Technical

MANUAL

USER'S MANUAL

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A. GENERAL INFORMATION

LS Optics is born from developing technology used in manufacturing wood drying systems for the sawmill industry. As a result of this, we found that the same principles can be used for both sludge drying systems and for heat recovery.

We have developed our sludge drying systems in close co-operation both with several Sewage treatment plants across Sweden and with the fish farming Industry in Norway. We have now accomplished to create a sustainable process who may be used for dewatering, drying and hygienisation of sewage sludge, biosolids, bio digestate or other substrates.

LS Optics is a material developer and supplier of equipment and solutions for recycling energy and material with focus on particularly finite resources. We design, engineer and assemble our products with established customer relations worldwide.

B. SYSTEM SUMMARY

B.1 Objectives

Recycling waste in today's world is a focus for all sector of activities. A modern circular economy is important to preserve the environment while providing added value to wastes produced by industries. Sludges are usually a byproduct of animal husbandry or human sewage systems and can be hard to deal with. These large amounts of wastes can be both harmful to the environment if not dealt with properly and costly because of the lack of disposal options. Filtering sludge, which consists in separating the solids from the liquid, is a reliable and cost-effective solution to handle large amounts of sludge. The dry sludge can be used for further purposes, such as biogas or fertilizer, while the cleansed liquid can be, in the case of water, be rejected without any environmental harm.

The use of a filtering unit fundamental for any waste-producing activity and a rotary vacuum filter is the combining a large filtering capacity with low maintenance cost. Drum filters can handle a wide variety of slurries, with different solid concentration and particulates sizes.

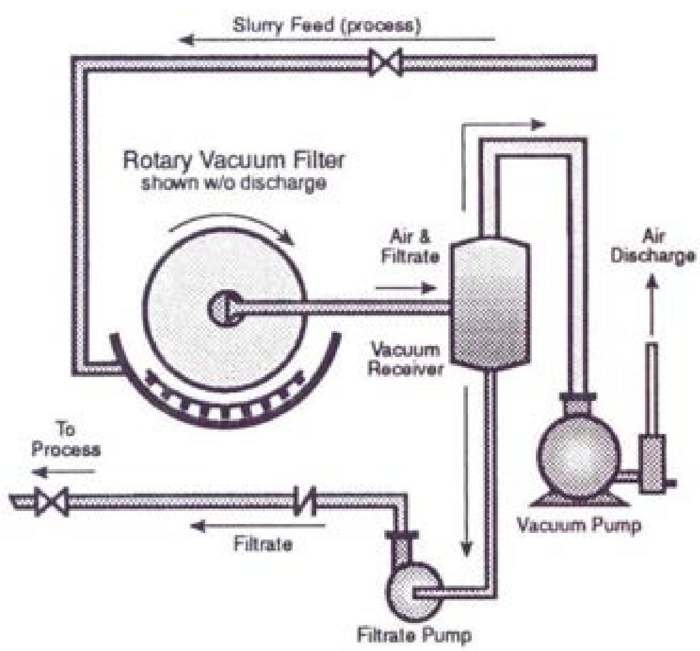
The filtering system is a continuous liquid-solid separation system than can be used in many types of applications. In the present prototype, fish sludge from land-based aquaculture is used as the main product.

The targets are:

- Cleanse, dry and sanitize the sludge in accordance with EU regulations and requirements of the Norwegian authorities. The regulation requires:
- Create a dry matter cycle.
- Cleanse the reject water from particles and organic material to achieve approved levels in accordance with EU regulations and requirements of the Norwegian authorities.
- The process treats the sewage sludge without any other additives. It is, therefore, possible to use the desiccated product as a fertilizer for farmland according to the EU sanitization regulations.
- Low energy consumption with mechanical drainage, which replaces heat consumption at the point of vaporization

B.2 Principle

The rejected sludge is collected in a big reservoir called the **buffer tank**. This tank of large capacity is holding the sludge before it goes through the filtering system. By gravity, the sludge flows towards the **sludge tank**, which is a smaller steel tank in which the **rotary drum** is immerged. An **agitator** is used to homogenize the sludge if the solids are setting too rapidly. The drum is a horizontal steel cylinder, its



cylindrical surface is covered by a **filter cloth** with a mesh size appropriate for the sludge characteristics.
A **vacuum tank** is located next to the drum and is used to separate the air and liquid discharge from the filter. It is connected to a **vacuum pump**. The vacuum tank is connected to the drum through two flexible pipes. The whole system is therefore under the same low pressure, which is used to **suck the sludge** through the cloth of the immerged drum. The vacuum sucks both the liquid and the solids onto the surface of the cloth. The liquid is able to go through the mesh while the solids are retained onto the drum. A **drive wheel** is used to rotate the drum, which allows the **filter cake** to dry while outside of the sludge and later be scraped off the drum by a **knife** located on one side of the drum. The newly scraped part of the cloth then re-enters into the sludge and goes through a new cycle of filter cake build-up/drying/discharge.

To keep a constant vacuum, the filter cake over the cloth needs to be air tight and act as a **seal**. Meanwhile, the vacuum sucks the moisture off the filter cake and the remaining moisture in the dried sludge is less than XX when it gets discharged from the cloth. The discharged product is carried away by a **screw conveyor** for further processing.

Water and air that go through the cloth flow through internal pipes towards the vacuum tank, where the clean water is then pumped out by a **water pump** and rejected.

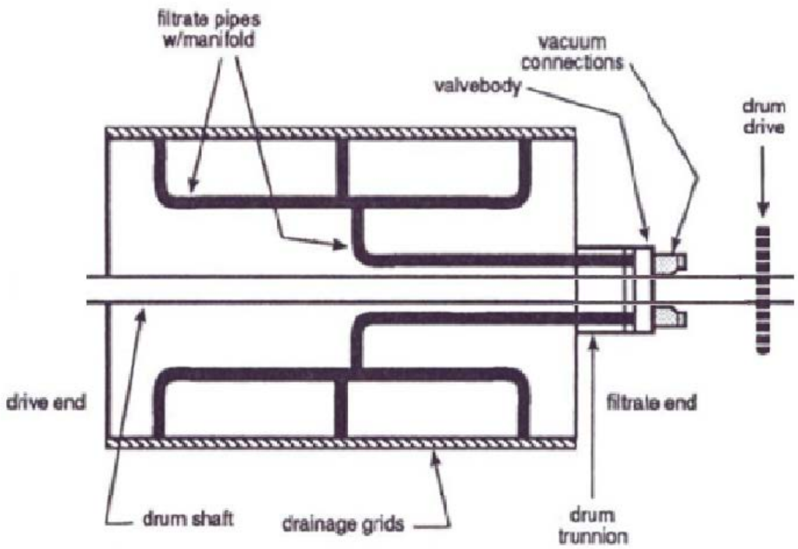


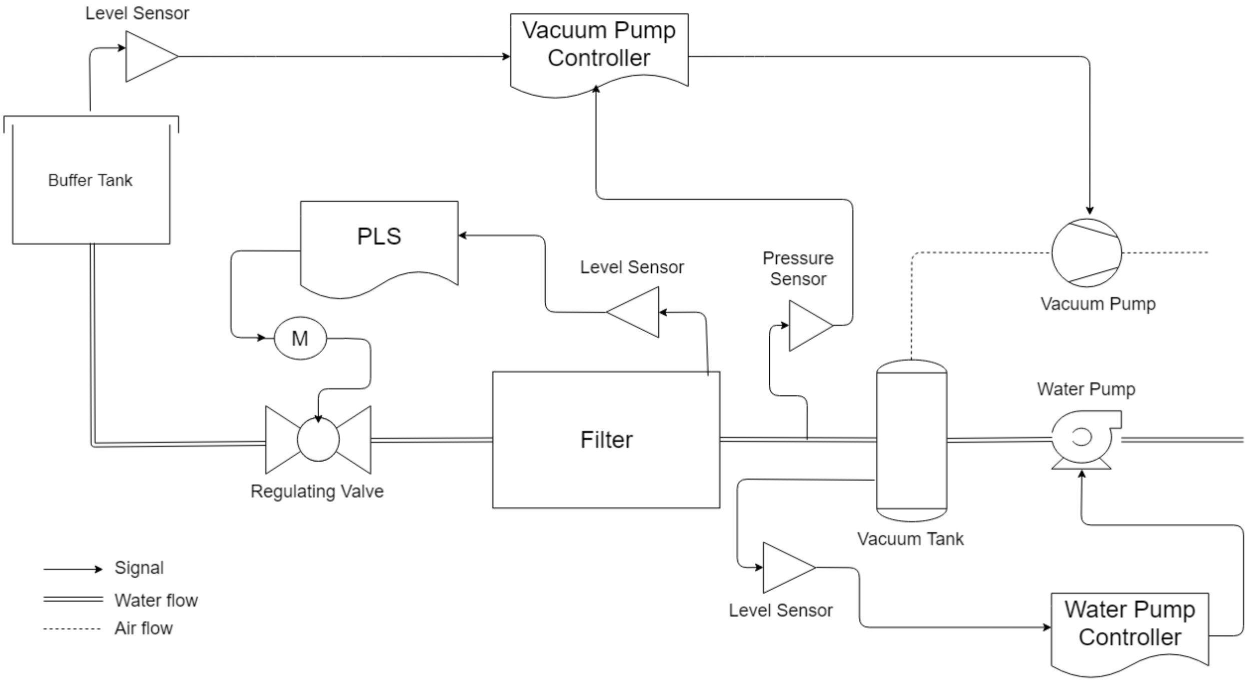
Figure 2: Schematic representation of the inside of the drum

B.3 Advantages

Drum filters offer many advantages. Among them, a high and continuous filtering capacity combined low operational and maintenance cost make drum filters a very efficient method of solids removal. The large diversity of applications make drum filters a versatile design.

B.4 System control

The filtering unit is equipped with several devices to monitor and control the proper functioning of the system. See below a schematic view of the system.



The different components are monitored by sensors and controllers so that the system runs as smoothly and as consistently as possible.

- the liquid levels in the following systems are measured by radar level sensor
  - buffer tank
  - sludge tank
  - vacuum tank
- the signal is transmitted to controller that will adjust parameters in the system to keep the levels within the preset ranges

- the sensor in the buffer tank interacts with the vacuum pump controller, which in turn adjusts the intensity of the vacuum to reach the desired flow through the cloth.
- the sensor in the sludge tank interacts with a regulating valve situated at the inlet side of the sludge tank. The opening of the valve is adjusted according to the level in the sludge tank.
- the sensor in the vacuum tank interacts with the water pump controller, which in turn adjusts the intensity of the water pump to adjust the water flow and keep a constant level in the vacuum tank
- a pressure sensor in the vacuum tank is used as a controlling device to monitor the pressure inside the vacuum tank

Figure 4: System sensors
(top left) Level sensor in the sludge tank. (top right) Level sensor in the buffer tank. (bottom). Pressure sensors and level sensor in the vacuum tnak

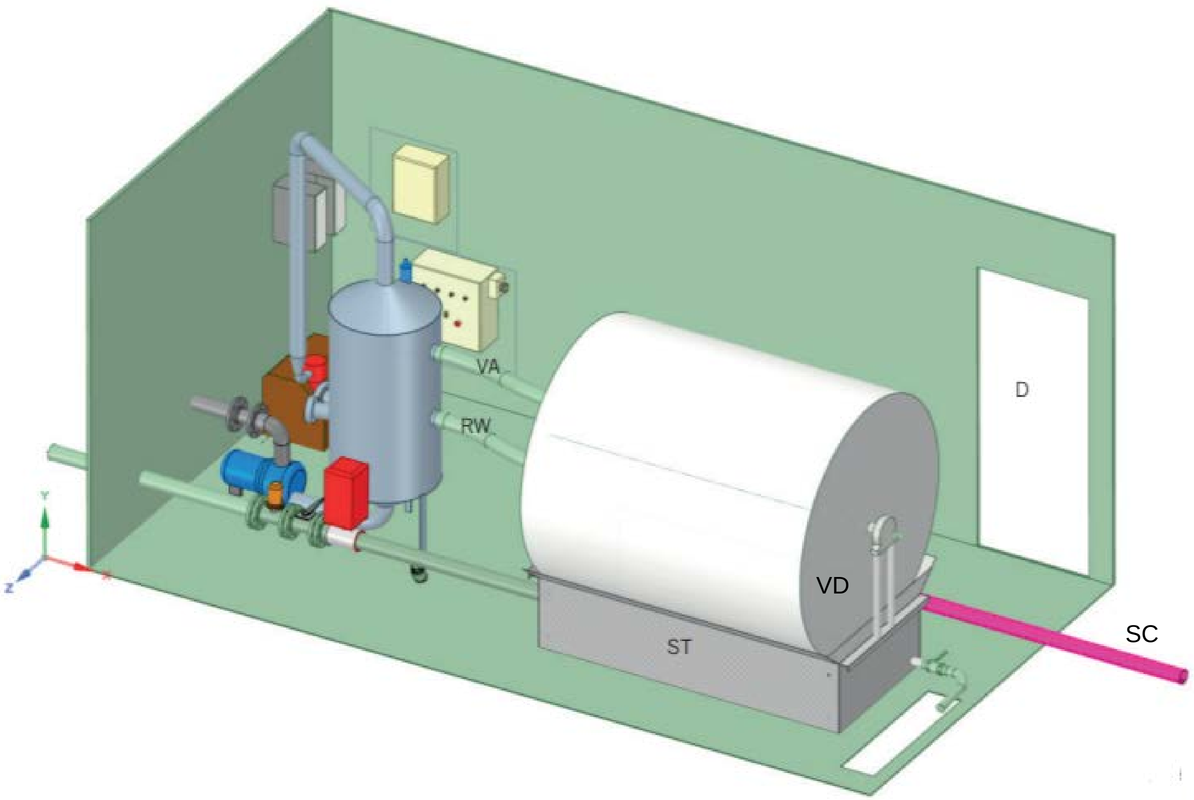
B.5 List of components

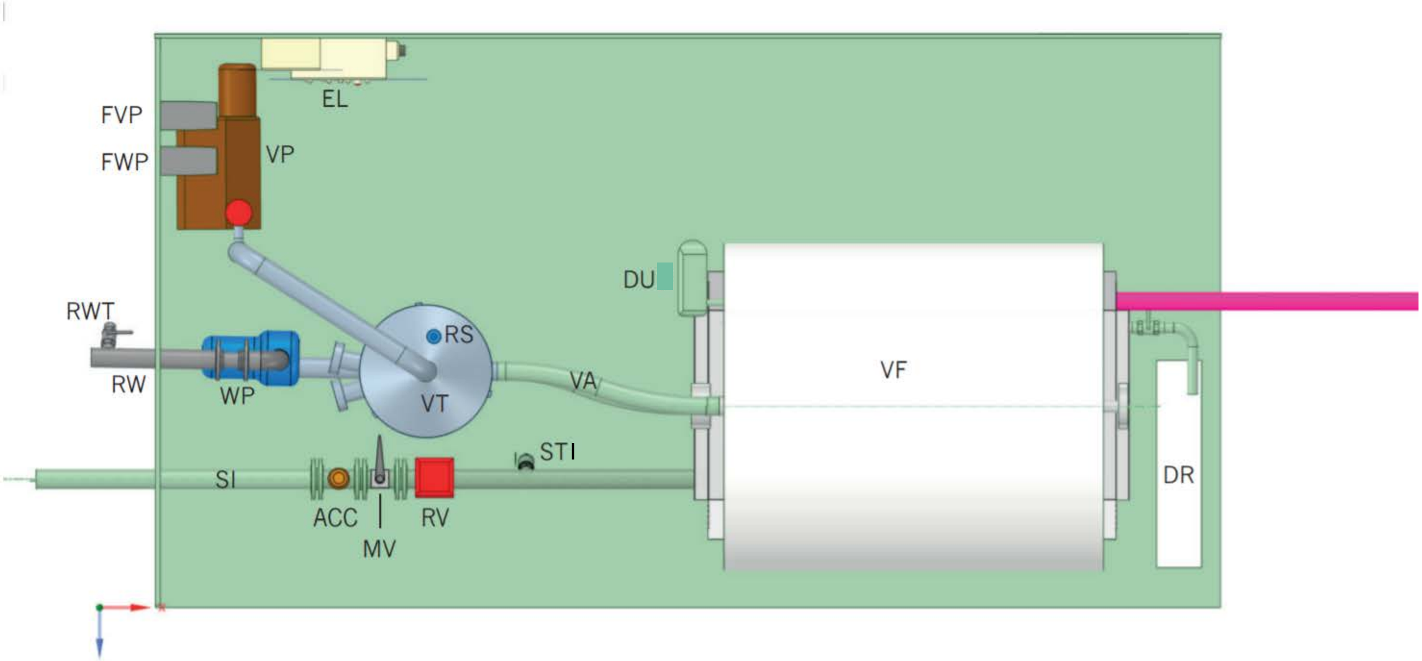
ACC = Activator
BF = Buffer tank
D = Door
DR = Drain
DU = Drive unit
EL = Electrical cabinet
FL = Floor
FVP = Frequence generator vacuum pump
FWP = Frequence generator water pump
KI = Wall
IP = Inlet pipe buffer tank
MV = Manuale valve
OF = Overflow pipe
OWV = One-way valve
PP = Pressure clock
PT = Pressure transmittor
RC = Radar sensor
RS = Radar sensor
RV = Regulating valve
RW = Reject water
RWT = Reject water out
SC = Screw conveyor
SI = Sludge in
ST = Sludge tank
STI = Sludge test in
VA = Vacuum air
VB = Vacuum box

VD = Vacuum drum
VF = Vacuum filter
VP = Vacuum pump
VT = Vacuum tank
VV = Vacuum Valve
WP = Water pump

B.6 Components description

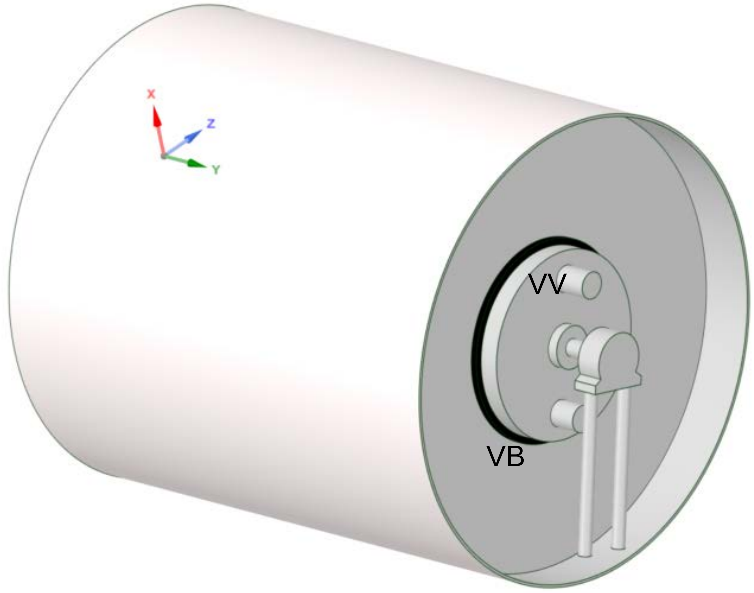
General lay-out





Drum

The drum filter is the main component of the filtering system. Its internal structure is made of pipes used to transfer the air and water from each section towards the vacuum tank. The surface of the drum is divided into sections and each section is connected to a pipe that transfers the filtrate towards the vacuum receiver.

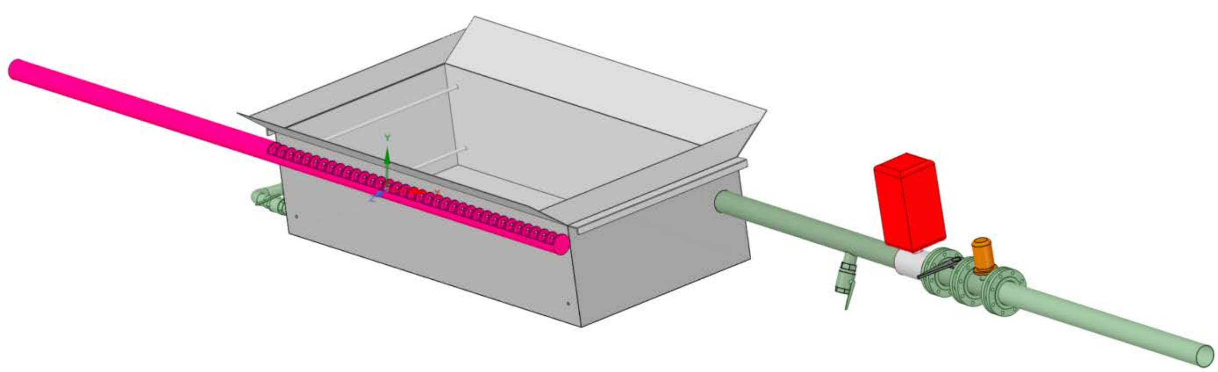


A steel wire is coiled around the drum, on which the edge of the knife is scrapping to remove the excess of the filter cake. The knife is a long stainless steel sheet attached to the sludge tank.

Filter cloth

The cloth is the most important element of the system. It is designed to let water flow through while retaining the solids on its surface. The parameters of the cloth are designed specifically for each application to obtain the optimal filtration.

Sludge tank

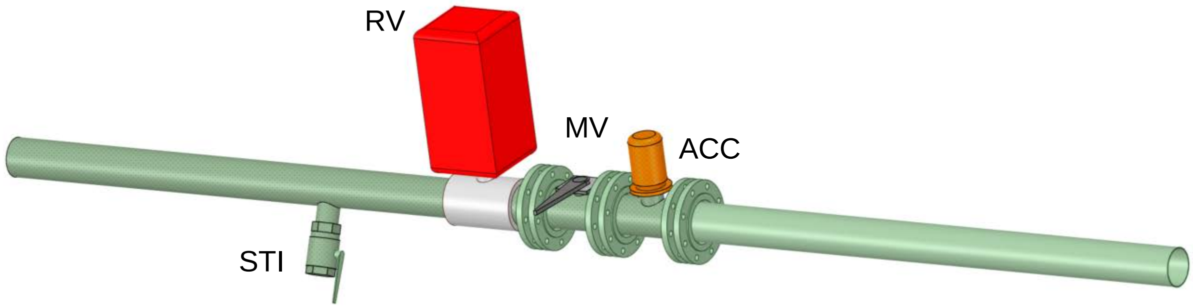


The sludge tank is a stainless steel tank used to contain the sludge in which the drum is immerged, as well as supporting the drum. The inlet pipe is equipped with a regulating valve, in red in the drawing above. A draining outlet, present on the back side of the tank, can be used to empty and clean the tank. The tank also includes 1600 inclined transversal steel tubes used for condensation.

The inlet pipe has a sampling valve to collect samples of the incoming sludge.

Inlet pipe

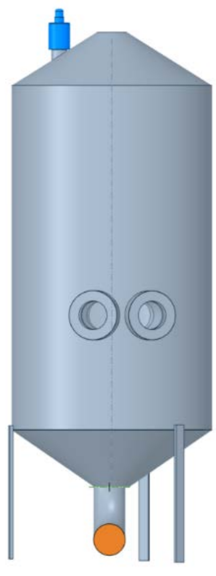
The inlet pipe leads the sludge from the buffer tank to the sludge tank. Three components are attached to the inlet pipe: an actuator, a manual valve and an electric valve.

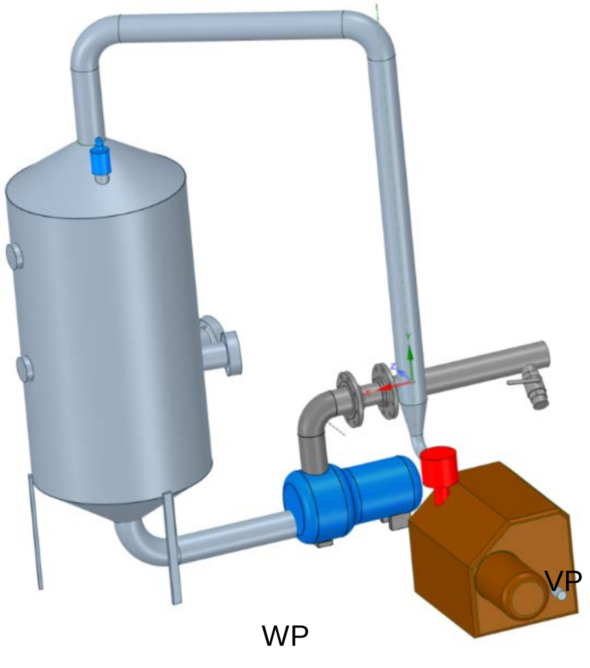


drum.

Vacuum tank

The vacuum tank is a steel structure acting as the receiver of the filtrate that has gone through the filter.





The top and bottom pipes on the cylindrical surface linked to the drum are for the air and water flows respectively. The pipe on the top cone is connected to the vacuum pump, while the one at the bottom cone is connected to the water pump.

Two small windows are present on the side of the tank. They can be used for maintenance and monitoring.

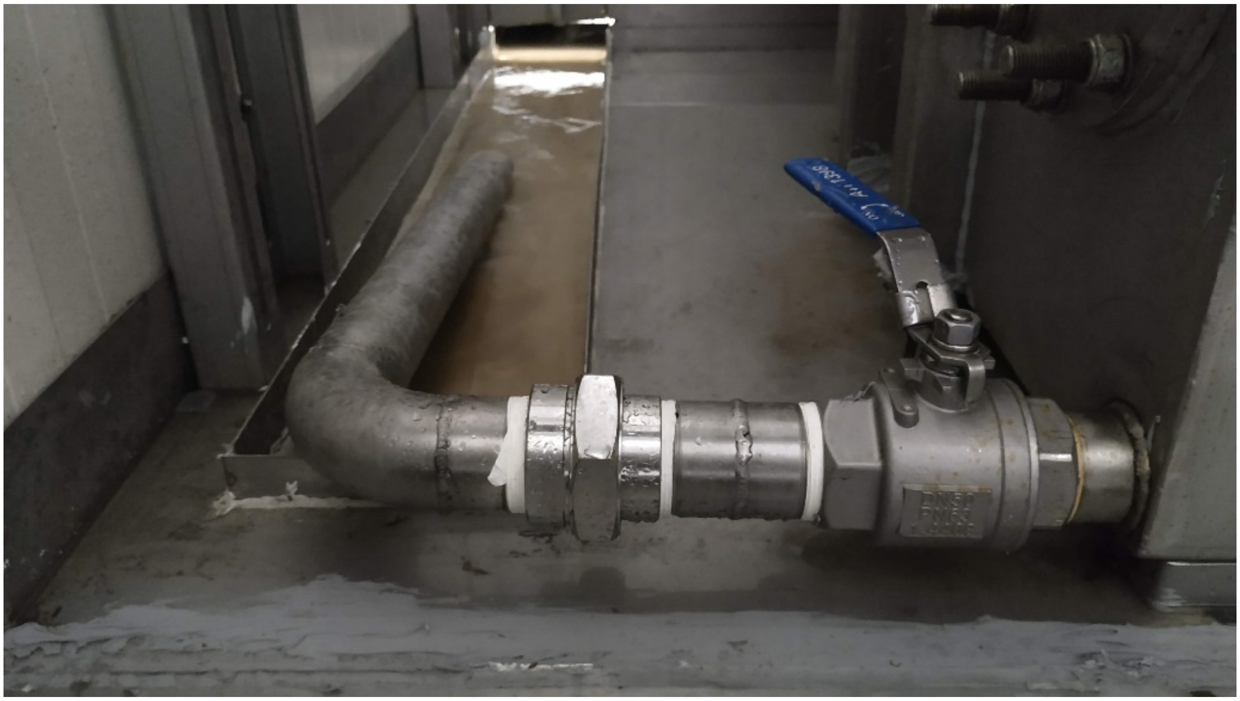
Drive Unit

The drive unit is used to rotate the drum. In order to provide a consistent and uniform motion, a chain and a chain wheel are used. The chain is welded on the inner side of the drum.

Figure 5: Picture of the drive system.

Drainage system

A valve is located at the bottom of the sludge tank and connected to a drainage hole included in the floor of the house to empty the sludge tank in a simple manner.



Water pump

The system is equipped with a 4kW water pump that pumps the water out of the vacuum tank. This pump needs to have a large flow capacity and suction head. Indeed, the vacuum in the tank counteracts the work of the pump, which needs to overcome the low pressure. A check valve needs to be placed on the discharge side of the pump.

A sampling valve is located after the non-return valve to take sample of the clarified water.

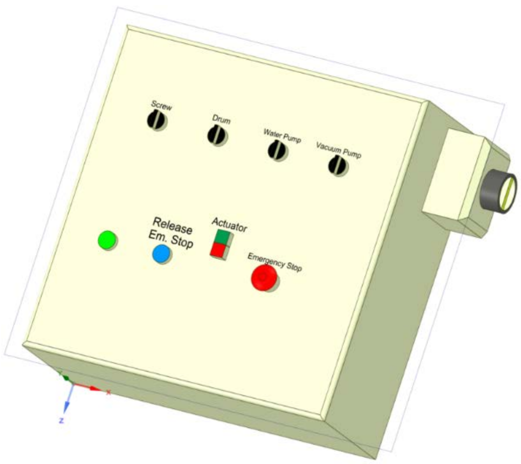
Vacuum pump

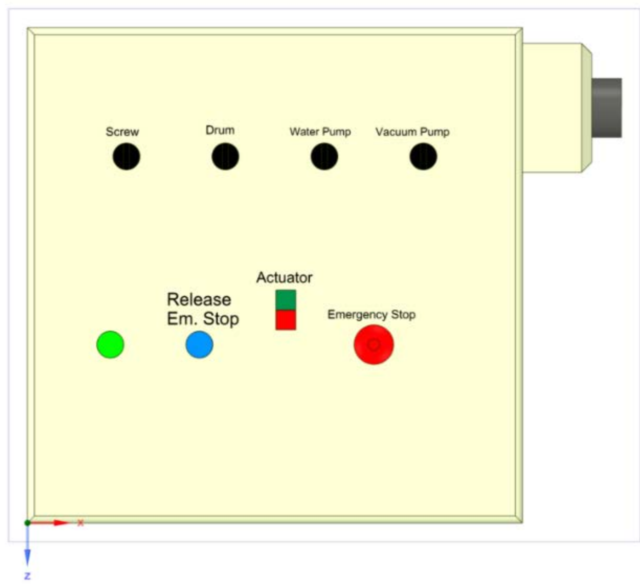
The vacuum pump is connected to the vacuum receiver used to create the vacuum needed in the system and pull the filtrate through the cloth. The pump used is a 6.5kW claw pump capable of achieving an absolute pressure of 200mbar with a 300m^3/h airflow. The pump is equipped with an air filter protected the pump from particles.

Control panel

The control panel is used to start and stop the system and the different units. The main switch is located on the side of the box. An emergency stop push button is present and needs to be engaged to start the system. When turning on the main switch, the blue light should be turned on and the emergency stop engaged; this button should then be pushed so that the green light turns on. The black buttons can then be used. The four top buttons are used to start/stop:

- the screw
- the drum
- the water pump
- the vacuum pump





Pump controllers

Pump controllers are installed to monitor the proper functioning of the pumps. It delivers real-time control and protection of the pumps. The overall energy consumption of the pumps is reduced, and the risk of failure greatly reduced.

Screw conveyor

After the filter cake is scrapped off the cloth by the knife, it falls towards the screw conveyor to be conveyed out of the housing.

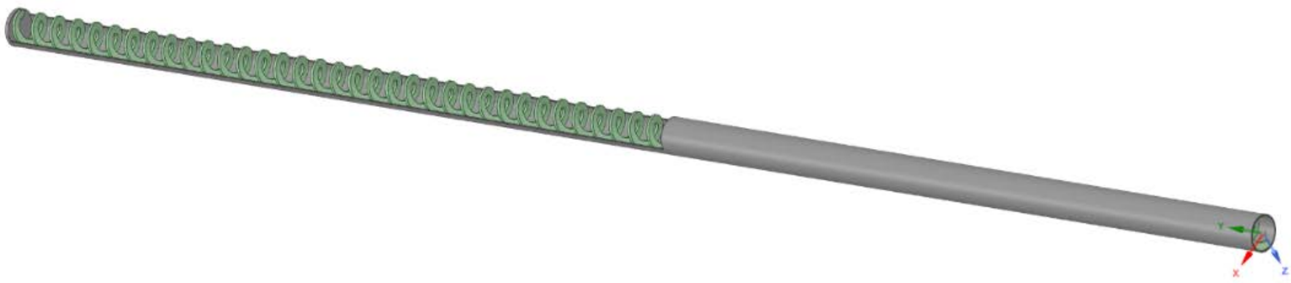
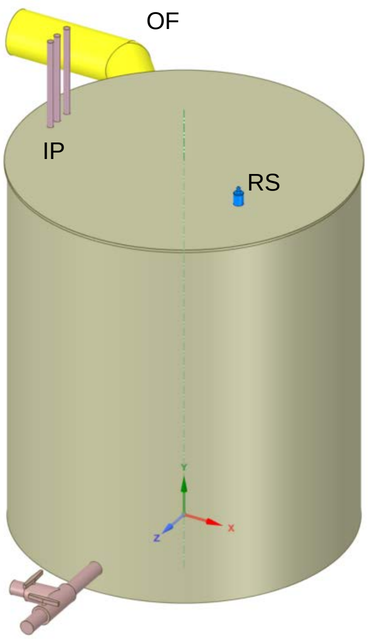


Figure 6: Screw conveyor motor

Buffer tank



The buffer tank is used as a buffer in the filtering system. It would be problematic to have a "lean production" approach because the sludge flow and its composition can vary. Therefore, a large reservoir is used to store the waste water and can cover for needs in more or less flow into the system.

The tank does have multiple inlet pipes that deliver the sludge. An overflow pipe (in yellow on the figure) is present in case the incoming sludge flow is too important.

A level sensor is located at the top of the tank to monitor the sludge level in the tank.

Two valves are present on the outlet pipe, one is used for drainage and the other one leads to the main circuit of the filtering system.

Housing

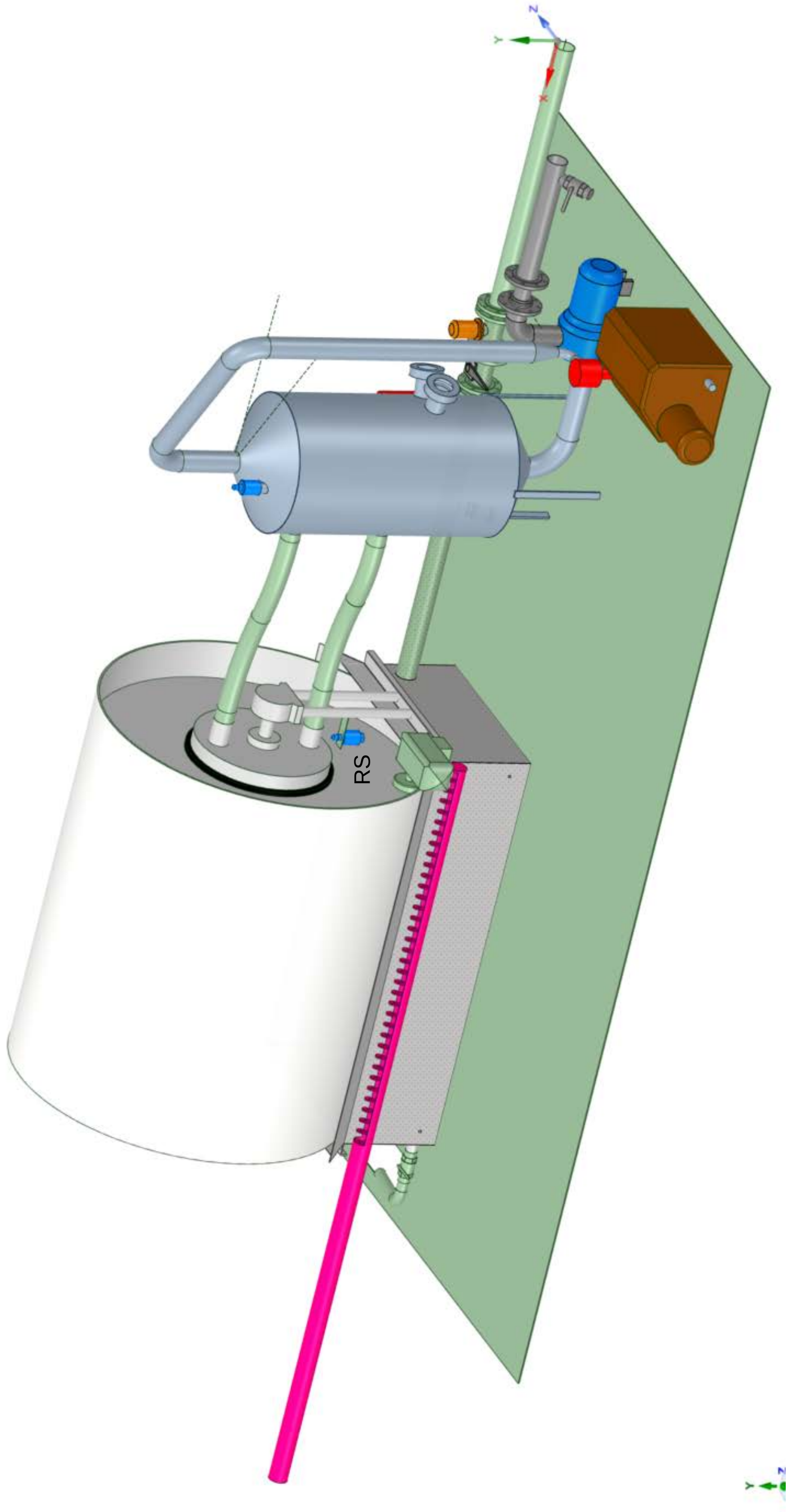
The house containing the filter and all the other components is heat and noise insulated. The floor is made up of stainless steel plates that are elevated from the actual ground for drainage purposes. The electric cables of the different components inside the house are all gathered into electric pipes.

Material

The material used for metallic parts is stainless steel 316L. This material was chosen for its great durability and corrosion resistance. It is also a great choice when a lot of welding is involved.

Figure 7: Outside views of the house – from top to bottom, left to right, side of the house / entrance door and screw conveyor / sludge inlet and filtrate outlet

Figure 8: Pictures of the drum without and the cloth and during installation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C. SPECIFICATIONS AND RESULTS

C.1 Pre-tests

Tests were done to assess the capability of the cloth to filter sludge. Fish sludge is a special type of waste which differs from other common wastes because of its low dry matter. Fish sludge can have as low as one hundredth the dry matter content in other sewages, at rates around 100mg/l. The suspended solids are also remarkably small, with an average size of xx and about 25% of them being smaller than 1µm.

The cleaning process is done without any additives or extra substances.

The rotary vacuum filter uses a patented membrane that utilizes the difference in partial pressure between solvents and solids. On the outside of the membrane, a filtering cake made of dry matter is built-up, which together with the membrane cleans the waste water and dries the cake.

The test are small scale experiments of the unit, using a small piece of cloth.

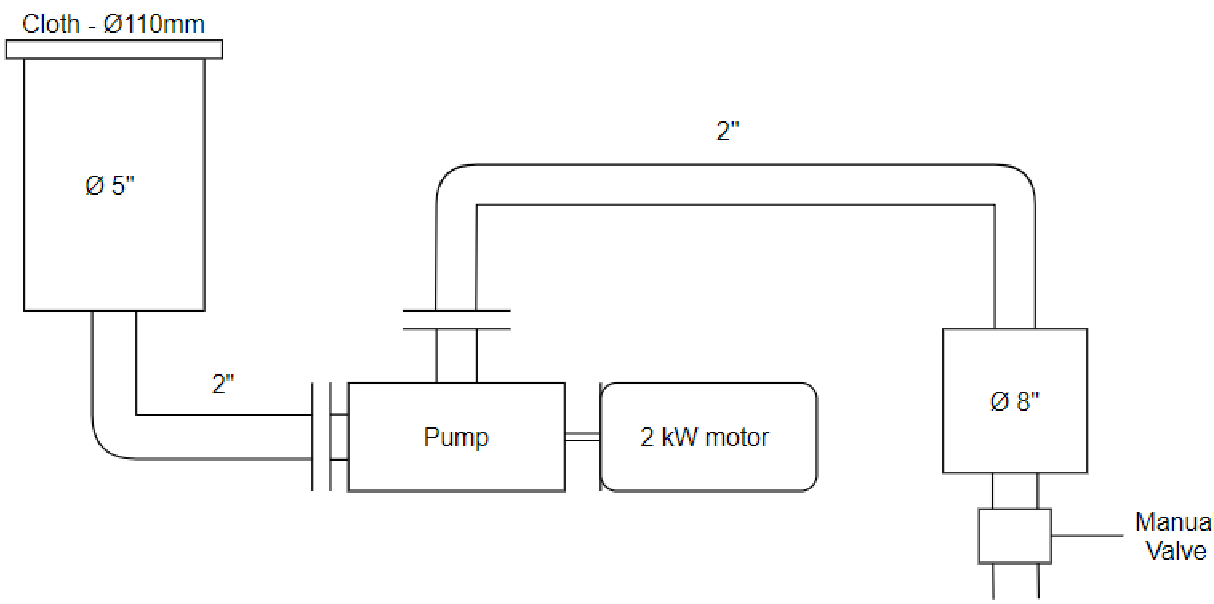


Figure 9 Schematic representation of the test experiments

Test I

Water flow: 5 L/min
Cloth diameter: 110 mm
Absolute pressure reached: 0.2 bar

Results

- Dry cloth
- Product on cloth – creation of a cake on the cloth.

The cloth is working as expected for a flow of 5 L/min. This test gives a theoretical capacity for the total surface of the filter of 526 L/min.

Test II

Water flow: 7 L/min
Cloth diameter: 110 mm
Absolute pressure reached: 0.1 bar

Results

- Wet cloth
- The low pressure is locking the cloth and it cannot function properly
- Poor results on the cloth

C.2 Analyses

Laboratory analyses are conducted to determine the exact composition of the sludge to be treated. The dry matter content and particle size distribution are assessed to get an accurate depiction of the sludge (see Figure below). This is important to assess the feasibility and the results that can be expected from a specific sludge type.

C.3 Results

Analyses concluded that the present filter has a high filtration capability of over 95%. The filtrate is clear

Analysis

Malvern Instruments

Malvern

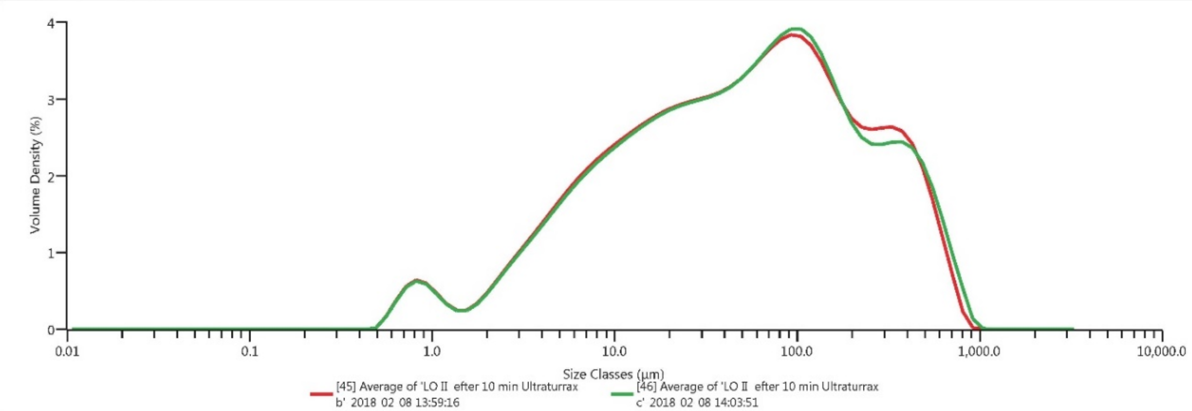
Measurement Details	
Operator Name	Mastersizer 3000
Sample Name	Average of 'LO II efter 10 min Ultraturrax b'
SOP File Name	Laxodling.msop

Measurement Details	
Analysis Date Time	2018-02-08 13:59:16
Measurement Date Time	2018-02-08 13:59:16
Result Source	Averaged

Analysis	
Particle Name	Sawdust
Particle Refractive Index	1.530
Particle Absorption Index	0.100
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.55 %
Laser Obscuration	7.22 %

Result	
Concentration	0.0114 %
Span	6.457
Uniformity	1.865
Specific Surface Area	530.5 m^2/kg
D [3;2]	11.311 µm
D [4;3]	113.001 µm
Dv (10)	5.024 µm
Dv (50)	51.011 µm
Dv (90)	334.386 µm

Frequency (compatible)



Result

Size (µm)	% Volume In	Size (µm)	% Volume In	Size (µm)	% Volume In	Size (µm)	% Volume In	Size (µm)	% Volume In	Size (µm)	% Volume In	Size (µm)	% Volume In	Size (µm)	% Volume In	Size (µm)	% Volume
0.010	0.00	0.046	0.00	0.214	0.00	0.991	0.39	4.583	1.37	21.205	2.44	98.114	3.19	453.960	1.77	2100.416	0.
0.011	0.00	0.053	0.00	0.243	0.00	1.125	0.27	5.207	1.51	24.092	2.47	111.473	3.09	515.772	1.42	2386.415	0.
0.013	0.00	0.060	0.00	0.276	0.00	1.279	0.20	5.916	1.64	27.373	2.50	126.652	2.91	586.001	1.00	2711.357	0.
0.015	0.00	0.068	0.00	0.314	0.00	1.453	0.20	6.722	1.76	31.100	2.53	143.897	2.69	665.793	0.58	3080.544	0.
0.017	0.00	0.077	0.00	0.357	0.00	1.651	0.27	7.637	1.86	35.335	2.57	163.490	2.46	756.449	0.17	3500.000	
0.019	0.00	0.088	0.00	0.405	0.00	1.875	0.39	8.677	1.95	40.146	2.63	185.752	2.29	859.450	0.00		
0.022	0.00	0.100	0.00	0.460	0.00	2.131	0.54	9.858	2.04	45.613	2.71	211.044	2.19	976.475	0.00		
0.024	0.00	0.113	0.00	0.523	0.13	2.421	0.68	11.201	2.12	51.823	2.82	239.780	2.17	1109.435	0.00		
0.028	0.00	0.128	0.00	0.594	0.31	2.750	0.82	12.726	2.20	58.880	2.94	272.430	2.19	1260.499	0.00		
0.032	0.00	0.146	0.00	0.675	0.47	3.125	0.95	14.458	2.27	66.897	3.05	309.525	2.20	1432.133	0.00		
0.036	0.00	0.166	0.00	0.767	0.54	3.550	1.09	16.427	2.34	76.006	3.15	351.670	2.16	1627.136	0.00		
0.041	0.00	0.188	0.00	0.872	0.50	4.034	1.23	18.664	2.39	86.355	3.20	399.555	2.02	1848.692	0.00		

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Figure 10: Particle size distribution of fish sludge

LABORA

NORSK AKKREDITERING TEST037

Sundsfjord Smolt A/S
Sundsfjord
8120 NYGÅRDSJØEN

Dato: 01.06.2018
Prøve ID: 2018-2894
ver 2

Gjelder: **Sundsfjord Smolt**

PRØVINGSRAPPORT

Prøvemottak: 29.05.18 Analyseperiode: 29.05.18 09:40 - 01.06.18

2018-2894-1 **Avløpsvann** Tatt ut: 28.05.18 15:35
Sted: Sundsfjord Smolt, før rensing
Merking: Avløpsvann. inlet sludge

Parameter	Metode	Resultat	Enhet	Måleusikkerhet
Suspendert stoff	7) NS-EN 872	**100**	mg/l	± 15
COD-Cr (kjemisk oksygenforbruk)	ISO 15705	**219**	mg/l O	± 33
*Suspendert stoff, membranfiltrering29)	Intern	**100**	mg/l	± 15

2018-2894-2 **Avløpsvann** Tatt ut: 28.05.18 15:35
Sted: Sundsfjord Smolt, etter rensing
Merking: Avløpsvann. outlet filtered

Parameter	Metode	Resultat	Enhet	Måleusikkerhet
Suspendert stoff	7) NS-EN 872	**4**	mg/l	± 1
COD-Cr (kjemisk oksygenforbruk)	ISO 15705	**<30**	mg/l O	
*Suspendert stoff, membranfiltrering29)	Intern	**3**	mg/l	± 1

*) Laboratoriet er ikke akkreditert for denne analysen
7) Glassfiberfilter Whatman GF/C benyttet til analyse.
29) Membranfilter 0,45µm Whatman benyttet til analyse.

< betyr: Mindre enn

Med vennlig hilsen

Kari Eidem

Kari Eidem
Fagleder kjemi

Kopi til
Sundsfjord Smolt A/S, Line Holm (E-mail)

Analyseresultatene gjelder for analyser av de angitte prøver i den stand de ble mottatt Labora AS.
Måleusikkerhet for mikrobiologiske analyser fås oppgitt ved henvendelse til laboratoriet.
røvetaking er ikke omfattet av akkrediteringen.
porten skal ikke kopieres i ufullstendig form, uten skriftlig godkjenning fra Labora AS.

Side 1 av 1

bora AS Klinkerveien 8, 8006 Bodø Telefon: 75 56 63 00 www.labora.no E-post: firmapost@labora.no Org.nr.: 986 284 311 MVA

Figure 11: Test results from samples of sludge before and after the filtration process

D. GETTING STARTED

D.1 Turning on

System off, inlet valves of the system closed, the holding tank should have a pipe linked to the reject water to keep a flow in the tank and avoid sedimentation.

When starting the system:

- Turn on the main switch
- Check that the emergency button is engaged
- Press the blue button
- If the green lamp turns green, the system is ready

D.2 System running

In normal running conditions the system has the following parameters:

Operating pressure in the vacuum tank: 0.25 bar
Water flow in the system: 15 to 20 l/s

The controllers and sensors are providing a fully automated system that can run indefinitely. No human monitoring is needing while the system is running.

The parameters to be set on the pump controllers are:

- Target pressure on the vacuum pump controller – set at 3.0 psi
- Target water height in the vacuum receiver on the water pump controller

The pump controllers allow the operator to monitor several parameters such as the RPM of the pumps, the current used, and the data given by the different sensors of the system.

D.3 Electrical parameters

The system uses a three-phase four-wire system, with each component separately earthed. The electric supply is 400V 32A, and the measured total current in the system is below 15A. This means that under normal conditions, the system has a total power of around 10kW.

D.4 Cake build-up

A rotary vacuum filter needs a constant vacuum to function properly. Thus, when starting up the unit with no filter cake around the cloth, the vacuum will not be strong enough because the cake is usually working as a seal increasing the vacuum.

Therefore, a special procedure is needed to build-up a filter cake over the surface of the cloth.

- Set the plastic cover over the cloth
- Verify that the cover is sitting right and covering the whole emerged surface of the cloth
- Set the rubber bands holding the plastic tightly around the drum
- Turn on the main switch
- Turn on the drive unit to rotate the drum
- Start the vacuum pump (the reference pressure is set at 99.9cm)
- Set the reference pressure down to 70 cm
- When the vacuum has reached -0.3 bar, start the water pump
- Reduce gradually the reference pressure down to 35 cm
- The vacuum pressure in the vacuum tank should reach -0.65 bar (i.e. 0.35 bar absolute pressure)
- The system now sucks water through the cloth, and the water level increases in the vacuum tank. The water pump starts when the level reaches 40 cm. The water pump then runs continuously.
- A cake forms on the surface of the cloth. When the filter cake reaches the desired thickness (roughly 2 mm), the drum can be rotated, and we can begin building up a cake on the following sections of the drum.
- The plastic cover is rolled up on one side of the immersed part, uncovering part of the cloth
- The drum is rotated so that the previously immersed part – now covered with a filter cake, takes the place of the uncovered part of the drum.
- The process is repeated until the whole surface of the cloth is covered with a 2 mm thick layer of cake

With this method, the plastic cover is gradually rolled up and the “seal” provided by the cover is progressively replaced by the cake. The whole procedure of building up a cake on the cloth takes around 5 hours but only requires to be done when the system is stopped and restarted completely.

A steel wire is coiled around the cloth to prevent the knife from ripping the cloth. It also keeps a constant 2mm thick filter cake around the cloth.

Figure 12: Installation of the plastic cover

D.5 Stop procedure

To avoid having to build-up the filter cake in case the system needs to be stopped for a short time, a special stop procedure needs to be followed:

- The water supply is stopped
- Once the water level in the sludge tank has gone down enough leaving the drum fully emerged, the sludge tank is slightly drained to leave clearance to the drum
- The rest of the system is kept on until no water comes out of the drum
- The drum drive unit is stopped
- The water pump is stopped
- The vacuum pump is stopped

This way, the filter cake on the surface of the cloth reaches a low moisture level, and is densely packed to hold onto the filter cloth until the system is turned on again.