



## DESIGN PROCESS OF DME STORAGE SYSTEM AS ASSEMBLY PARTS OR MAINTENANCE SPARE PARTS INVENTORY IN OFFSHORE OIL DRILLING PIPING SYSTEM

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### Abstract

*Discharge Manifold Equipment (DME) is an output pipe from a pump that bears an essential role in a piping system in offshore oil drilling, so it is a must to assure good bears condition whenever used. It is not an easy thing because DME is a significant and heavy component. Also, unfavourable conditions of offshore climate can accelerate its corrosion. Storage with the modular rack uses an offshore container certified DNV 2.7-1 / EN 12079 will be designed to fulfil those needs. The storage has an important role as an element in inventory, both the storage system for assembly parts or maintenance spare parts. This storage will be design using 4 (four) phases from VDI 2221 methods, namely; task clarification, conceptual design, embodiment design, and detailed design. Hydraulic power will be added to the system to support the piston movement so that the storage rack can be moved automatically by the hydraulic system. This storage has given the best solution for a systematic storing DME in the piping system of offshore oil drilling.*

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### INTRODUCTION

A storage system cannot be separated from parts or material flows in all spheres of the economy. The need for storage of all kinds of materials occurs because of the different rate of production and consumption and flow at all levels of the logistic chain. Moreover, the storage forms an inevitable part of the production technology. We can deal with inventory in warehouse issues in different ways, regarding building solutions, the organization, and technical equipment [1].

The storage has a vital role as a supporting element of spare parts inventory in maintenance activities. Inventory management is essential to ensure the smooth operation of the maintenance department [2]. Inventory management operations determine the storage efficiency of a product or spare part in a plant, especially for offshore plants that have limited storage area [3]. The right storing can maintain spare parts in good condition for a longer time. The maintenance activities aim basically to maintain the reliability and availability of plant. A slight disturbance in

the plant system can cause a huge loss because the loss of opportunities to get profit, to minimize waste, save raw material, save energy, decrease in productivity and customer trust [4]. The condition can have a significant impact on the economic aspect of plant operations. This productivity makes a direct impact on the financial aspect of the plant [5]. The main objectives of inventory management are to ensure the availability of spares and materials for the maintenance tasks and increase the productivity of the maintenance department.

Discharge Manifold Equipment (DME) is the output pipe of the pump can be a valve, swivel, or treating lines used to transmit liquids or chemicals that have been mixed with water than in the pump into the well. DME is required for stimulation work. Stimulation work affects the DME equipment component, in which the steps are needed and are included in the mounting sequence. Moreover, the conditions of the work area, such as distance, ground level, various disruptions that may occur, and road access

determine how to place the DME equipment between the pump tool and the wellhead [6].

Based on the work done, the appropriate DME equipment, determined at the beginning and then taken to the drilling site. There is a combined optimization of the work. Doing a hydraulic fracturing requires more pumps and more DME [6]. A hydraulic fracturing or frac job in another term is the practice of injecting a well with the bulk of fracturing fluids under high pressure to break the rocks. This action performed on both open-hole and cased-well perforations; hydraulic fracturing quickly replaced explosive fracturing [7]. In the snubbing and coiled tubing work which is a delivery device for liquids or chemicals at specific depths also requires DME to be connected from the pump to their unit. Given the critical role of DME in the hydraulic fracturing process, its availability must be maintained during the process and for its maintenance. DME that was damaged during processing should be replaced within a short period of time. That is why DME must always be available in the plant in a certain amount.

The condition on offshore platforms, generally, several DME is just laid on the floor without any place for storing. Without the right storing, the corrosion process of DME will faster and can shorten the lifespan of the damage to the DME screw until the seal can cause leakage when used. Generally, before the storage is designed, several DME is just laid on the floor of offshore platforms without any place for storing. During the assembly process, the DME is installed, lifted, and unloaded by the operator manually. This condition often causes back injuries of the operator. If DME is storing systematically in storage, the operator can be more comfortable with making the data management of DME inventory. So the provision of DME for assembly part or maintenance spare parts can be available according to the needs. Based on these problems a storage system will be designed for DME inventory spare part during hydraulic fracturing process and for supporting maintenance requirement in plant

**METHOD**

Research conducted using four principal design, such as Task clarification to analyze the problem, Conceptual design, Embodiment design, and Detailed design.

From task clarification, the design process will be continued with determined the requirement list that contains the Demand (D) and Wish (W) of the design requirement. Then functional structures of design will be generated as a framework of design work. The principal solutions

will be collected to make the alternative design solutions of conceptual design.

Then the best conceptual design will be selected from the generated conceptual variant design. The embodiment design will be made base on the chosen conceptual model. Generally, the conceptual design will convert to be a 3D model using CAD software. In this phase, the manufacturing and assembly operation aspects will be considered. The output of the design process is a detailed design, namely design 2D, for guiding the manufacturing process to realize the system to be the product. [7]. Product design uses a flowchart, as shown in Figure 1.

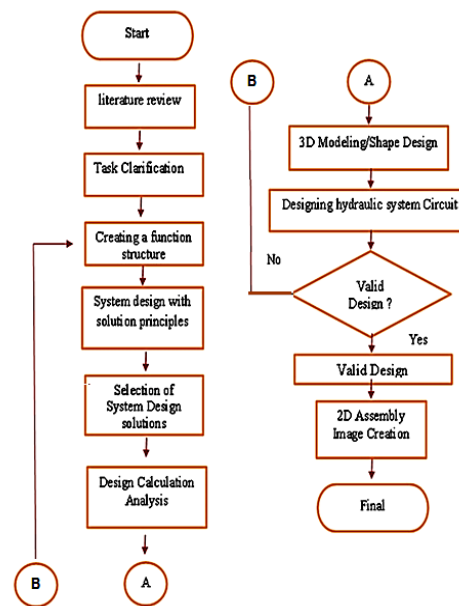


Figure 1. Design Process with VDI 2221 Approach

**Method Tools & Materials**

The specification of the container standard that uses for DME Storage can be seen in Figure 2. The DME type specification can be seen in Figure 3, Figure 4, Figure 5, Figure 6, Table 1, Table 2, and Table 3, Table 4, respectively.



Figure 2. Offshore Container [8]

Standard: *Offshore Container* certified DNV 2.7-1/EN 12079  
 Outer size: 10'x8'x 8', or 2.991x2.438x2438 m  
 Inside size: 2.700 x 2.344 x 2.344 m  
 Max. Gross load: 9380 kgs on a 30° vertical axis  
 Tare mass: 1900 kgs  
 Payload: 7480 kgs

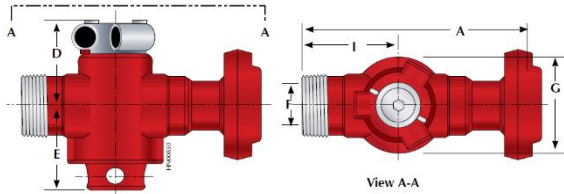


Figure 3. LoTorc Valves Dimension

Figure 3 shows the dimensions of LoTorc Valve, as listed in Table 1.

Table 1. Specification Halliburton LoTorc Valves [9]

| Sizes Valves | Connection type   | Work press. (psi) | Weight (kg) | Dimension (inches) |     |     |      |     |   |
|--------------|-------------------|-------------------|-------------|--------------------|-----|-----|------|-----|---|
|              |                   |                   |             | A                  | D   | E   | F    | G   |   |
| 1"           | 2" T 1502 x Nut   | 15000             | 27          | 12                 | 4,6 | 4,7 | 0,9  | 5   | 5 |
| 1"           | 1,5" T 1502 x Nut | 15000             | 26          | 12                 | 4,6 | 4,7 | 0,9  | 5   | 5 |
| 1,75 "       | 2" T 1502 x Nut   | 15000             | 43          | 15,2               | 5,3 | 5,6 | 1,75 | 6,5 | 6 |

Figure 4 depicts the dimensions of Swivel Single Wings as listed in Table 2.

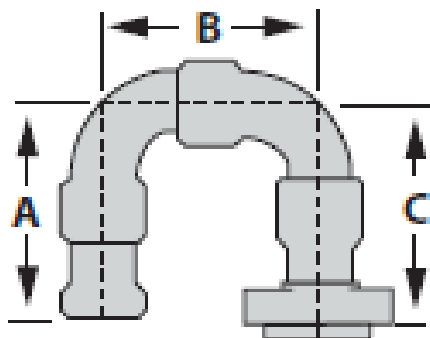


Figure 4. Swivel Single Wings Type 10 Dimension

Table 2. Specification FMC Single Wings [9]

| Model     | Connection type (MxF) | Work press. (psi) | Weight (kg) | Dimension (inches) |      |      |
|-----------|-----------------------|-------------------|-------------|--------------------|------|------|
|           |                       |                   |             | A                  | B    | C    |
| 1,5" LS15 | 1,5" 1502             | 15000             | 20          | 10,1               | 9,4  | 10,1 |
| 2" LS15   | 2" 1502               | 15000             | 28          | 10,9               | 10,7 | 10,9 |

The dimensions of Swivel Double Wings in Figure 5 can be seen in Table 3.

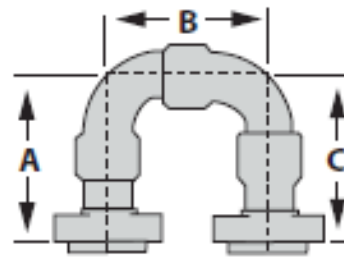


Figure 5. Dimension Swivel Double Wings

Table 3. Specification FMC Swivel Double Wings [9]

| Model     | Connection type (M x M) | Work press. (psi) | Weight (kg) | Dimension (inches) |      |      |
|-----------|-------------------------|-------------------|-------------|--------------------|------|------|
|           |                         |                   |             | A                  | B    | C    |
| 1,5" LS15 | 1,5" 1502               | 15000             | 23,5        | 10,1               | 9,4  | 10,1 |
| 2" LS15   | 2" 1502                 | 15000             | 32          | 10,9               | 10,7 | 10,9 |

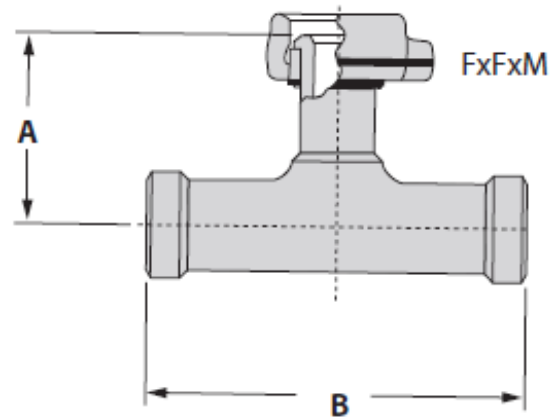


Figure 6. Swivel Double Wings Dimension

The dimensions of Swivel Double Wings in Figure 6 can be seen in Table 4.

Table 4. Specification FMC Tee [9]

| Model | Connection type (F x F x M) | Work press. (psi) | Weight (kg) | Dimension (inches) |       |
|-------|-----------------------------|-------------------|-------------|--------------------|-------|
|       |                             |                   |             | A                  | B     |
| 2"    | 2" 1502                     | 15000             | 17          | 6,06               | 12,12 |
| 2"    | 2" 1502                     | 15000             | 21          | 6,06               | 12,12 |

## RESULTS AND DISCUSSION

According to Figure 1, the design process will start with task clarification. The task is a result of the abstraction process from the requirement list consisting of a group of demands and wishes of the storage designed. Demand is a mandatory specification required to be owned by design. While wishes, on the other hand, is optional depending on the design need. It is better when fulfilled, but not a mandatory requirement.

The abstraction process will conversion the quantitative requirement to become a qualitative requirement to give a designer more space to dig the solution for the design.

The task of storage is to store and protect three types of DME from offshore climate, which are placed in groups according to their type on a rack that can enter and exit quickly. The DME Storage requirement list can be seen in Table 5.

Table 5. The DME Storage Requirement List

| THE DME STORAGE REQUIREMENT LIST   |  | D/W |
|--|--|-----|
| <b>Force:</b>  |  |     |
| - Capacity : 40 unit DME, weight 1134kg  |  | D   |
| - Lotorc valve 1,75" x 2" Nut : 6 units, @ 43kg  |  |     |
| - Lotorc valve 1" x 2" Nut : 4 units, @ 27kg   |  |     |
| - Swivel 2" single wing : 8 units, @ 28kg  |  |     |
| - Swivel 2" double wing : 2 units, @ 32kg  |  |     |
| - Check valve 2" : 2 units, @ 40kg   |  |     |
| - TEE 2" : 8 units, @ 17kg   |  |     |
| - Lotorc valve 1" x 1,5 Nut : 3 units, @ 26kg  |  |     |
| - Swivel 1,5" single wing : 3 units, @ 20kg  |  |     |
| - Swivel 1,5" double wing : 2 units, @ 24kg  |  |     |
| - Check valve 1,5" : 2 units, @ 39kg   |  |     |
| - Max. Hydraulic Pressure available powerpack) : 3000 psi (accord.                                 |  | W   |
| - Source's Compatibility   |  | D   |
| <b>Safety and Ergonomic:</b>   |  |     |
| - With safety equipment to prevent explosion due to internal pressure of hydraulic pressure system |  | D   |
| - With safety equipment to prevent environment pollution because of the leaking in the system      |  | W   |
| - With safety to prevent pressure trap in the system   |  | D   |
| - With rack height adjustment  |  | D   |
| - DME will grouped accord. the type  |  | D   |
| - Capable to work as storage at work shop or offshore site   |  | D   |
| <b>Operation:</b>  |  |     |
| - Capable of manually operated by one person   |  | W   |
| - Button operation   |  | W   |
| - The rack can pull in and out of the storage automatically  |  | D   |
| - The maximum pressure on the system cannot be set by the operator                                 |  | D   |
| <b>Maintenance:</b>  |  |     |
| - The design is made uniform in order to facilitate the supply of spare parts                      |  | W   |
| - The design uses a hydraulic system to match existing equipment                                   |  | D   |

After the task of storage is clarified, it is then translated into a functional structure, as shown in Figure 7.

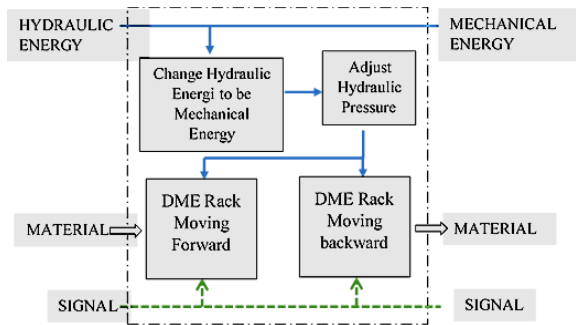


Figure 7. Function Structure

The creation of design morphology was done to explain the changes in the concept or solution that occurred during the design process. The following will explain the design morphology used in Table 6.

Table 6. Combining of Solution Principles

| No | Subfunction      | Solution Principles |                          |                   |
|----|------------------|---------------------|--------------------------|-------------------|
|    |                  | A                   | B                        | C                 |
| 1  | Energy sources   | Manual              | Step Motor               | Hydraulic         |
| 2  | Mobilizer        | Sprocket            | Piston                   | Fixed rack        |
| 3  | Control Signal   | Lever Valve         | Button                   | Manual            |
| 4  | How to stop      | Manual              | 90 degrees Automatic     | Stroke piston     |
| 5  | Motion mechanism | Sliding reel        | Bearing, sprocket, chain | Shelf with Castor |

According to Table 6, the design concepts variant will be generated from combining the principles of the solutions as below:

- Design Concept Variant 1: C1-B2-A3-C4-A5
- Design Concept Variant 2: B1-A2-B3-B4-B5
- Design Concept Variant 3: A1-C2-C3-A4-C5

**Design Concept Variant 1**

Design Concept Variant 1, as shown in Figure 8, is a DME storage that uses an existing source of the hydraulic pump. Then a hydraulic piston drives the DME rack in or out the storage by open or closes the lever valve supply or hydraulic supply cap. The rack movement can be controlled and can stop at any time by utilizing the minimum and maximum length of the piston. A sliding reel uses to withstand construction loads.

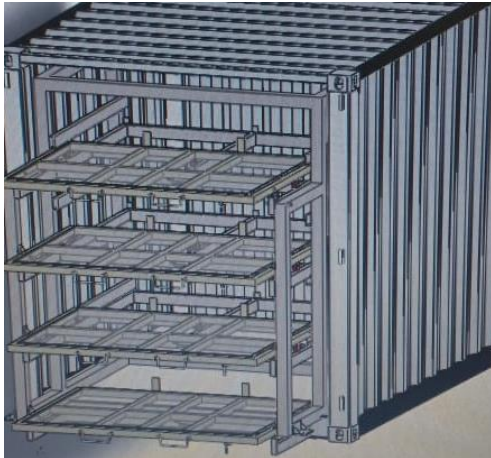


Figure 8. Sketch Conceptual Design Variant 1

**Design Concept Variant 2**

Design concept Variant 2, as depicted in Figure 9, is a DME storage that uses an electric motor as a driving resource. The storage will be equipped by a chain which connected with a power supply sprocket to pull the shelf movement. Thus, it enables it to rotate with a radius per 90° only with pressing the button that is automatically set at the junction box.

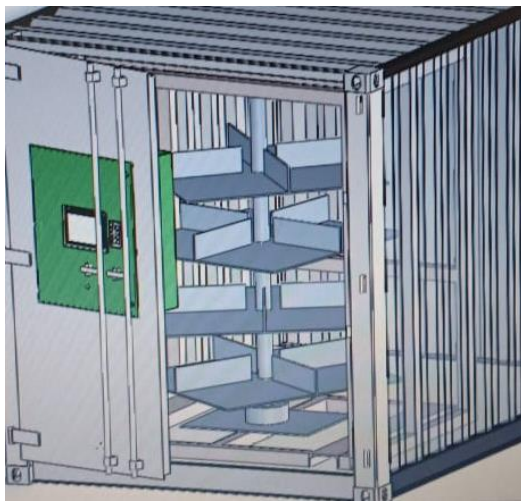


Figure 9. Sketch Conceptual Design Variant 2

In this box, there is an electric circuit as a controller of the construction base of rack motion using bearing as a shelf holder.

**Design Concept Variant 3**

Design concept Variant 3 is a design of DME storage use a fixed shelf, as shown in Figure 10. The DME is arranged in the storage according to its type; afterwards, the technician will put and picked it up manually. The storage is equipped by a thrust rack with the castor that use to help the rack into and out of the storage.



Figure 10. Sketch Conceptual Design Variant 3

Based on the three variants of the DME storage design concept above, then the stakeholder will be interviewed to select the best design concepts. Design concept selection aims to create a design that best suits the demand and wishes of the customer. Consideration for the concept design selection is seen from two aspects, namely in terms of technical and non-technical using score standard 1-5.

Table 7. Technical assessment

| Technical aspects     | Conceptual Design Variants |    |    |
|-----------------------|----------------------------|----|----|
|                       | 1                          | 2  | 3  |
| Construction strength | 4                          | 4  | 4  |
| Ease of operation     | 5                          | 4  | 5  |
| Simple design         | 5                          | 4  | 4  |
| Automation            | 4                          | 4  | 1  |
| <b>Total</b>          | 18                         | 16 | 14 |

1= very bad      4= good  
 2= bad            5= very good  
 3= average

Table 8. Non-Technical Assessment

| Non-Technical aspects            | Variant Conceptual Design |    |    |
|----------------------------------|---------------------------|----|----|
|                                  | 1                         | 2  | 3  |
| Ergonomic                        | 4                         | 3  | 4  |
| Ease of manufacture and assembly | 5                         | 3  | 5  |
| Maintenance                      | 4                         | 4  | 5  |
| Source's                         | 5                         | 3  | 3  |
| Compatible                       |                           |    |    |
| <b>Total</b>                     | 18                        | 13 | 17 |

**Main Concept Selection**

All the data, design concept variants, and possibilities that have been obtained and discussed with stakeholders could serve as the base to create a morphological matrix to assist in sorting and evaluating each variant. Each variant will be compared with each other, considering the desires of consumers and the results of the assessments that have been made in Table 7 and Table 8. The variant design concept 1 is the solution chosen from 3 combinations of principles of the solution.

The design concept of variant 1 is a semi-automatic storage concept with an energy source from a hydraulic pump. Fluid with an absolute pressure will enter the directional valve, which is regulated by the lever-actuated valve to rack 1, rack 2, rack 3, and rack 4 that can move the hydraulic piston. The actuated valve lever will push the selected rack out with a limitation on the piston stroke. Then the DME can be taken outside the storage so that it can facilitate the technician to do his job both during maintenance and the supply of spare parts when installing the pipe system from now on.

Afterwards, the embodiment design will be modelled using 3D CAD with DFMA consideration. DFMA (Design for Manufacturing and Assembly) is one of the DfX (Design for Excellence) design philosophy to optimize the design based on manufacturing and assembly consideration [10]. DFMA results in product simplification, and standardization of materials, manufacturing process and product design [11]. The DFMA considerations to sheet metal parts considering factors such as standardization of geometric shapes and integral part design through parts count reduction [12]. Design for easy and quantified assembly with suitable manufacturing ways, design for easy maintenance and improved design efficiency are the outcomes of the work [13]. The 3D DME Storage model can be seen in Figure 11.

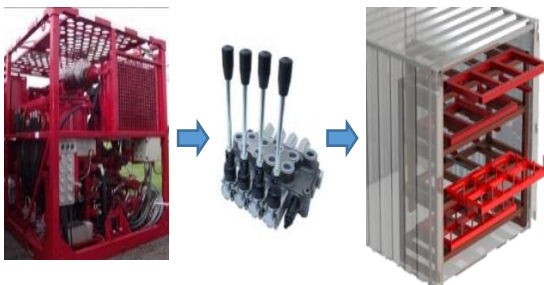


Figure 11. The 3D Model of DME Storage Embodiment Design

**Design Calculation Analysis**  
**Rack Design Calculation**

A load on a rack is shown in Figure 12. Based on this figure, the calculation of the strength of a load material [14, 15, 16] is listed in Table 9.

The use of hollow square 80 x 80 x 2.5 mm has the tensile strength of material 275 N/mm<sup>2</sup> [9], then based on the calculation above then the maximum tensile strength that arises because of the load on the rack is still below the tensile strength of the material rack. ( $\sigma_{bmax} < \sigma_{material} = 275$  N/mm<sup>2</sup>). It means the construction is safe.

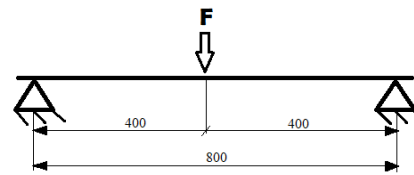


Figure 12. Load on rack

Table 9. Calculation strength of a material

|                                   | Rack 1  | Rack 2  | Rack 3  | Rack 4  |
|-----------------------------------|---------|---------|---------|---------|
| Mass (kg)                         | 180.2   | 336.2   | 250.6   | 402.6   |
| Force (N)                         | 1767.2  | 3297.6  | 2458.9  | 3949.5  |
| M <sub>b</sub> max (N.mm)         | 353456  | 659526  | 491794  | 789901  |
| W <sub>b</sub> (mm <sup>3</sup> ) | 15020,8 | 15020,8 | 15020,8 | 15020,8 |
| σ <sub>b</sub> max (N/mm)         | 23.5    | 43.9    | 32.7    | 52.6    |

**Rail Sliding Capacity Calculation**

Based on the calculation of the weight of the shelf and DME, the maximum load is on the rack 4 that is 402.6 kg, added safety factor 1.5, and then the maximum load is 603.9 kg, as:

$$F_1 = m \cdot g \tag{1}$$

$$N = \frac{F_{max}}{Load\ Capacity} \tag{2}$$

Then, the maximum load can be concluded, and the racks will require four rails with a 660 mm track length suit to the sliding rail specification in the catalogue [17].

**Calculation of Hydraulic Cylinder**

The pressure of the hydraulic cylinder required obtained by the following equation:

$$P = \frac{F_{max}}{Area} \tag{3}$$

Then, the hydraulic cylinder required in the design is 800 Psi [18].

**Hydraulic Circuits**

A hydraulic circuit is graphically shown in Figure 13. The circuit uses 4 units 2-inches diameter hydraulic pistons [19], using 4 levers to control the actuated directional valve, which can be selected which rack to move. As a pressure control [3], there is a pressure relief valve set at 1000 psi according to the needs used to move the rack as the calculation above. Besides that, a throttle valve is also installed to regulate the piston's hydraulic movement faster or slower with the source coming from a power pack, which has a pressure of 3000 psi [20].

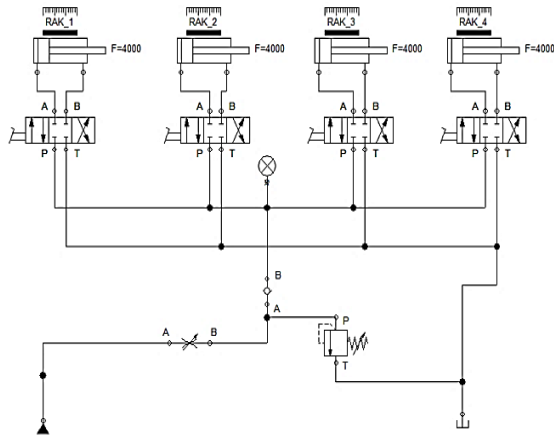


Figure 13. Hydraulic circuit

**Design Specification of DME Storage Part**

According to calculation and the main concept selection, the design meets the customer needs. The design already has the 1-ton capacity or 40 DME and use the existing 10 ft. container and utilize the available equipment source, then the parts of DME Storage can be seen in Table 10 that shows the parts of DME storage complete with dimensions, numbers and the type of standard

The final step of the DME storage design process is drawing detailed designs or working drawings. This detailed design is an orthogonal projection from the 3D model of the embodiment design. The detailed design, as shown in Figure 14, consists of the assembly design and the part design. This detailed design is equipped with dimensions, tolerances, roughness symbol, and welding symbols to support its manufacturing process.

After the DME Storage has been manufactured, an illustration of how to organize the DME in the storage that is placed according to the type of DME on each shelf, as shown in Figure 15.

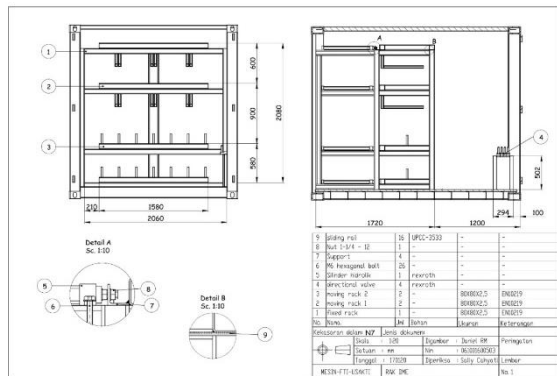


Figure 14. The Detail Design of DME Storage

Table 10. Parts of DME Storage

| No | Part Name                                | Specification  | n      |
|----|--|--|--------|
| 1  | Hollow Square, (EN10219) Grade S275J0H   | 80x80x2,5mm, L=2000mm  | 5      |
| 2  | Hydraulic cylinder                       | Rexroth (T1 MS2/2"/1,375"/25") Travel Length 660 mm, capacity: 1687 N/Pair | 4      |
| 3  | SPCC Sliding Rail (3553-26)              |  | 2 pair |
| 4  | Hollow Square, (EN10219) Grade S275J0H   | 80x80x2,5mm, L=640mm   | 16     |
| 5  | Hollow Square, (EN10219) Grade S275J0H   | 80x80x2,5mm, L=1580mm  | 8      |
| 6  | Circular Hollow, (EN10219) Grade S275J0H | Ø26,9 x 2 mm, l=150mm  | 28     |
| 7  | Hollow Square, (EN10219) Grade S275J0H   | 80x80x2,5mm, L=600his mm   | 12     |
| 8  | Hollow Square, (EN10219) Grade S275J0H   | 50x50x2,5mm, L=220mm   | 12     |
| 9  | Hollow Square, (EN10219) Grade S275J0H   | 80x80x2,5mm, L=420mm   | 6      |
| 10 | Hollow Square, (EN10219) Grade S275J0H   | 80x80x2,5mm, L=720mm   | 26     |
| 11 | Hollow, EN10219) Grade S275J0H           | 150x80x3mm, L=2080mm   | 1      |
| 12 | Hollow, EN10219) Grade S275J0H           | 150x80x3mm, L=760mm  | 4      |
| 13 | Hollow, EN10219) Grade S275J0H           | 80x80x2,5mm, L=2080mm  | 4      |
| 14 | Directional valve                        | Rexroth 4/3-way manual handle w/ lever                                     | 4      |

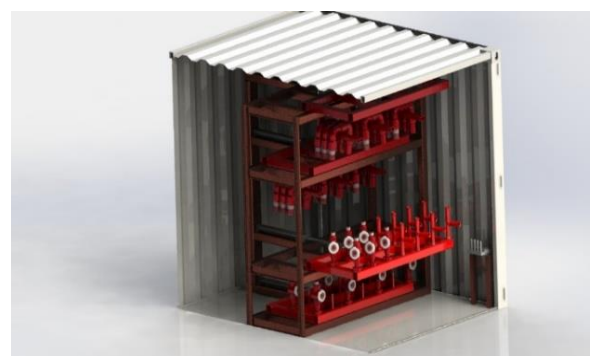


Figure 15. DME Placement According to Types in Rack DME Storage

**CONCLUSION**

In the design of storage systems for Discharge Manifold Equipment (DME), there are several conclusions. First, the design process has already resulted in a design of the DME storage

with a semi-automated system rack type of DME. The placement of DME is grouped according to the DME types in each rack. This storage has rack dimensions of 2000 mm x 2000 mm x 1720 mm build from a hollow material square 80 x 80 x 2.5 mm that came in a 10ft., the storage system was able to accommodate 1174 kg such as requirement list.

Then, the DME storage system uses semi-automatic with hydraulic piston diameter 2 inches with a pressure 800 psi and sliding rail 4 pieces with a power of 1687 N/pair and a length of 660 mm trajectory controlled by a lever-actuated directional valve. The hydraulic circuit is limited according to customer demand by utilizing the source of the Powerpack, which has a minimum pressure of 3000 psi and able to be converted to 1000 psi in series with the installation of pressure relief valve so compatible for DME storage both on-site and in the yard.

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