LAPIN AMK
Lapland University of Applied Sciences

Improvement of Hydraulic Power Unit Design for Hose Loading Station

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Bachelor's Thesis
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Tämän opinnäytetyön tavoitteena oli luoda uusi suunnittelumalli hose loading station -yksikölle kustannussäästöjen saavuttamiseksi työtuntien määrässä ja osien hinnassa National Oilwell Varco yhtiölle. Tämä kustannusten alentamisen vaatimus on syntynyt asiakkaiden tarpeesta, sillä aikaisemmin öljyala on kukoistanut, koska öljyn hinta on ollut korkea ja asiakas on vaatinutkin korkeatasoisia laitteita öljyntuotantoon ja jalostukseen. Nyt kun öljyn hinta on pudonnut huomattavasti ja markkinat ovat epävakaat, niin asiakkaat haluavat saavuttaa kustannussäästöjä vaatimalla halvempia tuotteita öljyn tuotantoa ja jalostamista varten.

Tämä kaikki on aiheuttanut sen, että kyseisen yksikön hintaa oli saatava alhaisemmaksi, laadun tai luotettavuuden heikentymättä. Mahdolliset kehitysideat annettiin alussa ja näiden avulla suoritettiin varsinainen työ. Tutkiminen aloitettiin alkuperäisestä mallista ja miten sitä voisi muuttaa, jotta siitä saataisiin halvempi tuottaa.

Seuraavassa vaiheessa luonnosteltiin kolme mahdollista vaihtoehtoa ongelmaa varten joista vain yhtä käytettiin lopullisessa mallissa. Kyseistä mallia varten laskettiin ja mitoitettiin käytettävät hydrauliikan komponentit ja mitkä näistä osista jätettiin pois, koska joitakin alkuperäisessä mallissa olevia osia ei tarvittu ja ne lisäsivätkin vain yksikön hintaa tarpeettomasti.

Käytetty tutkimusmateriaali oli suurimmilta osin yrityksen omaa materiaalia, mutta myös joitakin nettisivuja, joista hain käytettävät komponentit ja laskukaavat.

Kaikki tavoitteet työlle saavutettiin ja saatua suunnitelmaa voidaan käyttää pienillä muutoksilla lopullista tuotantoa varten.

Avainsanat Hydrauliikka, voimayksikkö, putkisto

Abstract of Thesis

Technology, Communication and Transport
Industrial Engineering and Management
Bachelor of Engineering (B.Eng.)

Author	Tero Köyhäjoki	Year	2016
Supervisor	Juha Kaarela		
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The objective of this thesis for National Oilwell Varco was to create new design for the hose loading station to achieve savings in labour and part costs. This demand for cost efficiency comes from customers as previously oil business has been blooming for many years and this bloom has given the huge demand for good quality equipment in oil drilling and processing. Now however oil price has dropped vastly and the oil market situation is very unpredictable so customers now want to achieve cost savings by demanding cheaper equipment for the use in oil drilling and processing.

This all had caused that new solutions had to be found for making production of hose loading station cheaper without compromising the quality and reliability. The task with possible area of improvement were given. Work was started from original design, which was first investigated and from which it was pointed out what could be changed to make new design more effective.

This gave three different possible solutions for the problem and one was chosen to be used in the final solution. For this design the hydraulic components like pipe and tank dimensions had to be calculated and also to find what kinds hydraulic components should be used and left out from the design as some of the components in HLS original design were obsolete and just increased the price of the mentioned unit unnecessarily.

All the research material used was mostly of the NOV own data but also websites were used to find out components and formulas for the hydraulic systems.

All the requirements for the thesis were achieved and this design can be used for the new design with some minor changes or improvements.

Key words Hydraulics, power unit, piping, hose loading station

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FOREWORD

I would like to thank the National Oilwell Varco for this interesting opportunity to do my thesis and especially the people involved in this project: Andreas Eilertsen, Ole Rekdal and other personnel in NOV Molde. I would also like to give thanks to my wife and child for understanding and supporting me for the whole time.

SYMBOLS AND ABBREVIATIONS

HPU	Hydraulic Power Unit
HLS	Hose Loading Station
SCM	Supply Chain Management
Rev	Revolution
Rpm	Revolution per minute
NOV	National Oilwell Varco

1 INTRODUCTION

This thesis was made for National Oilwell Varco, which is a worldwide leader providing equipment to oil and gas sectors. The office where I have completed my assignment is located in Molde, Norway and they specialize in offshore cranes, hose loading stations and winches. The research subject for this work was to improve the design of the Hydraulic Power Unit (HPU) for the Hose Loading Station (HLS). HPU produces hydraulic pressure to be used in the HLS for hydraulic motors driving the hose reels.

The purpose of work was to improve the design of the HPU unit so that it would have a more simple design, smaller size and it would be cheaper to be produced. The work included investigation for possibility to use a ring-line system that would consist of only 2 hydraulic pipes from the HPU delivered to all the motors instead of having 2 pipes from the HPU for each motor in the current design.

The new design for the HPU was made with AutoCAD and the assembly and installation time with building cost had to be calculated for the current and new system so that both systems could be compared.

2 PRESENTATION OF THE COMPANY AND CASE

National Oilwell Varco is a worldwide leader providing equipment to oil and gas sectors. The company headquarters is based in Houston Texas, but it operates around 1200 locations across six continents with nearly 64000 employees (Master Rig int'l, National Oilwell Varco 2015). The company designs and produces heavy hardware for oil well drilling including mud pumps, rotary tables for rigs, draw-works (hoisting machinery), derricks, top drives, blowout preventers, riser equipments and even complete drilling rigs. The location where this thesis was carried out was located in Molde, Norway and its specialty is offshore cranes, winch systems and hose reel stations. (National Oilwell Varco, About NOV 2015)

For a long-time, oil prices have been high which has kept the oil industry busy and products have to be manufactured with only the highest quality in mind without considering too much the price. Now that oil prices have come hugely down it has caused uncertainty and hesitation in market. The effect of this is that the customers try to keep operating expenses as low as possible and to find the cheapest possible solutions with quality in the second place. That is why the NOV did give the possibility to do the thesis as to investigate solutions to lower the material costs and manufacturing costs for the HLS. The main points to concentrate were the piping, valves and the HPU. In piping the purpose was to find a way to use less piping and also to route piping according to my own design. In valves and the HPU it was solved how to get rid of valves inside HPU and where the new valves could be installed. The components to be used for the HPU had to be found with the solutions how to make it smaller and more compact.

3 FRAME OF REFERENCE

The purpose of this thesis was to review the current HPU design, come up with new fresher, simpler and cheaper solutions for the design and then choose one of the solutions for the final design. This design had to be made considering assembly and material cost reduction. After the research and, design the original and new designs were compared to each other to see how big cost savings were achieved. The things to keep in mind with the new design reliability had to be at same level as the original design. Some of the functions which are considered as luxury or unnecessary could be taken out or changed to another type.

Comparing prices was done by calculating all the needed components for the whole assembly and estimating the assembly time. The purpose of the whole work was to offer the company a possible solution in achieving cost savings and it will not be the final design used for production as this will need further fine tuning. A same type of research will be done also by a team inside the company and they will compare the results with their own to see if they got the same solutions and possibly combine some of the solutions to further improve the design. In this thesis any prices or sensitive information cannot be published.

3.1 Methods and execution of work

The work was carried out mainly in the NOV office and at home. The company laptop included all needed software. The software for the designing work was AutoCAD mechanical and Autodesk inventor. Microsoft Office was used for price calculation and material list. For parts and current design the company has its own software called Rig Office, which has all schematics and parts/numbers needed. Beside that search engines like Google and some known part supplier’s websites like Parker were used to find special parts and information as needed. Supply chain management was helping with the prices and information for the parts and other engineers helped with the design, selection of parts and required standards. During work the standards required by regulatory bodies, rules and regulations had to be followed.

The work did start with finding out the current system cost and how it is divided into labour and parts. The next step was to come with different solutions and simple designs and descriptions of these solutions. Those ideas were presented to other engineers to choose one to be used for the final design. The chosen solution was continued and schematics were finished for the second presentation. This second presentation then should either accept the design or give some tips if some fine adjusting was needed.

3.2 Current situation and design of hose loading station

The loading of fluids and dry bulk materials between supply vessels and fixed or floating production or drilling units have been necessary to maintain in continuous operation. This is done by using of an HLS whose main function is to store the loading hoses and to be a foundation for the loading hoses during loading operations. The On/Off-loading operation is executed by un-reeling the loading hose, lift it on-board to the supply vessel by using a crane, connect it to the vessel bulk system and reel it back when the refilling is finished. When the loading operation is completed, the fluid will be drained back to the supply vessel storage tank and finally the hose is reeled back onto the reel. No manual handling of the hoses is necessary as the crane is used for guiding the hose both on and off the vessel. In Figure 1 the hose loading station can be seen in a typical environment. (National Oilwell Varco, Hose loading systems 2015)

Figure 1. Hose loading station in its working environment (NOV picture archives)

The HLS is a standalone machine and has no interface or communication with any other monitoring system in the vessel. 1 to 12 hose reels are placed on a frame with working platforms and handrails. Each reel is driven by a hydraulic motor with fail safe multi-disc brakes and they are powered by the hydraulic power unit called HPU. Only one hose reel is to be operated at a time. The hose reels are easily controlled by forward-backward motion of the portable control lever or the fixed control lever located inside the control cabinet. The reeling time is approx. 2-3 minutes, depending on the length of the loading hose. In **Error! Reference source not found.** 8 reel station and hydraulic power unit in middle can be seen. (National Oilwell Varco, Hose loading systems 2015)

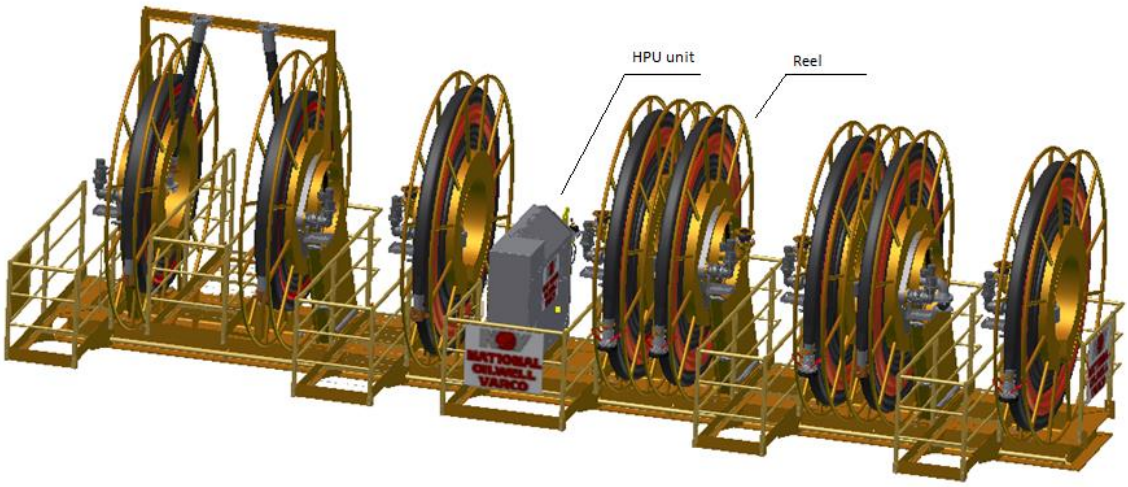

Figure 2. 8-reel station with hydraulic power unit (NOV picture archives)

The HPU, driven by an electric motor, is located inside the control cabinet. The control cabinet also contains a local control panel with push buttons for start and stop, a valve selection block for choosing which reel to drive, oil level/temperature switches and an emergency push-button. The HLS is also delivered with a remote control unit equipped with a pilot control valve and emergency stop button.

3.3 Areas and focusing points of improvements

For the long time the oil price has been high and climbing up. This has meant that oil industry has needed a new, safe and quality equipment without considering the cost too much. This has caused that the cost factor has not been taken into account so far in manufacturing. Now that oil price has fallen down and stayed low for some time it has caused a lot of market turmoil and uncertainty. This has then driven customers to look for where they can save. The customers now evaluate the products that have a lower price instead of the highest quality or standards. The purpose of this work is to answer the customers' demands to lower the price of this hose loading station. (Eilertsen 2015)

Some areas to concentrate on in the research were given and those included investigation if the design of the control cabinet, HPU and hydraulic system can be further improved. The control cabinet can be seen in the Figure 4. Original HPU design was designed to house both the HPU, local control panel and the valve selection block, regardless if the HLS contains 2 or 12 reels. The valve selection blocks were delivered as a 4 valve or a 6 valve selection block. These two types of valve blocks were combined according to the number of hose reels to be delivered. This means that even for a 4 reel HLS, the cabinet was big enough to house a 12 reel valve selection block. Between the valve selection block and each hose reel, a pair of 16mm hydraulic pipes were installed. This meant that a total of up to 24 individual A and B lines plus one set of leak line were installed on a 12 reel HLS. (Eilertsen 2015)

This meant that there was an opportunity to improve the design by investigating the possibility for a ring-line system which has only one pair of A and B lines, branching to each hose reel motor. This would eliminate valve selection blocks in the HPU unit which again would help to reduce the size of the HPU unit and the number of the pipes between the HPU unit and the HLS unit motors. The next step was to investigate how and where to mount the valves and what valve types to be used. Part of the project was also to investigate the potential for cost savings, evaluation of fabrication and assembly cost and time for the original and new design. The main idea was to reduce the size of the HPU that it would be more compact and to reduce the cost of the system by reducing the number of needed pipes and by using less material for the whole system. This original routing of the pipes can be seen in Figure 3.

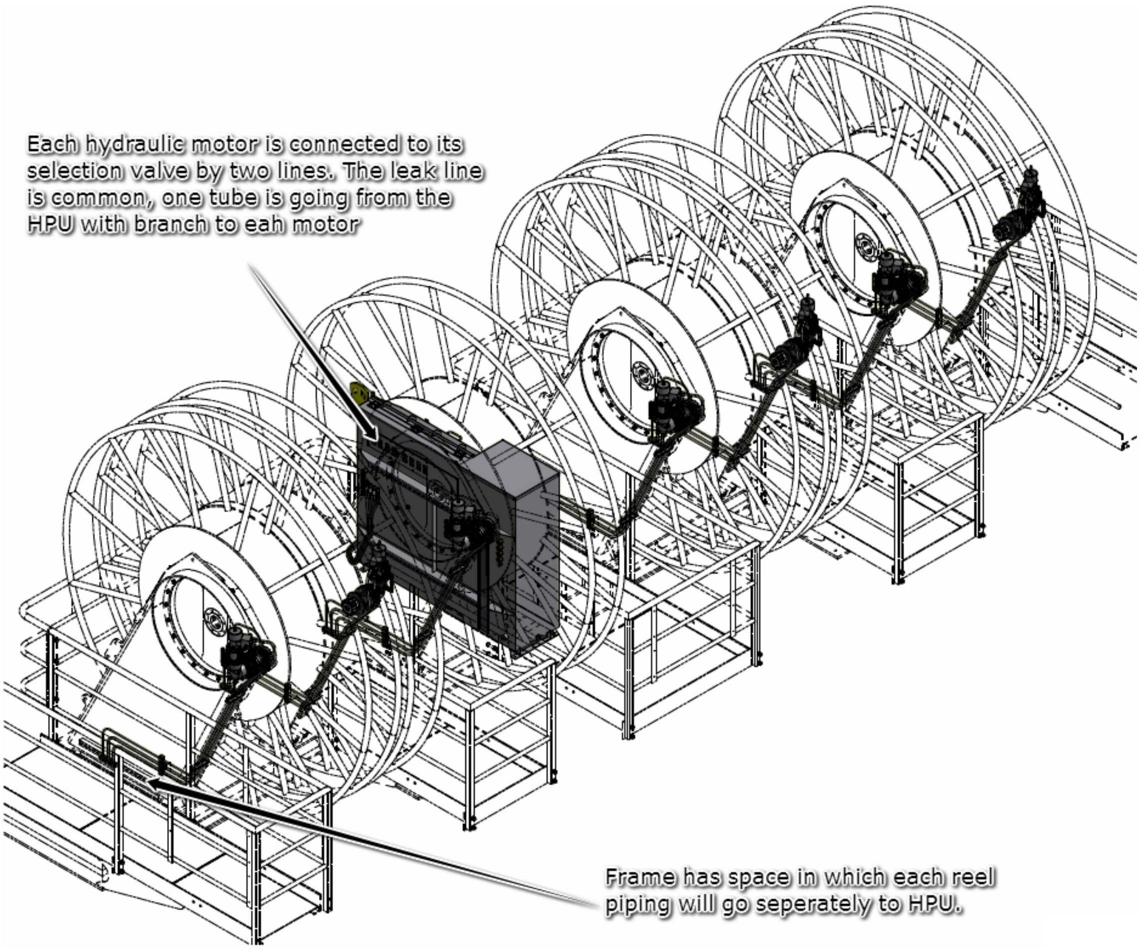

Figure 3. Original routing of pipes (NOV picture archives)

4 DEVELOPMENT ACTIVITY AND PROGRESS

Naturally the work was started with getting familiar with the current design and system, how it works and where to start the improvements. This meant that some estimates of the cost had to be made and how the cost is divided into parts and labour. This information was then later used to compare the new design to the current design and find out if the new design had succeeded to reach the cost savings. The work was carried out in cooperation with the supply chain management and a group of the engineers who helped with the design, prices, parts and other information that was needed.

When the cost estimate was done it was pointed out that cost were distributed very evenly between labour and used parts. It was noted out also that it takes two full working weeks for two persons to carry out the assembly of the whole hydraulic system which means total of 150 hours. The conclusion was that a good place to save many in assembly hours and in part prices was the piping itself as the piping was slightly complicated and required a lot of work in bending and installing. The calculations were made for the Table 1 using the original design 3D model for the pipe lengths. The table shows how the number of piping increases related to the reel number. This current piping means also a lot of consumed fastening materials for piping even though fastening materials are not very costly, but this still adds final costs and mostly labour.

Table 1. Number of reels and required piping

Reels	**Used piping**
6	95m
8	130m
10	175m
12	230m

Totally three new solutions and hydraulic schematics were made for the design, including short descriptions for how the design would work and how it would help to lower the price. Next the three design ideas are explained.

4.1.1 First design

The first solution consisted of getting rid of all the valves inside the HPU so that it would consist only of the following original design parts: hydraulic pump, electric motor, tank, filters and oil level/temperature instrument. Besides this the separate pressure relief valve was to be installed to control the hydraulic pressure in the system since the original design valve block was to be removed and this block included the pressure relief valve internally. This way the cabinet for the HPU would be considerably smaller. Controlling the HLS would happen from the HLS standing platform where the hydraulic valves will be mounted in rails so that every reel would have its own valve mounted next to it. This way the remote control valve with hoses and components could be also removed from the original design. This would be also easier to use since the end user would not need to carry a heavy remote control with long hoses around the station anymore because the operating would happen exactly at the location of the reel to be operated. This also would remove some possible dangers which could happen when carrying the remote control and if the hoses get possibly stuck somewhere in the deck and cause the operator to stumble. Beside, this design was very simple and used a minimal number of parts, which also would increase the reliability and ease of maintenance. In this design the only flaw was that there was no possibility for electrical remote controlling or at least it would be very costly to make necessary changes to have electrical control applied to this system.

4.1.2 Second design

The second solution consisted generally of the same principle as the first one. The selector valves would be removed from HPU, but the original remote controlled valve would be left in place including the remote controller. The selector valves would be then mounted near the reels so that every reel has its own 6/2 selector valve. This way it is also possible to adjust the HPU size to have it slightly smaller, but not as small as in the first design. The remote control function would stay intact so it could have also the electrical remote control possibility as the original design had. The reel to be used had to be chosen by closing or opening selector valves located near each reel before operating. This design offers the least cost savings between the three designs, but also the least modification and changes to the original design.

4.1.3 Third design

The third solution was more special and advanced among all the solutions. The HPU station would have a different hydraulic pump and instead of a gear pump it would have a remote pressure controlled piston pump, which could be controlled directly with the same remote control unit as in the original design. This pump would heat the oil less than the vane pump since it can adjust the output flow depending on the requirement and system load, also the idle temperature raise would be significantly lower than in the vane pump. This lesser heating would mean that the hydraulic reservoir could be even smaller and thus this would offer savings in the used materials. This gives the advantage of the remote control system and the ease to upgrade it to the electrical remote control. The hydraulic piloted remote control has its disadvantages as mentioned in the first design, but the possibility for electrical control gives the best and safest choice for the user. The selection of the reel to be used would happen by manual selector valves located near each reel motor. This of course means that the user has to walk to each reel to be operated to open the valve first and to be sure that other valves are closed or otherwise more than one reel will turn during operating.

This solutions was presented to the engineers to be discussed and see if it was possible to continue further with one of the designs. It was agreed that the first design offered the cheapest and the simplest solution for the current market where reliability and price matter the most. So the next step was to finish the first design, make a 3D model of it with a full hydraulic schematic and make price estimations so it could be compared to the original design. The other solutions were abandoned as this would have made the work too complicated and unnecessary long as time was also a limiting factor.

4.2 Calculations and completing final design

Equations used for calculation:

Equation 1

$Q = D * n/1000$

where

Q	is	flow rate (l/min)
D	is	displacement (cm^3/rev)
n	is	revolutions per minute (rpm)

Equation 2

$T = D * p/20 * \pi$

where

T	is	torque (Nm)
p	is	pressure (bar)

Equation 3

$$P_{id} = 4.61 * \sqrt{\frac{Q}{V}}$$

where

P_{id}	is	pipe inner diameter (mm)
V	is	velocity (m/s)

Equation 4

$V_t = H * L * W * 1000$

where

V_t	is	tank volume in l
H	is	height in m
L	is	length in m
W	is	width in m

For the final design some important things were calculated e.g. how big the flow rate would be in the system and possible tank dimensions to contain the right amount of oil. Formulas form Bosch Rextroth were used for calculations (Bosch Rexroth. 2013. Hydraulic Formulary. 4-9.). The reel has the speed of 14s / revolution and it is required to stay around the same. This meant that the hydraulic system and gears would be kept original in this design. The electric motor used to drive the pump is ABB 3-phase 11kW 1500rpm at 50Hz and 1735rpm at 60Hz. The pump is a Parker vane pump, which is very reliable. The pump production is 25cm^3/rev so with that data the following rate was calculated regarding both 50Hz and 60Hz with Equation

$$25cm^3 * 1500rpm/1000 = 37.5l/\min for\ 50\ Hz$$
$$25cm^3 * 1735rpm/1000 = 43.4l/\min for\ 60\ Hz$$

As we can see that with 1500rpm the production would be ~38l/min and this was true as long as the electric motor that drives the pump was used with 50 Hz system, but in some platforms the electric system is 60 Hz so it means that the electric motor will run at 1735rpm. That would mean that the same hydraulic pump would produce ~43l/min. The pressure relief valve that was directly mounted to the pump to minimize the overall size of the unit was chosen for this design. If an inline valve was chosen, which was mounted freely between the pump and valve, it would have meant that a place had to be found for it and add extra bracket in the design. For final flow rate calculations the overall efficiency had to be taken into account, which is around 85% for the vane pump as seen in Table 2**Error! Reference source not found.**. This means that with 1735rpm around ~37l/min flow rate can be got in real life use.

Table 2. Typical overall efficiencies of hydraulic pumps (Brendan Casey, Machinery Lubrication 2015)

Pump type	Overall efficiency %
External gear	85
Internal gear	90
Vane	85
Radial piston	90
Bent axis piston	92
Axial piston	91

The piping in the whole system had to be calculated to match with every part of the design. Having an oversized piping was of course possible and this causes no problem in the system, but this just would make the piping more expensive without any real benefit. Using too small piping causes very high pressure losses in the pressure lines and also an insufficient flow rate, which would have made the reels to turn too slowly and cause long reeling times. The calculated pump flow rate had to be taken into account in the overall piping design and especially in the return pipe between the pressure relief valve and return filter.

In the return line the small piping will cause the pressure to raise too high which can cause many problems with breaking down the valve or pump besides producing a lot of extra heating to the oil. The suction pipe and the hose sizing are also very critical as too a small pipe causes starvation and cavitation in the pump which leads to the pump failure and even more severe failures if the particles from the pump travel further in the system. The suction is also important to avoid too sharp bending radiuses in the pipes and hoses as that can cause cavitation too.

The highest flowrate was used for calculating pipe dimensions used in the the system so that this unit can be safely used with the both 50hz and 60hz systems. The pressure relief valve in the system will stay the same as in the original design 150bar as this will be enough for the new design too. From the following table Table 3 the velocity used in the calculation can be found.

Table 3. Maximum velocity in pipe for specific pressure or for tank / suction line (Hydra products, oil pipe diameter 2015)

Pipe	Recommended velocity
Pressure up to 100bar	Max. 3.25 m/s
Pressure from 100 up to 150bar	3.5 up to max. 5m/s
Pressure from 150 up to 200bar	5.25 up to max. 7m/s
Pressure from 200 up to 350bar	7.25 up to max. 9m/s
Return / tank line	1.25 up to max. 3m/s
Suction line	0.5 up to max. 1m/s

The flow rate was chosen to be 4m/s as this would fall between 3.5 and 5m/s and give some tolerance for the flow. By using Equation 3 the needed pipe minimum inner dimension for all the pressure and return pipes was calculated.

$$P_{id} = 4.61 * \sqrt{\frac{37/min}{4m/s}} \approx 14mm$$

This would mean that the ideal dimension for piping would end up being ~14mm so 20x2.5mm pipe was chosen for the design as its inner diameter would be 15mm which fits perfectly for the required flow rate. The calculation for piping also revealed that the original 16x2mm piping with the inner dimension 12mm had been in limits when using the 60Hz system. It also leads to the conclusion that this choice of dimension in the piping could also allow oil to run cooler as the flow rate is lower.

For the suction line piping value of 0.8mm/s was decided to use, which were between recommended 0.5-1.0m/sec. This would mean that ~31mm inner dimension was needed for so 1 1/2inch connections, hoses were chosen. This allowed the line between the tank and pump to be closed during the service for the pump or filter change.

The hydraulic oil reservoir redesign was also important part of the work to get the HPU smaller, which then gave the possibility to make the whole HLS smaller in size. The oil reservoir has also other purposes besides providing enough space for the oil in the whole system and these other purposes are to keep the oil cooler as the reservoir acts as a radiator to dissipate heat from the oil and also to act as a settling tank where the heavy particles of contamination can settle out from the oil and remain on the bottom of the tank until removed by cleaning or flushing the reservoir (Metal Tanks, Hydraulic reservoir guide).

The oil tank dimensions and the design are also in a great role for the overall design and the sizing was important to keep the oil cool for longer times. There were some other available options for more effective cooling like external coolers, bigger oil capacity and surface area so the heat dissipates better to the atmosphere. For this design there was no need for external cooling as the machine was only used during the medium filling process so it were staying on only relatively a short period of time. The company has ready-made estimates for the general use and the total running time was 100 minutes from which the actual driving time was around 30 minutes. The oil capacity was chosen to be kept at the minimum the same as in the original design as this would keep the oil cool enough during the whole operation. The amount of oil in the original design was 110L and with the already calculated usage it will heat up from 20°C ambient up to ~52°C in the total running time of 98 minutes. (Noria Corporation, Hydraulic systems and fluid selection)

The real design work was started with finishing the hydraulic drawing for the system so that a better insight to the whole system could be achieved. It was also important to see what components are required and how the 3D model for the unit itself could be designed. In the beginning there was consideration to use a different types of pumps, motors and gears for the system, but as options for these were looked and some calculations made the conclusion could be made that it was best to leave the gears, motors and pump original as it performed very well currently and it would work the same way with the new design too. Changing the mentioned parts to another type would mean a lot of extra work in the company without any achieved benefit.

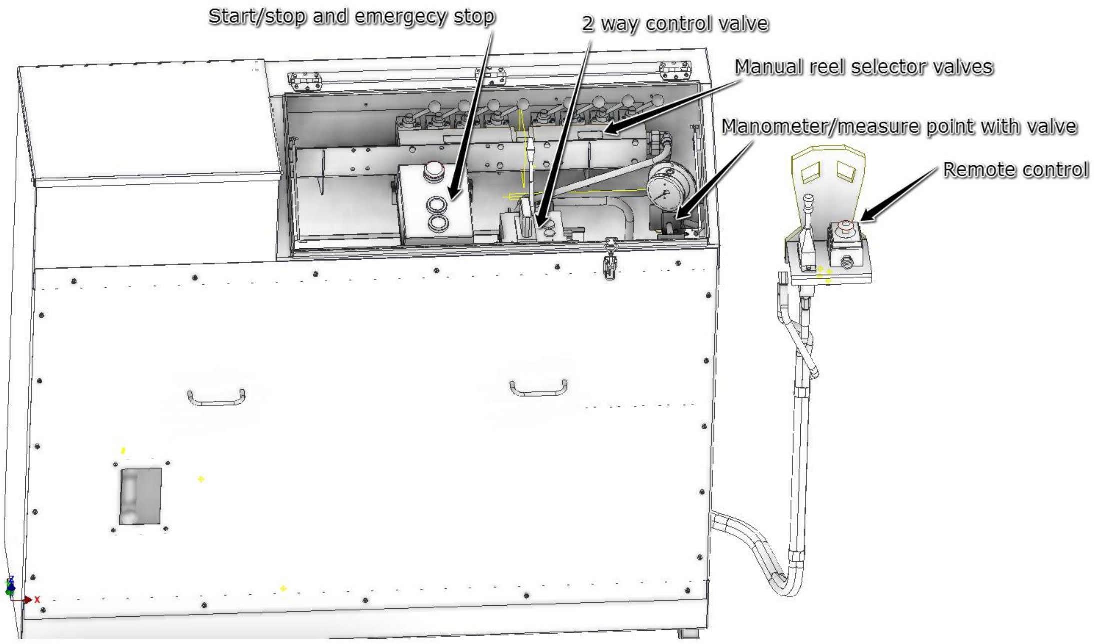

Figure 4. Original HPU design

The original HPU cabinet can be seen in Figure 4. It consists of stainless steel cabinet with all components inside it. As mentioned the selector valves were located also inside this cabinet with a control valve. Between every reel motor and selector valve go 2 pipes. This meant that ordinary 8 reel stations had 16 separate pipes going out of the cabinet. This caused a lot of used time for bending/ installing pipes and routing the pipes in the station frame.

In the new design the tank was changed so that it was now taller, but smaller in length and width since this was now possible as the valve blocks were removed from the HPU. The dimensions that were ended up with are depth 400mm, height 800mm and width 400mm. The oil level will reach the height of 600mm which meant that the tank will now contain maximum of 120L. The remote control was decided to drop out with a 2 way valve block and the selector valves as these were not needed anymore. The stainless manometer/measure point valve was also removed because that is not necessarily needed as in the case of a broken manometer the whole system can be turned off to replace it. Now instead the manometer is mounted directly after the pressure relief valve with T connection for the measure point. From the filtration system the pressure filter was decided to be removed as the original design had both a pressure and return filter, but having two filters in this system did not bring that great benefit compared to the price increase and that is why the pressure filter was dropped out as it was the more expensive part of this two (Parker Filtration`s. 2006. Handbook of hydraulic filtration, 32-33). The reason for this decision was that usually the particles in the oil do not come from tank itself, but from the hydraulic system as the pump, valves and motors and return filter can filter these particles out from the system. In the case of a broken pump the user will usually notice it without operating the system or at minimal when operating only one of the reels. This would mean that in the worst case only one motor would break with the pump.

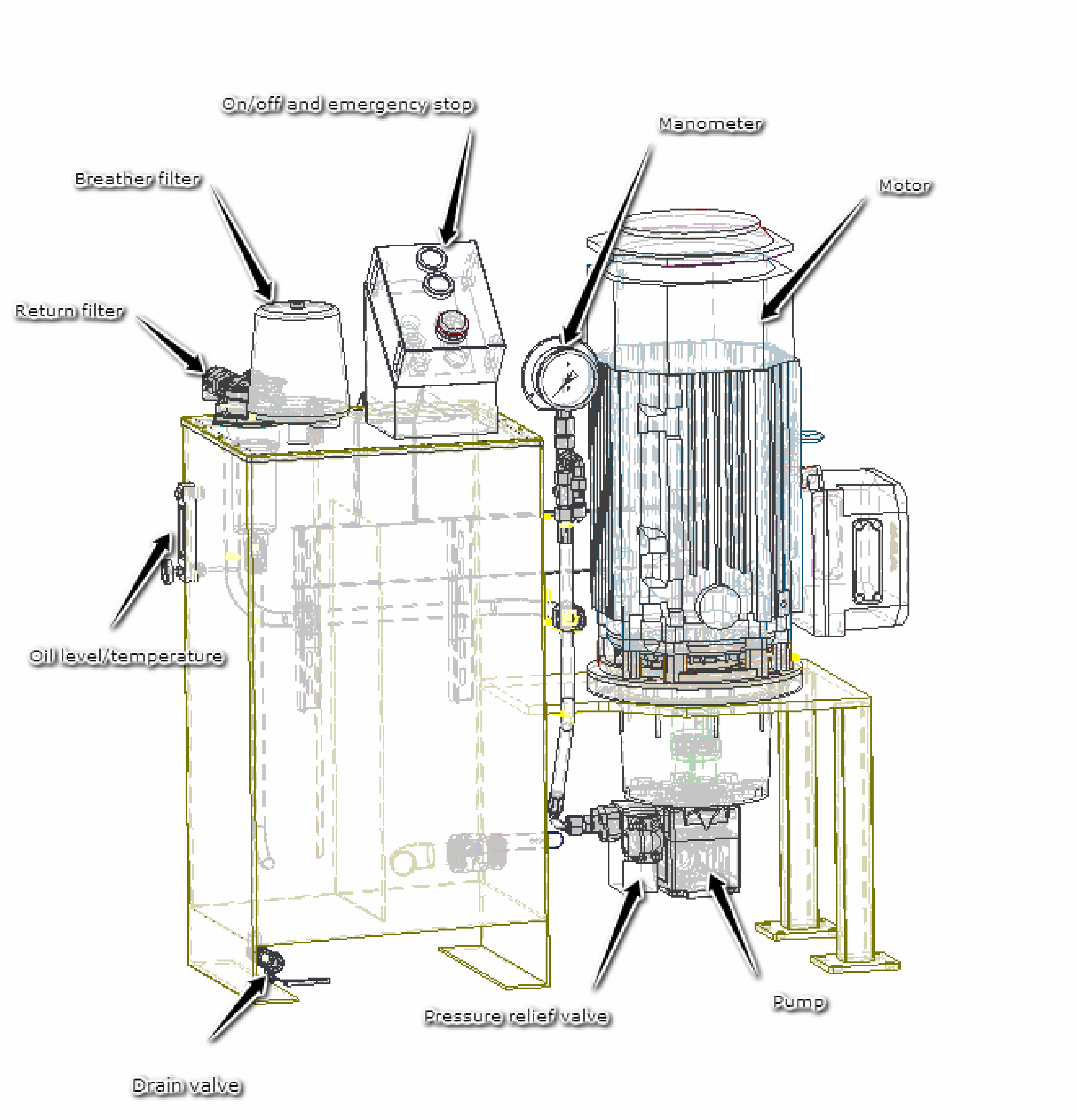

Figure 5. HPU design version 1 front view

The design version 1 was finished as seen in Figure 5. In this design it can now be seen how the pump and motor are placed outside of the tank. The bottom of the tank was tilted towards the drain valve to be able to empty the tank totally. This makes any possible particles to stay on the tilted side and not end up in the suction line. This design was good otherwise, but there were some problems as can be seen: the motor/pump stand has been welded from one end to the tank and the other was standing on two feet. The tank was only 5mm thick stainless and motor/pump unit weighs nearly 200kg so it was possible that this stainless wall would bend or even worse the stress tears the wall and causes a leak. This was noticed in the early stage and a new solution was needed.

The design was changed with version 2 which can be seen on Figure 6. The Pump/motor unit is now separated from the tank itself and the support now has three feet instead of two. This allows the mentioned combination to be moved freely away from the tank and allows more flexibility. The connection between the tank and pump unit is made by hoses for removing any possible vibrations. The manometer was now mounted together with cable tray supports.

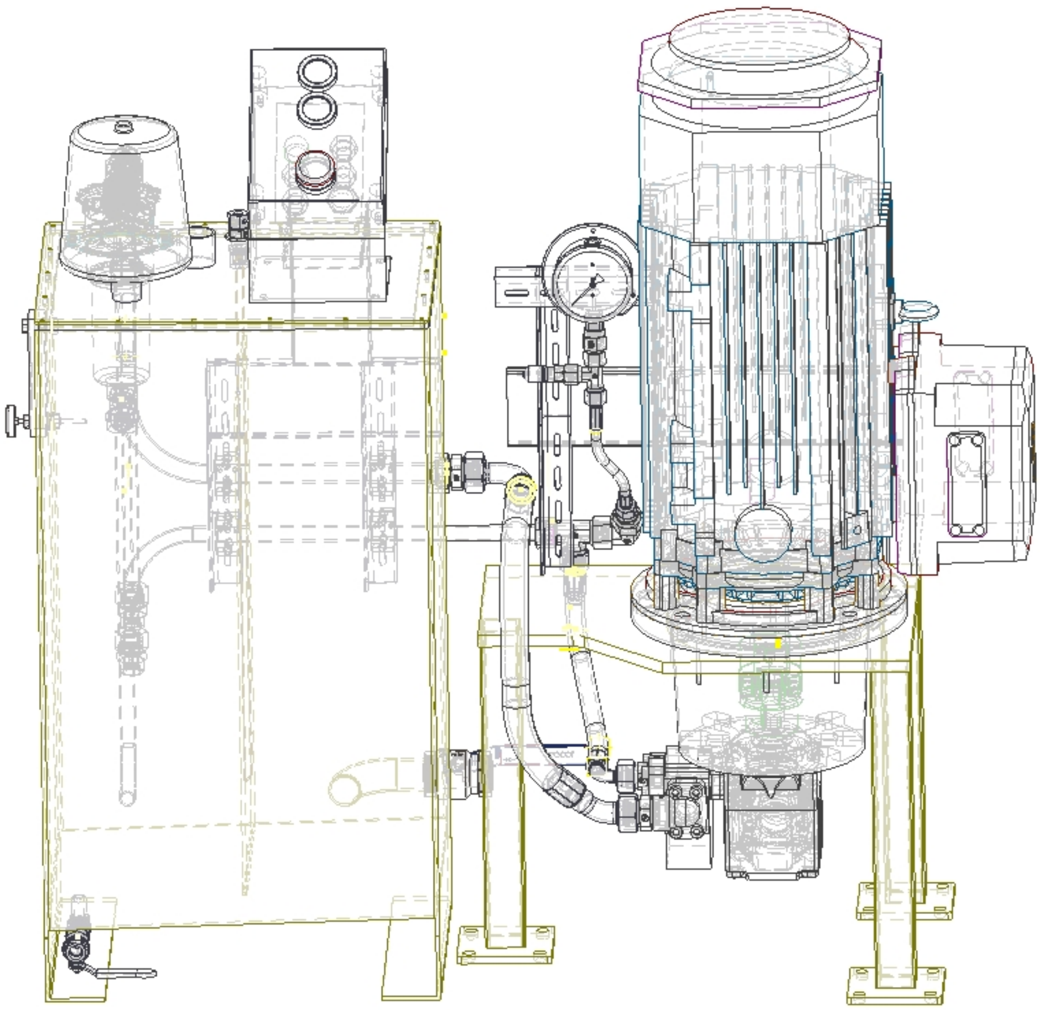

Figure 6. HPU design version 2

Another thing that was uncertain with the design was the fact of having the motor and pump outside of the tank and with no enclosure around it. This did bring a question if the noise level would be too high and it was important to find out the motor and pump volume level in dB(A) at used rpm range. The noise level that was found from the data sheet was 64db(A) for each part and after consulting with one of the engineers the conclusion was that this noise level was still under the maximum level and the gear in the reel actually produces much more noise anyway. This all meant that the enclosure would not be needed and no any extra material would be needed to have an enclosure for the motor/pump unit.

The piping was designed to go in the support beam for the hose loading station. This allowed shortest the possible piping distances and also a good protection for the pipes. The valves will be mounted in every platform between the two reels. This allows the valve pipes connected to the mainline by T connections which allowed the use of straight ready cut pipes between each T connection. This new piping was more modular so it could be now possible to have all the pipes made ready beforehand by a robot bender for a faster and cheaper production.

The HLS needed also a new solution for how to mount the valves and what type of valves could be used. Maintenance had also to be taken into account for the design as the lubrication of the reels happens usually when the operator drives the reel and inserts lubrication into the lubrication point. In the original design this was easy with the remote control, but now that there will be no remote this had to be considered and weighed in the final design.

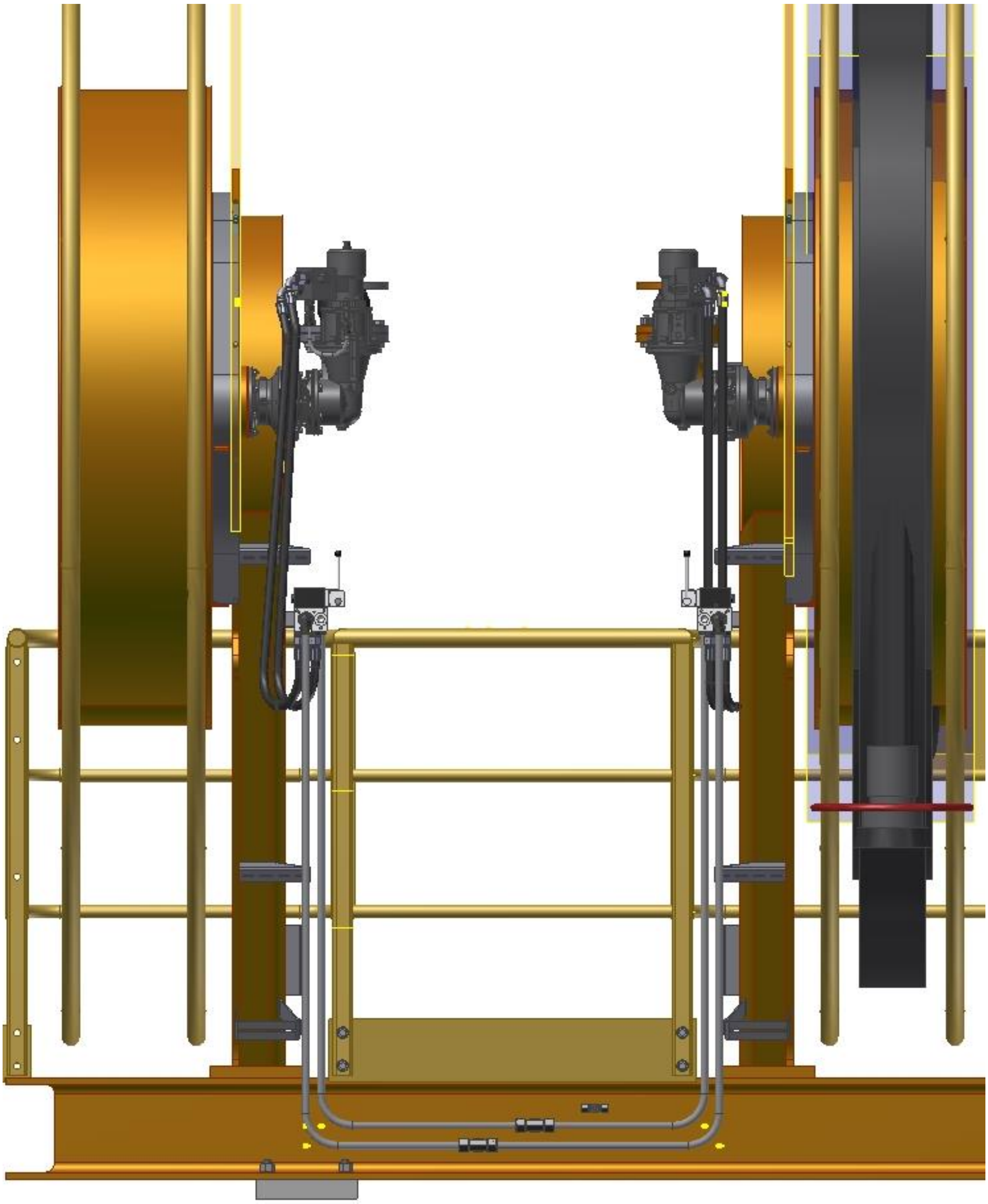

Figure 7. HLS valves mounting design 1

Totally two new mounting solutions were designed for the valves and piping, first one can be seen in Figure 7 and it has a separate valve to each reel and it being mounted directly next to reel. Piping would have second T connection under the platform for dividing the mainline to each of the valves. This would allow also operator easily to lubricate the gear while driving the reels as the lubrication hole would be located next to the valve.

In the second design one 2 handle valve block was installed at the end of each platform. This would allow a better view of loading for the operator and would have almost no effect on the piping length. It is still possible for the operator to lubricate the gear though the distance will be around 1 meter from the valves to the lubrication point so this would mean it has to be done by two persons. One person driving the reel and the other lubricating. In the following Figure 8 is the final setup for the valves pipes and hoses. Two pipe coming from HPU and connecting to the mainline. The mainline extends to the length of the whole frame and it is connected to each valve unit with T connections. The valve is mounted in a stainless plate that is mounted on the railing by pipe clamps. The mainline has T connections and will continue again straight to the next reel where there will be the next T connection and a valve unit.

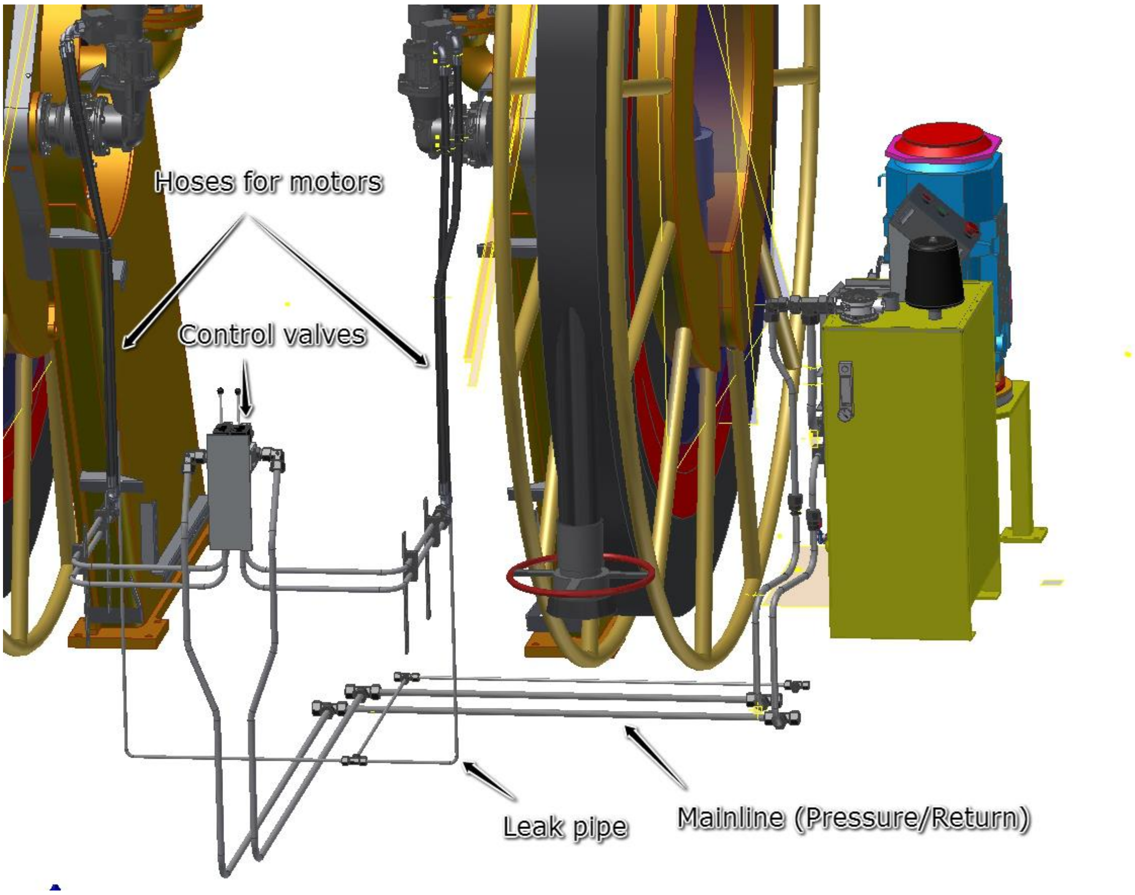

Figure 8. Final valves mounting design

Overall this all offered very good savings in number of piping which was calculated in Table 4**Error! Reference source not found.**. The table shows the estimated number of original design piping compared to the new design and how many meters in the piping this design will save. As it can be seen in the table, some savings in the piping can be achieved and also its complexity will be reduced vastly as now the piping will consist a lot of straight pipes and T connections. This means that the cost of the assembly will be a lot lower too. Estimated work amount in the current design for the 8 reel station piping and connections is 155 hours. The new design was estimated to lower this work amount from the original design 155 hours to 70 hours. The original design consists of 16x2mm piping and with the new design the piping size will be increased to 20x2.5mm to have a better flow and a smaller pressure drop which means less oil heating, but of course the price will be slightly higher.

Table 4. Original and new design required amount of piping.

Reels	**Original design**	**New design**	**Saved amount**
6	95m	50m	45m
8	130m	75m	55m
10	175m	100m	75m
12	230m	110m	120m

As can be seen in Table 4, this new design would mean big saving in the amount of piping to be used. With the new design the remote control was removed with the 2 way valve block and so the cost reduction in the control valves will be achieved as now every reel has its own simple selector valve instead of a big and very costly selector valve block inside the HPU cabinet. Now that the HPU will not have a cabinet and the size was smaller it allows more mounting options and the area width where it is mounted can be narrower.

The casing itself will now consist of only the oil tank itself which has a top cover for on/off and emergency button, return filter, oil level switch. The electric motor and pump in the HPU will be left outside of the casing for some extra saved space and material. This also offers an easier access to the pump for maintenance as in the original design the pump is located inside the oil reservoir and that means the reservoir has to be opened and oil drained to access the pump.

For the cost savings in labour the estimation was made that working hours of the hydraulics assembly would be reduced from 150 hours to 80 hours which would mean ~47% reduction in the assembly time based on the reduced number in piping and complexity. This gives again lot needed cost savings and gives more value to this design, even this estimation was not yet fully accurate as it has to be tested in a real assembly line as it was based on experience and calculation. The cost savings that was estimated to be achieved can be seen in Table 5.

The estimated savings in piping would be around 40% based directly on reduced piping and adding little extra cost for the increased piping dimension. Labour costs were estimated based on how the deducted piping and simplicity of new HPU design will affect to the required work amount. Other parts savings of 30% were achieved with the removed stainless casing of the HPU including EX certified cable glands, removed HPU casing, selector valves which will be replaced by the new direct control valves and removed parts like remote control, stainless valve for manometer and measuring point, removed pressure filter. All of this will add even more for savings, but this was harder to estimate as percentage because there was no good enough reference point for the prices of these specific parts so some estimation of 30% was made for these. All of these savings are not that huge of course when the whole HLS price will be taken into account, but still gives the cost deductions which were looked for.

Table 5. Estimated cost savings in percentage

Cost savings in piping	40%
Savings in work hours for hydraulics	45%
Cost savings in other parts	30%

5 POSSIBLE FURTHER DEVELOPMENTS

During this assignment as there were discussions with engineers this new design would allow to make the system modular later on. The new design of piping allowed that each reel could be one module that has flanges that could be bolted to the next one, this modular design would allow the customer to buy more reels on the station or remove reels easily if ever required. There was also discussion that the reel sizes could be possibly reduced as the reels were little oversized. This could help achieve again more savings in materials as a smaller pump and motor would be required to drive the reels because of the reduced torque requirement.

Another possible considerations for the hydraulic pump could be a variable displacement type vane pump which would offer more compact package, better flow control and reduced heat production because when the pump is running without a load, it will circulate only on minimal amount of oil. This could allow even a smaller tank and less oil to be used in the system.

Finally the company could go further with the third design as this has totally different approach for the pump/control system. It would use a vane type pump, which would lower power consumption and also heat production. Lower heat production again would give a chance to use smaller tank dimensions and less oil and lower production cost and also maintenance costs.

6 CONCLUSIONS

The thesis project was very interesting overall and offered a good insight of product developing and also into financial aspects of the product and its developing process. This also showed how fast the business can change and has to adapt to new demands in the market, like a sudden demand for lower prices. This is connected to the oil price and it probably will have a huge impact still on all oil related business in future.

This thesis purpose was to respond to the demand of cost savings and to have capability to produce cheaper hose loading stations in oil rigs and boats. Some research had to be done for current design and also how it could be possible to do the new design, with focus on the production cost with still having the same functionality and reliability. This gave challenges in many tasks as designing, cost and time calculations for production of the station.

A big challenge was also the complicated rule and safety requirements in oil industry and especially in offshore equipment, which gave often questions if the right mounting position or if the right equipment for the offshore purpose was chosen. Luckily the engineers from NOV were ready to answer any of the questions related to these requirements and rules.

At end of this thesis the design was finished and it can be used for the production design with some small changes. The final conclusion is that the work succeeded though it will still need some adjustments e.g. material strength calculations for the pump/motor unit so that it can be built for testing.

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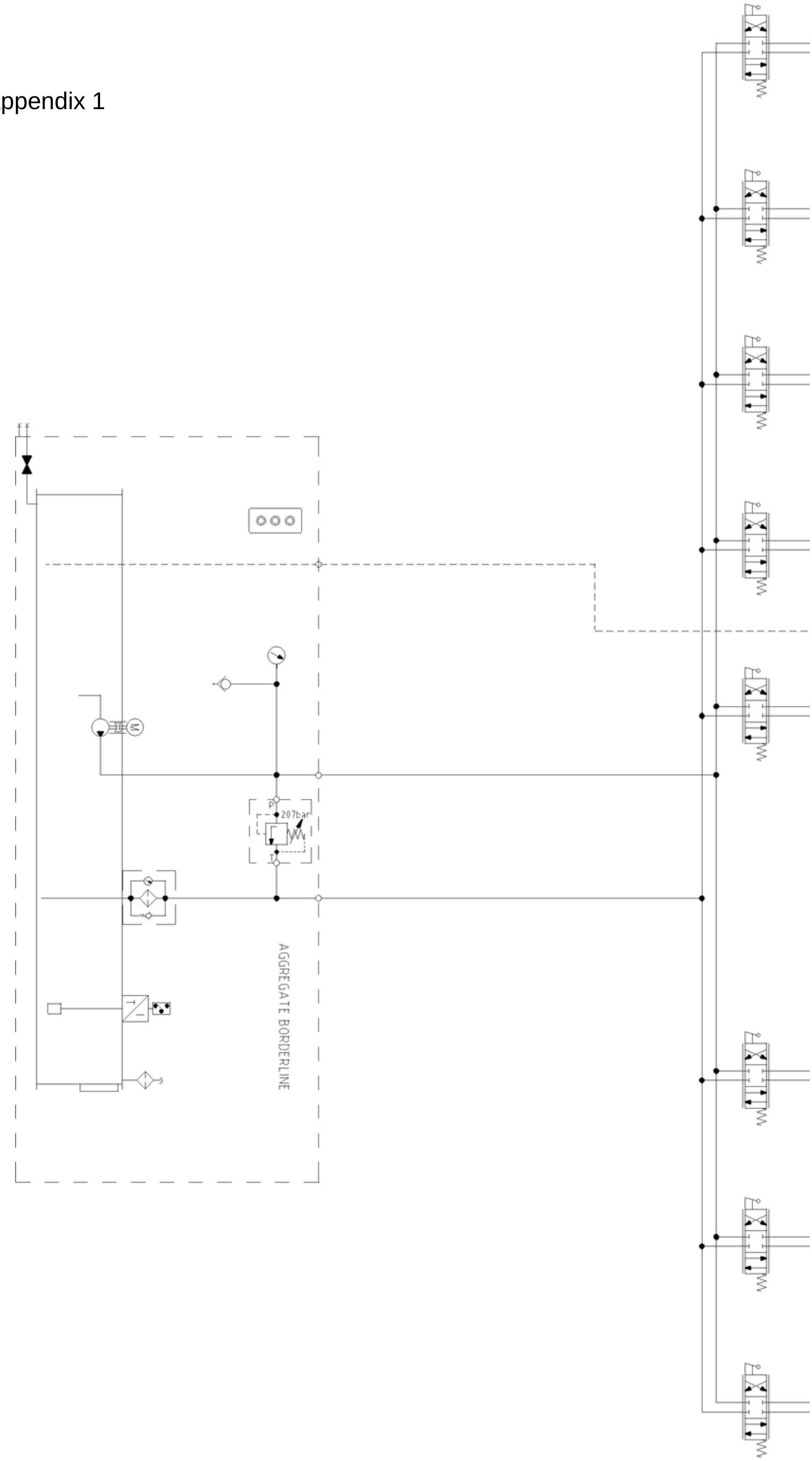
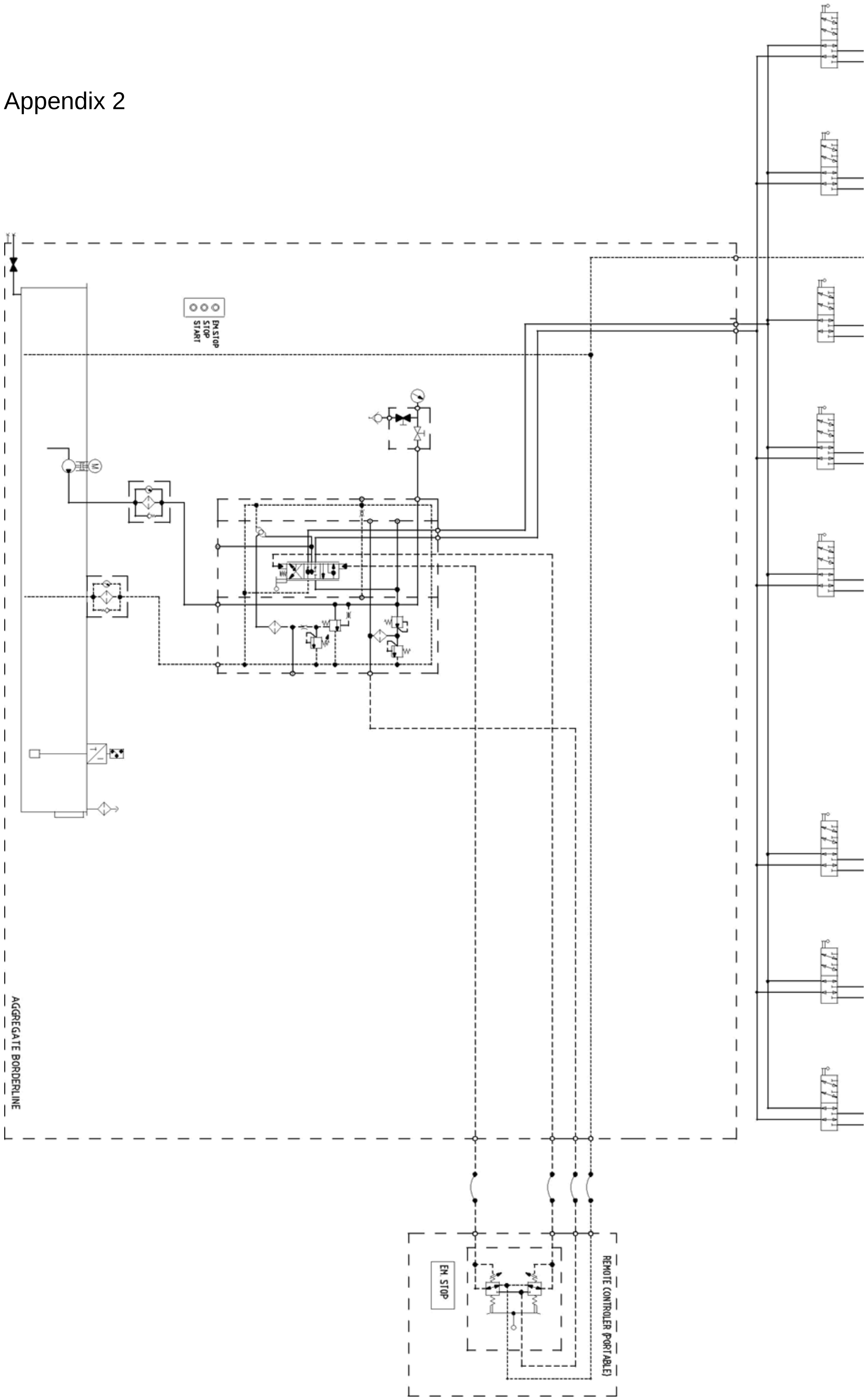
APPENDICES

Appendix 1



Appendix 2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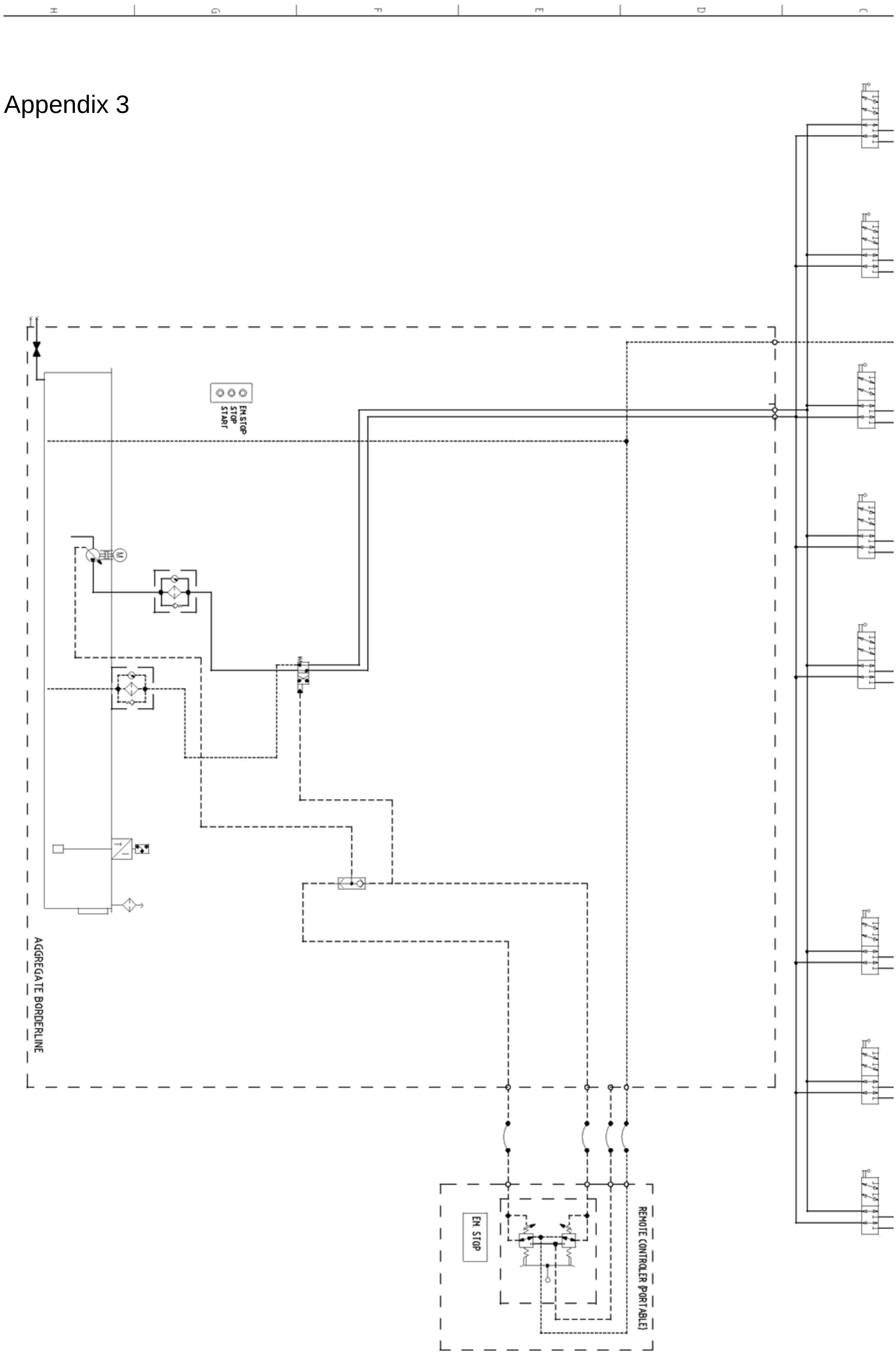
START
AGGREGATE BORDERLINE
EM STOP
REMOTE CONTROLER (PORTABLE)

Appendix 3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