INTERNship REPORT

- IMPROVING THE MICROFERM CONCEPT -

Name: Colin de Pijper (S1014501)
Company: HoSt Biogas B.V
Mentor: M. te Braak
City: Enschede, the Netherlands
Period: 01-03-2016 to 31-05-2016
University of Twente
Master Mechanical Engineering, Design engineering
Content

Preface ................................................................................................................................. 3

1. Introduction .................................................................................................................... 4

2. Analysis current situation ............................................................................................. 5

2.1 Introduction to the process ......................................................................................... 5

2.2 Overview installation ................................................................................................. 5

2.2.1 Feeding pump ........................................................................................................ 5

2.2.2 Digester .................................................................................................................. 5

2.2.3 After digester ......................................................................................................... 5

2.2.4 Warm water circuit ............................................................................................... 6

2.2.5 Biogas cooling & compressor ................................................................................ 6

2.2.6 Gas upgrading ........................................................................................................ 6

2.2.7 Control valve .......................................................................................................... 6

2.3 Process parameters .................................................................................................... 7

3. Problem description ...................................................................................................... 9

3.1 Analysis current situation .......................................................................................... 9

3.1.1 Digester ................................................................................................................ 9

3.1.2 After digester ........................................................................................................ 9

3.1.3 Container & skid ................................................................................................... 10

3.2 Development possibilities .......................................................................................... 10

3.2.1 Digester ................................................................................................................ 10

3.2.2 After digester ........................................................................................................ 10

3.2.3 Container & skid ................................................................................................... 10

4. Conceptual design ........................................................................................................ 11

4.1 Biogas calculator ....................................................................................................... 11

4.2 Digester ..................................................................................................................... 13

4.3 After digester ............................................................................................................. 14

4.3.1 Construction of the tank ....................................................................................... 14

4.3.2 Mounting the pipes .............................................................................................. 14

4.3.3 Heating of the tank .............................................................................................. 15

4.4 Container & Skid ....................................................................................................... 15

4.5 Overview design options ......................................................................................... 16

5. Detailed design ............................................................................................................ 17

5.1 P&ID .......................................................................................................................... 17
Preface
During this internship Host provided me with a lot of help and information so I would like to thank the company for this opportunity. A special thanks goes to Marcel te Braak and Gijs Olde Loohuis for assisting me closely at HoSt.
1. Introduction

HoSt bv. is situated in Enschede, the Netherlands and is specialized in engineering and building durable installations. These are divided into two categories, the first being combustion powered installations to generate electricity, and the second is biogas generation from organic materials. This report is made for the latter category and more specific in the biogas upgrading area. The microferm concept is taken as a starting point to adjust future installations to specific demands. These demands are regarding the amount of gas to be upgraded and another important aspect is the maximum amount of manure that can be processed. The installation that is designed must be transported easily and the building time on site must be low, because the object is to build a lot of these installations in a short time.

The structure of the report is as follows. The current microferm installation is analysed in terms of equipment, layout, and process parameters. Based on this data and a visit to the site the development possibilities are stated. These are given in terms of the main components and are elaborated later on. In the conceptual design phase a datasheet is used to determine the dimensions and capacities of the digester for the required amount of manure and biogas production. For the previous mentioned development categories some solutions are provided to make a more detailed design. The design choices are based on costs, building time, ease of transport, and the experience of HoSt. The required amount of heat for the process is calculated by determining and calculating the heat loss of the process. After these calculations the general layout is made and adjusted to come up with the most efficient design in terms of safety zones, costs, quick building time, and transportability.

This resulted in a general design layout for the new microferm concept. Based on this design an estimation of the costs can be made to see if the installation is feasible. This is kept outside the scope of this report, because this information is confidential and depending on the number of installations that will be build.

At last an overview of the installation and some recommendations are given regarding the layout and details of the design.
2. Analysis current situation
First a short introduction is given to the process together with its goals and purpose. Next, the current installation on which this report is based is analysed. An overview of the process is given to describe how the installation functions basically. Next, the most important process parameters are stated, in terms of input and output, to give an idea about the order of these numbers. This is done by using the biogas calculation sheet provided by HoSt.

2.1 Introduction to the process
The current installation in Den Bommel, The Netherlands, is used to produce biogas by the so called microferm. This is developed for farmers who process manure of their own company. The microferm enables farmers to do this by a natural digesting process which leads to biogas in the end. This can be converted to electricity and heat, or upgraded to natural gas quality. Depending on the size of the farm, farmers can be entirely self sufficient in their energy need and an excess in electricity or natural gas can be delivered to the local energy grid. Besides the production of energy, a reduction in toxic emissions of methane and ammoniac is an important goal as well.

2.2 Overview installation
In order to make digesting possible a couple of main components are required. These are the feeding pump, digester, after digester, warm water circuit, biogas cooler and compressor, gas upgrading, and control valve. Each component will be discussed shortly.

2.2.1 Feeding pump
The feeding pump pumps the manure from the manure pit through the heat exchanger to the digester and after digester. After the pump a flowmeter is installed to count the amount of manure and functions as a dry run protection. If the flow of the manure becomes below a specific value a warning signal is given. The heat exchanger warms the cold manure which has a temperature of roughly 5°C to a temperature of 40°C by water from the warm water circuit.

2.2.2 Digester
The digester is used to convert the manure to biogas and digestate. Inside the digester tank a mixer, liquid level sensor, temperature transmitter, pressure meter, high level meter and heating pipes are installed. The paddle mixer is controlled by time during the digesting phase of the digester. It rotates in the same direction most of the time, but every now and then it rotates in the counter direction to make sure the mixture remains homogeneous. The temperature, level, and pressure sensors are used to control the process and control several valves to obtain constant conditions inside the tank. The temperature inside the tank must remain between 40°C and 50°C at all times to keep the biological converting process going to obtain biogas. This gas contains about 55 to 60% methane, 40 to 45% Carbon-dioxide, and low concentrations of other gasses.

2.2.3 After digester
The after digester is fed by the digester through an overflow pipe. The manure that is pumped into the after digester can still produce some biogas. So the after digester has a double membrane roof, which remains under tension by a blower, and is used as a biogas buffer. This buffer makes a steady process possible and can be used in emergency situations when there is no biogas produced. Usually the amount of gas in this buffer is enough for about 5 hours of gas production. Due to the use of a double membrane the inner pressure has some margin because this can vary during the digesting
process. A submergible mixer and the same type of sensors as those in the digester are part of the equipment in the after digester. The mixer is time controlled during the digesting phase. The fan blower which holds up the membrane roof must be operating at all times. The sensors are used to control the conditions in the tank to obtain steady state conditions. The manure which is digested is called digestate, and is drained continuously to a manure pit. It can be used afterwards as fertilizer for the meadow for example.

2.2.4 Warm water circuit
The warm water circuit contains heat suppliers and a heat demander. The heat demander is the manure heat exchanger and the heat suppliers are the oil cooler of the compressor, air-water heating pump, and the gas boiler. Heat of the oil cooler is tapped at all times. Heat from the other suppliers is used to control the temperature inside the digester to keep it around 52 °C. The digester is warmed by pumping water from the header through the heat exchanger. The internal pump of the heating pump pumps a constant amount of water. The compressor for biogas upgrading delivers an amount of heat that must be tapped of in the oil cooler at all times. This is done by using cooled water from the heat exchanger. The gas boiler is only used as a backup device when the heating pump lacks power to keep the digester at the demanded temperature, for example during very cold circumstances when it is freezing outside.

2.2.5 Biogas cooling & compressor
The biogas that is produced in the after digester must be cooled, cleaned and compressed before it can be upgraded to natural gas quality in the membrane section. There are two biogas coolers, the first one cools and dries the gas from 40°C to 5°C and leads the dry biogas through a carbon filter to remove $\text{H}_2\text{S}$. It is important to remove any water particles from the gas because this must not end up in the gas grid and the $\text{H}_2\text{S}$ must not exceed a certain percentage to be able to reach the quality which is required if the gas is delivered to the gas grid. Next the biogas is compressed. The second cooler cools the compressed gas from 55°C to 10°C with heated water from the first cooler. Next the cooled gas is guided aside the warm gas to obtain a temperature of at least 20°C above the water dew point which is about 35°C. This process is also described using AutoCad P&ID. The relevant data is shown in the sheet in appendix B.3. This will be further elaborated later on in this report.

2.2.6 Gas upgrading
When the biogas is cleaned it is led through the membranes by a three way valve. In these membranes the biogas (60% $\text{CH}_4$, 40% $\text{CO}_2$) is upgraded to green gas (90% $\text{CH}_4$, 10% $\text{CO}_2$). These membranes are based on the principle of different degrees of permeability. $\text{CO}_2$ permeates through the membrane easily so it is led through (permeate), $\text{CH}_4$ permeates poorly so it is not led through by the membrane (retentate). The degree of separation is controlled by differences in pressure on the permeate and retentate side of the membrane.

2.2.7 Control valve
The upgraded green gas has to meet some requirements before it can be fed into the gas network. No more than 11% of carbon-dioxide must be remaining and more than 89% of the gas must be methane. A GC checks whether or not the gas meets these conditions before the gas can be fed into the network. The requirements are concerning amongst others the gas composition, Wobbe index, caloric value, water dew point, and temperature. The specific values are not important for this report.
2.3 Process parameters

The main process parameters are estimated by using the HoSt Biogas Calculator. This sheet calculates the amount of biomethane and biogas that can be upgraded given a certain amount of manure. The sheet can be found in figure 2.2. The first step is to fill in the amount of manure that will be fed in over a year. This can be found in the column under Massa. Each type of manure has its own characteristics and composition which are predefined in the sheet. This data contains among others the ratio between the liquid and solid part of the manure, the amount of methane and the organic load. The organic load is a key factor in the digesting process and must be kept under a certain value. If the organic load becomes too high foam will form inside the digester. This foam is undesired because this means that the bacteria that keep the digesting process going are dying, which is a bad thing. The forming of this foam can be checked by a sight glass as shown in figure 2.1. The organic load is a great factor during design choices. Based on these data the potential amount of biogas is calculated. Next the number of digesters are chosen, in this case a digester and after digester are used. The volume of the digester is calculated based on the retention time of the manure inside the digester and the organic load. This last parameter is limited to certain boundaries so care must be taken regarding this value. The same calculation is done for the after digester and the dimensions of the digester are calculated by the required amount of volume to make the actual digesting possible. Both digesters are specified so the gas upgrading can be determined. During the digesting process biogas is produced which is upgraded to biomethane using membranes. The amount of biomethane is given in Nm³ per hour that is fed into the local gas skid. The last thing that is calculated is the amount of heat and electricity used by the digesters and other components based on the main components like heating of tank(s) and other equipment like blowers, pump, etc. This installation can produce 21 Nm³ per hour with 8250 tonnes of manure per year.
Figure 2.2 - Example Biogas calculator
3. Problem description
This chapter describes what can be improved in future installations based on the current one. First the current installation is analysed to see where improvements can be made. Each main component will be elaborated. Then an overview is given of the components that will be redesigned in this report.

3.1 Analysis current situation
The main components of this installation are the digester, after digester and the container including the skid with the equipment. These three parts are discussed to determine what can be adapted or modified to improve future installations.

3.1.1 Digester
The current digester is a so called polem tank. This is a tank made of polyester with a diameter of 4 metres and a height of 12 metres. These are the maximum dimensions for transport without the use of special transport trucks with guidance. The tank has a frame on top to support and mount the mixer inside the tank. The motor of this mixer is mounted outside the tank and the blades are mounted inside the tank. This mixer cannot be placed in one piece because the hole is too small so the blades are mounted to the shaft by a mechanic inside the tank. This situation is not ideal because it is hard to reach the blades if they are broken and have to be replaced. In that case the entire digester must be emptied in order for the mechanic to be able to enter the tank. Another issue with this construction is the need for a support frame. If the tank would be strong enough to support the mixer the frame could be unnecessary and therefore the tank can become cheaper.

The tank has a manhole at the bottom of the tank as well as a feeding point for the manure. This feeding pipe goes up to the top from the inside to pump the manure from above. Halfway of the tank there is a feeding point from the digester to the after digester and a digestate overflow pipe which works as a safety valve to prevent flooding. These pipes are all placed and connected on site. There is a rule of thumb that states that work in the field costs three times more than if it would be performed at a factory. This is not a proven rule, but it is based on the experience that HoSt has in this industry. So locating, mounting and connecting of these pipes is a quite expensive job.

3.1.2 After digester
The after digester is a tank which consists of an insulated concrete wall and floor, and an insulated membrane roof. The first cannot be transported for obvious reasons so it is built on site. First the floor is poured, next the walls and when those are dry the roof is installed. The after digester contains some pipes as well, so holes must be made in the tank. This is done on site by locating where the pipes must enter and leave the tank and then drilling the holes. This is a very labour intensive job because the concrete walls are reinforced with steel and are about 20 cm thick. When the holes are drilled the pipes are mounted usually using a linkseal packing to make sure that there is no leakage. The pipes are supported by clamps which are mounted to the tank by anchor bolts, so those must be drilled in the tank as well. Two sight glasses are attached to check the tank when it is in use. The first one is to see through and the other one contains a lamp. The sight glasses are bolted on the inside of the tank. A platform is mounted beneath the sight glasses to enable a person to actually use the sight glasses.
When all pipes and other attributes are attached to the tank the walls are insulated and the insulation is protected by surrounding it with pile sheets. It becomes clear that the after digester requires a lot of work that must all be done on site. It is mentioned before that this is very time and cost consuming, so here may lie some possibilities to reduce the costs.

### 3.1.3 Container & skid

The pipes to the digester and the ones that come from the after digester all go through the skid which contains the equipment. This skid holds among others a manure heat exchanger, heat pump, carbon filters, biogas cooler, emergency cooler, and a biogas blower. This skid is attached to a 20ft container in which the compressor and membranes are placed. In the container a control room is placed next to the compressor. The skid and container are placed separately and must be connected on site. There is a lot of piping between all components so this again means a lot of work to connect them. Care must be taken during this job because there is gas flowing through the pipes so for safety and efficiency reasons all flanges must outline properly to prevent leakages from occurring.

### 3.2 Development possibilities

There are several possibilities to improve future installations. These are divided into three categories.

#### 3.2.1 Digester

The digester is currently made of polyester, but this might not be the best material to use, so the use of a steel tank must be investigated. Another point of investigation is the dimension of the tank. This is currently the maximum dimension to be able to transport it by normal road transport. However if the tank can be produced smaller it might become cheaper and more easy to transport. Furthermore it must be investigated if this digester is required at all, because the installation can also work with a single, larger digester like the after digester in the current installation.

#### 3.2.2 After digester

The after digester is the one that requires most work currently. So for this tank the greatest saving might be realised. First of all the tank is poured on site, but there are also prefab tanks available on the market. That might reduce the time required to build the installation. Another issue is drilling the holes for piping and instruments which requires a lot of time on site. This must be investigated to see whether there are possibilities to prevent drilling holes or doing this during manufacturing in the factory in case of a prefab tank. The after digester is usually heated by Niroflex rings, which are mounted on the inside along the wall. This can be done by other heat exchangers as well so that must be investigated.

#### 3.2.3 Container & skid

The container and skid are now two separate parts which are mounted together on site. This is not ideal because all pipes between them must be mounted and outlined in the field, which is cost and time consuming. If they can be attached beforehand or in another way it could save time and costs. Another issue is the placing of the equipment on the skid. This is not done in a logical and efficient manner so that leaves some room for improvement as well. Furthermore due to the placing of the pipes some parts are hard to reach which makes maintenance harder to perform. When redesigning this part it must be kept in mind that it will be transported on the road, so the maximum dimensions apply for this case as well.
4. Conceptual design

This chapter describes the steps to redesign the current installation. It will start with determining the general layout of the installation with the dimensions of the digesters. Next a calculation will be done to the heat requirement of the installation.

4.1 Biogas calculator

The basis for each installation is to determine how much manure is available and will be used to produce biogas. In the Netherlands the maximum amount for small users is determining for this kind of installation. The limit for small users is 40 Nm$^3$ of natural gas per hour to be fed in the gas skid. If one goes beyond that number other rules and legislation apply which are less beneficial. So the aim is to develop an installation that is able to deliver 40 Nm$^3$/hr of biomethane and process the

![Biogas calculator data sheet for the single digester concept](image)
necessary amount of manure. This is done by using the HoSt Biogas calculator which is mentioned before. After filling in some values by trial and error to understand the working principle of the calculations of this sheet it turned out that two different situations could be obtained. The first one is based on obtaining the 40 Nm$^3$/hour by a single digester. That requires 16.000 tonnes of cow manure per year. That is comparable to a livestock of 400 cows, which is twice as much as most farmers have in the Netherlands. So the second case is based on half of that number, so 8.000 tonnes per year. Another argument to choose less manure is that two digester are required to process that amount of manure which means higher investment costs for the installation. In figures 4.1 and 4.2 the datasheets for the biogas calculation can be found. These figures show the dimensions of the digester tanks and how much biogas can be upgraded. During determining these values a couple of things must be checked. First the organic load of a digester, which must not become higher than 14
kg OS/m³d. If this does become too high the retention time and volume of the digester are adapted to obtain the right value. The retention time cannot be adapted to any value. From previous installations the target values are 6 days retention time for the digester and 14 days for the after digester. This is the time that each bulk of manure remains in the digester. For a single digester a retention time of 40 to 50 days is desirable. These values are based on experience and analysis from previous installations HoSt has built.

Based on the biogas calculations two different concepts can be obtained, namely the single digester and the combination of a digester and a after digester. The main aspects are summarized in table 4.1.

Table 4.1 – Summary of specifications for each layout

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Layout 1</th>
<th>Layout 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum dimensions tank for transport (Ø x h)</td>
<td>Ø4x12m</td>
<td>-</td>
</tr>
<tr>
<td>Gas infeeding limit</td>
<td>40 Nm³/hour</td>
<td>40 Nm³/hour</td>
</tr>
<tr>
<td>Maximum organic load</td>
<td>14 Kg OS/m³d</td>
<td>14 Kg OS/m³d</td>
</tr>
<tr>
<td>Target retention time digester</td>
<td>6</td>
<td>40-50</td>
</tr>
<tr>
<td>Target retention time after digester</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Number of tanks [-]</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Cow manure [tonnes/year]</td>
<td>8.000</td>
<td>16.000</td>
</tr>
<tr>
<td>Dimensions digester [m]</td>
<td>Ø4x12</td>
<td>Ø16x7</td>
</tr>
<tr>
<td>Dimensions after digester [m]</td>
<td>Ø8x6</td>
<td>-</td>
</tr>
<tr>
<td>Organic load [kg OS/m³d]</td>
<td>13,4</td>
<td>3,1</td>
</tr>
<tr>
<td>Biomethane flow average [Nm³/hour]</td>
<td>20</td>
<td>38</td>
</tr>
<tr>
<td>Biomethane flow max [Nm³/hour]</td>
<td>26</td>
<td>38</td>
</tr>
<tr>
<td>Minimum required operation hours [hours/year]</td>
<td>6.930</td>
<td>8.692</td>
</tr>
<tr>
<td>Retention time digester</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>Retention time after digester</td>
<td>29</td>
<td>-</td>
</tr>
</tbody>
</table>

These will both be further elaborated in the remaining of this chapter.

4.2 Digester

By the calculations of the biogas calculator it becomes clear that the dimensions of the digester must remain the same. If this tank becomes smaller the organic load becomes too high. So the only possibility is to investigate if the tank can become cheaper if it would be made from another material. A design is made from steel, as can be seen in figure 4.3. In this design all holes for the piping are taken into account as well.

Some manufactures have been asked to made an offer according to the drawings in appendix A. The offers were varying from €41.500 to €80.000. The original polyester tank costs €52.440 including isolation, stairs and platform. For the steel tank an extra platform is not necessary to support the mixer, so with €11.000 difference, a steel digester might be an interesting option, because isolation will usually cost less than €10.000.

Figure 4.3 – Steel tank
4.3 After digester
The after digester has most room for improvement, as mentioned in the previous section. There are three main points which will be investigated. Starting with the way the tank will be produced, next the mounting of the piping, and at last the type of heating.

4.3.1 Construction of the tank
There are two basic principles of building a concrete tank. The first way is building the tank by prefab elements which are connected to each other by steel cables. The elements are produced in a factory, so the building time on site is relatively short. In appendix C the positions on the steel rods are given. These are very important for determining the positions of the pipes which will be discussed later. The second way is more common namely pouring concrete in a steel mould which is filled with steel reinforcements. This way a solid reinforced wall is created. There is a third option, namely that the client already has a tank which limits the next options for locating the pipes.

4.3.2 Mounting the pipes
There are different sizes of pipes that must be connected between the container and the digester. Besides the piping there are other kinds of equipment that are mounted as well, among other temperature and level transmitters, sight glasses, high pressure valves, and a mixer. Basically there are three options to mount these pipes and equipment. The first one is drilling holes in the wall of the digester and mounting the pipes with a linkseal to prevent leakages. This option is not ideal, because the locations must be determined on site which means that the accuracy is not ensured and special equipment must be delivered on site to perform the work at the top of the digester. Drilling holes on site costed around €3.000 in previous projects with the same amount of piping that goes to the digester. One way to reduce the time on site can be obtained in the situation that a prefab tank is used. In that case the holes can be drilled during the manufacturing of the elements. That way a higher accuracy could be obtained and the pipes can be mounted beforehand. An example is given in figure 4.4. So after installing the prefab digester the pipes can easily be connected to the container by connecting the flanges of the pipes between the container and the digester. However, there are some limitations to the location of the holes because of the steel connecting rods. The element shown in figure 4.4 has an height of 7 metres. The location of the steel rods for that size is shown in appendix C, according to the supplier. It can be seen that the location of the sight glasses is not ideal as they are supposed to be 600mm below the top of the wall. The fill height is up to 700 mm below the top of the wall, so if the sight glasses are placed low they become useless. This is one example of the limitations that the steel rods cause.

Figure 4.4 – Example prefab wall element with premounted piping
The second option can be used if a poured tank is used. The idea is to attach a plate to the steel reinforcement of the walls. This plate, as shown in figure 4.5, can be provided with holes, so that drilling on site is not necessary. The plate will have a closed edge on it to which the mould of the walls is closely connected. This is done to prevent the concrete to flow in front of the plate which would close the holes. As an extra precaution some foam is placed inside and in front of the holes to prevent the concrete of closing the holes. The plate can be produced with flanges on it to simplify mounting of the pipes. It must be noted that these flanges must remain within the thickness of the walls, otherwise the mould cannot be placed closely around the plate.

The third option is to leave the walls intact and mounting a frame on top of the wall (figure 4.6). This means that the membrane roof must be adapted to make room for the frame. The roof will be attached to the frame so the frame must be strong enough the forces of keeping the roof under tension. These forces can become relatively large so if this option is chosen the frame itself and the connection to the wall must be calculated thoroughly. The adaptation of the roof will cost around €1500 according to the supplier for this size of hole.

4.3.3 Heating of the tank
In order to enable the digesting process in the tank it must be heated to remain at a temperature of around 50°C. There are three ways to heat the tank. The first and standard option is currently used in various digesters and is called Niroflex rings. These are pipes that are mounted along the inside of the walls. These rings are connected by a header which requires just two connecting pipes to the skid. The second one can be compared to a frying pan, namely placing a heating element in the tank. This can be achieved when a frame is mounted through the roof. The last option is internal wall heating. This can be applied in the case of a poured tank. Heating pipes are then connected to the reinforcements. If the heating in the wall is not sufficient it can also be applied to the floor.

4.4 Container & Skid
The equipment that is used, like the heat pump, biogas cooler and carbon filters, are now mounted on a separate 20ft. Skid, which means that the components are connected on site. This skid is attached to the 20ft. container which houses among others the compressor and membranes. This way of building takes a lot of installation time on site. This problem can easily be solved by using a 40ft. container in total which can be transported in one piece. So a 20 feet container can be used
with a 20 feet container floor which can be placed on top of each other or behind each other. Another option can be to use a 30 feet container together with a 10 feet floor. Some of the equipment can be placed inside the container. The last option is to use a 40 feet container which has holes in the walls and roof to provide sufficient ventilation for the heat pump. By using these standard containers the piping between the original skid and container can now be connected during manufacturing. It can be transported as a whole, so that on site the container and digester are the only two components that must be connected.

The last thing that needs some improvement is the platform to reach the pressure relief valve and the sight glasses. This is now attached to the tank wall by using anchor bolts. However, it is desired to leave the tank walls intact, especially in the case of internal wall heating. So the platform can be placed on top of the container to prevent drilling holes in the digester tank. The platform must be designed in such a way that it can be transported in one piece and mounted to the container easily and quickly.

4.5 Overview design options

In the previous sections some options are given to improve the design of the total layout. In table 4.2 each option is repeated to provide a quick overview.

Table 4.2 – Overview of (dis)advantages for each option

<table>
<thead>
<tr>
<th>Option</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tank</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prefab</td>
<td>Short build time</td>
<td>Limited freedom in locating holes</td>
</tr>
<tr>
<td>Poured</td>
<td>Design freedom</td>
<td>Long build time</td>
</tr>
<tr>
<td>Existing</td>
<td>No build time</td>
<td>Less design freedom</td>
</tr>
<tr>
<td>Drilling holes</td>
<td>Design freedom</td>
<td>Time consuming and costly</td>
</tr>
<tr>
<td><strong>Throughputs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plate</td>
<td>Quick mounting of pipes</td>
<td>Only possible for poured tank</td>
</tr>
<tr>
<td>Frame</td>
<td>No drilling or tank adjustments required</td>
<td>Roof must be adapted</td>
</tr>
<tr>
<td><strong>Heating</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating element</td>
<td>Easy to mount and remove for maintenance</td>
<td>Only possible when a frame is used for the throughputs</td>
</tr>
<tr>
<td>Niroflex rings</td>
<td>Commonly used</td>
<td>Lots of drilling inside the tank required</td>
</tr>
<tr>
<td>Inside the wall</td>
<td>Large heating surface</td>
<td>Installation of heating pipes is time consuming</td>
</tr>
<tr>
<td><strong>Platform</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attached to wall</td>
<td>Design freedom</td>
<td>Drilling holes undesired</td>
</tr>
<tr>
<td>On container</td>
<td>Quick and easily mounted</td>
<td>Only possible when container and skid are placed on each other</td>
</tr>
<tr>
<td>Separate frame</td>
<td>Can be applied to each layout</td>
<td>Extra transport and mounting costs</td>
</tr>
<tr>
<td><strong>Size container + skid</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40 ft.</td>
<td>Piping can be premounted and transported as a whole</td>
<td>Platform required because the roof is too low for the tank height</td>
</tr>
<tr>
<td>20 ft. + 20 ft.</td>
<td>Can be placed on top or behind each other</td>
<td>Requires some installation of pipes on site</td>
</tr>
<tr>
<td>30 ft. + 10 ft.</td>
<td>Can be placed on top or behind each other</td>
<td>Requires some installation of pipes on site</td>
</tr>
</tbody>
</table>
5. Detailed design

In this chapter the choice and layout for a single digester is further elaborated. This is done by creating a P&ID of the total layout. In this P&ID the components, equipment and piping dimensions are given. Next the heat loss and therefore the required heat is calculated. The required length of heating pipes is determined to check if this is feasible. At last a design of the concrete tank is made.

5.1 P&ID

In appendix B the P&ID’s of the new installation can be found. These sheets contain the technical information about the process, equipment and connecting pipes. These sheets are provided by the process engineer and adapted for the new situation. The capacity of this installation is about two times the current installation. For that case the use of two digester in the form of a microferm digester and an after digester would not be feasible, because the organic load in the microferm would become too high. It can be used if the installation would be used at its full capacity, so for a maximum of 8000 tonnes manure per year. However, the objective is to design the installation in such a way that it can process 16,000 tonnes per year, so for that reason the choice is made to use a single, larger digester. In this digester the organic load is lower due to a larger retention time of the manure. One of the consequences is that some of the piping is enlarged in diameter to cope with the higher flow rate of biogas and other components, like the heating pump, are enlarged to be able to keep the digester at the right temperature.

The relevant information for this phase are 1) the components 2) the connections between the components and 3) the size, pressure classes and material of the pipes. Based on this information the entire layout is created and redesigned to provide the least amount of pipes to keep costs low.

5.2 Calculation of heat loss

The amount of heat that is required for the digester is determined by calculating how much heat is lost. The steady state process is analysed and in that situation the temperature inside the tank is kept at a constant of 40°C and the average outside temperature is taken at 0°C. The digester is placed on soil which will have an average temperature of 10°C. The digester’s wall and floor are made of concrete with XPS insulation panels around it and the roof is an insulated membrane roof. The heat loss is calculated in three parts, first the walls are considered, next the floor and at last the roof.

In figure 5.1 a schematic overview of the heat loss is given. At the right side the manure must be kept

![Figure 5.1 – Schematic overview of heat loss through wall by convection and conduction](image)
at constant temperature of 40°C. At the inner surface of the wall convection takes place between the manure and the wall. In the concrete wall heat is conducted through the wall itself to the insulation. At the outer surface heat is lost by convection with the surrounding air at lower temperature. The equation for heat loss is given in eq. 5.1

\[
\dot{Q} = \frac{\Delta T}{R_{total}}
\]  

(5.1)

First the difference in temperature is calculated by

\[
\Delta T = T_{inside} - T_{outside} = 313 - 273 = 40 \text{ K}
\]  

(5.2)

The Total resistance is given by the combination of convection and conduction

\[
R_{total,wall} = R_{conv,manure} + R_{cond,wall} + R_{cond,insulation} + R_{conv,air}
\]

\[
= \frac{1}{h_{manure}A_{wall,inside}} + \frac{\Delta T_{wall}}{k_{concrete}A_{wall,inside}} + \frac{\Delta T_{insulation}}{k_{insulation}A_{wall,outside}} + \frac{1}{h_{air}A_{wall,outside}}
\]  

(5.3)

The required values are summarized in table 5.1 and hold for a tank of Ø16 x 7 metres.

Table 5.1 – Properties required for calculation

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat transfer coefficient manure-concrete</td>
<td>58,8</td>
<td>(\text{W/m}^2\text{K})</td>
</tr>
<tr>
<td>Heat transfer coefficient wall-air</td>
<td>25</td>
<td>(\text{W/m}^2\text{K})</td>
</tr>
<tr>
<td>Heat transfer coefficient floor-soil</td>
<td>1</td>
<td>(\text{W/m}^2\text{K})</td>
</tr>
<tr>
<td>Heat transfer coefficient insulated roof-air</td>
<td>0,95</td>
<td>(\text{W/m}^2\text{K})</td>
</tr>
<tr>
<td>Thermal conductivity concrete</td>
<td>0,7</td>
<td>(\text{W/m-K})</td>
</tr>
<tr>
<td>Thermal conductivity insulation</td>
<td>0,04</td>
<td>(\text{W/m-K})</td>
</tr>
<tr>
<td>Area wall inside</td>
<td>351,8</td>
<td>(\text{m}^2)</td>
</tr>
<tr>
<td>Area wall outside</td>
<td>365,5</td>
<td>(\text{m}^2)</td>
</tr>
<tr>
<td>Area floor</td>
<td>201,1</td>
<td>(\text{m}^2)</td>
</tr>
<tr>
<td>Area roof</td>
<td>251,3</td>
<td>(\text{m}^2)</td>
</tr>
<tr>
<td>Thickness wall</td>
<td>0,25</td>
<td>(\text{m})</td>
</tr>
<tr>
<td>Thickness insulation</td>
<td>0,06</td>
<td>(\text{m})</td>
</tr>
<tr>
<td>Thickness floor</td>
<td>0,3</td>
<td>(\text{m})</td>
</tr>
<tr>
<td>(T_{outside})</td>
<td>273</td>
<td>(\text{K})</td>
</tr>
<tr>
<td>(T_{inside})</td>
<td>313</td>
<td>(\text{K})</td>
</tr>
<tr>
<td>(T_{soil})</td>
<td>283</td>
<td>(\text{K})</td>
</tr>
<tr>
<td>(\Delta T_{wall})</td>
<td>40</td>
<td>(\text{K})</td>
</tr>
<tr>
<td>(\Delta T_{roof})</td>
<td>40</td>
<td>(\text{K})</td>
</tr>
<tr>
<td>(\Delta T_{floor})</td>
<td>30</td>
<td>(\text{K})</td>
</tr>
</tbody>
</table>
The heat loss resistance equation can be constructed for the floor regarding the schematic overview in figure 5.2

![Schematic overview of heat loss through floor by convection and conduction](image1)

\[ R_{\text{total, floor}} = R_{\text{conv, manure}} + R_{\text{cond, floor}} + R_{\text{cond, insulation}} + R_{\text{conv, soil}} \]

\[ = \frac{1}{h_{\text{manure}} \cdot A_{\text{floor}}} + \frac{t_{\text{floor}}}{k_{\text{concrete}} \cdot A_{\text{floor}}} + \frac{t_{\text{insulation}}}{k_{\text{insulation}} \cdot A_{\text{floor}}} + \frac{1}{h_{\text{air}} \cdot A_{\text{floor}}} \]  \hspace{1cm} (5.4)

The last case is heat loss through the roof, see figure 5.3. The amount of conduction through the roof is neglected, because it is a relatively thin membrane. So the roof is only subjected to convection by surrounding air. Therefore the heat loss becomes

\[ \dot{Q}_{\text{roof}} = h_{\text{air}} \cdot A_{\text{roof}} \cdot \Delta T = 9.55 \text{ kW} \] \hspace{1cm} (5.5)

The total heat loss can now be calculated:

![Schematic overview of heat loss through roof by convection](image2)

\[ \dot{Q}_{\text{total}} = \frac{\Delta T_{\text{wall}}}{R_{\text{total, wall}}} + \frac{\Delta T_{\text{floor}}}{R_{\text{total, floor}}} + \dot{Q}_{\text{roof}} = 7.58 + 2.05 + 9.55 = 19.18 \text{ kW} \] \hspace{1cm} (5.6)
5.3 Calculation of required length pipes

The requirement of the heat follows from the host biogas calculator. The amount of heating pipes, Niroflex rings, can be calculated by using an excel sheet provided by HoSt. To verify this model the situation of the single digester is calculated to compare the outcome manually. In figure 5.4 a schematic overview of the cross section is given. The pipe with hot fluid enters the tank, goes around along the wall of the tank and exits the tank. The hot medium is water and the medium that must be heated is the manure. This manure is kept at constant temperature of around 40 °C, so it is assumed that the cold manure that is fed each time does not significantly change the temperature of the tank. Because the temperature of the medium in the tank is constant, the surface temperature of the heating pipe is also considered to remain at this temperature. The water that enters the pipe has a temperature of 55 °C and the specific properties are given in table 5.2. The pipe is made of steel and the properties of the pipe can be found in table 5.1. The heat transfer coefficient is determined from measurements of tanks that are already in use, so that value is taken to get the most realistic outcome.

The calculation is based on the fact that inside the pipe forced convection takes place. The amount of heat that is required follows from the heat loss through the walls and roof. The required length of the pipes can be calculated for a given diameter of the pipe. It is usual to take DN50 for the size of these pipe, so this is used for the calculation.

\[
\dot{Q} = hA_s\Delta T_{im}
\]  

(5.7)

In this equation the mean temperature difference and surface area are unknown. The mean temperature difference is given by eq. 5.8
All temperatures are known, except for the exit temperature. This is calculated by

\[ T_e = T_s - (T_s - T_i) \exp \left( -\frac{hA_s}{mc_p} \right) \]  

It turns out that the only variable is \( A_s \), which is given by

\[ A_s = \pi DL \]

So these equations must be solved for \( A_s \) to find the required length of the pipe. This is done in Matlab by substituting equations 5.8 in 5.7 and 5.10 in 5.9 and then solving for \( L \).

This gives a required length of the pipes of 37.6m. The excel sheet gives a value of 37.91 so the difference is not significantly and therefore the model in excel is verified and will be used in the other situation as well.

### Table 5.2 – Properties of water at 55°C

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density ( \rho )</td>
<td>985,2</td>
<td>[kg/m³]</td>
</tr>
<tr>
<td>Thermal conductivity ( k )</td>
<td>0,649</td>
<td>[W/m·K]</td>
</tr>
<tr>
<td>Specific heat ( c_p )</td>
<td>4183</td>
<td>[J/kg·K]</td>
</tr>
<tr>
<td>Prandtl number</td>
<td>3,25</td>
<td>[-]</td>
</tr>
<tr>
<td>Material</td>
<td>Stainless Steel</td>
<td>[-]</td>
</tr>
<tr>
<td>Outer diameter</td>
<td>0,063</td>
<td>[m]</td>
</tr>
<tr>
<td>Inner diameter</td>
<td>0,057</td>
<td>[m]</td>
</tr>
<tr>
<td>Heat transfer coefficient</td>
<td>225</td>
<td>[W/m²K]</td>
</tr>
<tr>
<td>Flowing medium</td>
<td>Water</td>
<td>-</td>
</tr>
<tr>
<td>Velocity of medium</td>
<td>0,3</td>
<td>[m/s]</td>
</tr>
<tr>
<td>Temperature of the medium</td>
<td>55+273</td>
<td>[K]</td>
</tr>
<tr>
<td>Required amount of heat</td>
<td>19,2</td>
<td>[kW]</td>
</tr>
</tbody>
</table>

### 5.4 Digestor

In this section the final choices are made for the type of digester that will be used. These are regarding the type of tank, the way that the piping is mounted, and the heating of the tank. These choices are mainly based on the costs, ease of construction, and building time.

#### 5.4.1 Type of tank

The two relevant options for the type of tank are a tank made of prefab elements and a poured tank. To gather more information about the two types and to discuss some details about it a meeting has been held with a manufacturer of each type. Both meetings were very useful. It turned out that both suppliers are able to implement a construction to be able to connect the piping. In the case of a prefab element some holes can be made in the panels to which flanges can be added. However, this requires further calculation, because steel rods are guided through the elements to set the tank under pretension. Another issue is that the elements are not flat at the outside, because there are some reinforcement ribs required. This makes it more difficult to mount the roof on the tank. It is
very important that the roof is not leaking, because the gas inside is explosive. According to the manufacturer this should not be an issue, but is requires more work.

The other meeting with the manufacturer of the poured tank was even more useful. After some discussion it turned out that they could provide the tank itself, a construction for the piping, and the heating of the tank. The last two will be discussed in the following sections. For the tank there are two options regarding the dimensions, the first one Ø16x8m and the second one Ø18x6m. the first option is cheaper compared to the second regarding the roof, but the second is cheaper regarding the tank. There was a large difference due to the production method. The maximum height of a tank that can be poured at once is six metres. So if a tank is higher than six metres the production time is longer and more labour intensive. The difference in costs of the roof for a Ø16m and Ø18m tank is 4000 euros more for the last one. The price of the tank itself is not significant.

The choice is made to take a tank of Ø18x6 metres, based on the lower costs of this option and the extra building time that is required for an Ø16 x 8 metres tank.

5.4.2 Piping
As mentioned before, the manufacturer of the tank is able to create a frame on which a plate can be connected with the piping. The frame is provided by the tank manufacturer and they will attach it to the steel concrete reinforcements of the wall and floor. To this frame a plate with flanges can be mounted. An example of the type of plate is given in figure 5.5. It is important that this frame is closely connected to the wooden mould to prevent that the concrete will flow inside the gap, which can be seen in the figure. As a precaution the hole is filled with foam which is removed afterwards. Due to the internal stresses the size of the hole in the tank must be 1000x1000mm at maximum. Another design limitation is regarding the location of multiple frames. This is the case, because the maximum size of the frame is not sufficient to locate all piping and equipment. The concrete is drilled after pouring to remove are bubbles inside the concrete. For this reason two plates cannot be located above one another, because the concrete under the lower plate is not sufficiently drilled which results in poor quality.

5.4.3 Heating
The type of heating that will be used is wall and floor heating. This consists of flexible tubes which are attached to the steel concrete reinforcement. The manufacturer installs this before pouring of the tank. They do not provide a header which can be connected to the skid, so a conceptual design is made for this. The location of the tubes that come out of the tank can be chosen anywhere. The amount of groups are determined from the allowable pressure drop in the tubes and therefore 24 groups are required. A header is made which is attached vertically to the digester for reasons of deaeration during the start-up phase.
The basic design is given in figure 5.6a. However, the use of wall and floor heating does provide a disadvantage. When the concrete is poured the locations of the tubes are not visible anymore, so there cannot be drilled deep holes in the wall to mount for example brackets for the piping. This problem can be solved by building a construction between the upper and lower plate to which the pipes can be mounted. This can be seen in figure 5.6b. The construction consists of two parts which are bolted on both plates. To provide some tolerance the upper part slides into the lower part and is fixed with bolts. This way problems due to a difference in height are eliminated. On the construction a couple of pipe clamps are welded according to the pipe size. These clamps consist of two parts which are bolted onto each other to fix the pipes. This way the pipes are supported sufficiently. At the outside of the tank the construction can be fixed to the floor because the floor heating tubes are only on the inside of the tank. So at the top it is bolted to the plate and below it is bolted to the floor by using anchor bolts as shown in figure 5.6c.

![Figure 5.6](image)

Figure 5.6 – a) Basic design of the header  b) Pipe support  c) Detail of mountings

5.5 Container

The container contains three main parts which are the control room, membrane and compressor room, and the equipment part. Each part is elaborated next.

5.5.1 Control room

The first part of the container in the control room. This room is about a quarter of the container, so 10ft., and is fully enclosed by walls and a roof. The control room contains the electrical cabinet which controls and monitors the entire process and its components. There is also a chromatograph which monitors the condition of the gas before it is fed into the gas skid. The control room contains two ducts which lead to the equipment part of the container. These two ducts are used for electrical wiring of the equipment.
5.5.2 Membrane and compressor room

Next to the control room is the membrane and compressor room located. The most important parts are the membranes and the compressor, as the name indicates. There is a little more attention paid to these components in comparison to the control room, but does require further optimization. A beginning is made to optimize the layout of this part by placing the membranes on top of the frame which holds the compressor, instead of mounting them on the wall as it is done in the current installation, see figure 5.7. This way the compressor, membranes and all further required components can be made as one part including all connections by one supplier. The other redesign is done by placing all sensors and transmitters on one pipe at the wall closest to the control room, because these require connections to the electrical cabinet. The compressor room is relocated to the middle of the container so the piping for water and gas are closer to the equipment outside and have to go through one wall instead of two. However, the double doors of the container are not part of the compressor room anymore so due to the size of the frame this room must be provided with double doors to be able to place the entire frame as one part in the room.

5.5.3 Equipment

Most attention is paid to this part, because this part was the main challenge. The previous rooms are comparable to the original situation, so the size of those components are not significantly different. The main differences are found outside. The heat pump is the largest component so this one is located first. The freedom in choosing a location for this pump was very limited due to the large dimensions, it cannot be placed transverse, and there must be sufficient area around for the air flow and due to Atex rules. The pump is not Atex certified so equipment and piping with biogas cannot be placed inside a perimeter of one metres around the pump. Therefore the pump is located on the left corner which leaves some space on the right side for a manure pump for example. Other large components are the two carbon filters. These filters contain active carbon which must be replaced after a couple of weeks. The filling point is on top of the filters and the flange on the front can be disconnected to let the used carbon flow outside, so these two parts must be easily accessible. The outlet flanges are faced to the front of the container so a wheelbarrow can be placed under the outlet and the connections for the piping are on the other side close to the biogas blower and other piping. The biogas blower is attached to the wall just beneath the roof with the connections for the pipes facing downwards. This way water that might be inside the pipes cannot flow into the blower which could cause failure of the blower. The biogas cooler is basically a large short pipe which narrows the freedom in choosing a location in this case as well. The choice is made to mount it in the upper right corner of the container along side of the heat pump. This is the only way to comply to the Atex rules, because it cannot be placed transverse in the container. The length is around three metres which is far more than the width of a container. Another option was to place it diagonally but
this turned out to be less efficient and more difficult regarding the piping. The last large components are the cold and warm water vessels. These contain only water so they are located as close as possible to the heat pump to keep the connecting pipes short. The warm water buffer however is placed a little further away to keep the inner part of the container accessible for people.

5.5.4 Atex zones
The installation must fulfil some safety requirements and among those is the Atex legislation. Explosive gas flows through the pipes and equipment so due to possible leakage there is a chance that explosives might occur near electric devices which are not Atex certified. The components that are not Atex certified are the heating pump and the manure pump. Therefore it is required that these components are outside the Atex zones. The zones have different degrees of explosive danger and the area around it that must be kept free is related to that. The pressure relief valve is the most dangerous part so this part has the highest level of Atex zone indicated in red shown in figure 5.8.

The clearance is an sphere with a radius of 2,3 metres, typical for first level zone, centered at the point where the gas is released. The second level zone is a clearance area with a radius of one metre. This zone is applied to all flanges and carbon filters, because these are less likely to leak. At the point where the road is attached to the tank there is also an Atex zone. This connection is regarded as a flange, so this requires a clearance of 1 metre. In figure 5.8b and 5.8c can be seen that this layout fulfils the Atex requirements, because the heating pump is outside the Atex zones as well as the manure pump. Another conclusion that can be drawn from figure 5.8 is that the design freedom to locate the components is quite low due to the Atex zones. This was already kept in mind during the conceptual design phase, because the pump are located at the end of the container and the other parts are placed closely together to obtain the smallest Atex zone.

5.5.5 Transport
One of the main goals was to design the installation in such a way that the transport can

![Figure 5.8 – a) Components with Atex zone  b) Side view  c) Top view](image)

![Figure 5.9 – Platform stacked under the heating pump for transport](image)
be done easily. For that reason a 40ft. container is chosen which is a standard and commonly used size to transport by trucks. However there are some components placed outside and on the container so these must be removed for transportation and installed afterwards. The main component is the platform on top of the container. This is too high and wide for transport, so it is placed underneath the heating pump and strapped to the floor (figure 5.9). When the container is on site the platform can be easily bolted on top of the container as well as the stairs and railings. A small problem might be the door handles so these can also be removed for transport and installed on site. The remaining components are all placed within the outer dimensions of the container, because this was a requirement at the beginning of the design process. In figure 5.10 can be seen that all components are within the outer dimensions of the container and it can be transported easily.

5.5.6 Connection container and digester
An important aspect is to connect the container to the digester quick and easily. There are four pipes between the container and the digester which are all connected with flanges. The flanges must be attached properly to prevent leakage of water or explosive gas. There is no guarantee that these four points are properly outlined, so it is chosen to make use of compensators. These are bolted between the flanges and consist of two flanges with flexible material between those flanges. The amount of displacement they can compensate is shown in figure 5.11. These values hold for pipe sizes of both DN65 and DN150, so they are used for the heating water, biogas, and digestate pipes. The relevant tolerances are shown in figure 5.12.
From the figure it can be seen that all pipes must be installed within a tolerance of 60mm horizontally and vertically with respect to each other. This should not be a problem because the pipes on the container can be installed relatively accurate as this is done at the factory. The pipes on the tank are likely to be placed less accurate because of the way the frames are installed. However the compensators are regarded to be sufficient to connect the pipes properly.

Figure 5.12 – Maximum tolerances for connecting each compensator
6. Final design

This chapter summarizes the final design as shown in figure 6.1. The most important design decisions for the digester and container are given. The connections between the container and digester and the transport are briefly discussed as well.

6.1 Digester

It is decided to choose for a single digester, because the original digester is too small for the amount of manure that must be processed. The original polem tank has the maximum dimensions to be transported on road without the use of special vehicles so the tank cannot become larger. Another option was to use two of these polem tanks but this would make the investment costs too high. So the idea of a digester and an after digester has been cancelled and therefore a single, large digester is chosen. This digester will consists of concrete walls of Ø18x6 metres which will be insulated afterwards. On top of those walls a double membrane roof will be mounted to provide a gas buffer and better insulation than a single membrane roof. The insulation is required to keep the temperature inside the digester at a constant temperature of around 50°C. The heat is provided by heating pipes inside the wall which are connected to the reinforcements of the wall and floor. This is done before the concrete is poured. Besides the heating pipes there are two frames connected as well. One frame is placed at the bottom of the wall and the other one is located as high as possible. These frame are used to bolt on two plates with pipes and flanges on it. The upper plate has a connection for the pressure relief valve, biogas pipe, two sight glasses, anti-foam pipe, and a temperature and/or pressure transmitter. The lower plate has connection for a sample point, digestate discharge pipe and serves as a manhole during the construction of the digester.

6.2 Container

The 40ft. container is chosen because it is cheap and easy to transport. The container is divided into three parts, two of 10 feet and one of 20 feet. The first one is the control room which houses the control cabinet and some gas analyzing instruments. Therefore it must be insulated and ventilated to meet the Atex rules. The second one is the compressor and membrane room, which houses the frame of the compressor and on top of the frame the membranes are placed. This saves space and makes it easy to place. This room is ventilated and insulated as well to keep a constant temperature.
which benefits the membranes. The last part is the open section of the container in which the
equipment is placed, see figure 6.2. All equipment is placed in such a way that a minimum amount of
pipes is required. The piping that must be connected to the digester is placed at one side of the
container. These are the heating and biogas pipes. Those are equipped with compensators to
prevent leakage. On top of the container a platform is placed to be able to reach the upper plate of
the digester. This platform is demountable so it can be transported inside the outer dimensions of
the container.

This way a plug-and-play installation has been developed which can handle the requirements for the
amount of manure and is able to produce 40Nm$^3$/hour. The digester can be made by only two
different suppliers. Namely one for the walls and floor, and the other one for the roof.
Simultaneously the container is fabricated and tested at the factory. When that is done the container
is transported to the location where it can be connected quickly. The costs are kept out of scope,
because the installation cannot be compared to the original microferm due to other requirements.
**Recommendations**

Before this design can be realized into a real installation there are still a couple of things that need more attention. The first one is regarding the container. To create sufficient air flow around the heat pump all walls are removed around the pump. However, during transport the container is filled with all equipment which weights around eight tonnes. Due to the removal of the walls the strength of the container is decreased, but by how much is hard to say. Therefore the container as it is now must be analyzes on strength and stiffness to make sure that it will not collapse during lifting of the container. The expectation is that the strength is not sufficient anymore, so reinforcements must be installed which are not obstructing the air flow for the heat pump.

Another aspect is regarding the connecting pipes between the container and the digester. It is assumed that these can be placed within a tolerance of 30 mm relative to each other. However, the frames in the wall are connected to the steel reinforcements so the location of those frames can also differ a couple of centimetres. This way the compensators might not be sufficient. One solution could be to use flexible tubes for the heating water and gas to connect the container to the digester.

The header for the heating pipes is not fully engineered and the location has not been determined yet. It is now placed vertically, but it might be better to mount it horizontally. The mounting itself required further attention, because it cannot be bolt on the tank wall because of the heating pipes inside. The header itself must be insulated to prevent freezing or heat loss so it can be placed behind the sandwich panels but other options must be investigated. So the basic design of the header is done, but before it can be used it requires more detailing.

The manure in the digester must be stirred at all times to generate a homogeneous mixture. The mixer that probably will be used is a mixer that slides along a pole. This pole is bolted to the floor and wall normally, but this is not possible because of the heating pipes in the wall. So the mixer needs further attention.

A couple of changes have been made to the components in this process like placing the membranes on top of the frame of the compressor. The compressor causes vibrations and despite the use of damper these might influence the functionality of the membranes. This must be tested, because this configuration has never been used before. Another ‘new’ component is the heat pump. This type of pump is new to HoSt and therefore it must be validated that it is sufficient to provide the required heat of the digester.

At last the costs are kept outside the scope of this report, but they are a key factor in the business case. During the design process the costs are kept in mind and decisions have been made based on the cheapest solution. However a thorough cost analysis has yet to be made to determine if the installation can be feasible for farmers regarding their investment costs.
Appendix A – Technical drawing of steel digester

<table>
<thead>
<tr>
<th>Item number</th>
<th>Item</th>
<th>Afmetingen</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tankbodem</td>
<td>Ø4300 x 10 mm</td>
</tr>
<tr>
<td>2</td>
<td>Tankwand</td>
<td>Ø4900 x 11250 x 10 mm</td>
</tr>
<tr>
<td>3</td>
<td>Tank bovenkant</td>
<td>Ø4900 x 10 mm</td>
</tr>
<tr>
<td>4</td>
<td>Mixer frame</td>
<td>PE186</td>
</tr>
</tbody>
</table>

Title: Microfem Steel

Surface texture in accordance with ISO 1381.
Standard tolerance in accordance with ISO 2768-cl.

Weight: 14173.5 kg

Drawn by: CdP
Checked by: MH
Approved by: -

Project: HoSt Standard

Scale: 1:50
Size: A3
Sheet: 1 of 3
<table>
<thead>
<tr>
<th>Item</th>
<th>Afmeting flens</th>
<th>Positie (graden)</th>
<th>Positie (hoogte)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M01</td>
<td>DN600</td>
<td>45</td>
<td>790</td>
</tr>
<tr>
<td>N01</td>
<td>DN150</td>
<td>45</td>
<td>11610</td>
</tr>
<tr>
<td>N03</td>
<td>DN100</td>
<td>55</td>
<td>11853</td>
</tr>
<tr>
<td>N04</td>
<td>DN150</td>
<td>255</td>
<td>1500</td>
</tr>
<tr>
<td>N05</td>
<td>DN150</td>
<td>270</td>
<td>2300</td>
</tr>
<tr>
<td>N06</td>
<td>DN150</td>
<td>217</td>
<td>5650</td>
</tr>
<tr>
<td>N07</td>
<td>DN100</td>
<td>15</td>
<td>290</td>
</tr>
<tr>
<td>N08</td>
<td>DN200</td>
<td>197</td>
<td>19786</td>
</tr>
<tr>
<td>N09</td>
<td>DN200, N100</td>
<td>30</td>
<td>11440</td>
</tr>
<tr>
<td>N10</td>
<td>DN100</td>
<td>50</td>
<td>2295</td>
</tr>
<tr>
<td>N12</td>
<td>DN100, N140</td>
<td>50</td>
<td>4230</td>
</tr>
<tr>
<td>N13</td>
<td>DN100, N140</td>
<td>50</td>
<td>2946</td>
</tr>
<tr>
<td>N14</td>
<td>DN80</td>
<td>73</td>
<td>11458</td>
</tr>
<tr>
<td>N15</td>
<td>DN50, N200</td>
<td>25</td>
<td>1300</td>
</tr>
<tr>
<td>N17</td>
<td>DN80</td>
<td>242</td>
<td>11458</td>
</tr>
</tbody>
</table>
Appendix B.1 – PID01

Wall and floor heating

DG01-K01
Appendix B.3 – PID03
Appendix B.4 – PID04
Appendix B.5 – PID05
Appendix C – Required locations of steel rods for Ø16x7m tank

Verticale doorsnede