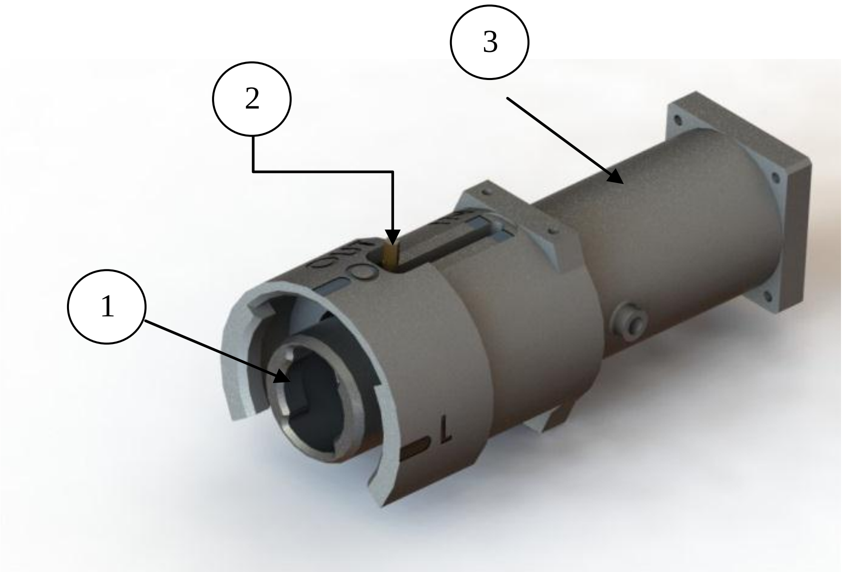


Figure 8.2-Cylinder and Rod

Table 8.3-Description

Number	Description
1	Rod
2	Guide pin
3	Hydraulik cylinder

Control box

The main purpose for a control box is to protect and attach the vulnerable hydraulic parts and pipes. Control box is made from a 3 mm painted sheet material which is divided into three different parts for easier manufacturing, see Figure 8.3 and Table 8.4.

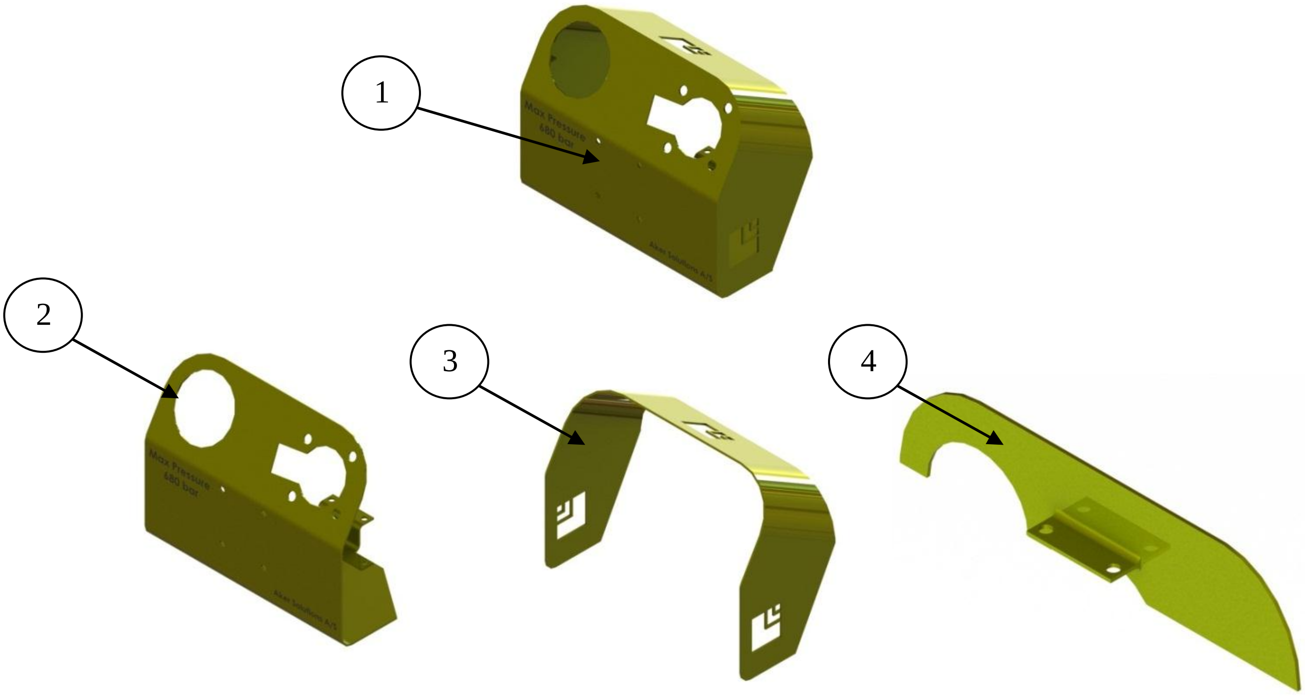


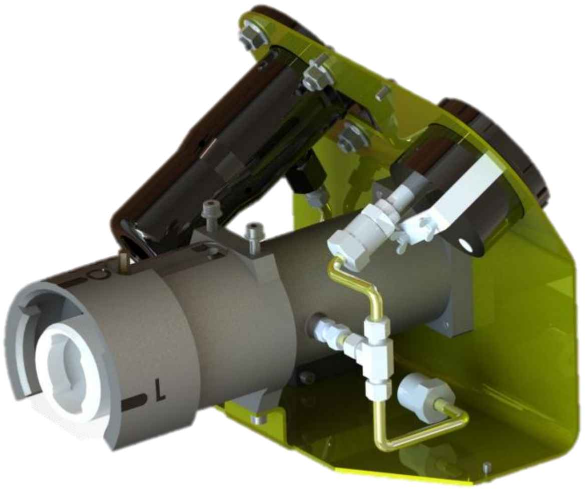
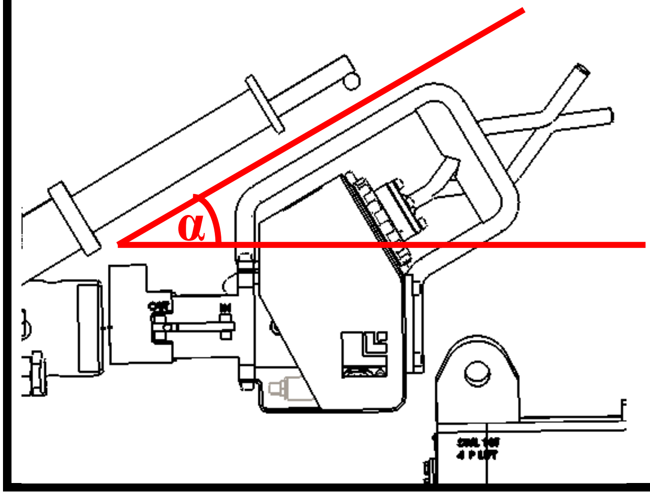
Figure 8.3-Control box

Table 8.4-Controll box

Number	Description
1	Control box
2	Front plate
3	Top plate
4	Back plate

Table 8.5 describes imported design criteria's for control box. These criteria's was imported to manage the design basis and at the same time include all hydraulic parts.

Table 8.5- Control box.

Figure	Description
	To minimize the size of the control box, parts and pipes are place strategically. The minimum bending radius on pipes has been taken in consideration.
	The control box is design so it builds from the backside of the cylinder and forward. This is important to reduce the length of the CT. The control box is mounted together with ROV handle with four bolts.
	To not impact the lever in the installation process, the control box is design with the same angle as the lever in locked position (α).

Mini booster and reducer

The mini booster (Figure 8.4) function is to increase the hydralic pressure with four times from ROV's hydralic power. This is important to achieve the high pressure to reduce cylinders dimensions. Mini boosters is a common part in standard tools to increase the ROV's hydraulic pressure. In the LDCT mini booster is connected to a reducer (Table 8.6) that limits the inlet pressure from ROV to required value see Diagram 8.1. The information about mini booster and reducer is taken from the company miniBooster [3],[4].

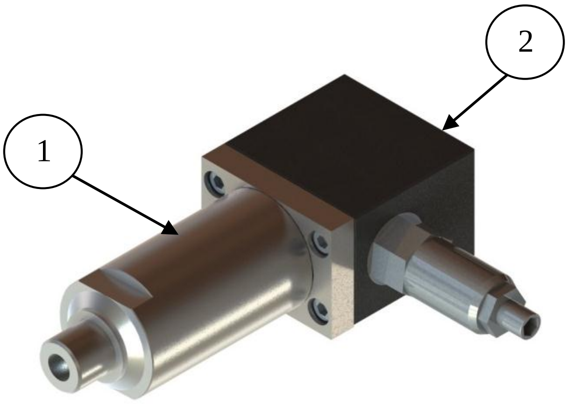


Figure 8.4-miniBooster with reducer

Table 8.6- miniBooster with reducer

Number	Description
1	Hydraulic pressure booster
2	Hydraulic pressure reducer

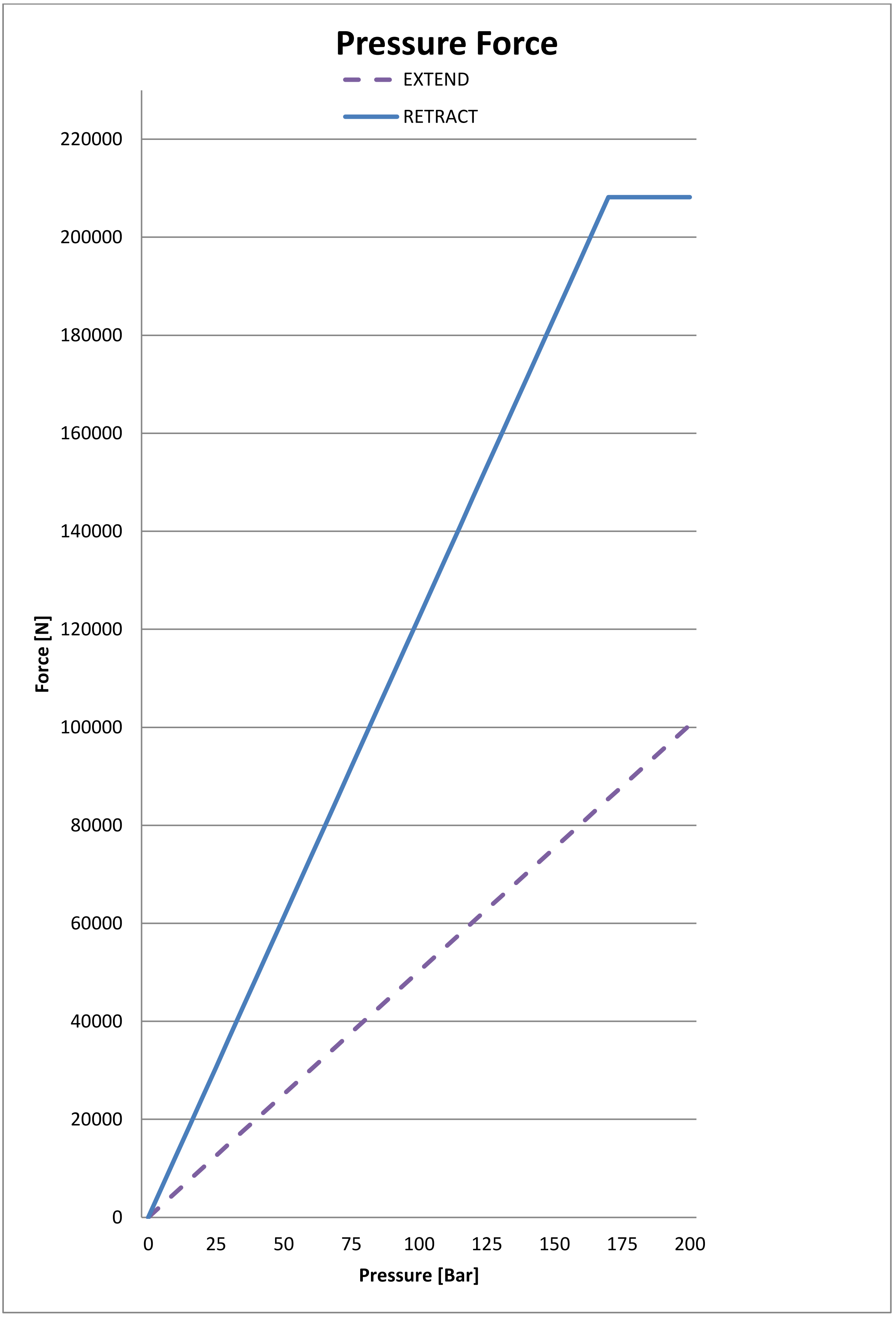


Diagram 8.1-Pressure/Force diagram

Receptacle

The receptacles see Figure 8.5 is the interface between ROV’s dual port hot stab and LDCT hydraulic system. This is a standard component which use in hydraulic subsea tools.

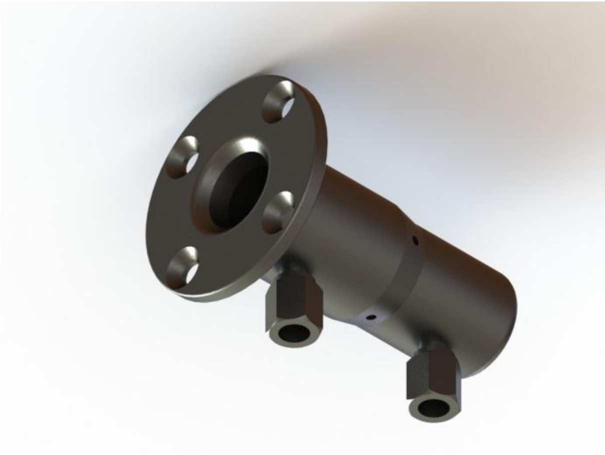


Figure 8.5-Receptacle

Pressure gauge

The pressure gauge see Figure 8.6 main function is to show the outlet pressure from pressure booster. This pressure gauge is a standard part for subsea tools.

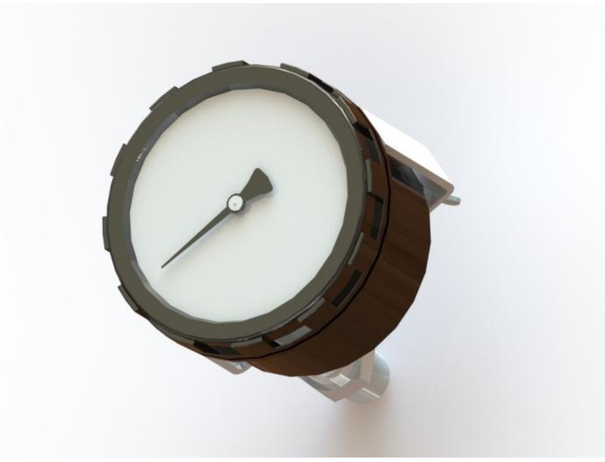
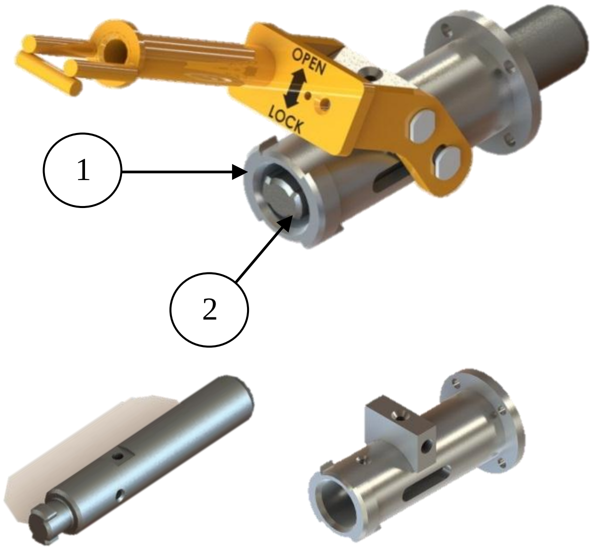


Figure 8.6- Pressure gauge

Lever System

To connect the CT to the lever system some changes in the exciting design were needed. The difference between the existing and the new design can be seen in Table 8.7.

Table 8.7-Lever system

<table>
<tr><th>Figure</th><th>Description</th></tr>
<tr><td>
</td><td>This is the new design with the interface for the LDCT. Design changes is marked and described in the figure.
<table>
<tr><th>Number</th><th>Description</th></tr>
<tr><td>1</td><td>Outer bayonet coupling on guide pin</td></tr>
<tr><td>2</td><td>Inner bayonet coupling on lock pin</td></tr>
</table></td></tr>
<tr><td>
</td><td>Replace version</td></tr>
</table>

8.3 FEM

To see if the rod design would manage a force of 20 metric tons several simulation in FEM was made in SolidWork. A green arrow is equal to a fixture, meaning it is locked to its position. A pink arrow shows where the evenly distributed force is disposed.

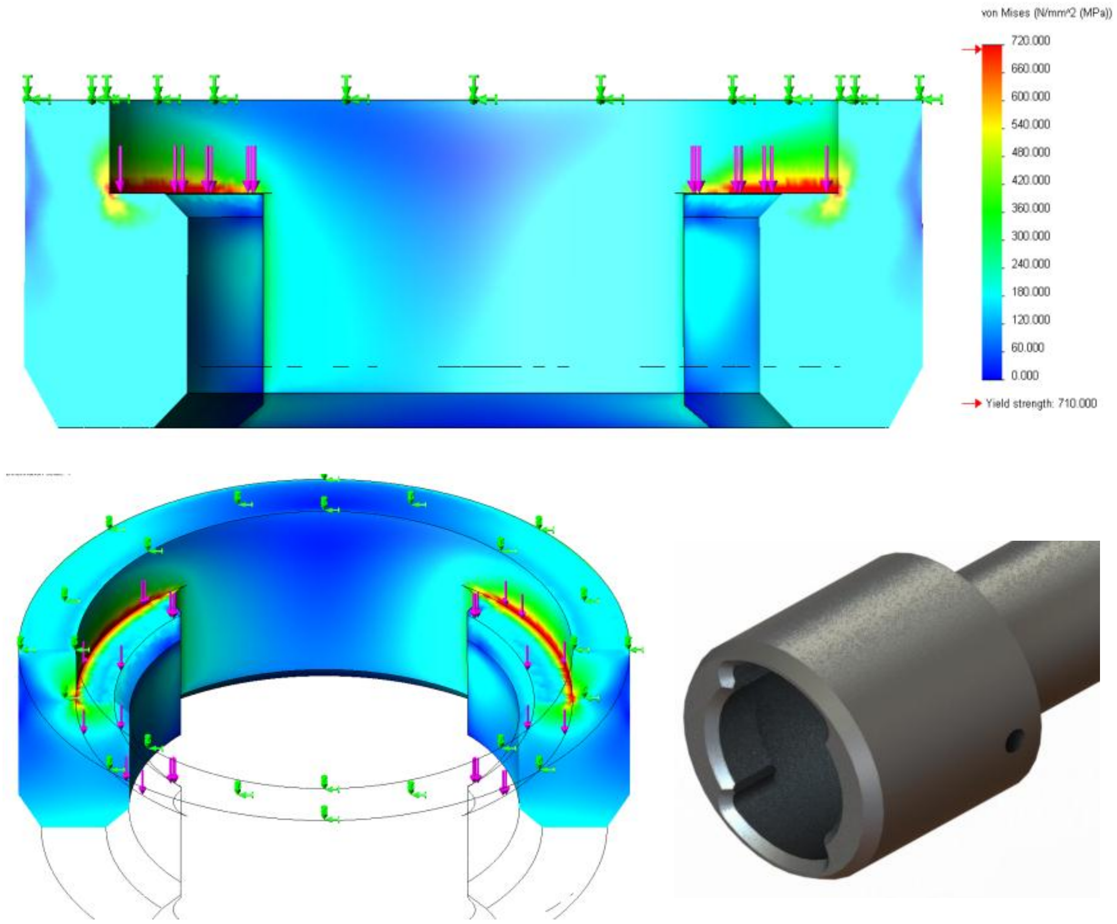


Figure 8.7-FEM-model of rod

Figure 8.7 showing von Mises stresses from 0 MPa to 710 MPa. Yield strength for the material is 710 MPa and everything over 710 will be showed as red.
Some area between flanged and outer surface are over 710MPa which means that some material around the edge will be plasticized and can be a problem due to fatigue. Aker Solution has a requirement that the strain energy have to be below 10% in a point and 2% in a section [9].

To control the results an existing tool was chosen to compare the rod, the tool and FEM-analyses can be seen in Figure 8.8. This is an existing tool at Aker Solutions and has a similar design as the LDCT.

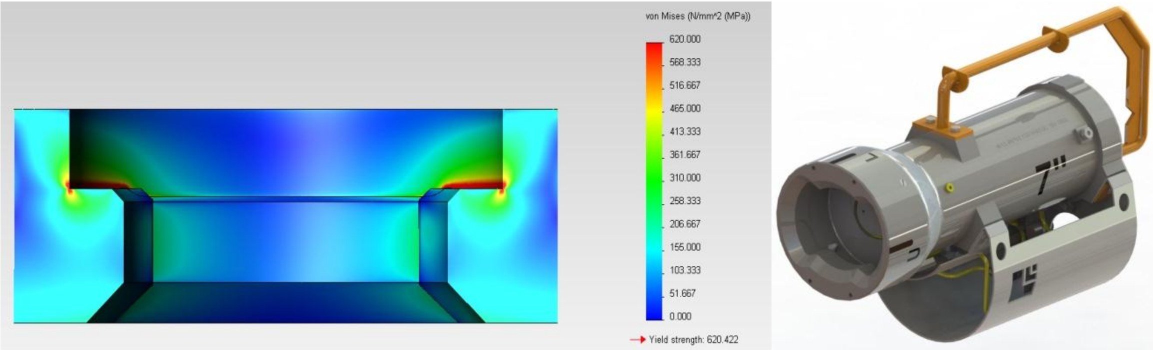


Figure 8.8-Bolt puller, FEM-model of von Mises

Both FEM-analyses, as shown in Figure 8.7 and Figure 8.8, has similar stress image which means that the LDCT probably manage the stress. Further calculations will be made by Finite Element Analysis Specialist personal at Aker Solution.

8.4 Drawings

All drawings are designed according to Aker Solutions standards and Aker Solutions templates for drawings are used.

Three kinds of templates are used, depending on what kind of tasked which is performed: welding, machining and assembly drawings.
If nothing is specified these standards below are used.

1. Unless otherwise specified dimensions are in millimeters, all standards referred to shall be the current issue.
2. Tolerancing ISO 8015 [5]
   General tolerancing ISO 2768-mK [6]
3. Unless otherwise specified deburr external edges and corners.
   Fillet radius: Max=0,8.
   Surface roughness RA 3,2.

All drawings can be seen in appendix C.

8.5 Hydraulic schedule

A hydraulic schedule was made to control if the piping would fit the control box. In Figure 8.9 and in appendix C shows the hydraulic schedule over the LDCT. This includes all hydraulic parts in the control box, see Table 8.8.

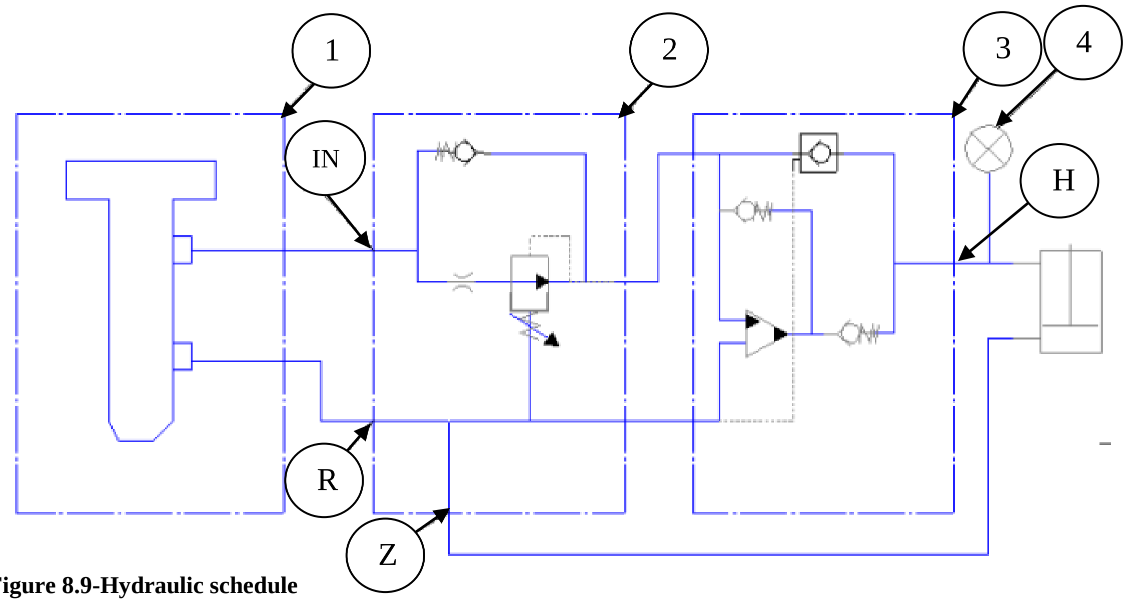


Figure 8.9-Hydraulic schedule

Table 8.8- Hydraulic schedule

Number	Description
1	Receptacle
2	Hydraulic pressure reducer
3	Hydraulic pressure booster
4	Pressure gauge
R	Hydraulic return
Z	Return from cylinder
IN	Low pressure hydraulic inlet
H	High pressure hydraulic outlet

8.6 Clearance

Tools for ROV need to be as uncomplicated as possible to operate. Therefore it is important that the clearance is in right place.

The LDCT is designed so that the outer bayonet coupling on the cylinder matches the installation tool before the rod and lock pin which makes it easy for the ROV to connect. When the outer bayonet coupling is in place, the ROV knows that the rod also has connected to the lock pin.

In Figure 8.10 shows the outer clearance and in Figure 8.11 shows the inner clearance.

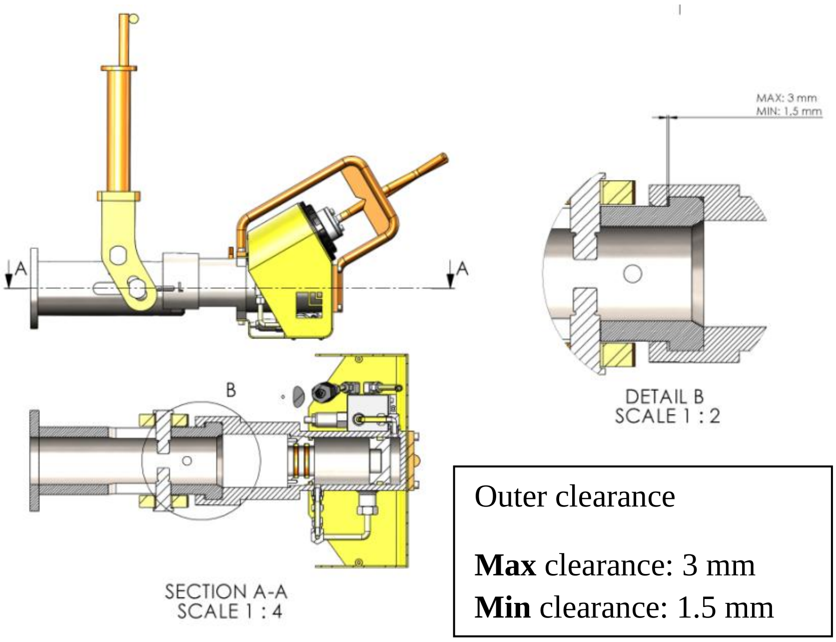


Figure 8.10-Outer clearance

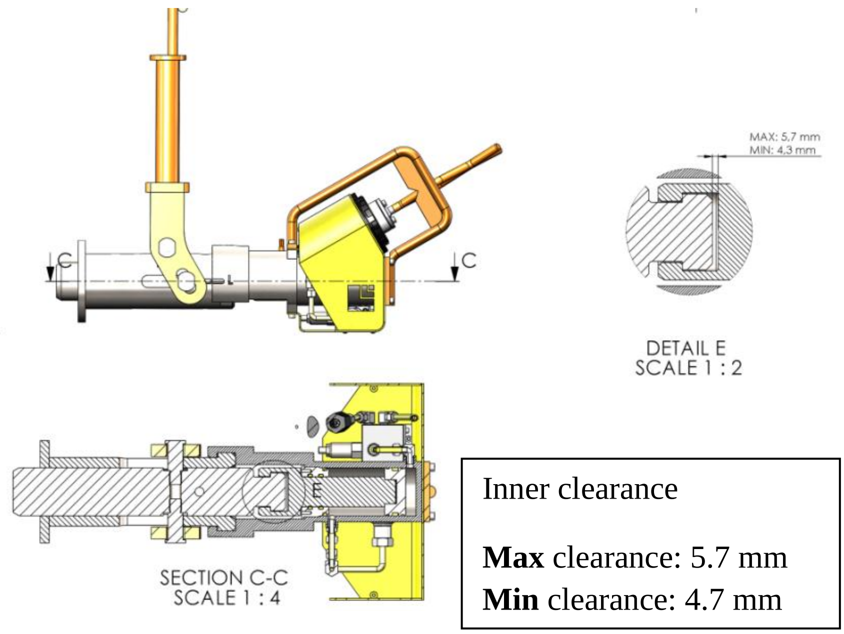


Figure 8.11-Inner clearance

9 CALCULATIONS

In this chapter minor calculations will be made. Calculations are made to determine the minimum diameter for: piston, cylinder and lock pin.

$F = Force$ $r = Radius$ $\tau_u = Tensile\ strength\ (shear)$
$P = Pressure$ $\sigma_u = Tensile\ strength$ $\tau_y = Yield\ strength\ (shear)$
$A = Area$ $\sigma_y = Yield\ strength$ $G = Shear\ modul$
$E = Youngs\ modul$ $D\ or\ d = Diamter$

9.1 Piston

Calculations determine the minimum diameter of the cylinder see Figure 9.1. Material used in this calculation is a Normalized carbon steel. The company who later will do the manufacturing of the hydraulic piston will set the final dimensions.

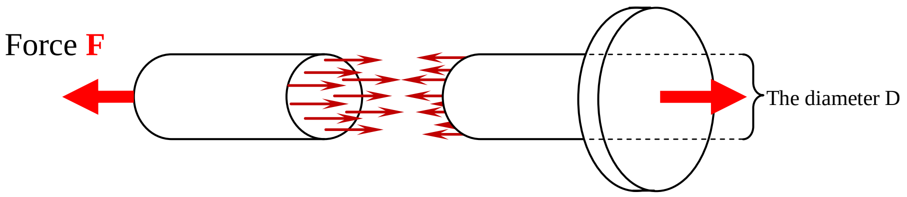


Figure 9.1-Piston stress

<u>Data</u>

Material: SS141650-01 (Normalized Steel) [8]
$\sigma_u = 690\ MPa$
$\sigma_y = 310\ MPa$
$E = 206\ GPa$

<u>Equations</u>

Force

$$F = 20\ ton = 9{,}82 * 20\ 000\ N = 196\ 400\ N \quad (9.1)$$

Area:

$$\sigma = \frac{F}{A} \rightarrow A = \frac{F}{\sigma} = \frac{196\ 400\ N}{310 \cdot 10^{6}\ Pa} = 633.5 \cdot 10^{-6}\ m^2 = 6.335\ cm^2 \quad (9.2)$$

Radius:

$$A = \pi \cdot r^2 \rightarrow r = \sqrt{\frac{A}{\pi}} = \sqrt{\frac{633.5 \cdot 10^{-6}}{\pi}} = 14.2 \cdot 10^{-3}\ m = 14.2\ mm \quad (9.3)$$

<u>Conclusions</u>

The hydraulic piston radius **r** needs to be at least **14.2 mm** to be able to fulfill the operation without any plasticization of the material.

9.2 Cylinder

Calculations to determine the inner diameter D for the hydraulic cylinder. Calculations of pressure and area are made to get the necessary force see Figure 9.2.

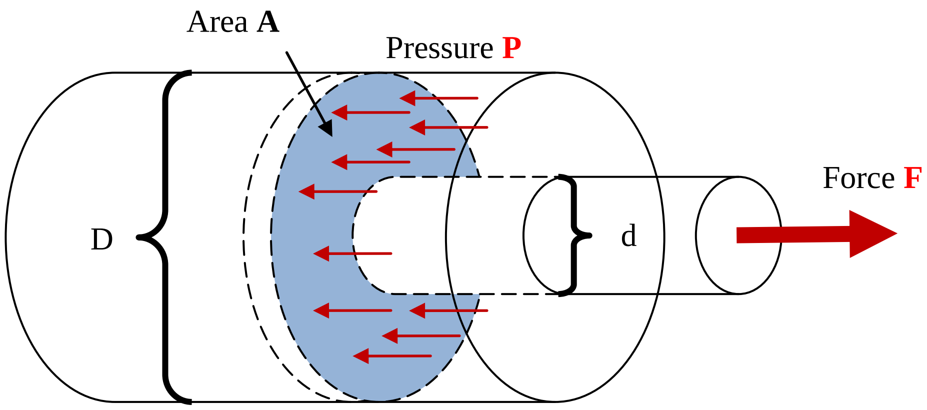


Figure 9.2-Cylinder

Data

$F = 196\ 400\ N$
$P = 680\ bar = 68 \cdot 10^6\ Pa$

Equations

Minimum required area.

$$F = P \cdot A\ \rightarrow A = \frac{F}{P} = \frac{196\ 400\ N}{68 \cdot 10^6\ Pa} = 2.89 \cdot 10^{-3}\ m^2 = 28.9\ cm^2 \quad (9.4)$$

Required diameter depends on the hydraulic piston diameter. In this equation a diameter of d=35 mm will be used for the piston.

$$A = \pi \cdot \frac{D^2}{4} \quad (9.5)$$

Minimum diameter

$$A_{pressure} = A_D - A_d = \pi \cdot \left(\frac{D^2}{4} - \frac{d^2}{4}\right) \rightarrow D = \sqrt{\frac{4 \cdot A_{pressure}}{\pi} + d^2} =$$

$$= 4\sqrt{\frac{2.89 \cdot 10^{-3}}{\pi} + \frac{(35 \cdot 10^{-3})^2}{4}} = 70 \cdot 10^{-3} m = 7.0\ cm = 70\ mm \quad (9.6)$$

Conclusions

Required minimum diameter **D** for the cylinder needs to be at least **70 mm** to get a force of 20 ton and a piston diameter of 35 mm. The required pressurized area is $2.89 \cdot 10^{-3}\ m^2$.

9.3 Shear stress analysis for the lock pin

Stress calculations to determine maximum force one edge will be able to handle.

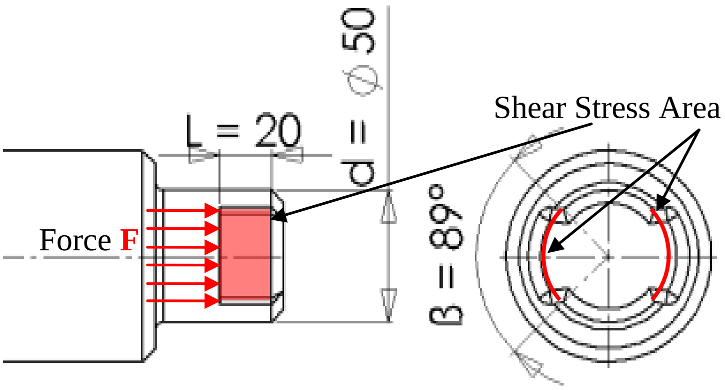


Figure 9.3-Stress areas

Data

$\sigma_u = 470\ MPa$

$\sigma_y = 355\ MPa$

$F_{required} = 196\,400\ N$

Calculations

Area calculations:

$$A = \frac{\frac{d}{2} \cdot \beta \cdot \pi}{180} \cdot L = 2 \cdot \frac{\frac{0.050}{2} \cdot 89 \cdot \pi}{180} \cdot 0.020 = 0.00155\ m^2 = 1553\ mm^2 \quad (9.7)$$

Force:

$$\tau = 0.6 \cdot \sigma_y \quad (9.8)$$

$$\tau = \frac{F}{A} \rightarrow F = \tau \cdot A\ (Two\ area) \rightarrow F = 2 \cdot \tau \cdot A \quad (9.9)$$

$$F = 2 \cdot 0.6 \cdot 355 \cdot 1553 = 661\,500N > F_{required} \quad (9.10)$$

Conclusions

The area which the force will be present is 1553 mm^2, According to our calculations will the structure manage a force **F** of **662 kN** which is around three times higher than the required one.

10 CONCLUSIONS

In this chapter the conclusions of our work will be handled. We have chosen to present our conclusion in point form. This gives a better and clearer view.

- A completely new contingency tool for the HCS system was developed from scratch.

- In theory our contingency tool solves the problem. This was the purpose of this project.

- We used a new type of pressure booster that includes a pressure reducer (HC2W 4,0-B-1S with CV2). This reduces the piping and makes our design possible to fit the envelope.

- A special made hydraulic cylinder was developed and approved by the company Malmorstad. This made it possible to reduce the length of the contingency tool.

- Calculations and FEM-analysis has been done to ensure the design would manage stresses.

- Minor changes on the installation tool were made to have an interface for the contingency tool.

11 DISCUSSION AND REFLECTION

Important discussion about relevant topics will be discussed in this chapter.

The purpose with this work was to develop a contingency tool to solve a problem in the HCS installation process. A contingency tool was developed which can be connected to the lever system. To lock the tool with the lever system, bayonet couplings were used.

The system is designed according to Aker Solution to manage a dragging force of 20 metric tons (around 200 000 N). The final design could not be tested due to a prototype was never produced. This tool will have around 20 times higher pull force than from the ROV and make this design reliable. A construction to manage a bigger force would be very hard to design.

To make the installation easier the CT to the IT had a built in clearance. This makes it easier for ROV to connect and operate the CT without needing to be in the exact right place in the installation process, making the installation process more confident.

To ensure the design theoretically; cylinder and rod was designed against the yield strength. Calculations and FEM-analysis was done in SolidWorks. Final calculations will be done by Finite Element Analysis Specialist and approved by Aker Solutions.

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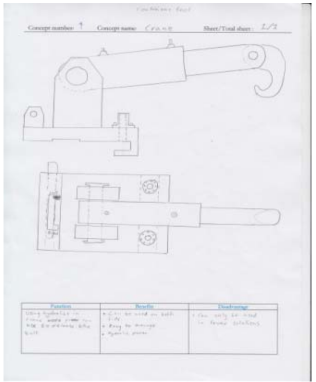
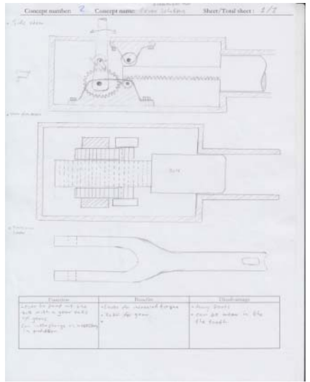
APPENDIX A PUGH-MATRIX

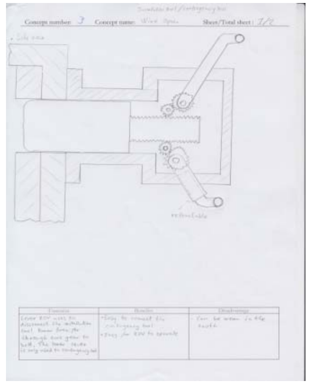
Pugh-Matrix

Pugh Concept Selection Process
Summary Chart: First elimination

PROJECT:







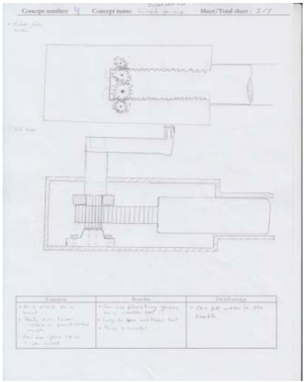
	Referens Weight factor	Koncept 1	Koncept 2	koncept 3
Will be abel to use contingency tool	-1	1	1	1
Meet the requirements of the envelope	1	1	1	1
No complex parts	1	1	-1	-1
No change of installations tool	-1	0	-1	-1
Easy to use	1	1	1	1
Easy to conect contingency tool	-1	1	1	-1
Manage natural conditions	1	1	-1	-1
Can be operat with ROV	1	1	1	1
Change the strength characteristics on the bolt	0	0	0	0
Number better: Σ+	+5	+7	+5	+4
Number worse: Σ–	-3	0	-3	-4
Number same: Σ0		1		

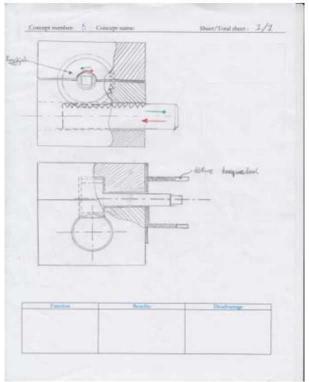
-1: Alternative is worse than the Datum on the Criteria

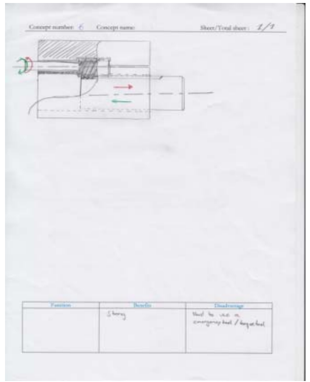
0: Alternative is indistinguishable from the Datum on the Criteria

1: Alternative is better than the Datum on the Criteria

Pugh Concept Selection Process
Summary Chart: First elimination
PROJECT:







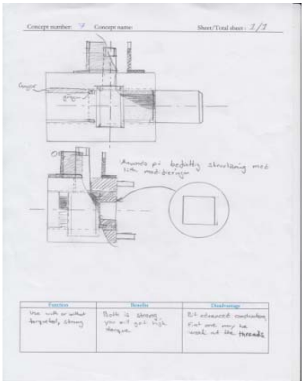
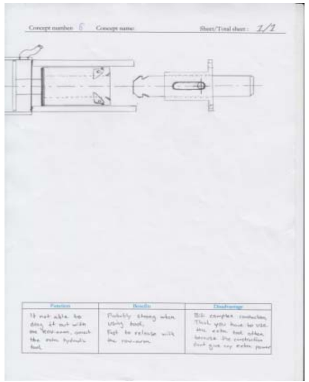
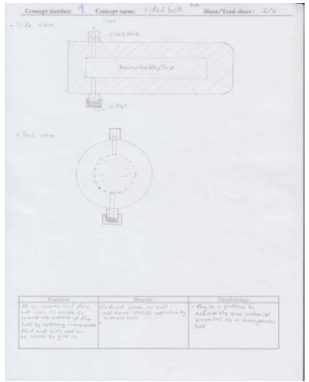
	Koncept 4	Koncept 5	Koncept 6
Will be abel to use contingency tool	1	1	-1
Meet the requirements of the envelope	1	1	1
No complex parts	-1	-1	1
No change of installations tool	-1	-1	-1
Easy to use	1	1	1
Easy to conect contingency tool	1	1	-1
Manage natural conditions	-1	-1	-1
Can be operat with ROV	1	1	1
Change the strength characteristics on the bolt	0	0	0
Number better: Σ+	+5	+5	+4
Number worse: Σ–	-3	-3	-4
Number same: Σ0			

-1: Alternative is worse than the Datum on the Criteria

0: Alternative is indistinguishable from the Datum on the Criteria

1: Alternative is better than the Datum on the Criteria

Pugh Concept Selection Process
Summary Chart: First elimination
PROJECT:

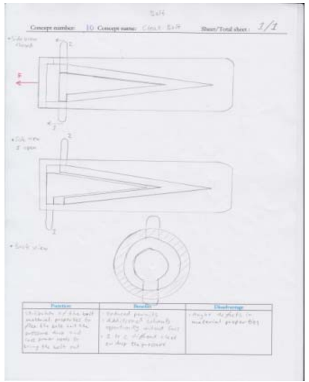
	Koncept 7	Koncept 8	Koncept 9
Will be abel to use contingency tool	1	1	0
Meet the requirements of the envelope	1	1	1
No complex parts	-1	1	-1
No change of installations tool	-1	-1	-1
Easy to use	1	1	1
Easy to conect contingency tool	1	1	0
Manage natural conditions	-1	1	1
Can be operat with ROV	1	1	0
Change the strength characteristics on the bolt	0	0	-1
Number better: $\Sigma+$	+5	+7	+3
Number worse: $\Sigma-$	-3	-1	-3
Number same: $\Sigma 0$			

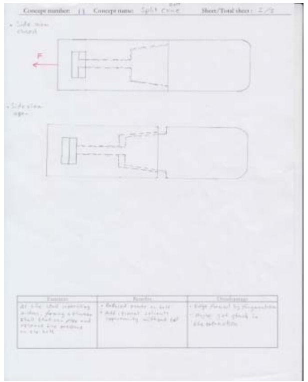
-1: Alternative is worse than the Datum on the Criteria

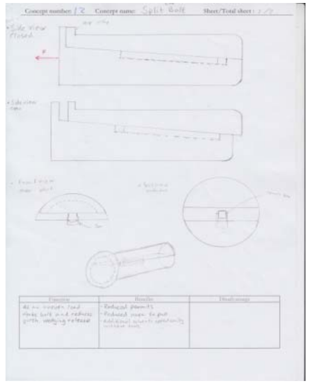
0: Alternative is indistinguishable from the Datum on the Criteria

1: Alternative is better than the Datum on the Criteria

Pugh Concept Selection Process
Summary Chart: First elimination
PROJECT:







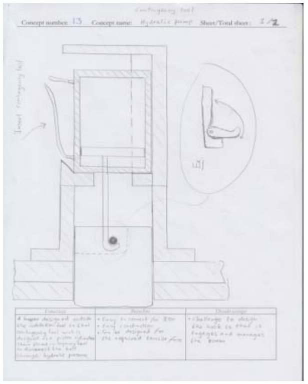
	Koncept 10	Koncept 11	Koncept 12
Will be abel to use contingency tool	0	0	0
Meet the requirements of the envelope	1	1	1
No complex parts	-1	-1	-1
No change of installations tool	-1	-1	-1
Easy to use	1	1	1
Easy to conect contingency tool	0	0	0
Manage natural conditions	1	1	1
Can be operat with ROV	0	0	0
Change the strength characteristics on the bolt	-1	-1	1
Number better: Σ+	+3	+3	+4
Number worse: Σ–	-3	-3	-2
Number same: Σ0			

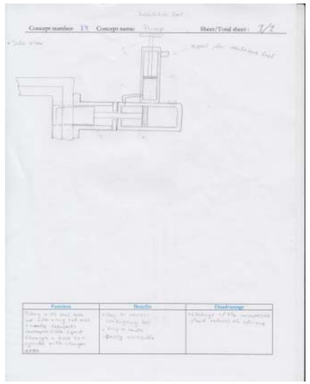
-1: Alternative is worse than the Datum on the Criteria

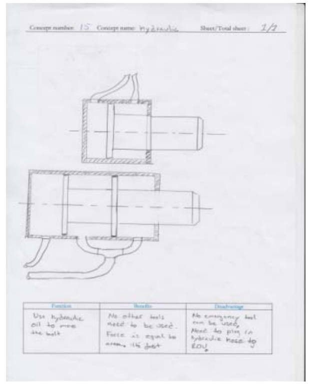
0: Alternative is indistinguishable from the Datum on the Criteria

1: Alternative is better than the Datum on the Criteria

Pugh Concept Selection Process
Summary Chart: First elimination
PROJECT:







	Koncept 13	Koncept 14	Koncept 15
Will be abel to use contingency tool	1	1	-1
Meet the requirements of the envelope	1	1	1
No complex parts	1	1	1
No change of installations tool	-1	-1	-1
Easy to use	1	1	1
Easy to conect contingency tool	1	1	0
Manage natural conditions	1	1	1
Can be operat with ROV	1	1	1
Change the strength characteristics on the bolt	0	0	0
Number better: Σ+	+7	+7	+5
Number worse: Σ–	-1	-1	-2
Number same: Σ0			

-1: Alternative is worse than the Datum on the Criteria

0: Alternative is indistinguishable from the Datum on the Criteria

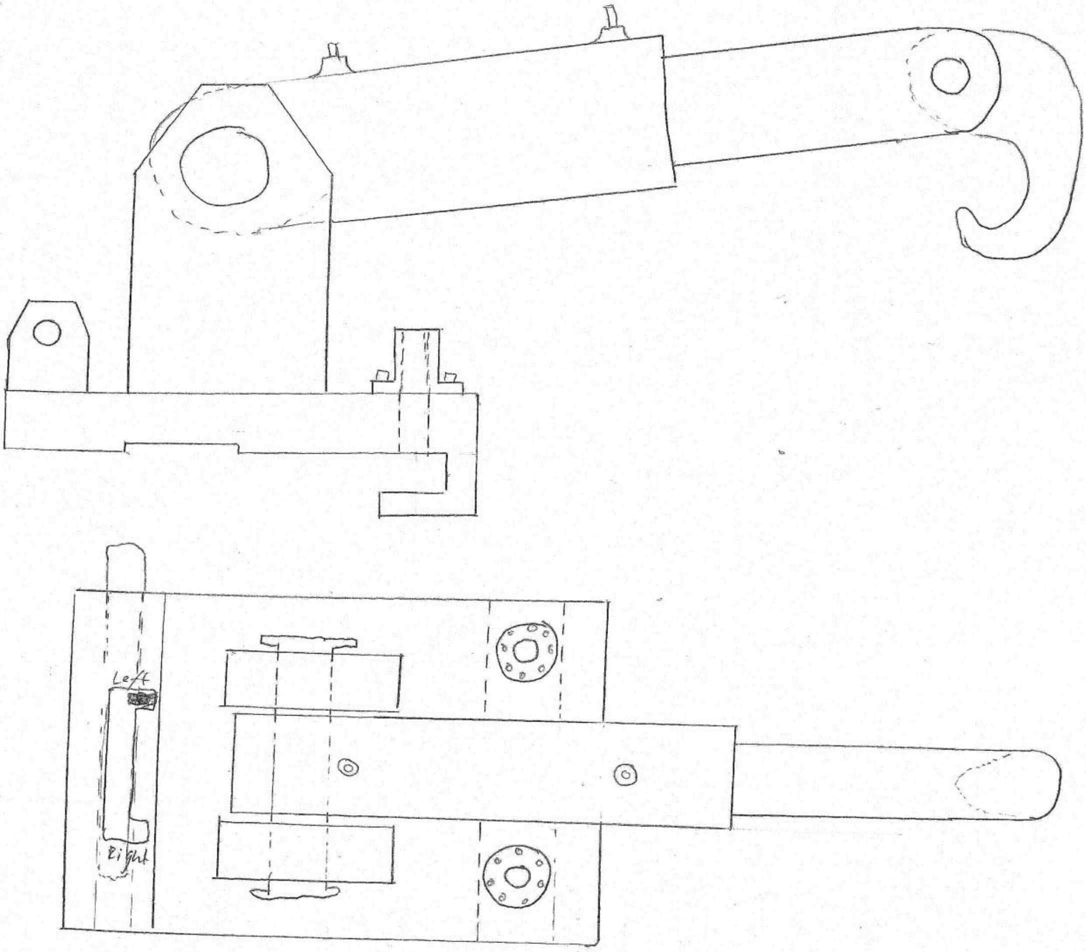
1: Alternative is better than the Datum on the Criteria

APPENDIX B CONCEPTS

Concepts

continious tool

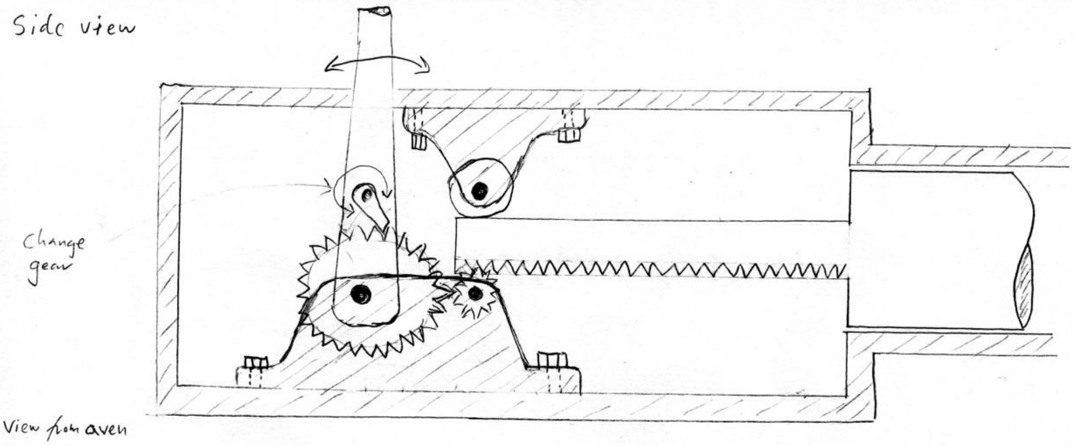
Concept number: 1 Concept name: Crane Sheet/Total sheet : 1/1



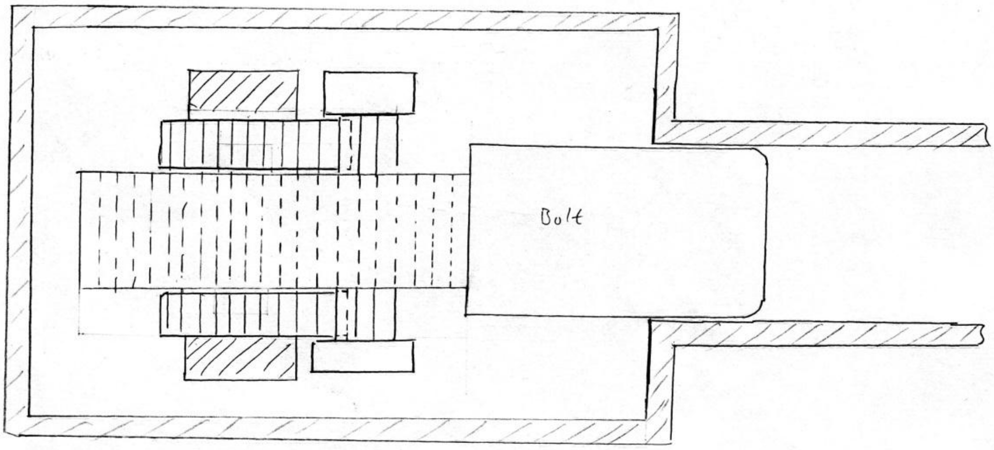
Function	Benefits	Disadvantage
Using hydralics in crane more power can use to release the bult	• Can be used on both side. • Easy to manage • Hydralic power	• Can only be used in lever solutions

Concept number: Concept name: Lever Solutions Sheet/Total sheet : 1/1

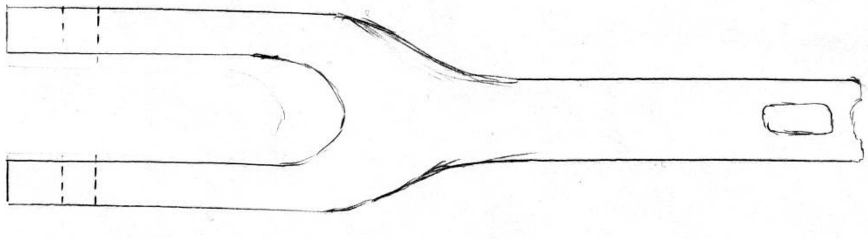
• Side view



• View from aven



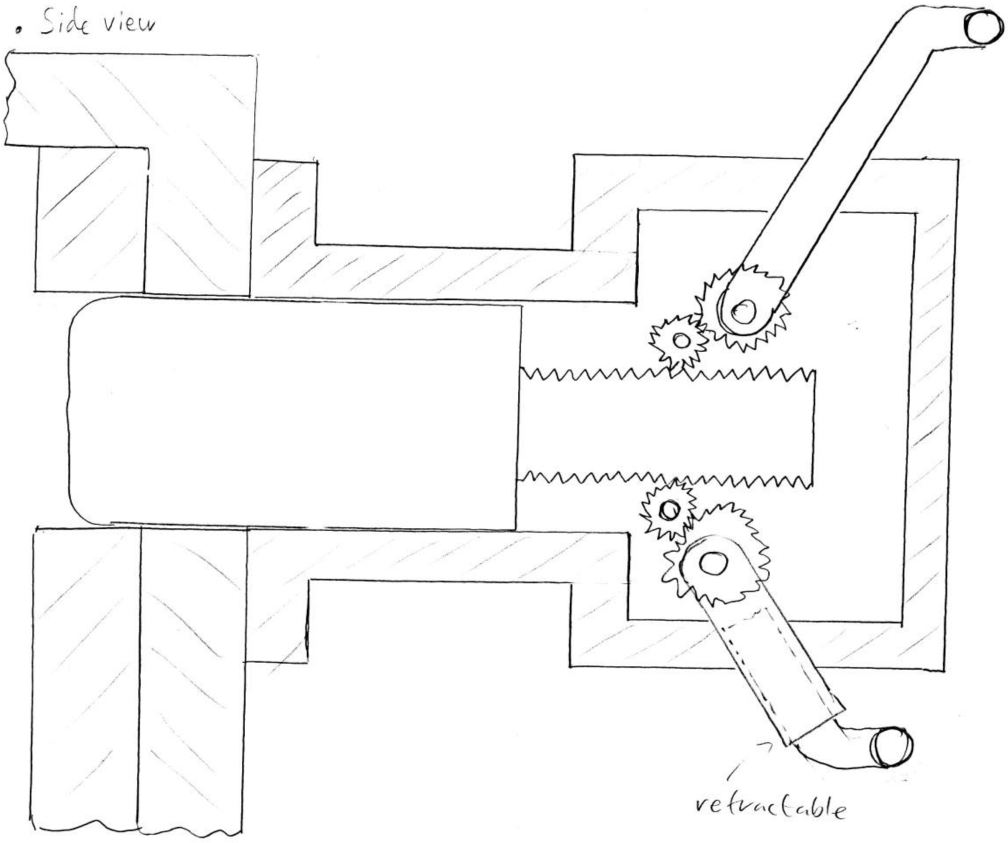
• Front view Lever



Function	Benefits	Disadvantage
Lever to pump out the bolt with a gear ratio of gears. Can interchange as necessary in produktion	• Lever for increased torque • Ratios for gear. •	• Many Parts • can be wear in the the tooth

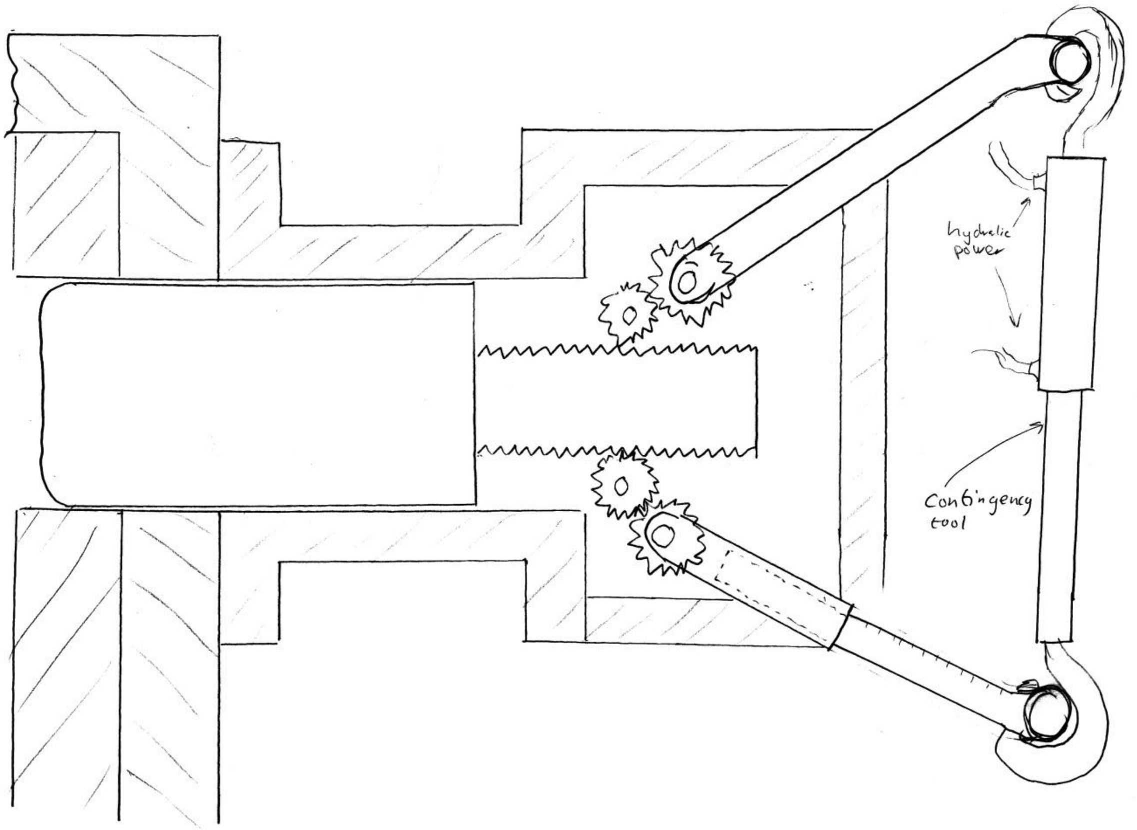
Installation tool / contingency tool

Concept number: 3 Concept name: Wine Opner Sheet/Total sheet : 1/2



Function	Benefits	Disadvantage
Lever ROV uses to disconnect the installation tool. Power transfer through two gear to bolt. The lower lever is only used to contingency tool	• Easy to connect the contingency tool • Easy for ROV to operate	• Can be wear in the tooth

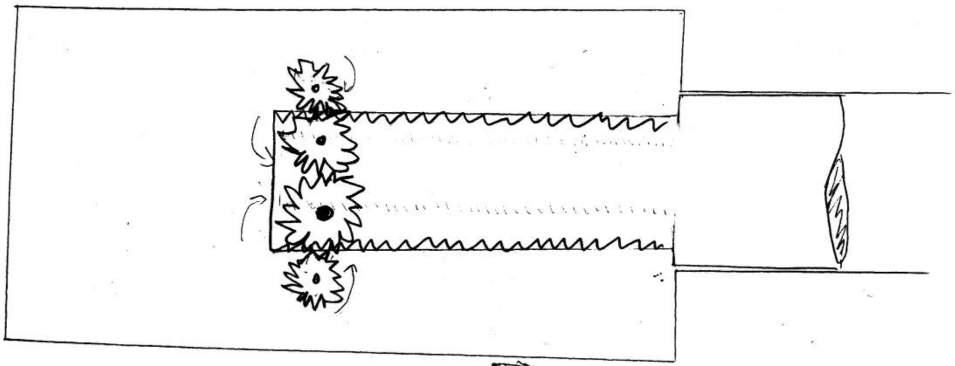
Concept number: 3 Concept name: Sheet/Total sheet : 2/2



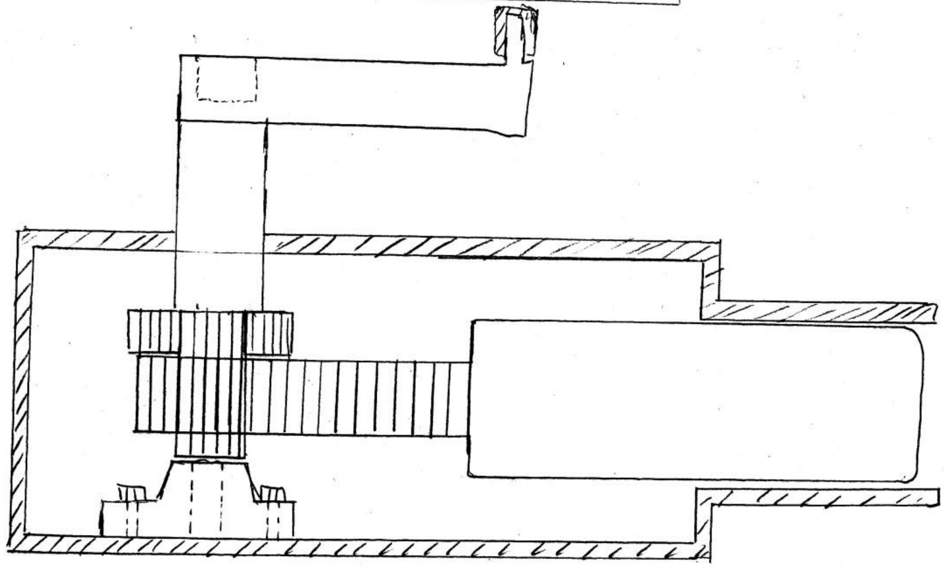
Function	Benefits	Disadvantage

Concept number: 4 Concept name: Vinch princip Sheet/Total sheet : 1/1

• View from aven

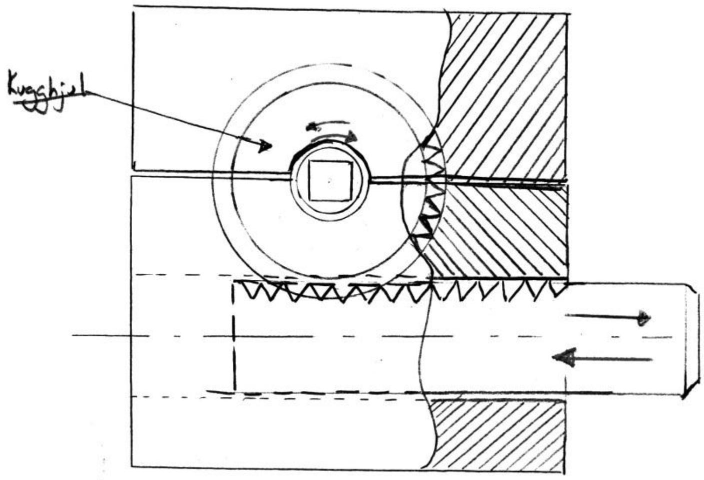


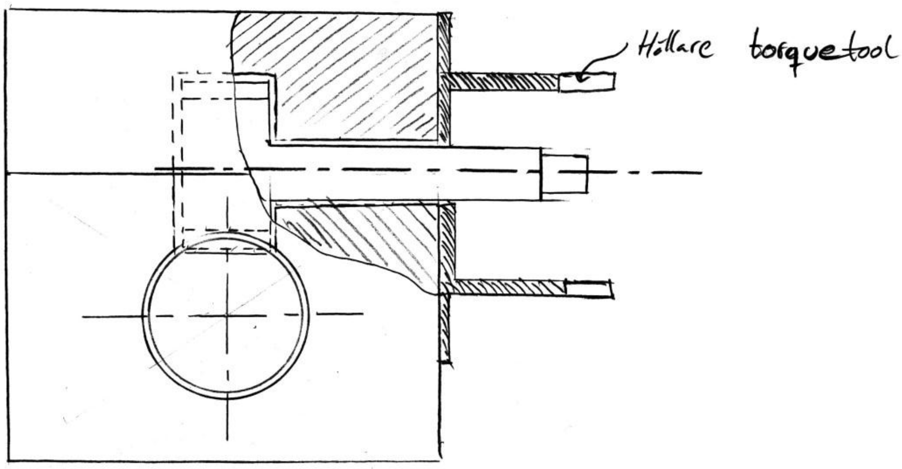
• Side view



Function	Benefits	Disadvantage
• As a vinch on a boat. • Skulle även kunna instalera en planet växlare ovanpå. • kan även göras som en singer variant	• Can use planetary gears as a contious tool (- • Easy to use continous tool • Easy to handel "	• Can be wear in the tooth

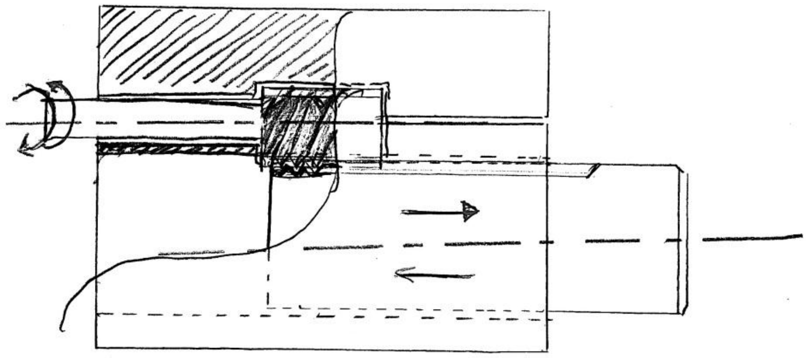
Concept number: 5 Concept name: Sheet/Total sheet : 1/1





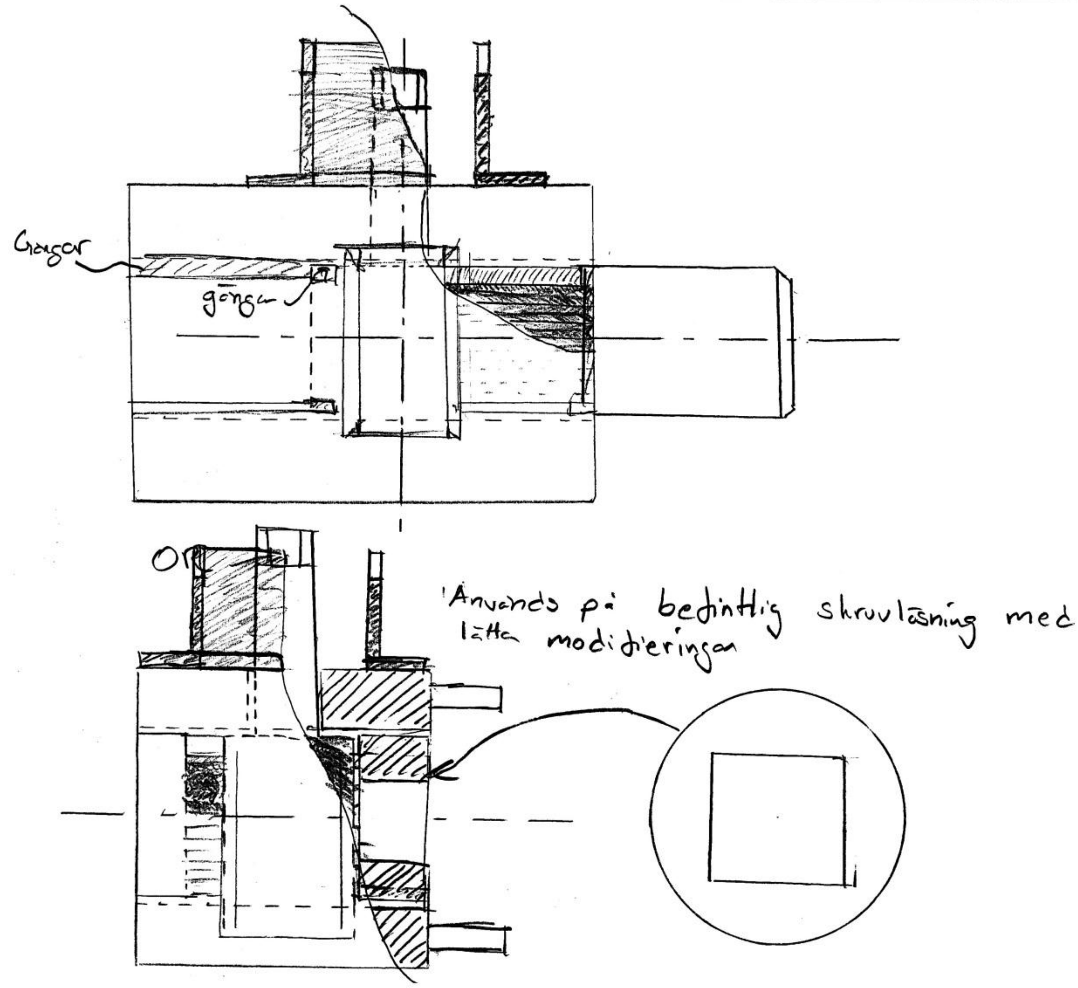
Function	Benefits	Disadvantage

Concept number: 6 Concept name: Sheet/Total sheet : 1/1



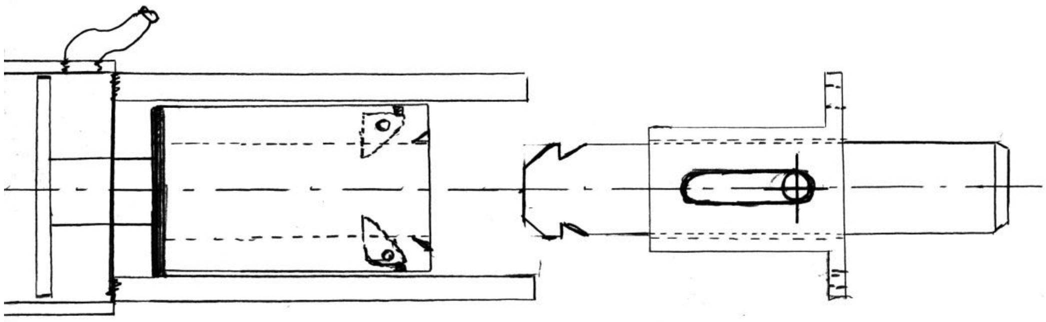
Function	Benefits	Disadvantage
	Strong	Hard to use a emergency tool / torquetool

Concept number: 7 Concept name: Sheet/Total sheet : 1/1



Function	Benefits	Disadvantage
Use with or without torquetool, strong	Both is strong, you will get high storque.	Bit advanced construction, First one may be weak at the threads.

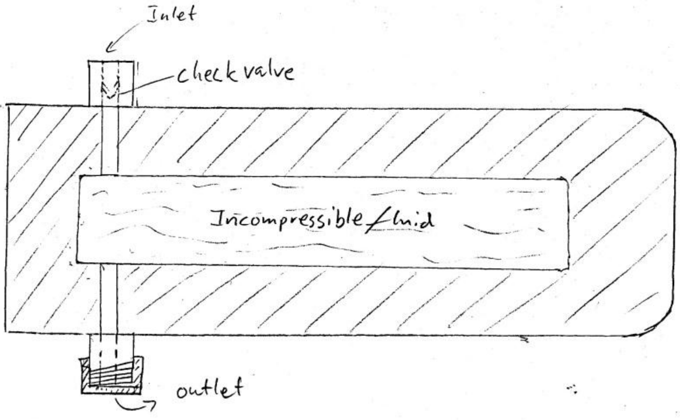
Concept number: 8 Concept name: Sheet/Total sheet : 1/1



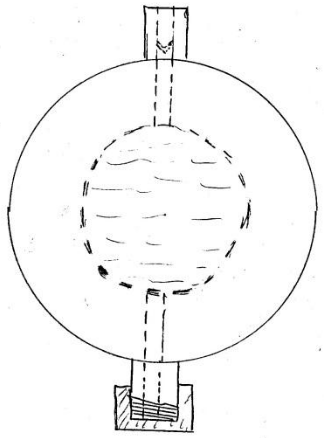
Function	Benefits	Disadvantage
It not able to drag it out with the ROV-arm, connect the extra hydraulic tool	Probably strong when using tool, Fast to release with the rov-arm	Bit complex construction. Think you have to use the extra tool othen. because the construction dont give any extra power

Concept number: 9 Concept name: Filled bolt Bolt Sheet/Total sheet : 1/1

• Side view

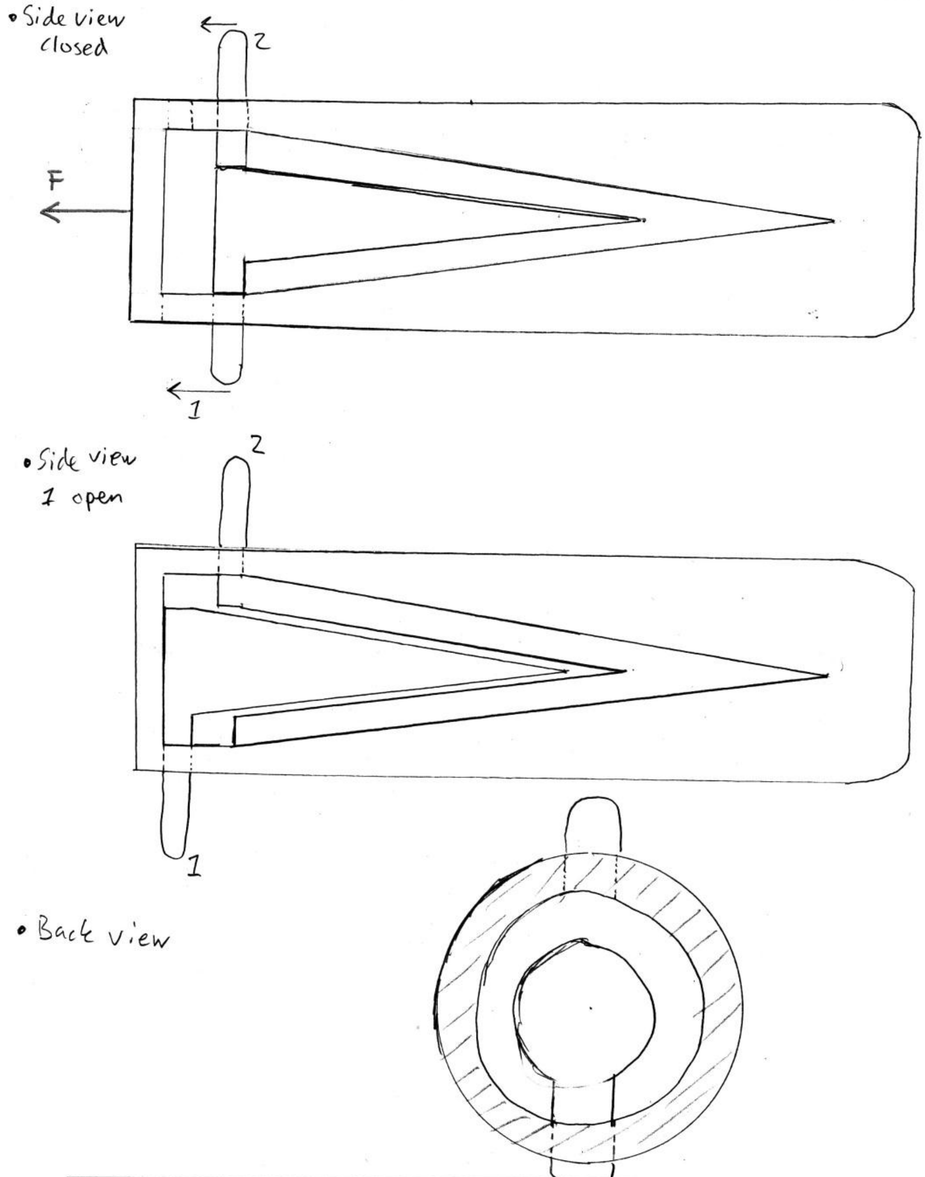


• Back view



Function	Benefits	Disadvantage
At an uneven load forks bolt when it's possible to release the pressure of the bolt by releasing incompressible fluid and bolt's wall can be easier to give in.	• Reduced power on bolt • Additional solvents opportunity without tools •	• May be a problem to achieve the same material properties as a homogeneous bolt

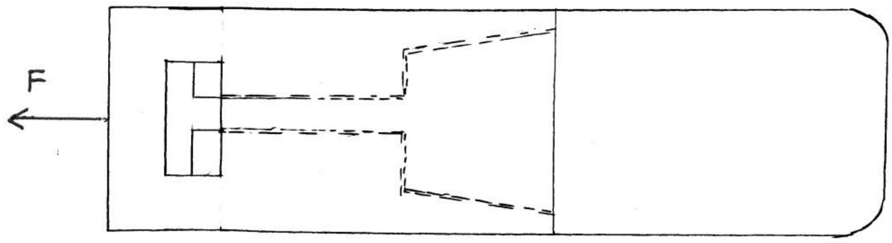
Concept number: 10 Concept name: Cleat Bolt Sheet/Total sheet : 1/1



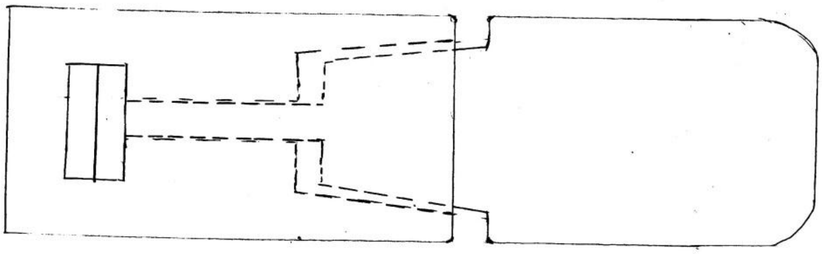
Function	Benefits	Disadvantage
Utilization of the bolt material properties to flex the bolt ant the pressure drop and less power needs to bring the bolt out	· Reduced permits · Additional solvents oppertunity witout tool · 1 to 2 diffent cleat to drop the pressure	· Maybe defects in material properties

Concept number: 11 Concept name: Split cone Sheet/Total sheet : 1/1

• Side view closed

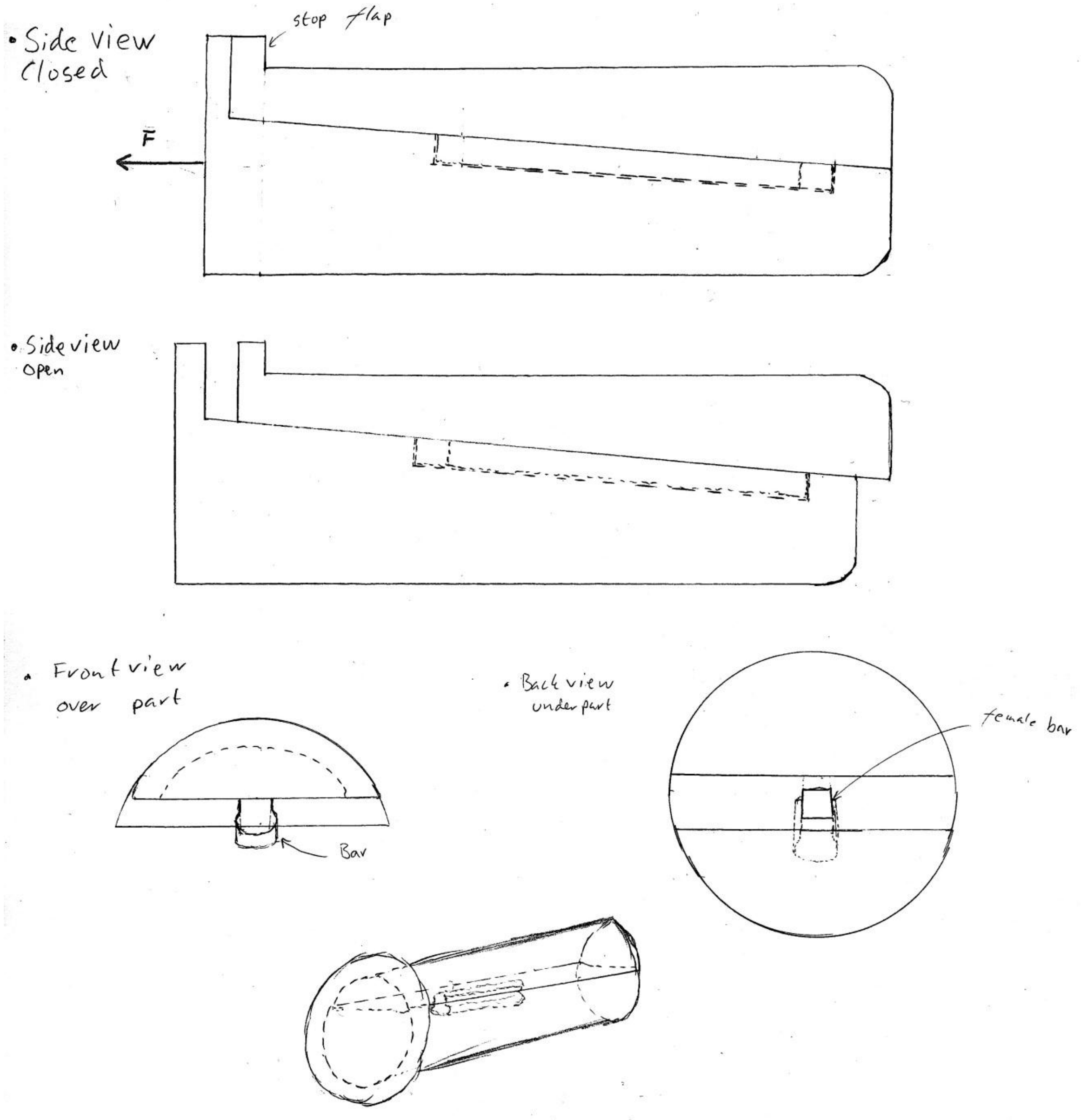


• Side view open



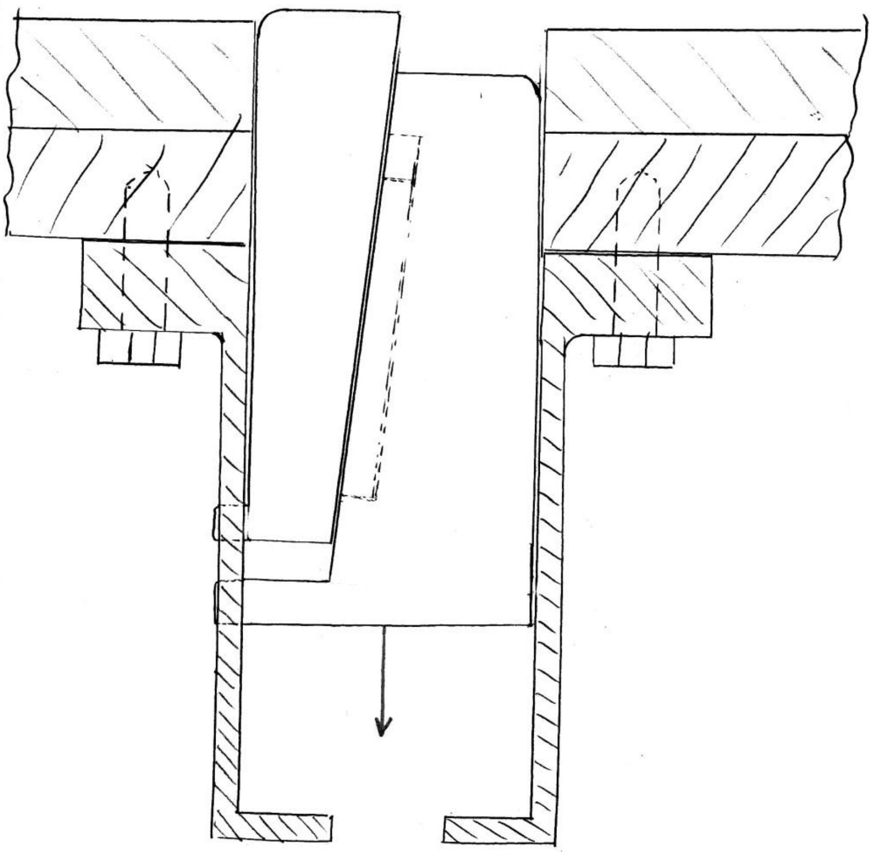
Function	Benefits	Disadvantage
At the stall separating pistons, forming a thinner shell that can flex and release the pressure on the bolt	• Reduced power on bolt • Additional solvents opportunity without tool	• Edge formed by fragmentation • Maybe get stuck in the extraction

Concept number: 12 Concept name: Split Bolt Sheet/Total sheet : 1 /2



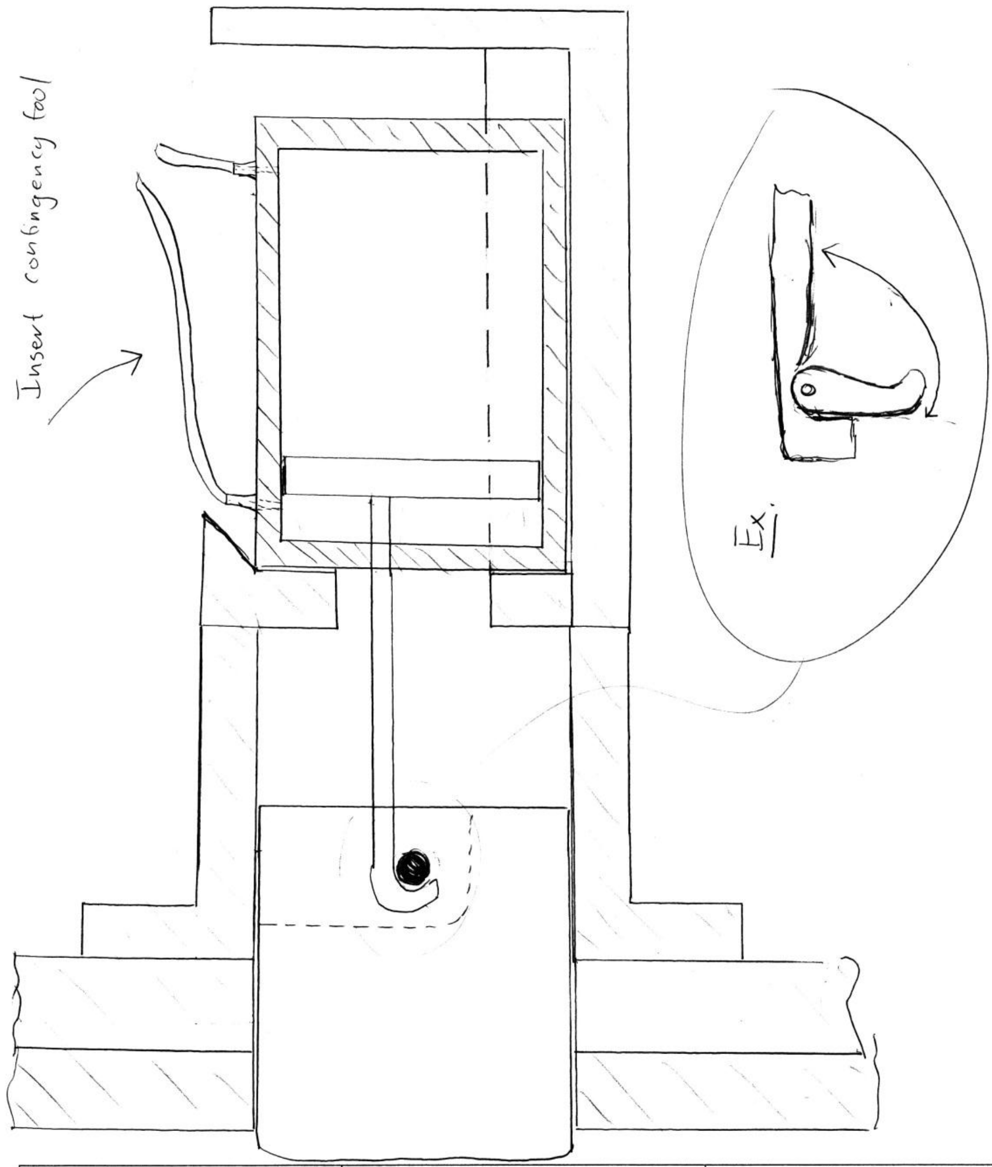
Function	Benefits	Disadvantage
At an uneven load forks bolt and reduces girth. wedging release	• Reduced permits • Reduced area to pull • Additional solvents oppertunity without tools	

Concept number: 12 Concept name: Sheet/Total sheet : 2/2



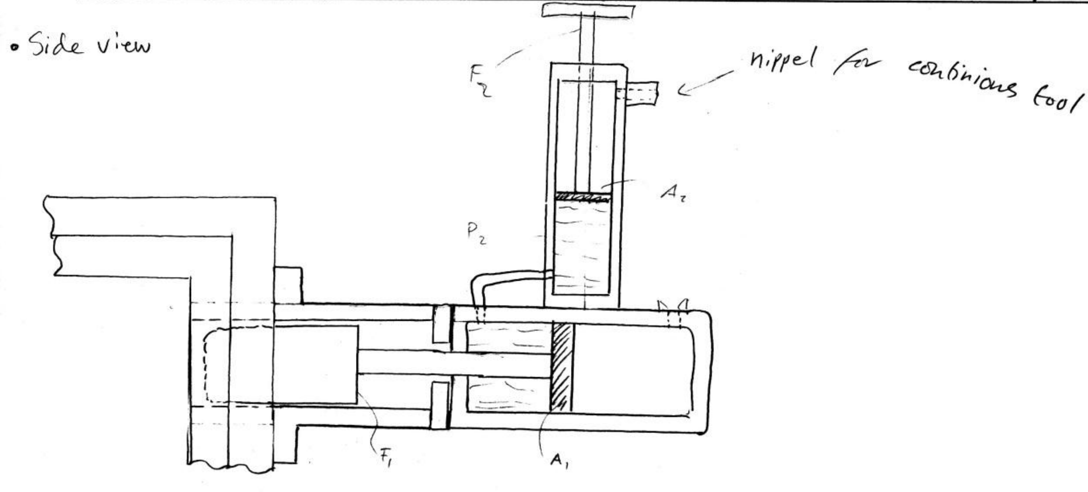
Function	Benefits	Disadvantage

Concept number: 13 Concept name: Hydralic pump Sheet/Total sheet : 1/1



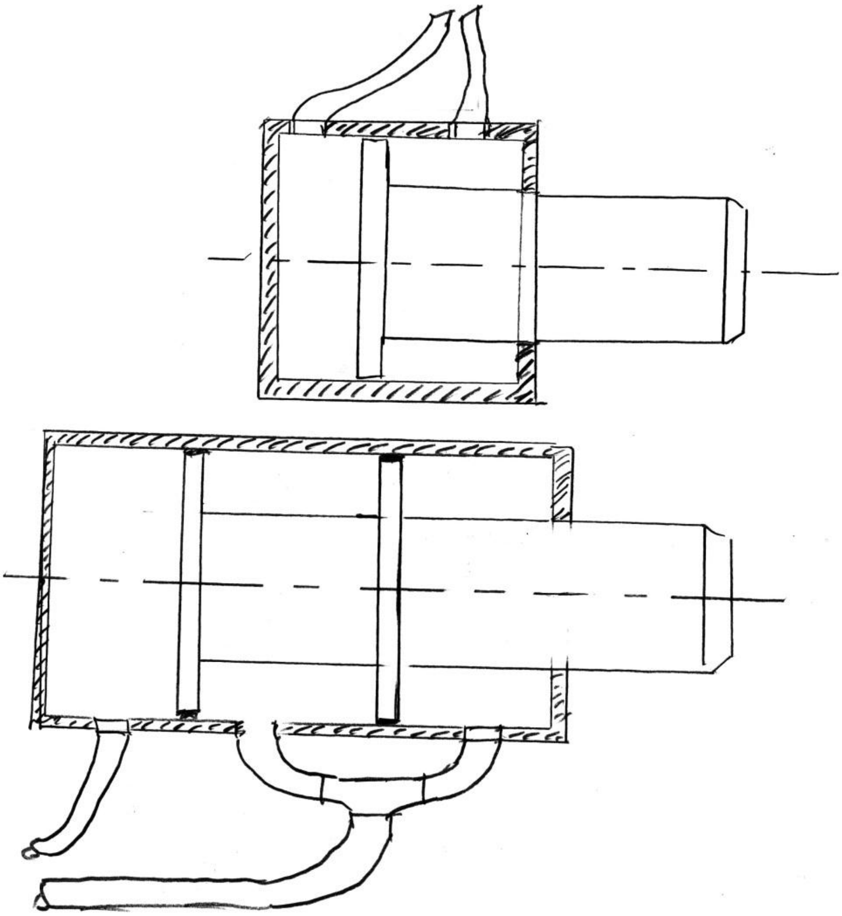
Function	Benefits	Disadvantage
A hopper designed outside the instellation tool so that contingency tool wich is designed as a piston cylinder There placed contingency tool to disconnect the bolt through hydralic pressure.	• Easy to connect for ROV • Easy construction • Can be designed for the required tensile force	• Challenge to design the hook so that it engages and manages the power.

Concept number: 14 Concept name: Pump Sheet/Total sheet : 1/1



Function	Benefits	Disadvantage
Pistong with smal area but with a long rod with a handle transmits incompressible liquid through a hose to a cylinder with a larger area.	• Easy to connect contingency tool • Easy to handle • Easily accessible	• Leakage of the incompressible fluid reduces the efficiency

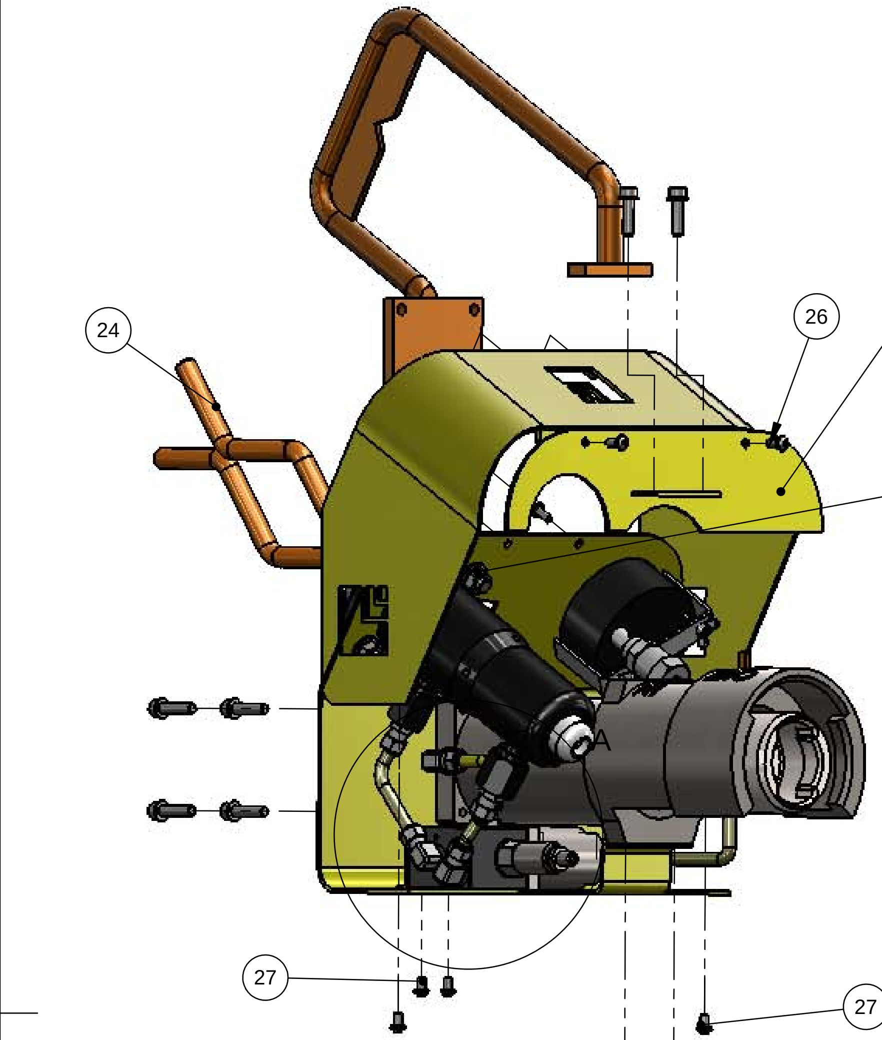
Concept number: 15 Concept name: hydraulic Sheet/Total sheet : 1/1

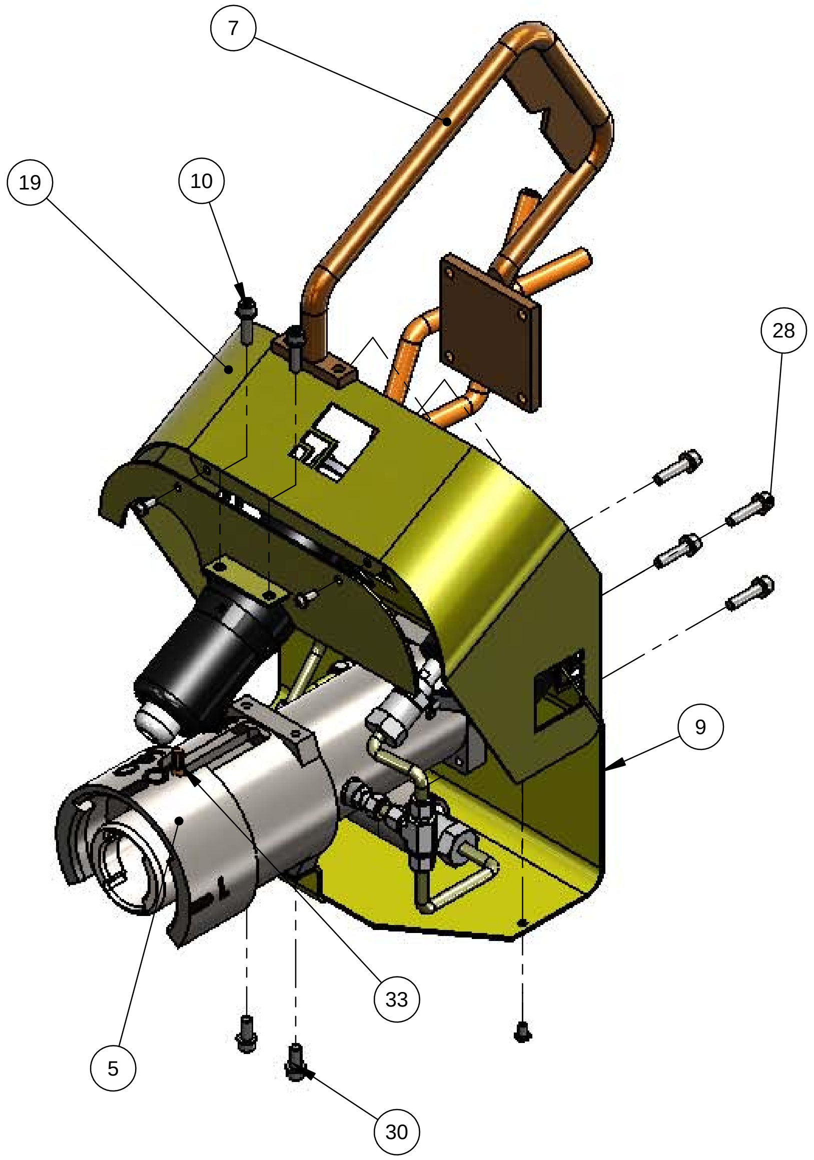


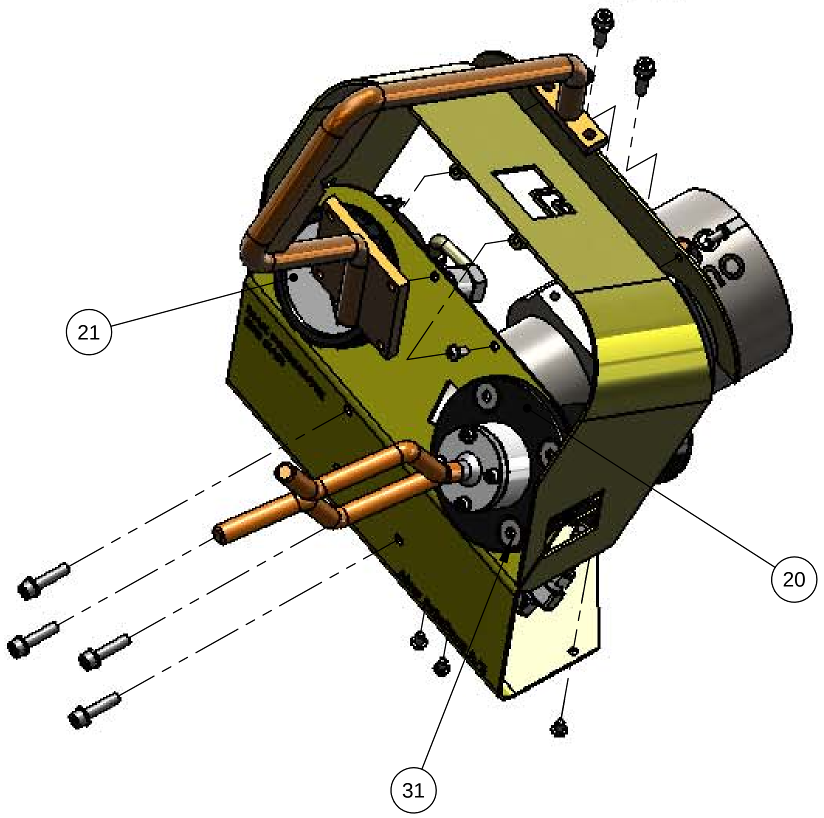
Function	Benefits	Disadvantage
Use hydraulic oil to move the bolt	No other tools need to be used. Force is equal to area. Its fast	No emergancy tool can be used, Need to plug in hydraulic hose to ROV.

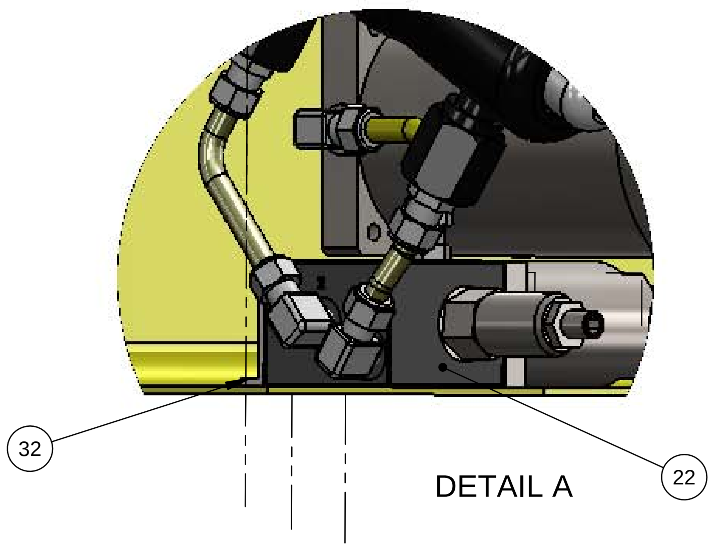
APPENDIX C DRAWINGS FOR MAUFATURING

Drawings









DETAIL A

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	10001618051	90boj	3
2	10001618061	C.Joint	2
3	MALE CONNECTOR-0.375Tx0.375 NPT	solidworks-lok male connector	2
4	MALE CONNECTOR-0.375Tx0.250 PIPE	solidworks-lok male pipe weld connector	2
5	10001617941	CYLINDER	1
6	MALE BRANCH TEE-0.375T	solidworks-lok tubing branch tee	1
7	10001617943	ROV HANDLE	1
8	10001618022	Tube_4-Final_concept	1
9	10001617944	CB_FRONT	1
10	ISO 4762 M8 x 30 --- 30N	socket head cap screw_iso	2
12	10001618050	SEAL BACK	1
17	Washer ISO 7091 - 6	plain washer normal grade c_iso	8
18	Washer ISO 7091 - 8	plain washer normal grade c_iso	8
19	10001617945	CB_TOP	1
20	10000450148	DP RECEPTACLE WITH CV	1
21	10001321221	MANOMETER, 0-250 BAR	1
22	10001617946	minibooster_pressure	1
23	10001618013	CB_BACK	1
24	10000451874	PROT STAB, DUAL , ISO A, FISHTAIL	1
25	Hexagon Flange Nut ISO - 4161 - M12 - N	hex flange nut gradea_iso	4
26	ISO 7380 - M6 x 16 --- 16N	socket button head screw_iso	4
27	ISO 7380 - M6 x 12 --- 12N	socket button head screw_iso	4
28	ISO 4762 M8 x 35 --- 35N	socket head cap screw_iso	4
29	ISO 4762 M5 x 12 --- 12N	socket head cap screw_iso	4
30	ISO 4762 M8 x 20 --- 20N	socket head cap screw_iso	2
31	ISO 10642 - M12 x 30 --- 30N	socket countersunk head screw_iso	4
32	10001618046	BRACKET	1
33	10001618033	GUID PIN	1
34	10001618035	SEAL FRONT	1
35	10001618036	SEAL1	2
36	10001618038	SEAL2	1
37	10001618040	SEAL3	1

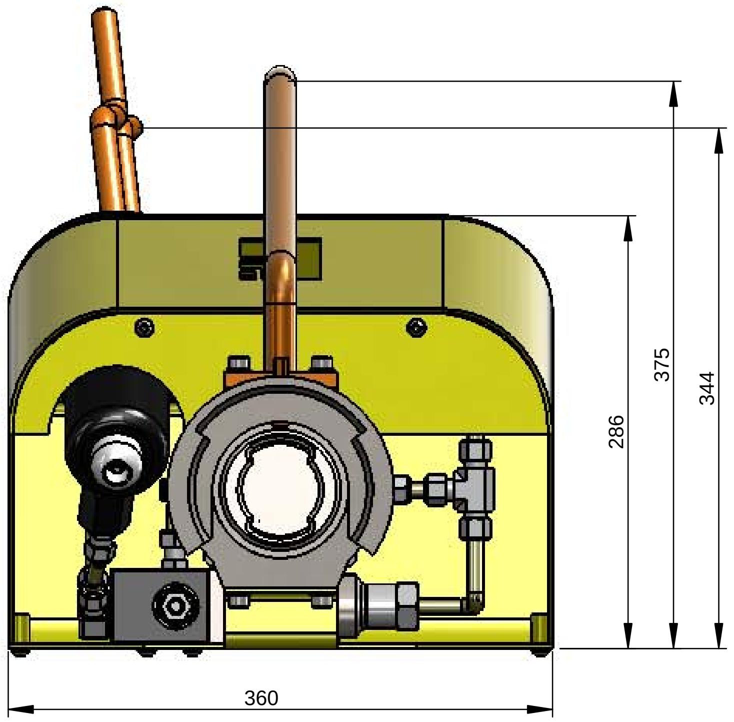
NOTES:

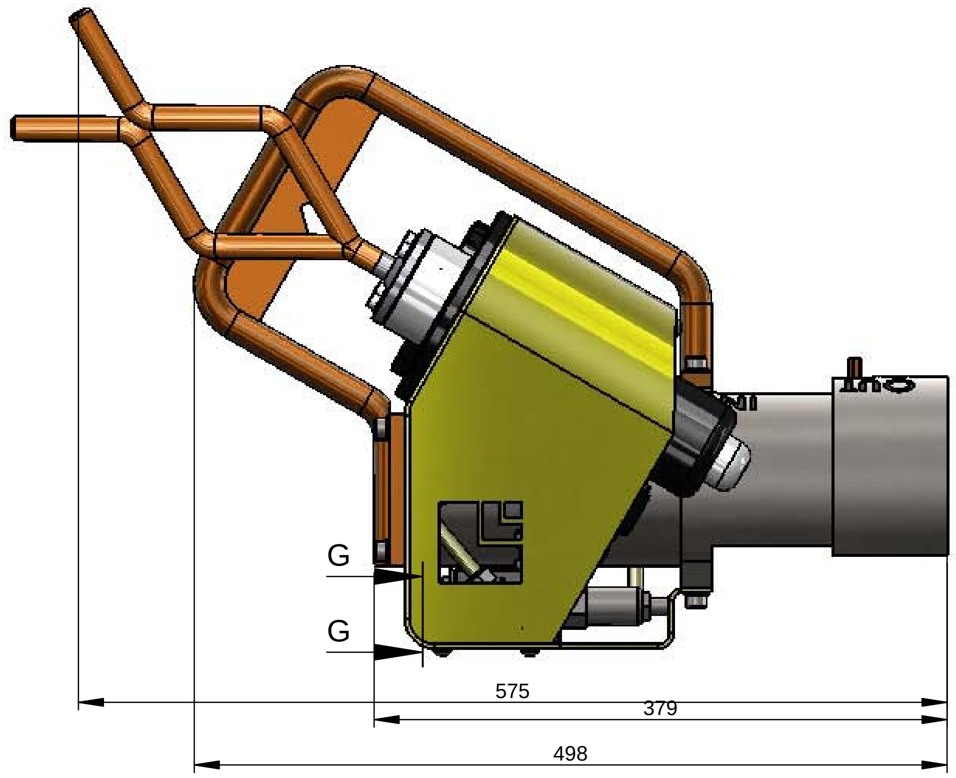
1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. PROCESS SPECIFICATION ACCORDING TO MATERIAL.

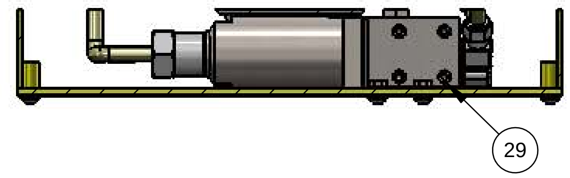
Title
LOCK DOG
LOCK DOG CONTINGENCY TOOL
ASSEMBLY

AkerSolutions
part of Aker

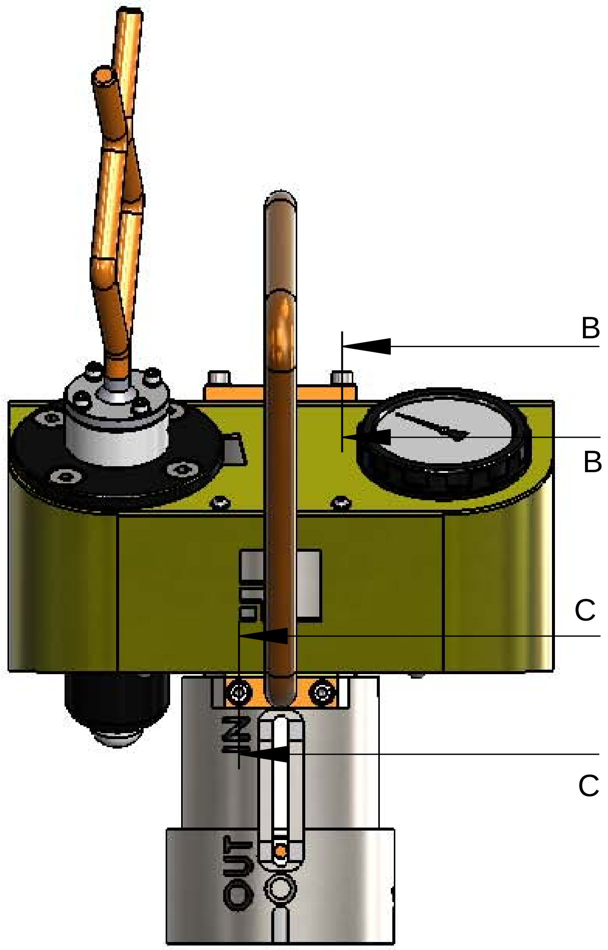
Modified by: PETTERSSON, JONAS2
Originator: PETTERSSON, JONAS2
Document no.: 10001631662
Doc. ver.: 00
ECO no.:
Checked by:
Material no. (part):
Plant: 100
Release date: 05.06.2012
Reason for issue: Created
Approved by:
Material spec.:
Weight: 38456.74
Size: A3
Sheet no.: 1 of 2



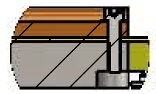




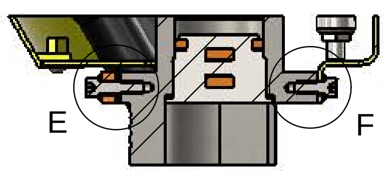
SECTION G-G



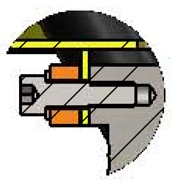
SECTION B-B



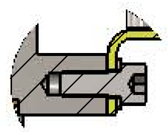
DETAIL D



SECTION C-C



DETAIL E



DETAIL F

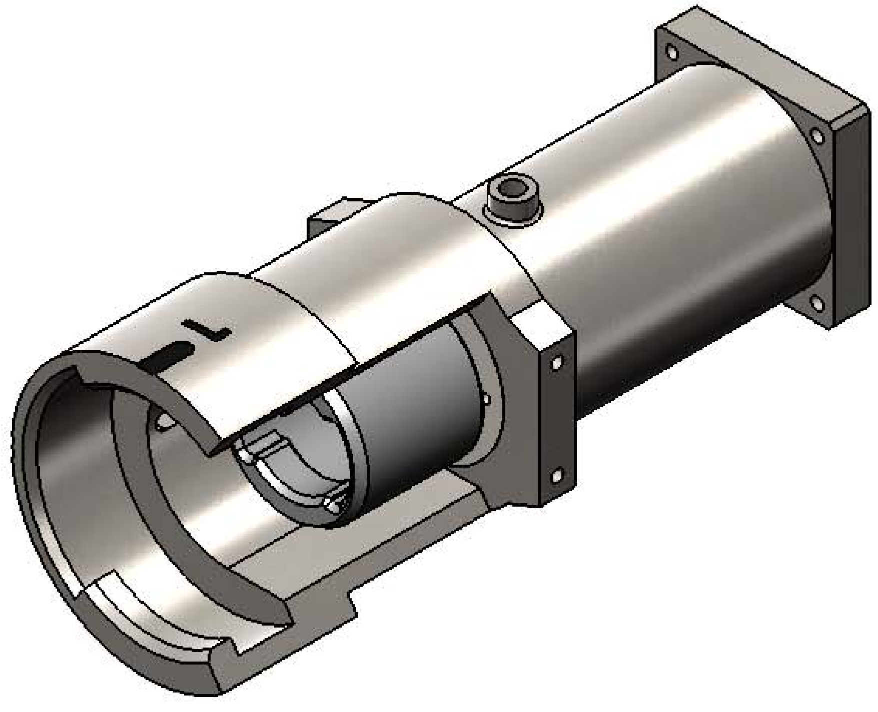
NOTES:

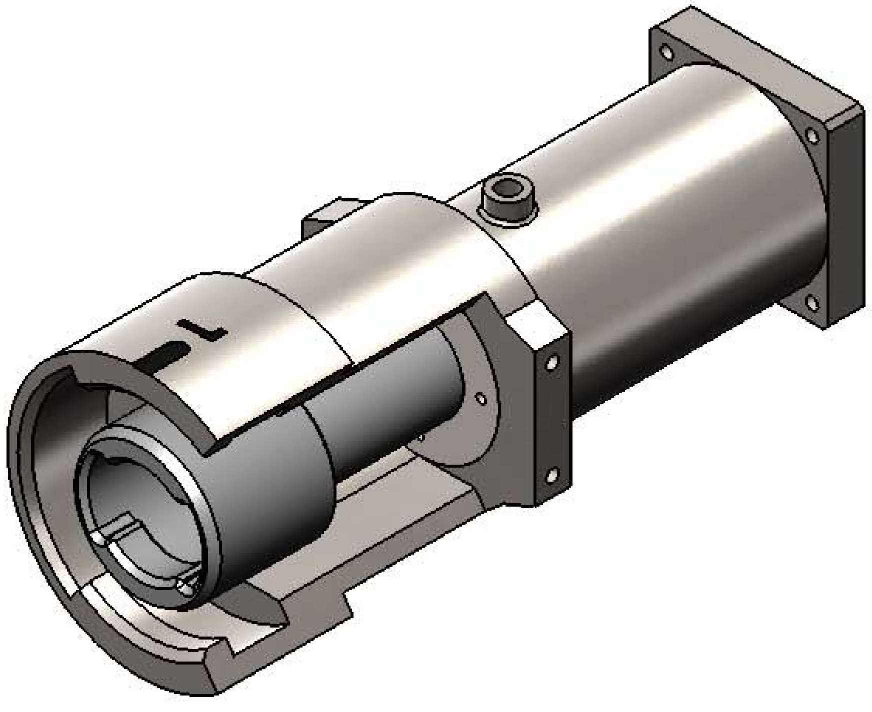
1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. PROCESS SPECIFICATION ACCORDING TO MATERIAL.

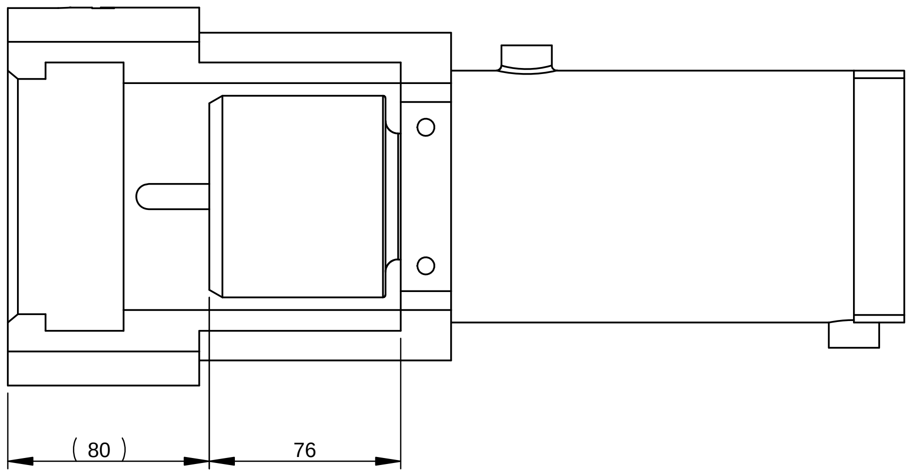
Title: LOCK DOG
LOCK DOG CONTINGENCY TOOL
ASSEMBLY

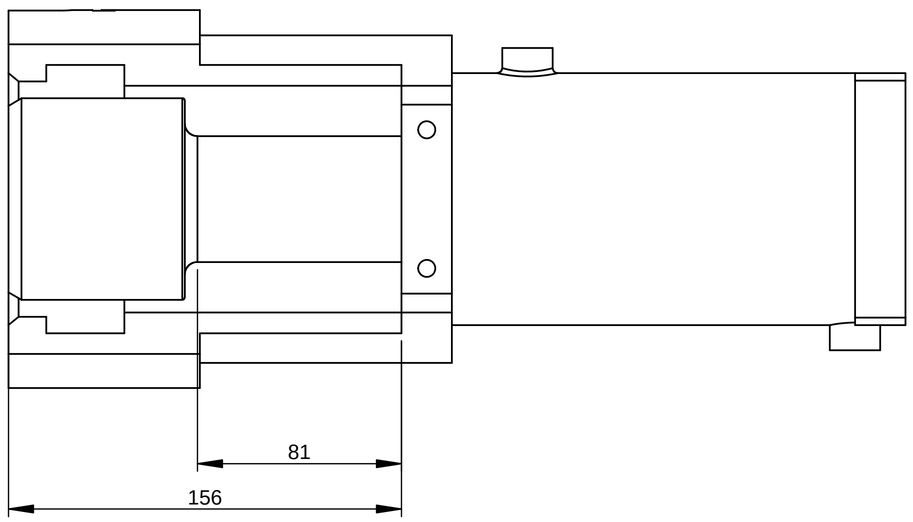
AkerSolutions™ part of Aker

Modified by: PETTERSSON, JONAS2	Originator: PETTERSSON, JONAS2	Document no.: 10001631662	Doc. ver.: 00 / ECO no.:
Checked by:	Material no. (part): / Plant: 100	Release date: 05.06.2012	Reason for issue: Created
Approved by:	Material spec.:	Weight: 38456.74	Size: A3 / Sheet no.: 2 of 2





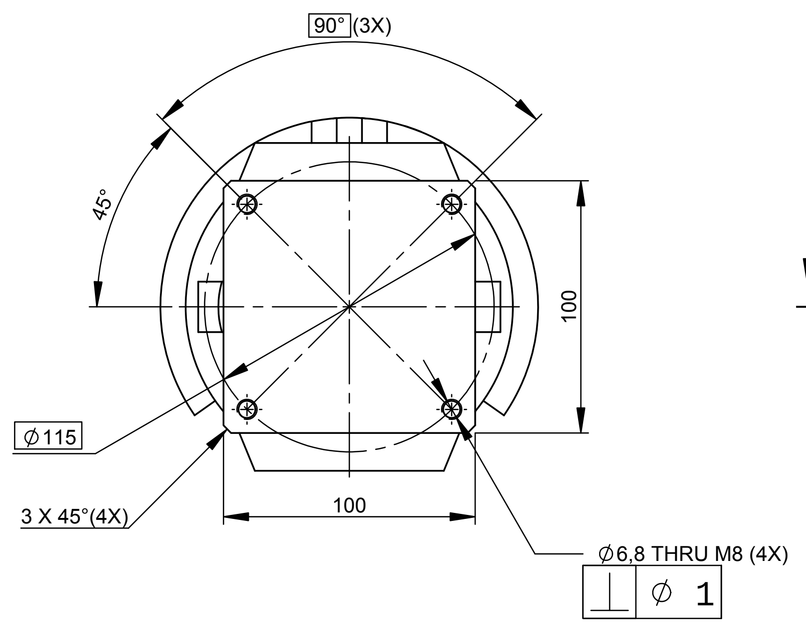


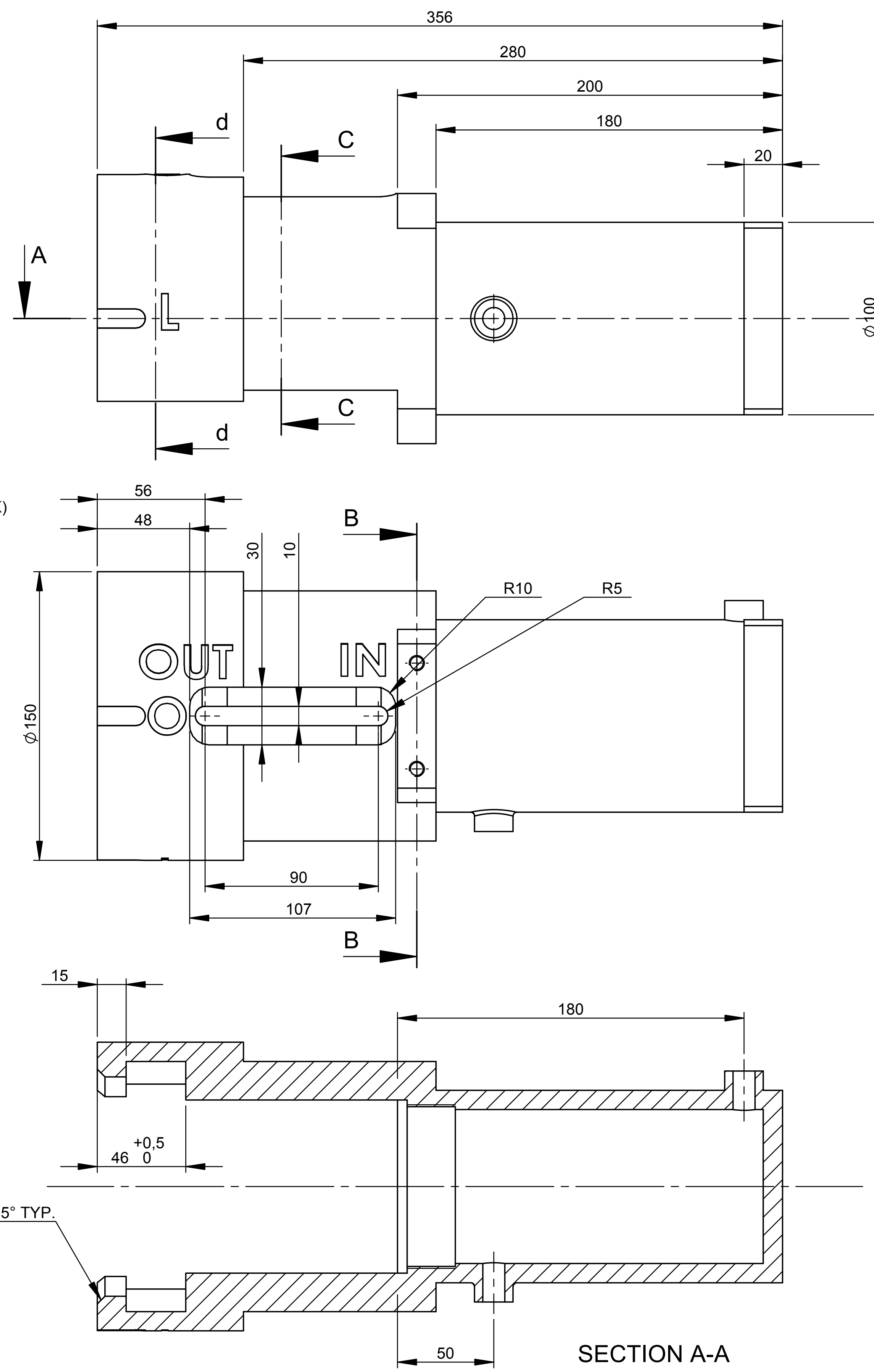


NOTES:

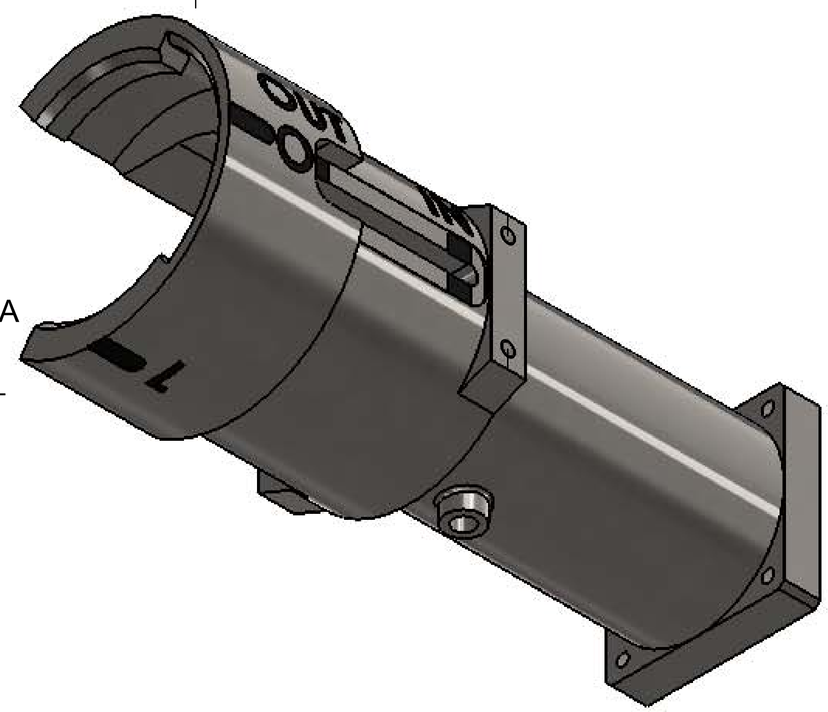
1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. PROCESS SPECIFICATION ACCORDING TO MATERIAL.

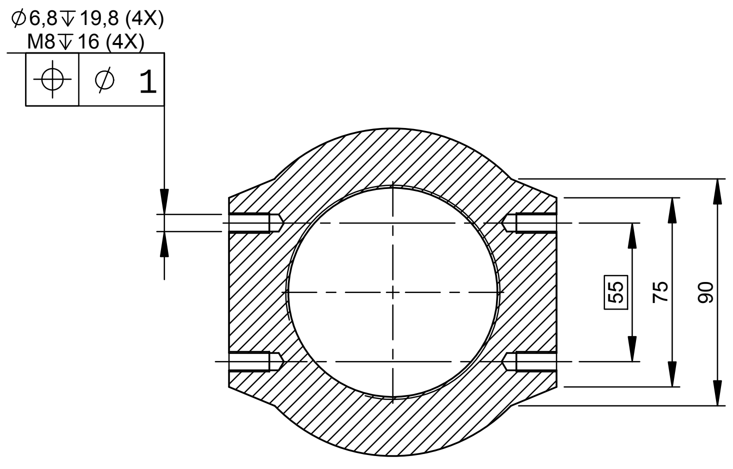
Title: ROD_CYLINDER LOCK DOG CONTINGENCY TOOL ASSEMBLY			AkerSolutions™ part of Aker
Modified by: PETTERSSON, JONAS2	Originator: PETTERSSON, JONAS2	Document no.: 10001631353	Doc. ver.: 00 / ECO no.:
Checked by:	Material no. (part): / Plant: 100	Release date: 05.06.2012	Reason for issue: Created
Approved by:	Material spec.:	Weight:	Size: A3 / Sheet no.: 1 of 1





SECTION A-A





SECTION B-B

NOTES:

1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. TOLERANCING ISO 8015.
   GENERAL TOLERANCES ISO 2768-mK.
3. UNLESS OTHERWISE SPECIFIED:
   DEBURR EXTERNAL EDGES AND CORNERS.
   FILLET RADIUS: MAX 0,8.
   SURFACE ROUGHNESS Ra3,2.
4. PROCESS SPECIFICATION ACCORDING TO MATERIAL.
5. TRACEABILITY MARKING ACCORDING TO TC 2.3:
   M/N: <MATERIAL NO.> REV.<REV.NO.>
   S/N: <PO NO.>-<PO LINE ITEM>-<SEQUENCE NO.>

   USE LOW STRESS PERMANENT MARKING

6. ALL SHARP EDGES TO BE REMOVED

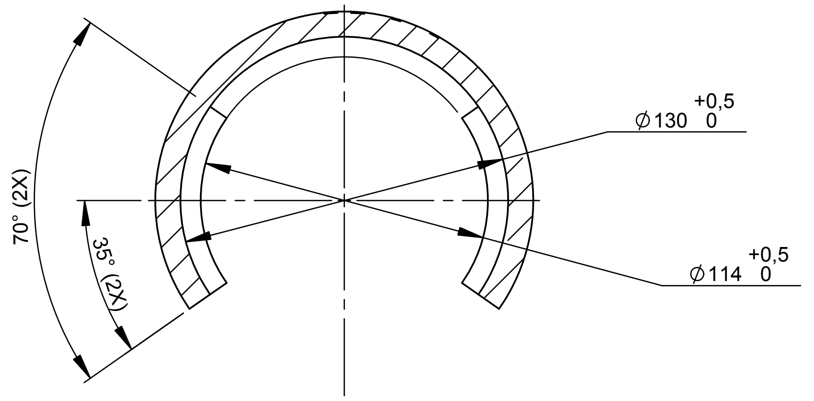
Machining dimensional tolerances ISO 2768-m (millimetres)

Linear dimensions		External radii and chamfer heights	
Range	Tol	Range	Tol
0.5-3	±0.1	0.5-3	±0.2
>3-6	±0.1	>3-6	±0.5
>6-30	±0.2	>6	±1
>30-120	±0.3	Angular dimensions	
>120-400	±0.5		
>400-1000	±0.8	≤10	±1°
>1000-2000	±1.2	>10-50	±0°30'
>2000-4000	±2	>50-120	±0°20'
		>120-400	±0°10'
		>400	±0°05'

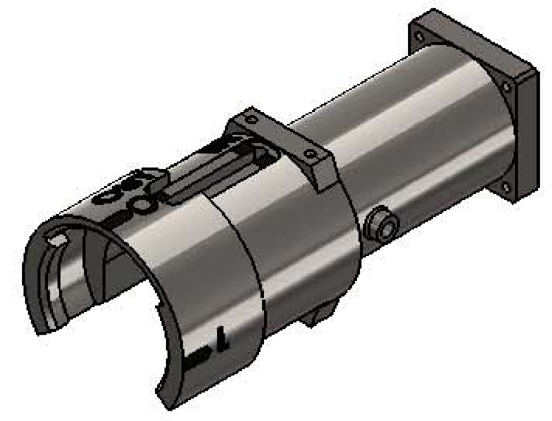
Title: CYLINDER
LOCK DOG CONTINGENCY TOOL
Tie-In

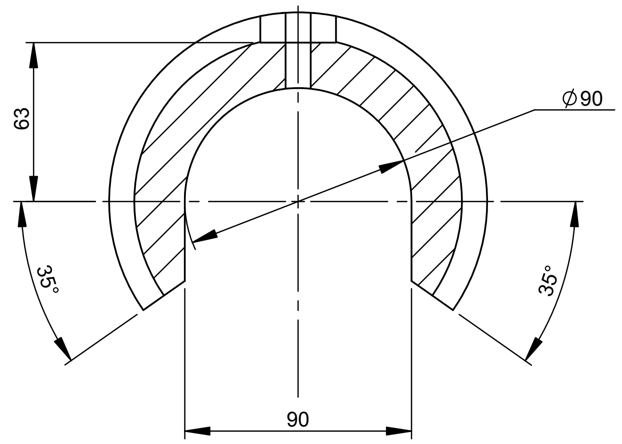
AkerSolutions™ part of Aker

Modified by: HOGLID, ERIK1	Originator: HOGLID, ERIK1	Document no.: 10001631592	Doc. ver.: 00 / ECO no.:
Checked by:	Material no. (part): / Plant: 100	Release date: 05.06.2012	Reason for issue: Created
Approved by:	Material spec.: S 165 M	Weight:	Size: A3 / Sheet no.: 1 of 2



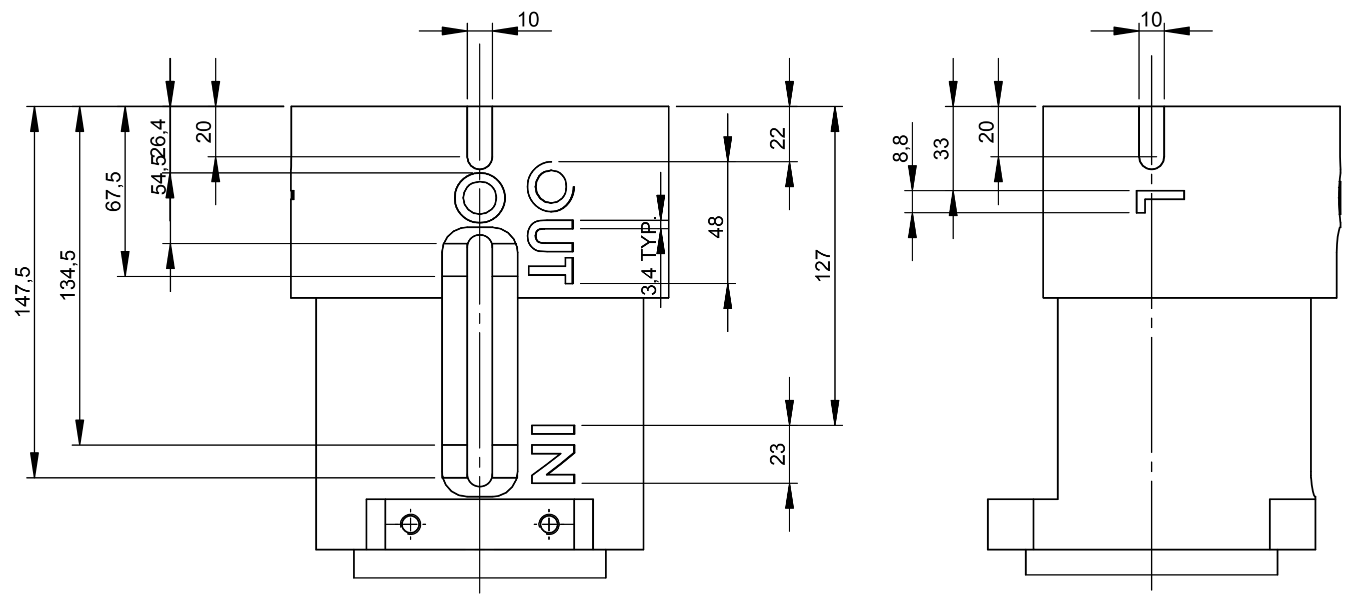
SECTION d-d





SECTION C-C

Dimentions for painting



NOTES:

1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. TOLERANCING ISO 8015.
   GENERAL TOLERANCES ISO 2768-mK.
3. UNLESS OTHERWISE SPECIFIED:
   DEBURR EXTERNAL EDGES AND CORNERS.
   FILLET RADIUS: MAX 0,8.
   SURFACE ROUGHNESS Ra3,2.
4. PROCESS SPECIFICATION ACCORDING TO MATERIAL.
5. TRACEABILITY MARKING ACCORDING TO TC 2.3:
   M/N: <MATERIAL NO.> REV.<REV.NO.>
   S/N: <PO NO.>-<PO LINE ITEM>-<SEQUENCE NO.>

   USE LOW STRESS PERMANENT MARKING
6. ALL SHARP EDGES TO BE REMOVED

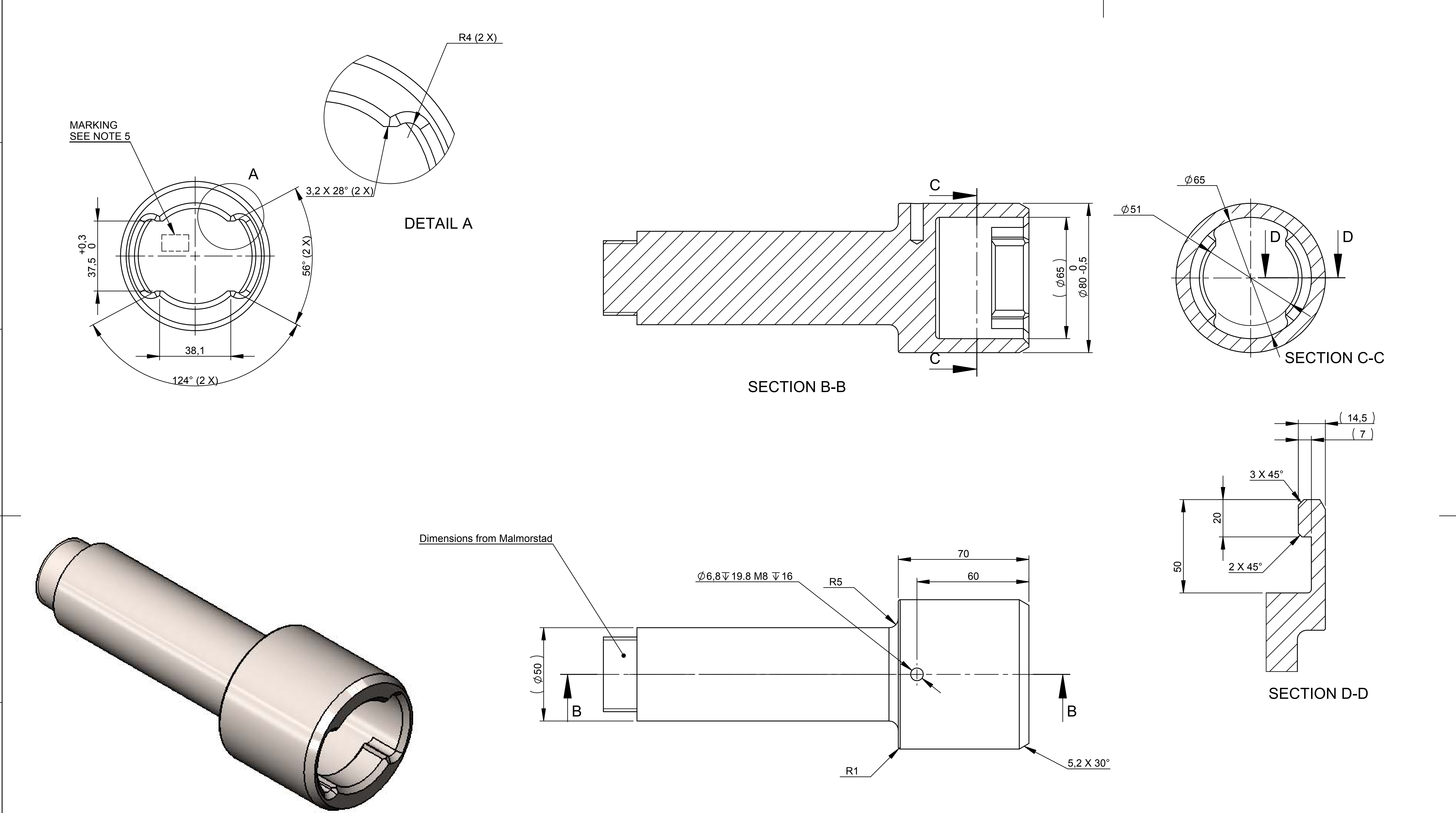
Machining dimensional tolerances ISO 2768-m (millimetres)

Linear dimensions		External radii and chamfer heights	
Range	Tol	Range	Tol
0.5-3	±0.1	0.5-3	±0.2
>3-6	±0.1	>3-6	±0.5
>6-30	±0.2	>6	±1
>30-120	±0.3	Angular dimensions	
>120-400	±0.5		
>400-1000	±0.8	≤10	±1°
>1000-2000	±1.2	>10-50	±0°30'
>2000-4000	±2	>50-120	±0°20'
		>120-400	±0°10'
		>400	±0°05'

Title: CYLINDER
LOCK DOG CONTINGENCY TOOL
Tie-In

AkerSolutions™
part of Aker

Modified by	HOGLID, ERIK1
Originator	HOGLID, ERIK1
Document no.	10001631592
Doc. ver.	00
ECO no.	
Checked by	
Material no. (part)	
Plant	100
Release date	05.06.2012
Reason for issue	Created
Approved by	
Material spec.	S 165 M
Weight	
Size	A3
Sheet no.	2 of 2



NOTES:

1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. TOLERANCING ISO 8015.
   GENERAL TOLERANCES ISO 2768-mK.
3. UNLESS OTHERWISE SPECIFIED:
   DEBURR EXTERNAL EDGES AND CORNERS.
   FILLET RADIUS: MAX 0,8.
   SURFACE ROUGHNESS Ra3,2.
4. PROCESS SPECIFICATION ACCORDING TO MATERIAL.

5.TRACEABILITY MARKING ACCORDING TO TC 2.3:
   M/N: <MATERIAL NO.> REV.<REV.NO.>
   S/N: <PO NO.>-<PO LINE ITEM>-<SEQUENCE NO.>

   USE LOW STRESS PERMANENT MARKING

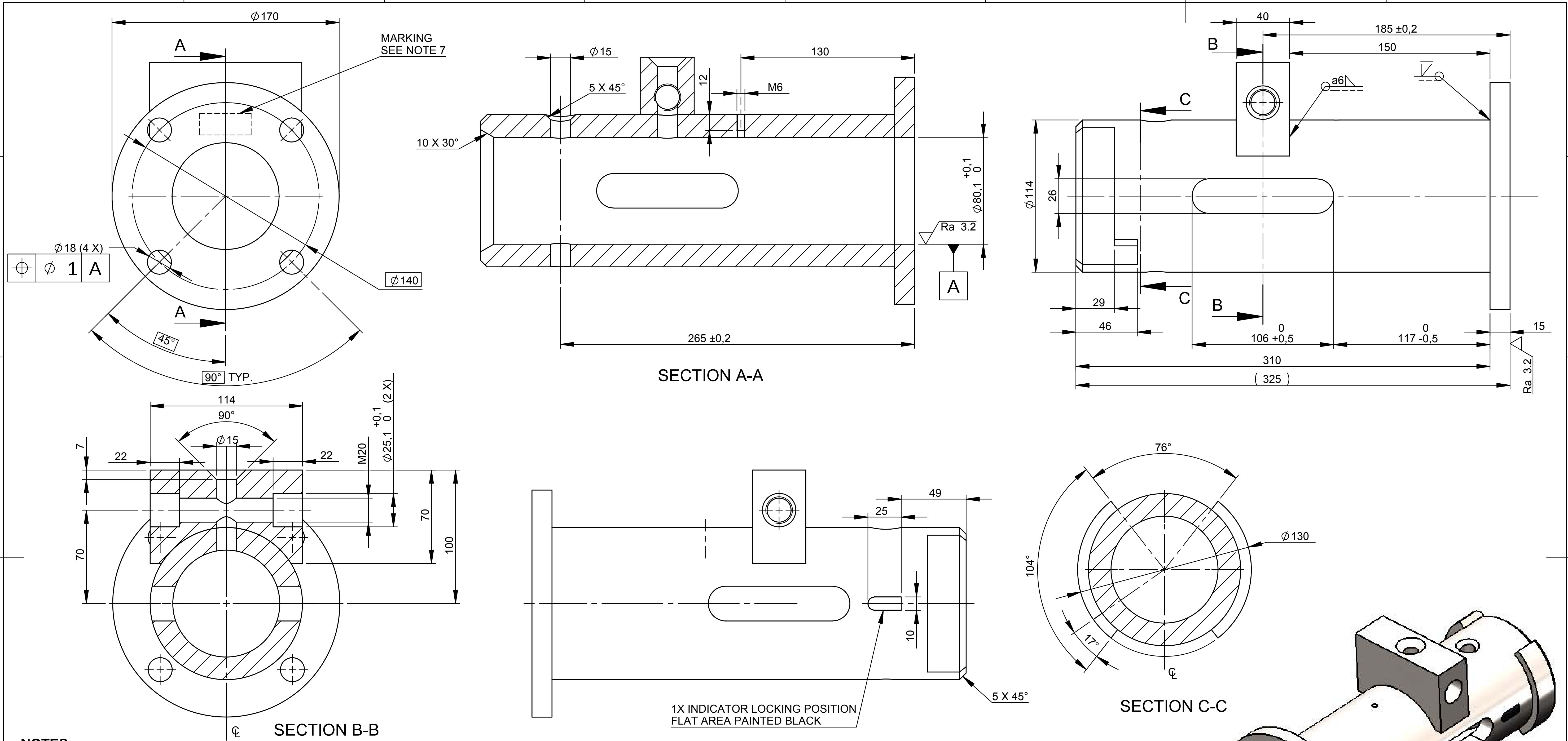
Machining dimensional tolerances ISO 2768-m (millimetres)

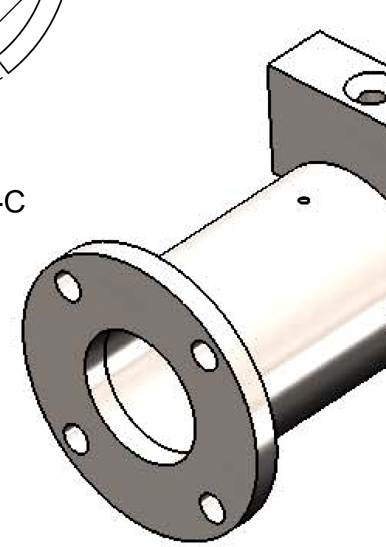
Linear dimensions		External radii and chamfer heights	
Range	Tol	Range	Tol
0.5-3	±0.1	0.5-3	±0.2
>3-6	±0.1	>3-6	±0.5
>6-30	±0.2	>6	±1
>30-120	±0.3	Angular dimensions	
>120-400	±0.5		
>400-1000	±0.8	≤10	±1°
>1000-2000	±1.2	>10-50	±0°30'
>2000-4000	±2	>50-120	±0°20'
		>120-400	±0°10'
		>400	±0°05'

Title
ROD
LOCK DOG CONTINGENCY TOOL
MACHINING

AkerSolutions™
part of Aker

Modified by	Originator		Document no.	Doc. ver.	ECO no.
PETTERSSON, JONAS2	PETTERSSON, JONAS2		10001631573	00	
Checked by	Material no. (part)	Plant 100	Release date 05.06.2012	Reason for issue Created	
Approved by	Material spec. S-165M		Weight	Size A3	Sheet no. 1 of 1





NOTES:

1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. TOLERANCING ISO 8015.
   GENERAL TOLERANCES ISO 2768-mK.
3. WELDING ACCORDING TO NORSOK M-101
   DESIGN CLASS 4, INSPECTION CATEGORY C.
4. ROUND SHARP EDGES, MIN 2mm U.N.O
5. SURFACE COATING WITH XYLAN 1424 ACCORDING TO SPEC. C-156
   COLOR: GREY
6. HOLES SHALL BE MASKED DURING SANDBLASTING/COATING.
7. UNLESS OTHERWISE SPECIFIED:
   DEBURR EXTERNAL EDGES AND CORNERS.
   FILLET RADIUS: MAX 0,8.
8. PROCESSSS SPECIFICATION ACCORDING TO MATERIAL.
9. ALL SHARPE EDGES TO BE REMOVED.
10. TRACEABILITY MARKING ACCORDING TO TC 2.3:
    M/N: <MATERIAL NO.> REV.<REV.NO.>
    S/N: <PO NO.>-<PO LINE ITEM>-<SEQUENCE NO.>

    USE LOW STRESS PERMANENT MARKING

Ra 6.3 (Ra 3.2)

ITEM NO.	QTY.	DESCRIPTION	MATERIAL	LENGTH
1	1	PLATE 20mm	AISI 316L	
2	1	PLATE 40mm	AISI 316L	
3	1	HOLLOW BAR	AISI 316L	290

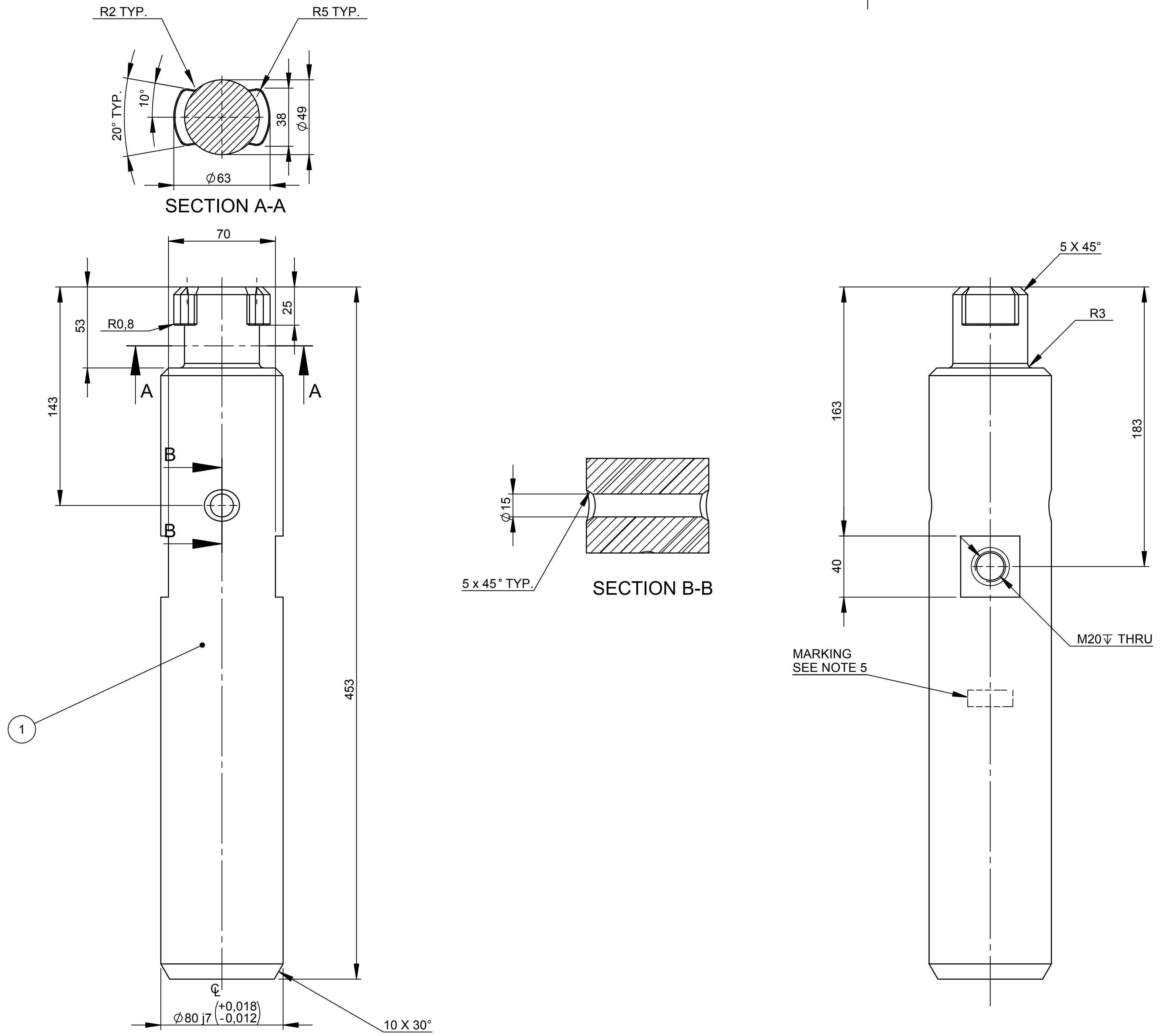
Machining dimensional tolerances ISO 2768-m (millimetres)

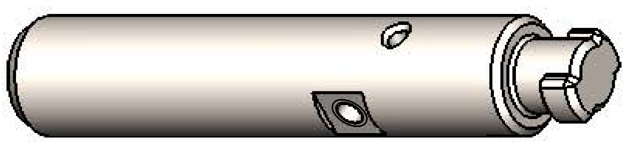
Linear dimensions		External radii and chamfer heights	
Range	Tol	Range	Tol
0.5-3	±0.1	0.5-3	±0.2
>3-6	±0.1	>3-6	±0.5
>6-30	±0.2	>6	±1
>30-120	±0.3	Angular dimensions	
>120-400	±0.5		
>400-1000	±0.8	≤10	±1°
>1000-2000	±1.2	>10-50	±0°30'
>2000-4000	±2	>50-120	±0°20'
		>120-400	±0°10'
		>400	±0°05'

Title
PIN GUIDE
LOCK DOG CONTINGENCY TOOL
MACHINING

AkerSolutions
part of Aker

Modified by: PETTERSSON, JONAS2	Originator: PETTERSSON, JONAS2		Document no.: 10001631531	Doc. ver.: 00 / ECO no.:
Checked by:	Material no. (part):	Plant: 100	Release date: 05.06.2012	Reason for issue: In Work
Approved by:	Material spec.: AISI 316L		Weight: 16.00	Size: A3 / Sheet no.: 1 of 1





NOTES:

1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. TOLERANCING ISO 8015.
   GENERAL TOLERANCES ISO 2768-mK.
3. UNLESS OTHERWISE SPECIFIED:
   DEBURR EXTERNAL EDGES AND CORNERS.
   FILLET RADIUS: MAX 0,8.
   SURFACE ROUGHNESS Ra3,2.
4. PROCESS SPECIFICATION ACCORDING TO MATERIAL.

5.TRACEABILITY MARKING ACCORDING TO TC 2.3:
M/N: <MATERIAL NO.> REV.<REV.NO.>
S/N: <PO NO.>-<PO LINE ITEM>-<SEQUENCE NO.>

USE LOW STRESS PERMANENT MARKING

Ra 3,2 UNLESS OTHERWISE NOTED

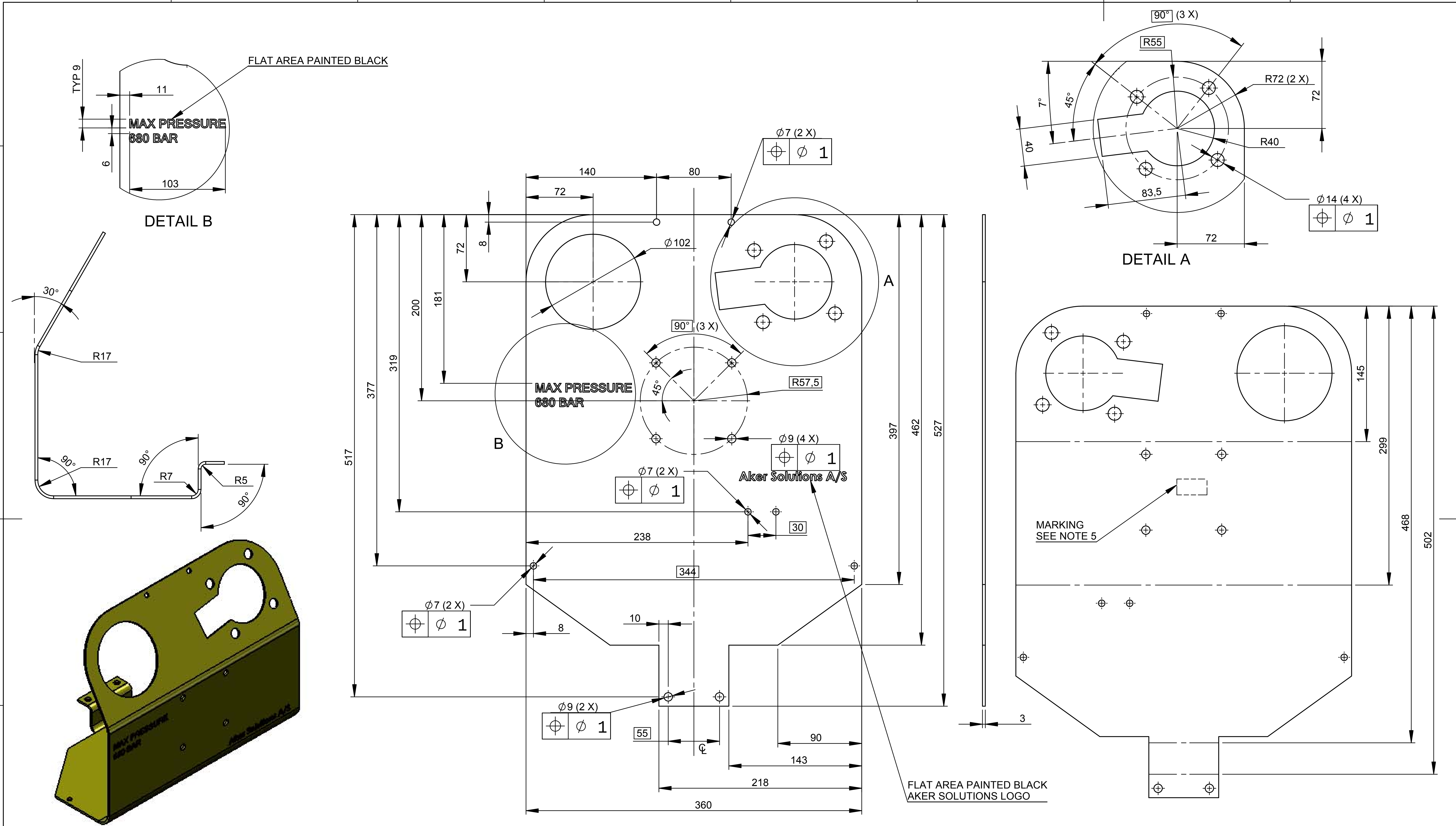
Machining dimensional tolerances ISO 2768-m (millimetres)

Linear dimensions		External radii and chamfer heights	
Range	Tol	Range	Tol
0.5-3	±0.1	0.5-3	±0.2
>3-6	±0.1	>3-6	±0.5
>6-30	±0.2	>6	±1
>30-120	±0.3	Angular dimensions	
>120-400	±0.5		
>400-1000	±0.8	≤10	±1°
>1000-2000	±1.2	>10-50	±0°30'
>2000-4000	±2	>50-120	±0°20'
		>120-400	±0°10'
		>400	±0°05'

Title
LOCK PIN
LOCK DOG CONTINGENCY TOOL
MACHINING

AkerSolutions™
part of Aker

Modified by: PETTERSSON, JONAS2	Originator: PETTERSSON, JONAS2	Document no.: 10001631556	Doc. ver.: 00 / ECO no.:
Checked by:	Material no. (part): / Plant: 100	Release date: 05.06.2012	Reason for issue: In Work
Approved by:	Material spec.: AISI 1020, Cold Rolled	Weight: 16	Size: A3 / Sheet no.: 1 of 1



NOTES:

1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. TOLERANCING ISO 8015.
   GENERAL TOLERANCES ISO 2768-mK.
3. UNLESS OTHERWISE SPECIFIED:
   DEBURR EXTERNAL EDGES AND CORNERS.
   FILLET RADIUS: MAX 0,8.
   SURFACE ROUGHNESS Ra3,2.
4. PROCESS SPECIFICATION ACCORDING TO MATERIAL.

5. TRACEABILITY MARKING ACCORDING TO TC 2.3:
   M/N: <MATERIAL NO.> REV.<REV.NO.>
   S/N: <PO NO.>-<PO LINE ITEM>-<SEQUENCE NO.>

   USE LOW STRESS PERMANENT MARKING

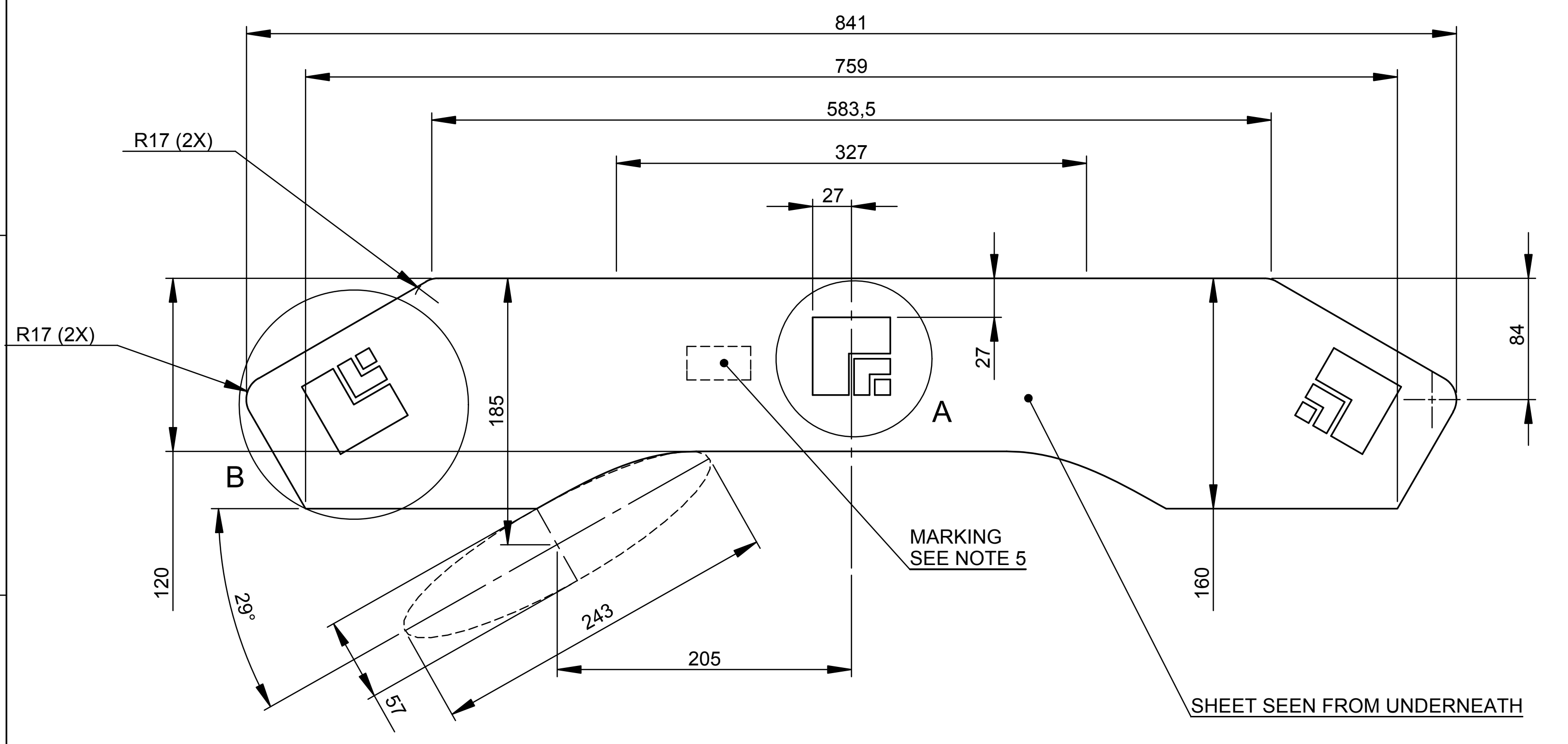
Machining dimensional tolerances ISO 2768-m (millimetres)

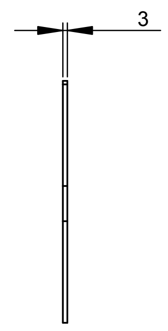
Linear dimensions		External radii and chamfer heights	
Range	Tol	Range	Tol
0.5-3	±0.1	0.5-3	±0.2
>3-6	±0.1	>3-6	±0.5
>6-30	±0.2	>6	±1
>30-120	±0.3	Angular dimensions	
>120-400	±0.5		
>400-1000	±0.8	≤10	±1°
>1000-2000	±1.2	>10-50	±0°30'
>2000-4000	±2	>50-120	±0°20'
		>120-400	±0°10'
		>400	±0°05'

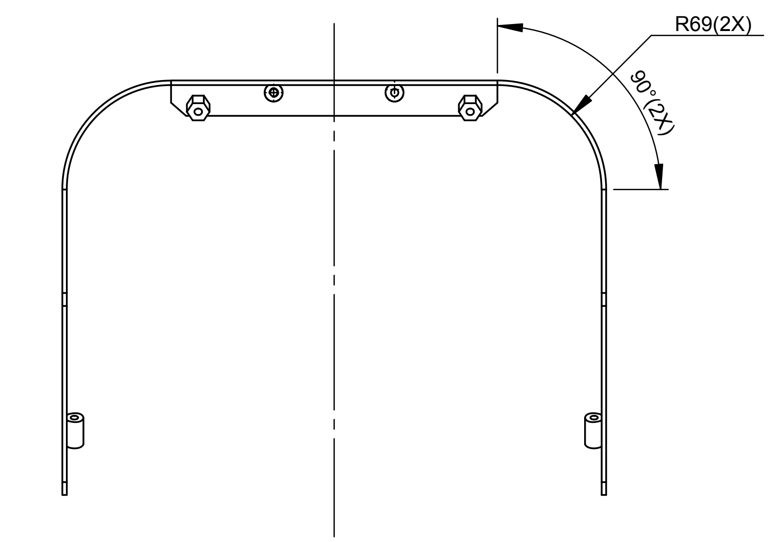
Title
CB_FRONT
LOCK DOG CONTINGENCY TOOL
MACHINING

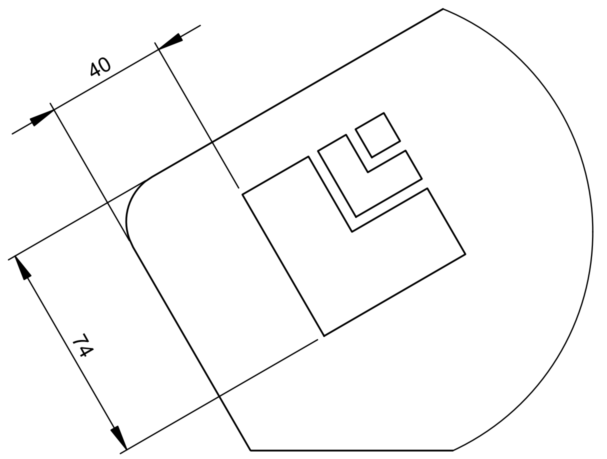
AkerSolutions
part of Aker

Modified by: PETTERSSON, JONAS2	Originator: PETTERSSON, JONAS2	Document no.: 10001631451	Doc. ver.: 00 / ECO no.:
Checked by:	Material no. (part): / Plant: 100	Release date: 05.06.2012	Reason for issue: In Work
Approved by:	Material spec.: UNSS3 2750	Weight:	Size: A3 / Sheet no.: 1 of 1

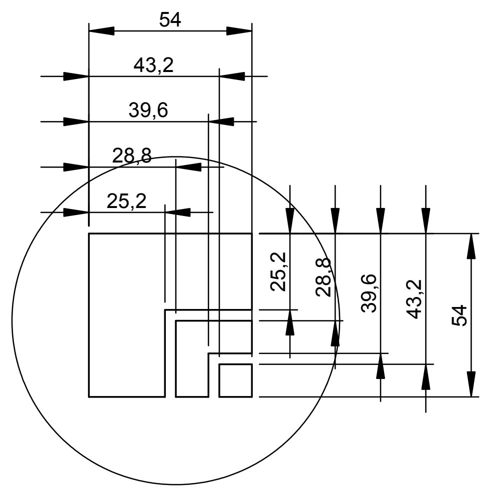




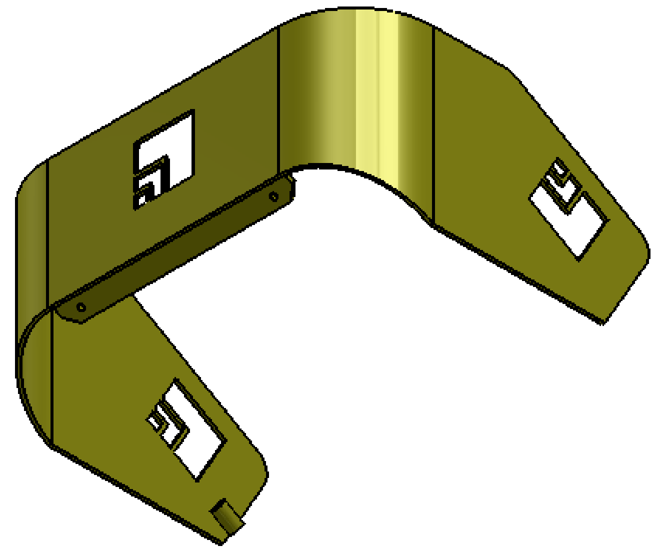




DETAIL B



DETAIL A



NOTES:

1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. TOLERANCING ISO 8015.
   GENERAL TOLERANCES ISO 2768-mK.
3. UNLESS OTHERWISE SPECIFIED:
   DEBURR EXTERNAL EDGES AND CORNERS.
   FILLET RADIUS: MAX 0,8.
   SURFACE ROUGHNESS Ra3,2.
4. PROCESS SPECIFICATION ACCORDING TO MATERIAL.
5. TRACEABILITY MARKING ACCORDING TO TC 2.3:
   M/N: <MATERIAL NO.> REV.<REV.NO.>
   S/N: <PO NO.>-<PO LINE ITEM>-<SEQUENCE NO.>

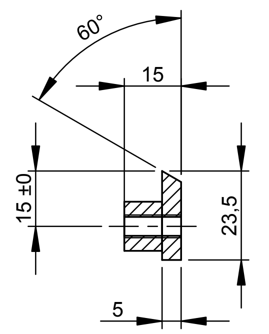
Machining dimensional tolerances ISO 2768-m (millimetres)

Linear dimensions		External radii and chamfer heights	
Range	Tol	Range	Tol
0.5-3	±0.1	0.5-3	±0.2
>3-6	±0.1	>3-6	±0.5
>6-30	±0.2	>6	±1
>30-120	±0.3	Angular dimensions	
>120-400	±0.5		
>400-1000	±0.8	≤10	±1°
>1000-2000	±1.2	>10-50	±0°30'
>2000-4000	±2	>50-120	±0°20'
		>120-400	±0°10'
		>400	±0°05'

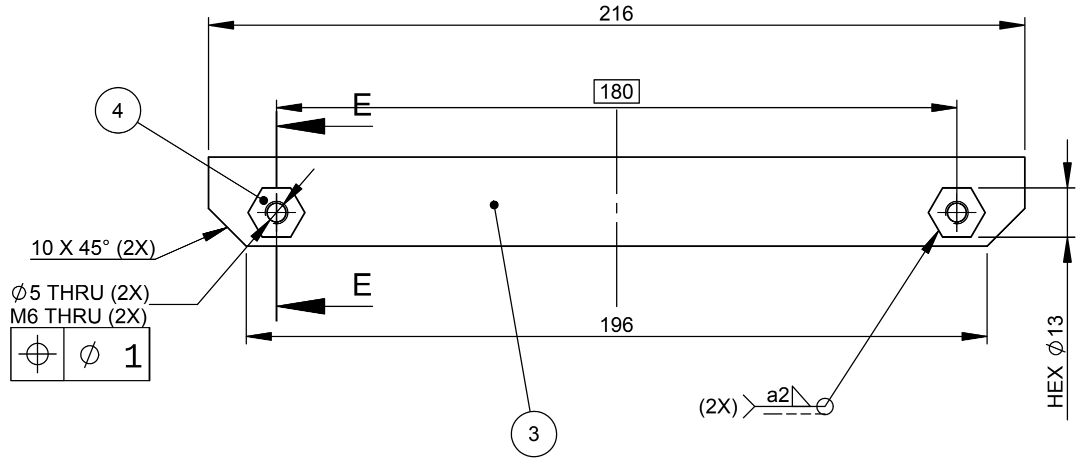
Title
CB_TOP
LOCK DOG CONTINGENCY TOOL
Tie-In

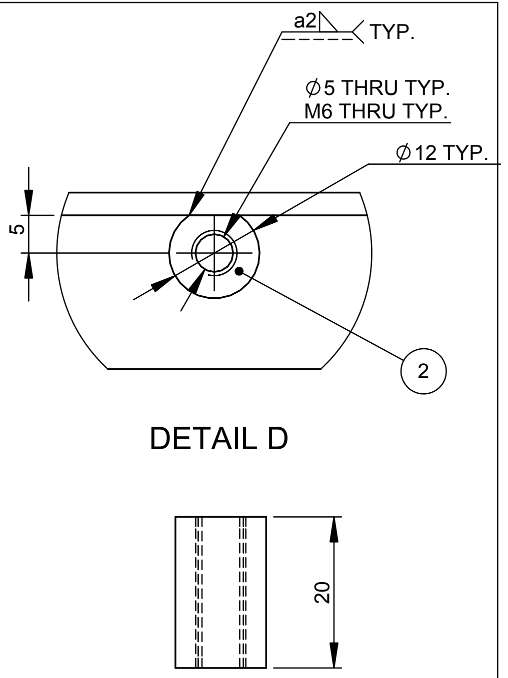
AkerSolutions™
part of Aker

Modified by: HOGLID, ERIK1	Originator: HOGLID, ERIK1		Document no.: 10001631569	Doc. ver.: 00 / ECO no.:
Checked by:	Material no. (part):	Plant:	Release date: 05.06.2012	Reason for issue: Created
Approved by:	Material spec.: UNS S32750		Weight: 2610.69	Size: A3 / Sheet no.: 1 of 2

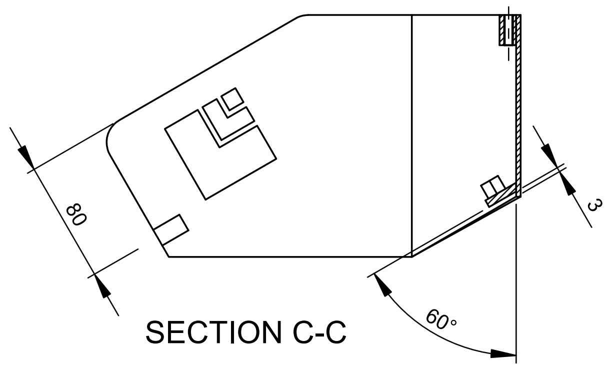


SECTION E-E

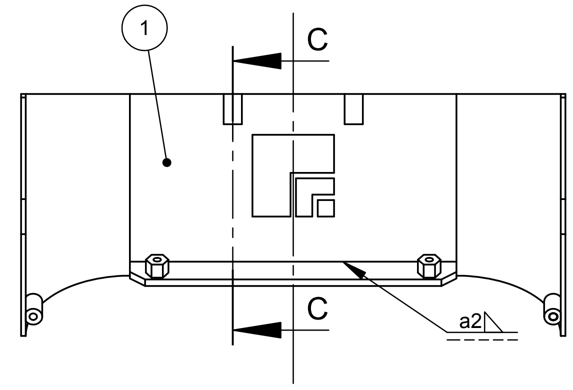


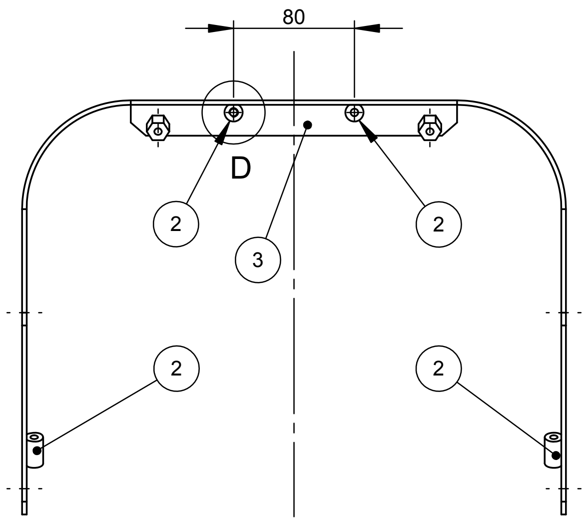


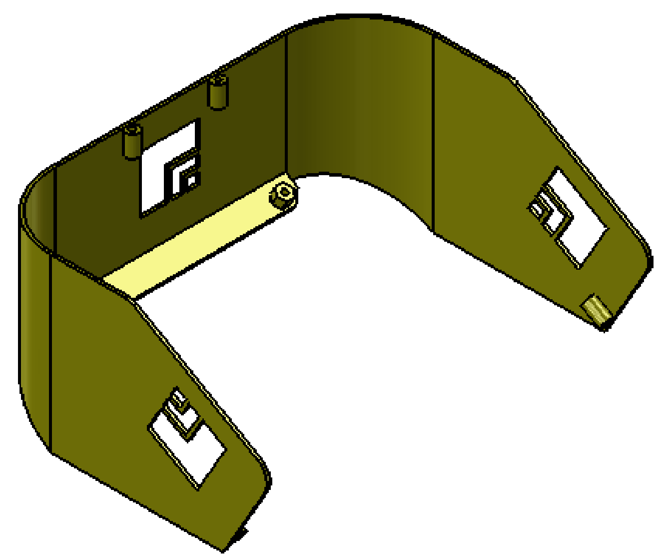
DETAIL D



SECTION C-C







ITEM NO.	QTY.	Description	LENGTH	MATERIAL
1	1	COVER PLATE		Stainless Steel (ferritic)
2	4	Threaded pin	BxH	Stainless Steel (ferritic)
3	1	Plate for attachment of back plate	bxh	Stainless Steel (ferritic)
4	2	Threaded nut	BXH	Stainless Steel (ferritic)

NOTES:

1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. TOLERANSING ISO 8015.
   GENERAL TOLERANSES ISO 2768-mK.
   GENERAL WELDING TOLERANSES ISO 13920-BF.
3. PROCESS SPECIFICATION ACCORDING TO MATERIAL.

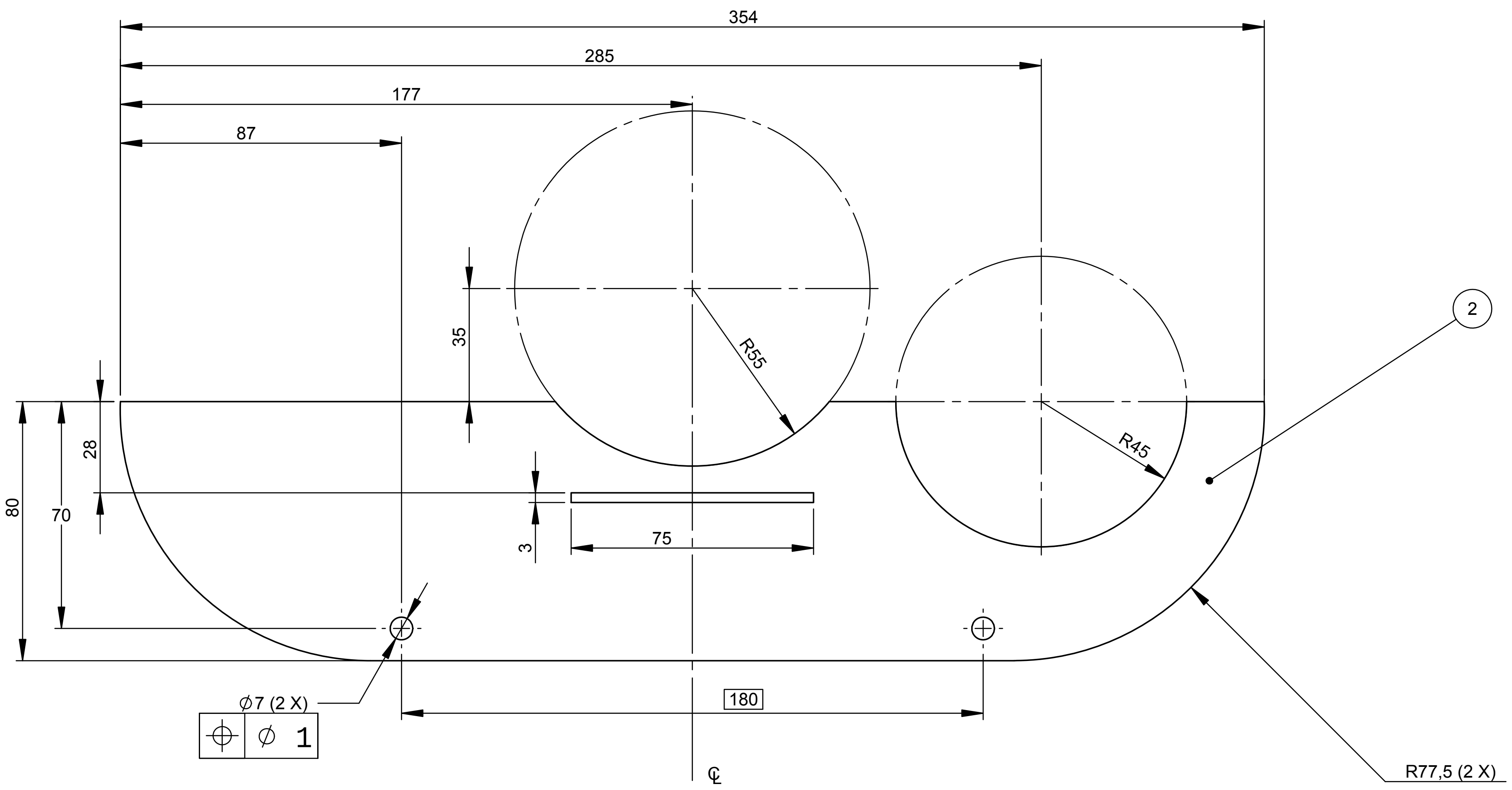
Welding dimensional tolerances ISO 13920-BF (millimetres)

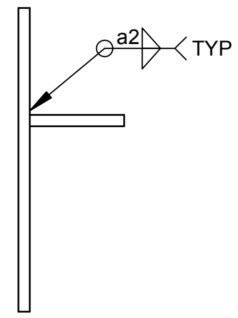
Linear dimensions	
Range	Tol
2-30	±1
>30-400	±2
>400-1000	±3
>1000-2000	±4
>2000-4000	±6
>4000-8000	±8
>8000-12000	±10
>12000-16000	±12
>16000-20000	±14
>20000	±16

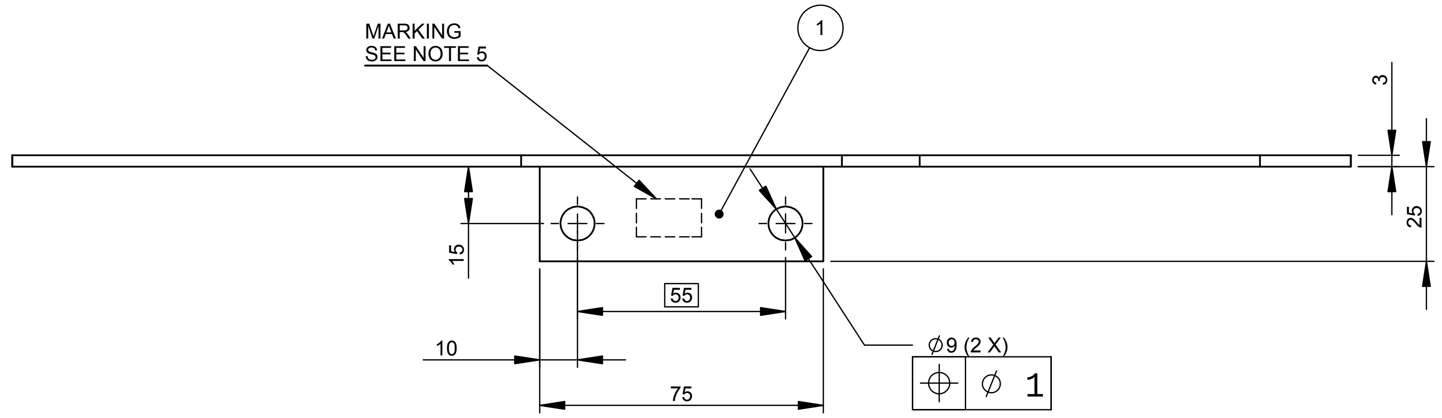
Title
CB_TOP
LOCK DOG CONTINGENCY TOOL
Tie-In

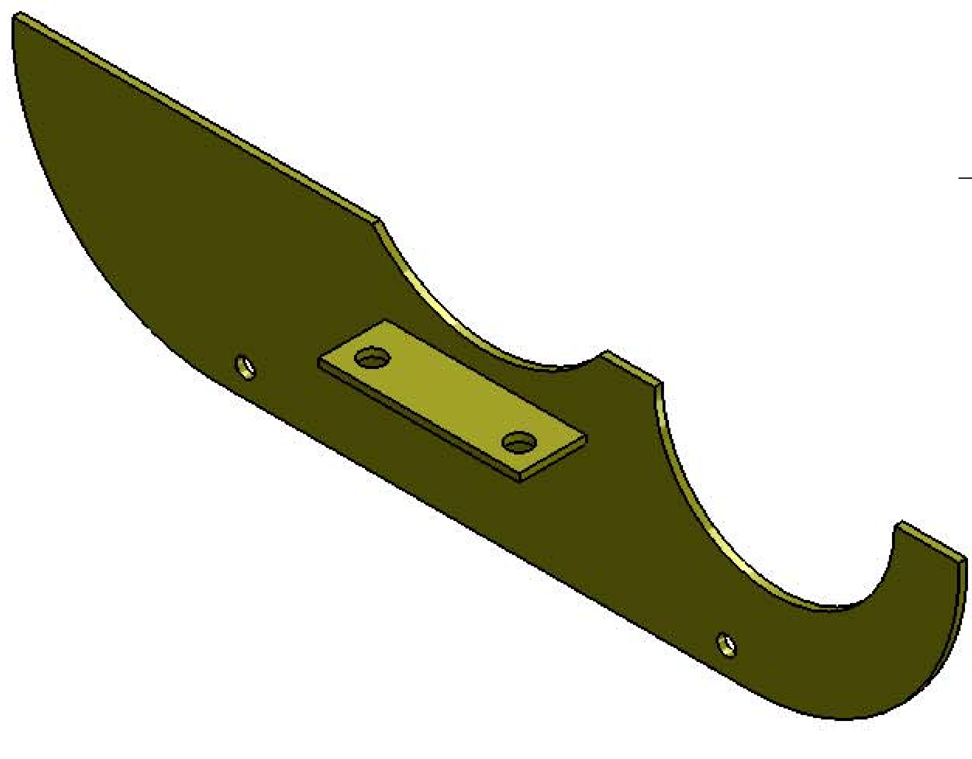
AkerSolutions
part of Aker

Modified by: HOGLID, ERIK1	Originator: HOGLID, ERIK1	Document no.: 10001631569	Doc. ver.: 00 / ECO no.:
Checked by:	Material no. (part): / Plant:	Release date: 05.06.2012	Reason for issue: Created
Approved by:	Material spec.: UNS S32750	Weight: 2610.69	Size: A3 / Sheet no.: 2 of 2









NOTES:

1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. TOLERANCING ISO 8015.
   GENERAL TOLERANCES ISO 2768-mK.
3. UNLESS OTHERWISE SPECIFIED:
   DEBURR EXTERNAL EDGES AND CORNERS.
   FILLET RADIUS: MAX 0,8.
   SURFACE ROUGHNESS Ra3,2.
4. PROCESS SPECIFICATION ACCORDING TO MATERIAL.

5. TRACEABILITY MARKING ACCORDING TO TC 2.3:
   M/N: <MATERIAL NO.> REV.<REV.NO.>
   S/N: <PO NO.>-<PO LINE ITEM>-<SEQUENCE NO.>

   USE LOW STRESS PERMANENT MARKING

ITEM NO.	QTY.	DESCRIPTION	MATERIAL	LENGTH
1	1	Flange for attachment	Stainless Steel (ferritic)	B*H
2	1	Back plate	Stainless Steel (ferritic)	

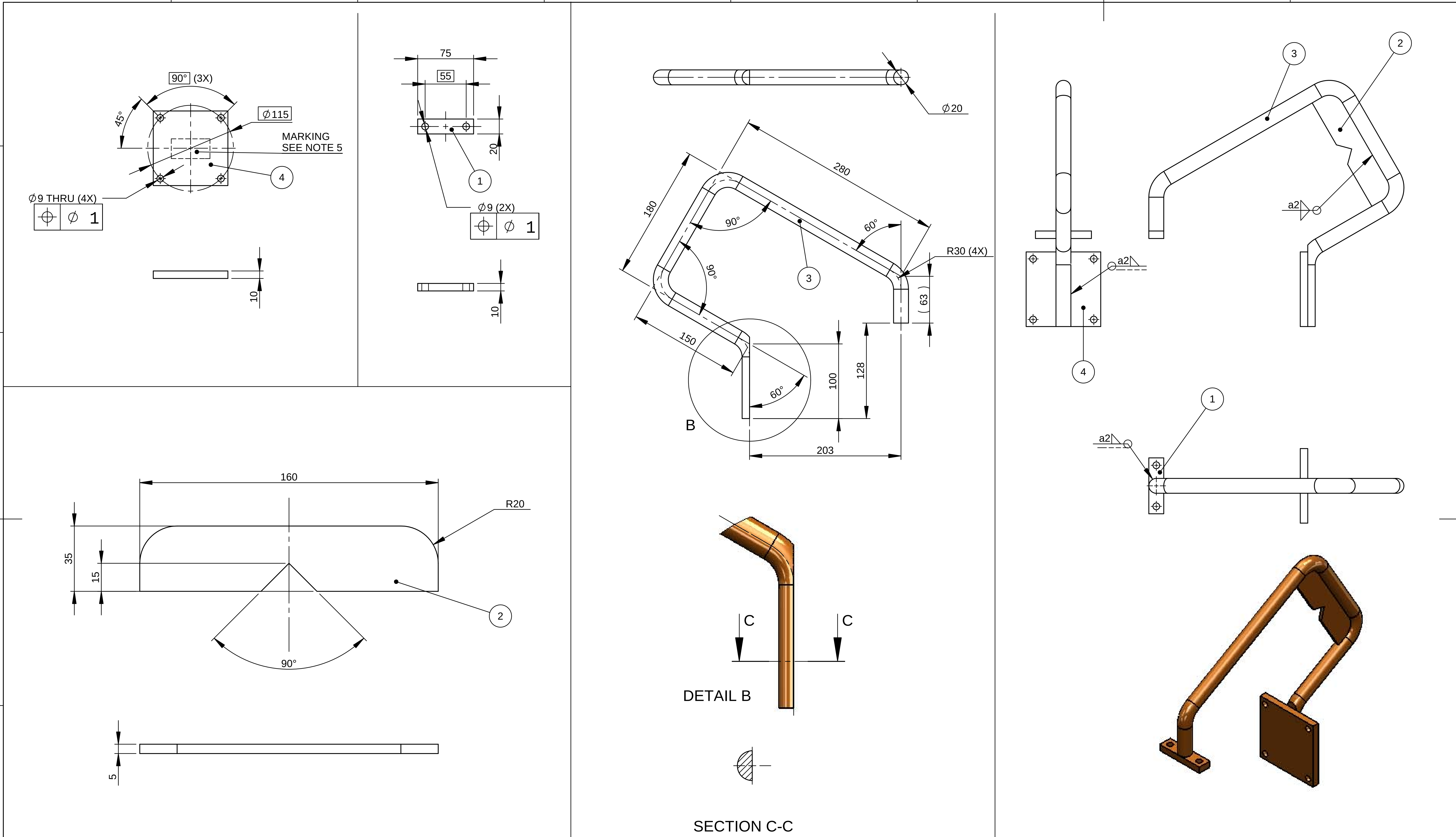
Machining dimensional tolerances ISO 2768-m (millimetres)

Linear dimensions		External radii and chamfer heights	
Range	Tol	Range	Tol
0.5-3	±0.1	0.5-3	±0.2
>3-6	±0.1	>3-6	±0.5
>6-30	±0.2	>6	±1
>30-120	±0.3	Angular dimensions	
>120-400	±0.5		
>400-1000	±0.8	≤10	±1°
>1000-2000	±1.2	>10-50	±0°30'
>2000-4000	±2	>50-120	±0°20'
		>120-400	±0°10'
		>400	±0°05'

Title
CB_BACK
LOCK DOG CONTINGENCY TOOL
Tie-In

AkerSolutions™
part of Aker

Modified by: HOGLID, ERIK1	Originator: HOGLID, ERIK1		Document no.: 10001631538	Doc. ver.: 00	ECO no.
Checked by	Material no. (part)	Plant: 100	Release date: 05.06.2012	Reason for issue: In Work	
Approved by	Material spec.: UNS S32750		Weight	Size: A3	Sheet no.: 1 of 1



ITEM NO.	QTY.	DESCRIPTION	MATERIAL
1	1	BRACKET FRONT	NORSOK M-120 Y05
2	1	ROV HINGE	NORSOK M-120 Y05
3	1	PIPE STRUCTURE	NORSOK M-120 Y05
4	1	BRACKET BACK	NORSOK M-120 Y05

NOTES:

1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. TOLERANSING ISO 8015.
   GENERAL TOLERANSES ISO 2768-mK.
   GENERAL WELDING TOLERANSES ISO 13920-BF.
3. PROCESS SPECIFICATION ACCORDING TO MATERIAL.

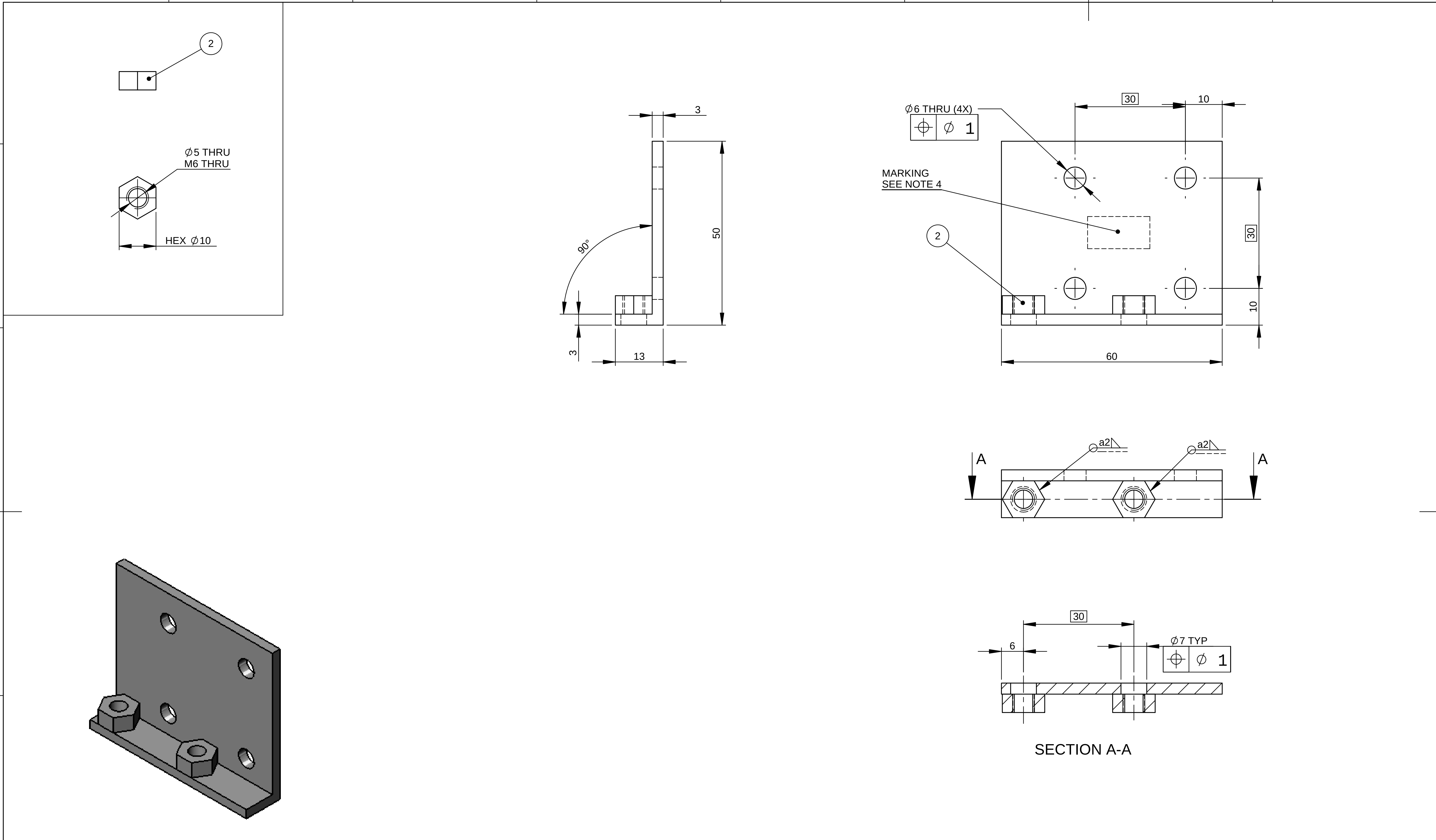
Welding dimensional tolerances ISO 13920-BF (millimetres)

Linear dimensions	
Range	Tol
2-30	±1
>30-400	±2
>400-1000	±3
>1000-2000	±4
>2000-4000	±6
>4000-8000	±8
>8000-12000	±10
>12000-16000	±12
>16000-20000	±14
>20000	±16

Title
ROV HANDLE
LOCK DOG CONTINGENCY TOOL
Tie-In

AkerSolutions
part of Aker

Modified by: HOGLID, ERIK1	Originator: HOGLID, ERIK1	Document no.: 10001631458	Doc. ver.: 00 / ECO no.:
Checked by:	Material no. (part): / Plant:	Release date: 05.06.2012	Reason for issue: Created
Approved by:	Material spec.: NORSOK M-120 Y05	Weight:	Size: A3 / Sheet no.: 1 of 1



ITEM NO.	QTY.	DESCRIPTION	MATERIAL
1	1	BRACKET	AISI316L
2	2	BRACKET	AISI316L

NOTES:

1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. TOLERANSING ISO 8015.
   GENERAL TOLERANSES ISO 2768-mK.
   GENERAL WELDING TOLERANSES ISO 13920-BF.
3. PROCESS SPECIFICATION ACCORDING TO MATERIAL.
4. TRACEABILITY MARKING ACCORDING TO TC 2.3:
   M/N: <MATERIAL NO.> REV.<REV.NO.>
   S/N: <PO NO.>-<PO LINE ITEM>-<SEQUENCE NO.>

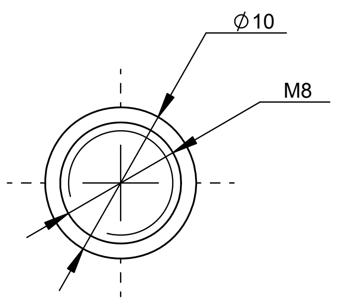
Welding dimensional tolerances ISO 13920-BF (millimetres)

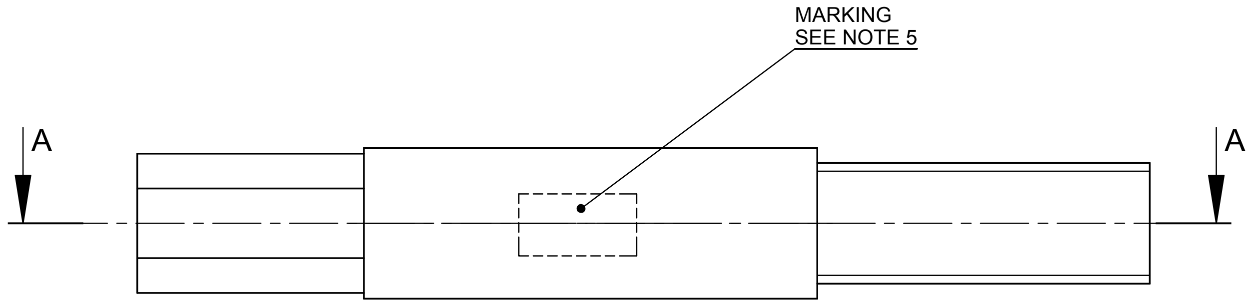
Linear dimensions	
Range	Tol
2-30	±1
>30-400	±2
>400-1000	±3
>1000-2000	±4
>2000-4000	±6
>4000-8000	±8
>8000-12000	±10
>12000-16000	±12
>16000-20000	±14
>20000	±16

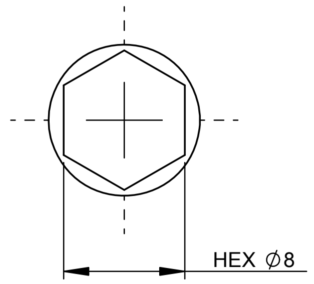
Title
BRACKET
LOCK DOG CONTINGENCY TOOL
WELDMENT

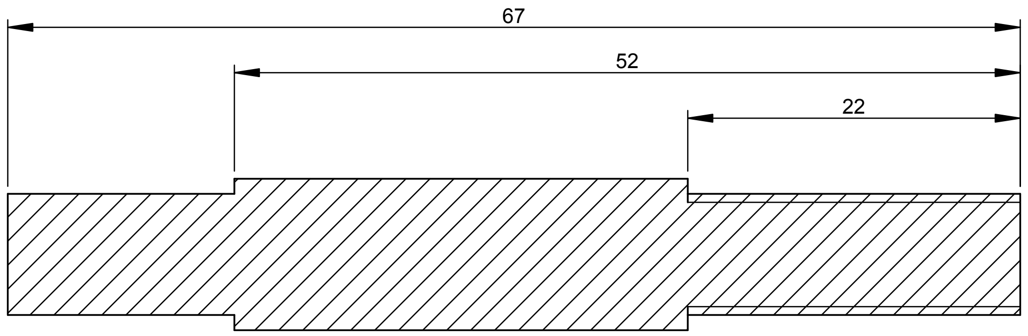
AkerSolutions™
part of Aker

Modified by: PETTERSSON, JONAS2	Originator: PETTERSSON, JONAS2	Document no.: 10001631427	Doc. ver.: 00 / ECO no.:
Checked by:	Material no. (part): / Plant: 100	Release date: 05.06.2012	Reason for issue: In Work
Approved by:	Material spec.: AISI 316L	Weight:	Size: A3 / Sheet no.: 1 of 1

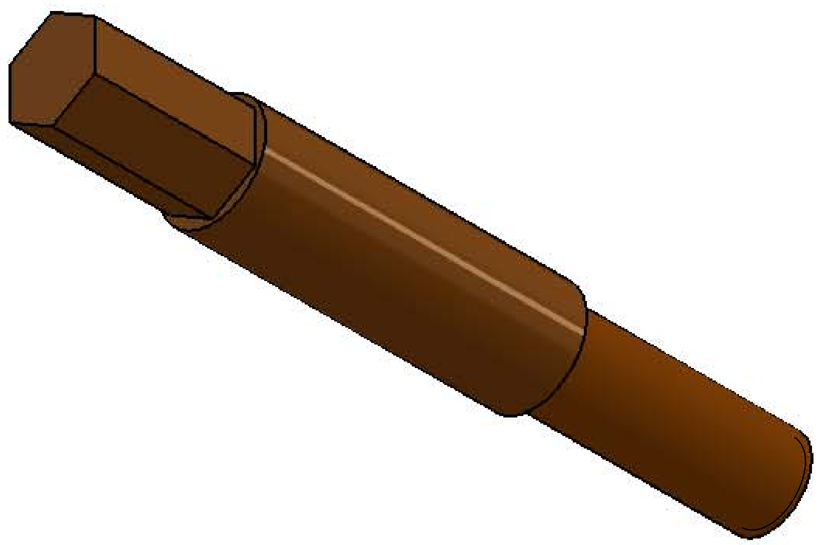








SECTION A-A



NOTES:

1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. TOLERANCING ISO 8015.
   GENERAL TOLERANCES ISO 2768-mK.
3. UNLESS OTHERWISE SPECIFIED:
   DEBURR EXTERNAL EDGES AND CORNERS.
   FILLET RADIUS: MAX 0,8.
   SURFACE ROUGHNESS Ra3,2.
4. PROCESS SPECIFICATION ACCORDING TO MATERIAL.

5. TRACEABILITY MARKING ACCORDING TO TC 2.3:
   M/N: <MATERIAL NO.> REV.<REV.NO.>
   S/N: <PO NO.>-<PO LINE ITEM>-<SEQUENCE NO.>

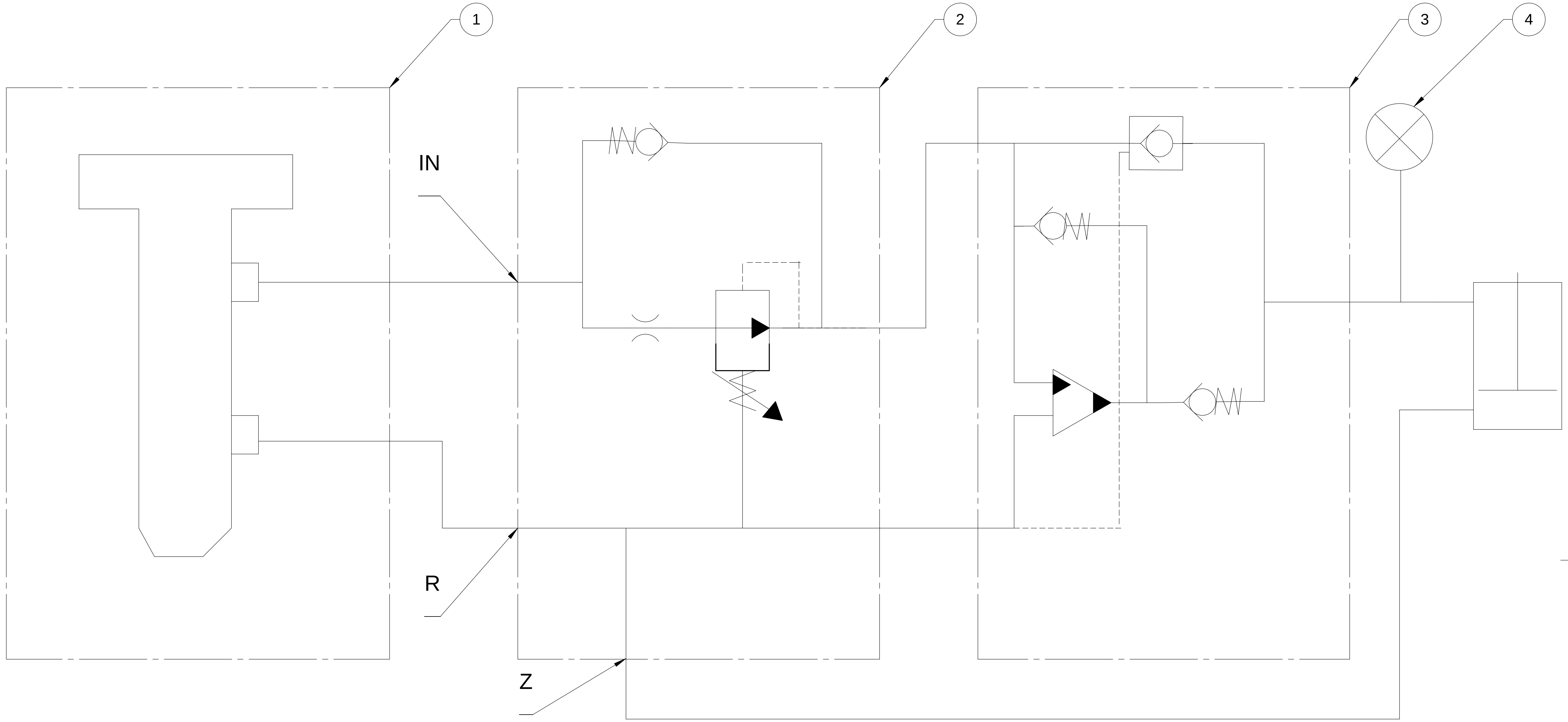
Machining dimensional tolerances ISO 2768-m (millimetres)

Linear dimensions		External radii and chamfer heights	
Range	Tol	Range	Tol
0.5-3	±0.1	0.5-3	±0.2
>3-6	±0.1	>3-6	±0.5
>6-30	±0.2	>6	±1
>30-120	±0.3	Angular dimensions	
>120-400	±0.5		
>400-1000	±0.8	≤10	±1°
>1000-2000	±1.2	>10-50	±0°30'
>2000-4000	±2	>50-120	±0°20'
		>120-400	±0°10'
		>400	±0°05'

Title
GUID PIN
LOCK DOG CONTINGENCY TOOL
Tie-In

AkerSolutions
part of Aker

Modified by: HOGLID, ERIK1	Originator: HOGLID, ERIK1	Document no.: 10001631617	Doc. ver.: 00 / ECO no.:
Checked by:	Material no. (part): / Plant: 100	Release date: 05.06.2012	Reason for issue: Created
Approved by:	Material spec.: UNS S2750	Weight:	Size: A3 / Sheet no.: 1 of 1



Item	Qty	Description	Specification
1	1	Receptical	
2	1	Hydraulic pressure reducer	CV2
3	1	Hydraulic pressure booster	HC2
4	1	Pressure Gauge	

NOTES:

1. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETRES
   ALL STANDARDS REFERRED TO SHALL BE THE CURRENT ISSUE.
2. PROCESS SPECIFICATION ACCORDING TO MATERIAL.

Title
HYDRAUKIC_DIAGRAM
LOCK DOG CONTINGENCY TOOL
DIAGRAM

AkerSolutions™
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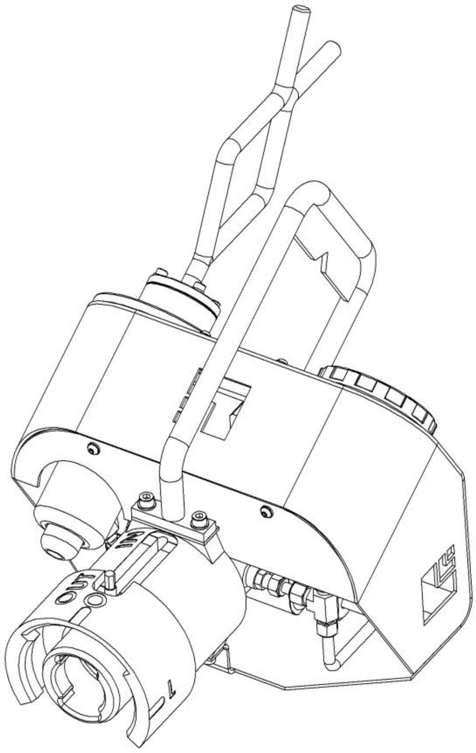
Modified by: PETTERSSON, JONAS2	Originator: PETTERSSON, JONAS2	Document no.: 10001631707	Doc. ver.: 00 / ECO no.:
Checked by:	Material no. (part): 10167265 / Plant: 100	Release date: 05.06.2012	Reason for issue: Created
Approved by:	Material spec.:	Weight:	Size: A3 / Sheet no.: 1 of 1

APPENDIX D OMM

OMM

Ver.	Status	Issue date	Made by	Checked by	Approved by
00	In Work	07.05.2012	Pettersson, Jonas Hoglid, Erik		
Originator:					

OMM, Lock Dog Tool 20 T
HCS Contingency Tool
TIE-IN TOOLING



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1. INTRODUCTION

1.1. Purpose and Scope

The purpose of this manual is to give instructions to install, operate and maintain the following equipment as supplied by Aker Solutions.

Name	Material No
Lock Dog Contingency Tool 20T HCS	10167265

1.2. Abbreviations

The following abbreviations are used in this document:

HCS	Horizontal Connection System
HIC	Hub Inspection Camera
HPU	Hydraulic Power Unit
ROV	Remotely Operated Vehicle
LDCT	Lock Dog Contingency Tool

1.3. Contact Addresses

Aker Solutions AS
Rosenlundsplatsen 2
PO Box 2122 411 20
403 13 Gothenburg, Sweden
www.akersolutions.com

2. HEALTH, SAFETY AND ENVIRONMENT

2.1. General

Safety is of prime importance when undertaking any work on or near the intervention tools. Only fully trained and suitably qualified personnel should work on the equipment and the prevailing site safety rules should always be fully adhered to.

2.2. Safety Notes

The following types of safety notes are used in this document:

NOTE! **Shall be used to highlight items/steps of special importance.**

Shall be used to highlight items/steps that may result in damage on equipment.

Shall be used to highlight items/steps that may result in personnel injury or seriously damage on equipment.

2.2.1. Product Specific

NOTE! **Always wear suitable protective clothing and safety glasses when there is a possibility of contact with hydraulic oil.**

This product has a pressure booster and operates with very high pressure when retracting cylinder. 680 Bar. Keep distance when pressurizing the tool.

3. TECHNICAL INFORMATION AND DATA

3.1. Technical Description

The LDCT is a double acting hydraulic cylinder, operated by ROV and designed for connecting and separating in case of wedging of Aker Solutions installation tool using on horizontal connecting system.

The LDCT has two connections points: One on the cylinder to connect to the installation tool and one on the rod to connect to the bolt. Those are designed to connect rod and cylinder in same time in one motion.

The cylinder is handled and operated by a ROV, by using the handle on the LDCT. This ROV handle is hinged for use on the AKS 12'' HCS. The hydraulic power to the cylinder is provided by the ROV. The interface between ROV and LDCT hydraulic system is based on a dual port hot stab with check valves to reduce leakage and water ingress. The hydraulic dual port receptacle is mounted on the LDCT and provided with Protection Stab for protection during transport and storage.

3.1.1. Main Components

Main components with reference are listed below:

1. Pressure gauge
2. Dual port protection stab
3. ROV handle with hinge
4. Control box
5. Outer bayonet coupling
6. Double acting cylinder with bayonet coupling
7. Guide pin

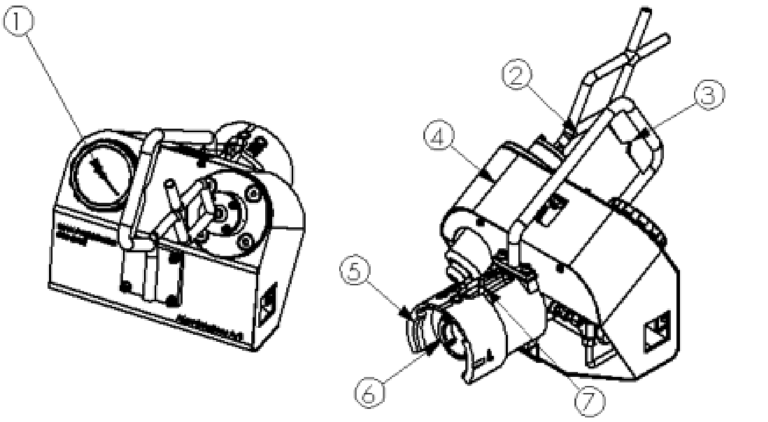


Figure 3-1: Main components

3.1.2. Interface Description

Table 1, Mechanical interfaces

Interface to	Interface type
LDCT cylinder	Bayonet coupling on LDCT and Installation tool
ROV	ROV handle on the LDCT

Table 2, hydraulic interfaces

Interface to	Interface type
ROV/HPU	Dual Port Hot Stab, ISO 13628-8, Type A

3.2. Technical Data

Table 3, General data

Measurement	Value
Operational force capacity	Pull 20 metric tonnes (680 bar) Push 10 metric tonnes (200 bar)
Max. allowable water depth	3 000 m (10 000 ft)
Design life	XX years
Operation temperature range	0 to + 50 ^{o}C
Input pressure	170-207 bar (2465 - 3000 psi)
Input flow	0-14 l/min (0 – 3.7 gal/min)
Maximum working Pressure retract (after booster)	680 bar (9860 psi)
Maximum working Pressure extend	200 bar (2900 psi)
Design Pressure hydraulic system	207 bar (3000 psi)
Check Valves	In Dual Port Hot Stab / In Dual Port Receptacle
Hoses/ piping	For subsea usage

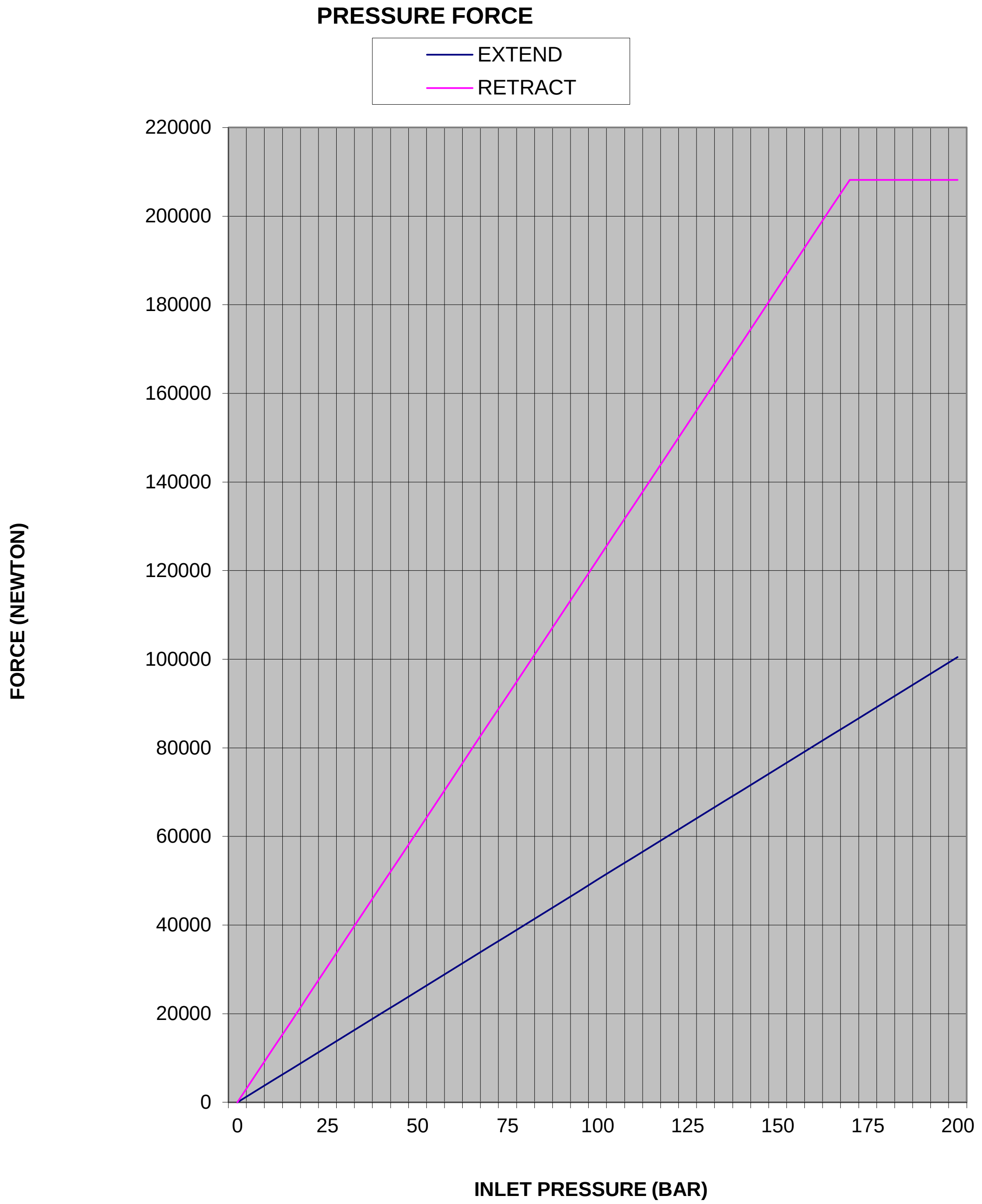


Figure 3-2: Pressure table

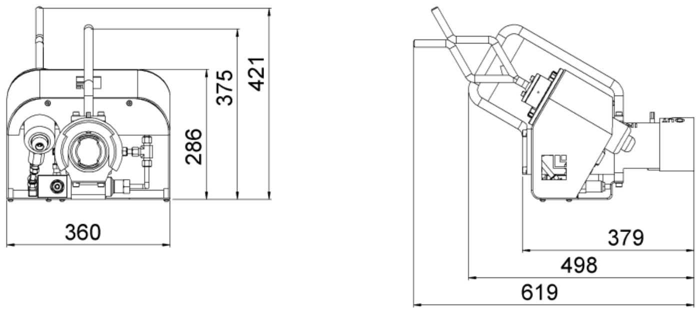


Figure 3-3 Envelope Lock Dog

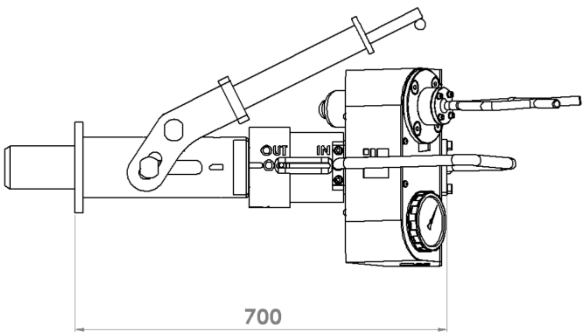


Figure 3-4 Envelope (retracting of Installation Tool).

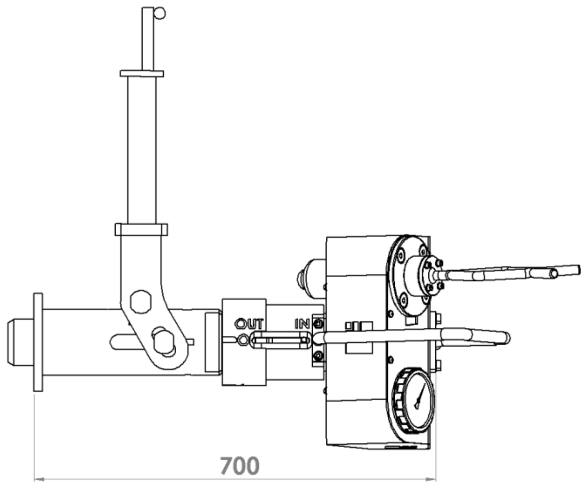


Figure 3-5 Envelope (extending of Installation Tool).

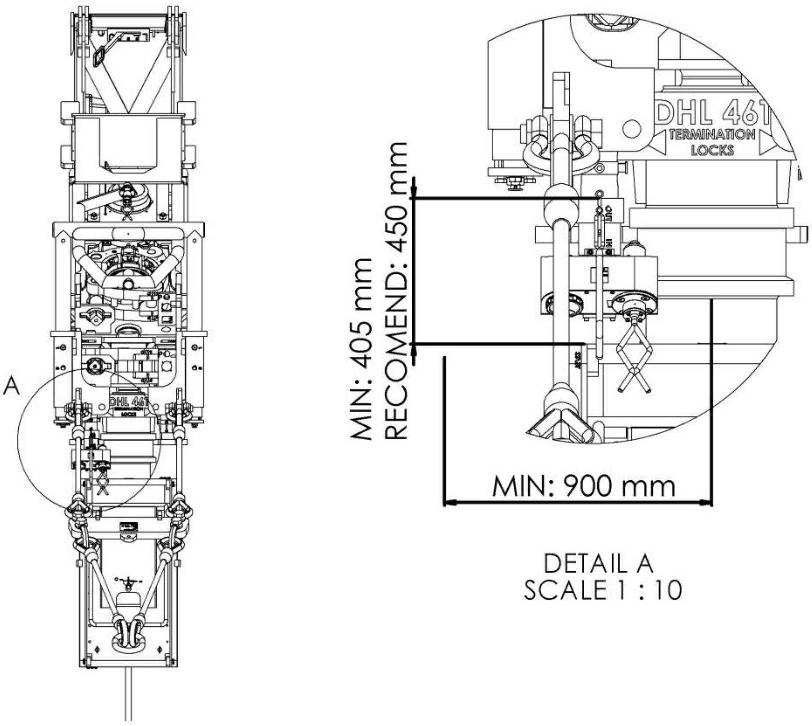


Figure 3-6 Envelope HCS with UTH (view above)

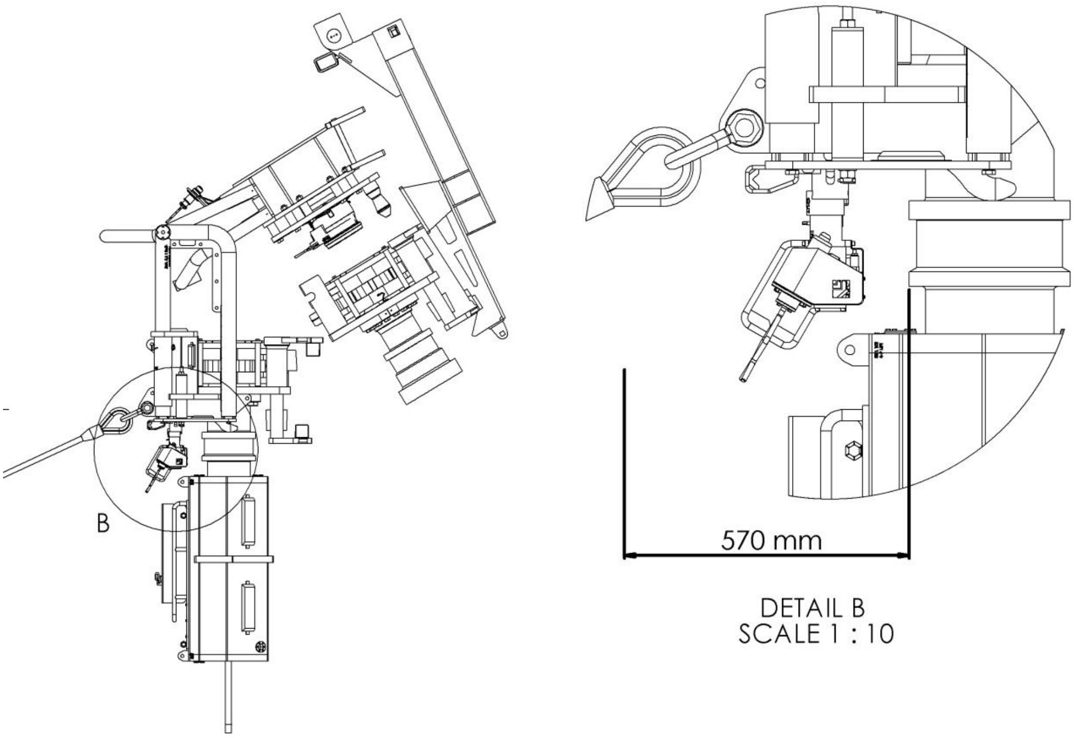


Figure 3-7 Envelope HCS with UTH (side view)

Table 4, Dimension and weight

Measurement	Value
Length	498 mm
Stroke length	80 mm
Width	360 mm
Height	375 mm (421 mm)
Weight in air	39 kg
Weight in water	35 kg

Table 5, Hydraulic data

Measurement	Value
Hydraulic fluid	Shell Tellus grade 22/ 32 or similar
Cleanliness of hydraulic fluid	NAS class 8 or better

3.3. Vessel Requirements

No special requirements.

3.4. ROV Requirements

The following requirements apply for the ROV:

- Arm for operating the tool.
- Dual port hot stab, ISO 13628-8, Type A
- Pressure and flow according to hydraulic requirement for tool.

4. PACKING, PRESERVATION AND STORAGE INSTRUCTIONS

4.1. Packing Instructions

When packing the LDCT, make sure that:

- It is placed in its dedicated transport box in such a way that unwanted movements are prevented; i.e. the LDCT should be secured by means of soft slings/ rope,
- To avoid mechanical damage, the piston rod is in its retracted position,
- To avoid ingress of unwanted objects, the protection stab is placed in the dual port receptacle.

4.2. Storage

- Storage temperature: High storage temperature can cause damage to seals. The LDCT should be stored and transported in a non-corrosive environment.
- Location: Indoor, in its transport box
- Sunlight: Minimal.

5. OPERATION

5.1. Installation and docking

5.1.1. Installation/docking for retracting cylinder

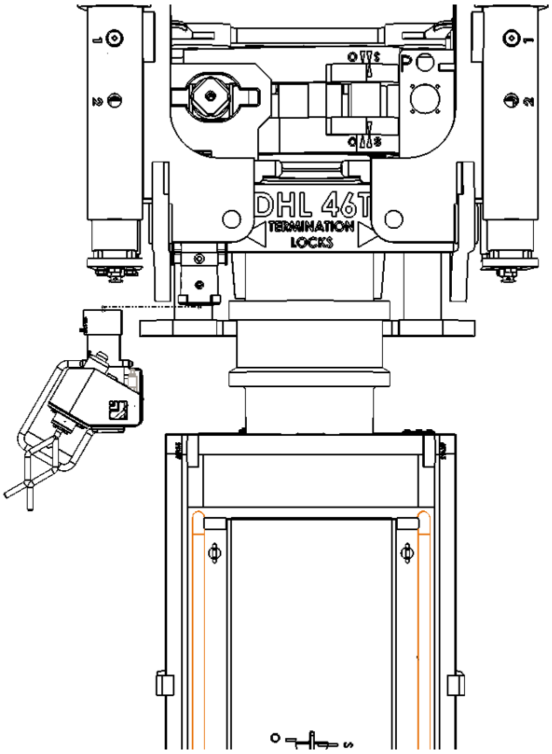


Figure 5-1 Position before connection to Installation Tool, typical (view above)

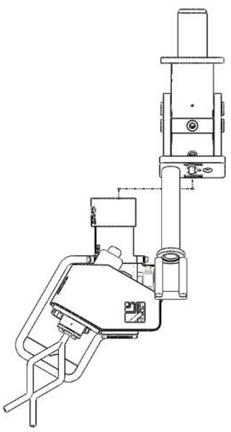


Figure 5-2 Position before connection with LDCT and Installation Tool.

Step	Description	Date/Signature
1	Install the dual port hot stab into the LDCT dual port receptacle.	
2	Fly the ROV with the LDCT to the HCS Installation Tool.	
3	Extend the cylinder fully. The LDCT is now ready for installation/docking.	
4	Before docking on Installation Tool, be sure that the handle on the Installation Tool is fully in lowered position.	
5	Attach the LDCT into the designated connection on Installation Tool.	

5.1.2. Installation and docking for extending cylinder

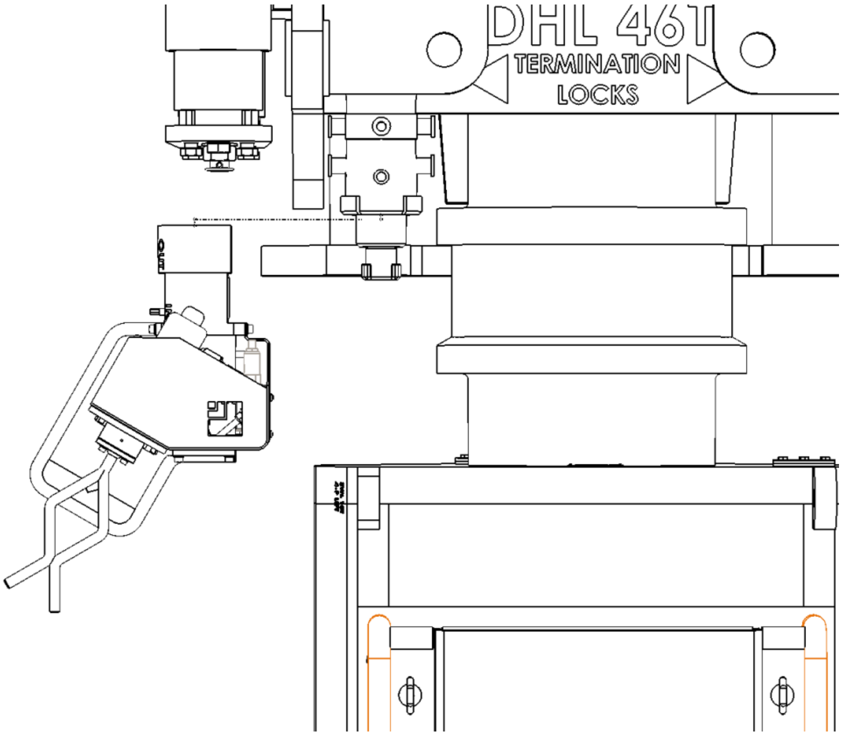


Figure 5-3 Position before connection to Installation Tool, typical (view above)

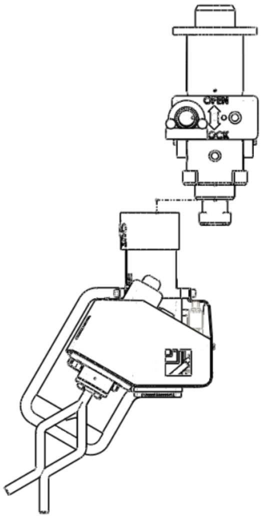


Figure 5-4 Position before connection with LDCT and Installation Tool.

Step	Description	Date/Signature
1	Install the dual port hot stab into the LDCT dual port receptacle.	
2	Fly the ROV with the LDCT to the HCS Installation Tool.	
3	Retract the cylinder. The LDCT is now ready for installation/docking.	
4	Before docking on Installation Tool, be sure that the handle on the Installation Tool is in fully vertical position.	
5	Attach the LDCT into the designated connection on Installation Tool.	

5.2. Normal Operation

5.2.1. Retracting cylinder

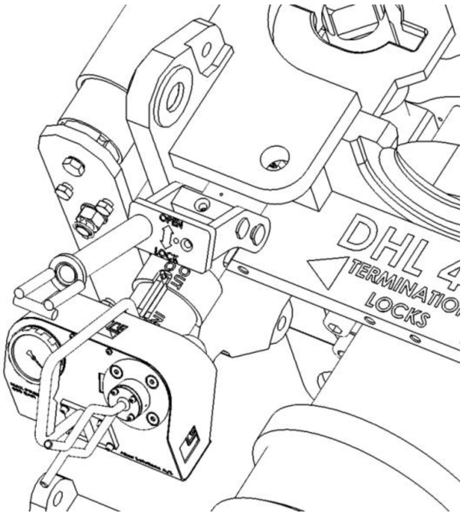


Figure 5-5 Tool in typical operating position

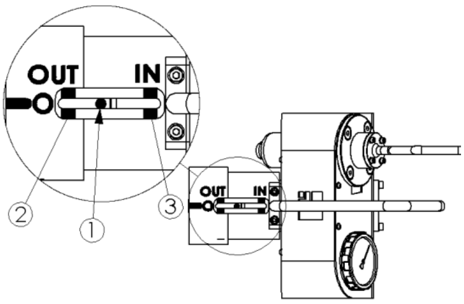


Figure 5-6 Position of Guide Pin (1).

Step	Description	Date/Signature
1	Verify that the cylinder is fully extended before connection (position 2).	
2	Connect the LDCT to Installation Tool by rotating the LDCT 90^0clockwise.	
3	Verify that the LDCT has fully connected to installation tool and to the bolt.	
4	Operate the LDCT to retract the cylinder fully(position 3).	

5.2.2. Extending cylinder

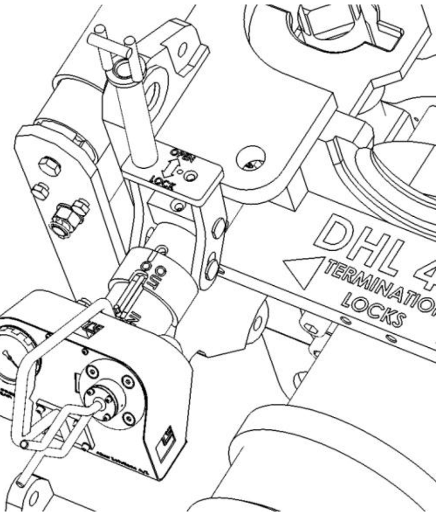


Figure 5-7 Tool in typical operating position

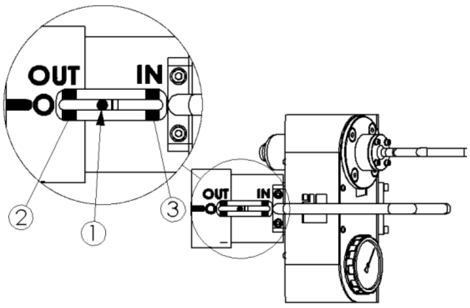


Figure 5-8 Position of Guide Pin (1).

Step	Description	Date/Signature
1	Verify that the cylinder is in the inner positions before connection(position 3)	
2	Connect the LDCT to installation toll by rotating the LDCT 90^0 clockwise.	
3	Verify that the LDCT has fully connected to installation tool and to the bolt.	
4	Operate the LDCT to extend the cylinder fully(position 2).	

5.3. Release

Step	Description	Date/Signature
1	Rotate the LDCT 90^0counterclockwise, pull the LDCT away from the installation tool until it's free.	

5.4. Recover

Step	Description	Date/Signature
1	Move the LDCT from the connection.	
2	Retract the LDCT piston completely.	

5.5. Retrieval

Step	Description	Date/Signature
1	Disconnect the hot stab.	
2	The LDCT can be retrieved to surface or continue with other subsea operations as required.	

6. TROUBLESHOOTING

If you find any faults or exceptional wearing use the following list as a guidance for corrective maintenance.

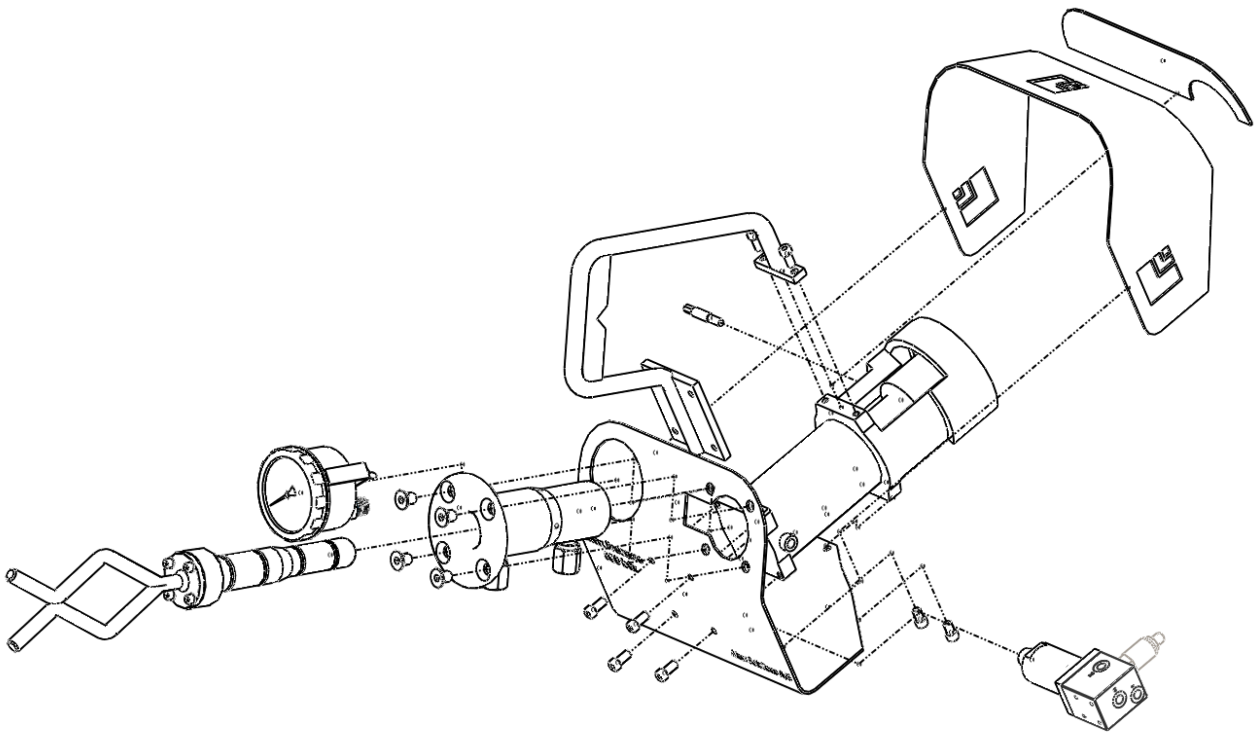
Observation	Possible cause	Action
Dirt on piston rod	Polluted environment	Clean piston rod in extended position, apply hydraulic oil on stem
None, or jerky motion of piston rod	Contaminated oil	Check oil quality (NAS class 8 or better)
	System fault	Check hydraulic medium supply (pressure according to specification)
	Pipe burst	Check oil supply
	External damage on pipes	Check pipe for damages/deformation
	External damage on rod	Check rod for damages/ deformations
Scratches in piston rod	Contaminated oil	Check oil quality (NAS class 8 or better)
	Too large perpendicular forces	Change operating conditions immediately Repair or replace piston rod Straighten up angle/ replace worn-out parts
Leakage from gland bushing	Contaminated oil	Check oil quality (NAS class 8 or better)
	Too high piston speed	Max. flow exceeds specification
	Worn seals	Seals to be replaced
	Damage of gland bushing	Replace together with seals
	Damage of piston rod	Replace together with seals
Leakage of hydraulic fluid	Ruptured line	Abort operation, retrieve ST to surface for repair
Not possible to retrieve LDCT from installed position on HCS installation tool.	ROV malfunction	Retrieve ROV to surface for other troubleshooting/ faultfinding activities.
	LDCT malfunction (ruptured line, bent piston rod, failed piston seal)	Cut hydraulic lines of ST to allow stroking by other means. Retrieve LDCT to surface for repair.

LDCT will not install properly		ROV inspection is required to find the cause of the problem. Remove the LDCT completely from its position and make a new attempt to install.

7. INSPECTION, MAINTENANCE & REPAIR

7.1. Corrective Maintenance

7.1.1. Assembly and disassembly



7.1.1.1. Assembly

1. Assemble mini booster on control box.
2. Assemble back side of control box.
3. Assemble hot stab receptacle (Dual port system).
4. Assemble pressure gauge.
5. Assemble all hydraulic tubing and fittings.
6. Assemble upper part of control box.
7. Assemble front part of control box.
8. Assemble ROV handle.

Further assembly (piston rod, piston, seals) and maintenance of these parts should only be carried out by the manufacturer.

7.1.1.2. Disassembly

Carry out the above work steps in the opposite order.