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From Pilot Studies to Full Scale Plant

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Natural gas is widely used as a primary energy source and is one of the most efficient fuel source. For this reason, more and more gas is utilized exceeding existent production facilities. Oil and gas companies therefore expand there measures and step behind borders finding and exploit new resources.
One area of major interest is the Barents Sea, a remote area far from industry and civilisation. There climate conditions, deep water approach and a very sensitive ecological environment are challenging. In the Barents Sea the gas is exploited some hundred miles off the shore and delivered through subsea installed pipelines to an onshore liquefaction plant. But the natural gas does not float through the pipeline that easy. The crude is a mixture of mainly hydrocarbon gas-hydrocarbon condensate-water fluid, contaminated with formation water and corrosion products. The system pressure may lead to clogging of the pipeline due to the gas hydrate formation inside the pipeline. This is a major incident, which has to be prevented under any circumstances. Historically methanol is used to inhibit the clogging. Since the northern Atlantic region and the Barents Sea bear very sensitive ecological systems, mono ethylene glycol (MEG) is used instead as a “green chemical” for inhibition at the wells. Despite of its price, MEG has the advantage of dissolving more salts in the solution than methanol does.

In this case, recycling is not that easy. In a first step solid, gaseous and liquid fraction has to be separated; this is done by the slug catcher. The gas is processed in the gas plant, the solids are discharged and the liquid, a MEG – water mixture processed further. In one step the remaining fine particles are removed, then the salt content is taken out followed by the distillation to a certain MEG – water ratio. At the end the purified MEG is stored and sent back to the wells in order to keep the production running.

In the MEG purification and recycling process the solid removal appeared as a still not sufficiently solved problem. The solids, corrosion products from the production pipeline and scale, together with the adherent condensate cause scale formation at downstream heated surfaces. The heaters needed to be shut down for mechanical cleaning periodically. This standstill for cleaning had to be avoided in a new production facility, built at the polar cycle by STATOIL, near Hammerfest: the Snøhvit project. New technologies were demanded. There are many filtration technologies available for purification of liquids. In this case EnviroChemie has chosen the membrane filtration with the main advantages of continuous operation and low to no solid contain of the filtrate. Opposite to gravity filtration the liquid in membrane filtration is routed perpendicular to the filtration surface. So the system is operated at higher solid concentration compared to other filtration techniques.

Pilot Test Laboratory

The first approach was done using the laboratory scale test plant. There a MEG-water sample from the slug catcher from an existing gas plant was shipped to EnviroChemie laboratory. Different plant settings were to be tried. Different materials of membranes and different pore sizes were applied. Ceramic membranes were used as stick membranes where the polymer membranes are of tubular construction. For plastic material polypropylene and PVDF were chosen for the filtration trails. In the pilot tests polypropylene membranes revealed the best performance regarding filtration rate per area and time. The filtration rate was stable over the whole filtration time of one day. Based on this result a small scale plant was designed to run field tests for a longer period of time on the gas production site.

Field Test

The field tests were scheduled at an onshore natural gas production plant. There special precautions have to be considered. Especially the safety terms has to be read twice to get the allowance to find entry to the plant, the Envopur® MFI 8 of EnviroChemie. The wiring and switch cabinet were all executed according the ATEX – regulations and local country specific regulations. These inputs were adapted to the test plant, the plant was inspected at the work shop by the customers authorities and finally delivered to its designation.

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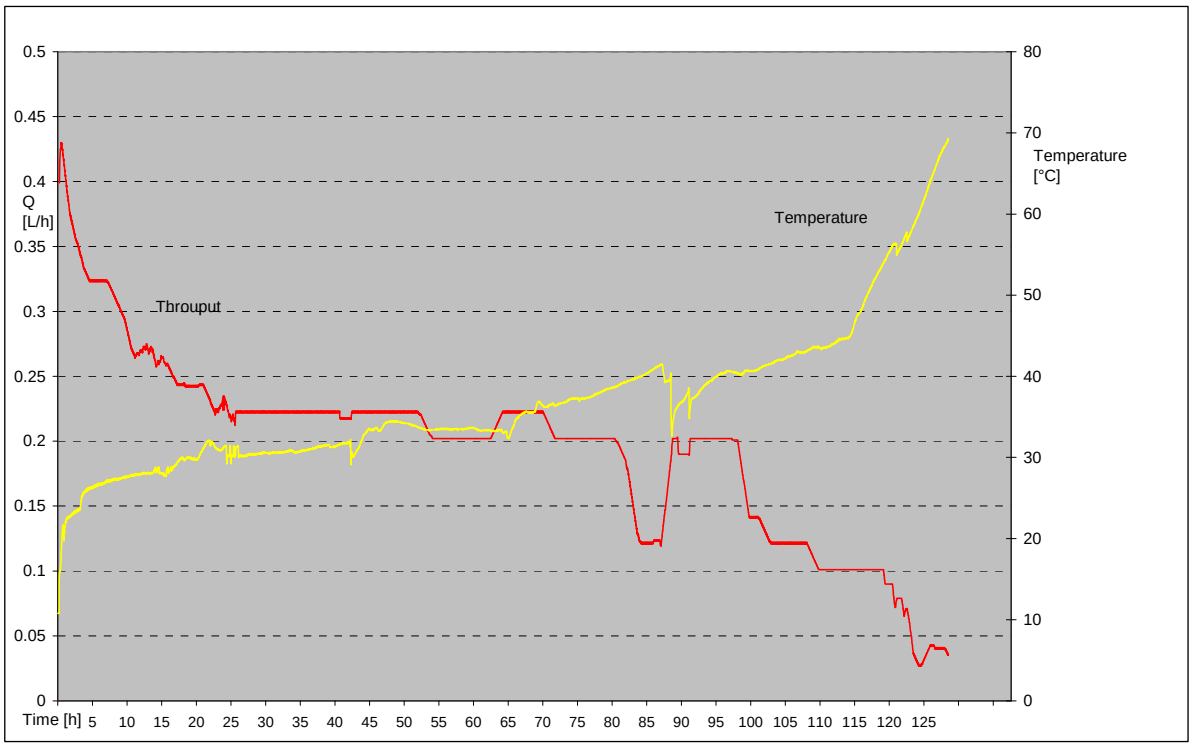
View of the pilot plant Envopur© MFI 8

The filtration of MEG began with the most promising membrane system, the polypropylene membrane assembly. At the test site a similar MEG, in terms of solids and water content which was expected to occur at the Barents Sea, was used. But first of all the solid concentration was adjusted by concentration of the solids. Then long term exposure of the membrane system was intended to do. Here the filtration rate against time and filtration rate against solid concentration in the feed volume was examined. The optimum filter length was determined as well. The filtration was started with the long arrangement.

As the filtration rate was less then already observed in the workshop testing, shorter membranes were implemented. The filter elements were shortened to find an efficient balance in terms of feed volume and efficient filtration rate. The most important to know was the filtration time in between the two cleaning events. Several filtration scenarios were done finding an optimum. The test plant therefore was designed to run completely automatically in order to operate overnight without any process uncertainty or safety violations.

Diagram1: Filtration Run



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The diagram shows the filtration rate against running time. The less the filtration rate the higher the temperature in the system rise. The circulation pump added more energy to the system than, on steady state, the filtrate is taking out. The full scale plant would be equipped with a heat exchange system therefore. The filtration rate then was determined in terms of pressure and volume flow per filtration circle. Following the filtration rate was optimised applying a back-washing pulse periodically. Did the filtration rate drop below a level set before; a chemical cleaning sequence was done. Here the optimised cleaning procedure regarding chemicals used, temperature and cleaning time were investigated. After the cleaning the filtration started again at the expected high level. One major point of interest is the concentration factor which could be archived. For this experiment the assembly was changed in order to concentrate the feed MEG as high as possible. The aim was a solid concentration of at least 5% in the concentrate; this could be reached under normal filtration conditions. The membrane plant was operated at an unchanged operation mode and was working without significant loss of filtration rate. Testing was extended using other membranes. The test skid was re-assembled for the recommendations of synthetic membranes as PVDS-membranes or the ceramic stick module arrangement. But both membrane types failed, had low throughput and did not outperform the polypropylene-system.

Full Scale Plant

The field tests described above set the foundation to a full scale plant. The whole arrangement of the Envopur® MFI micro filtration plant is divided into three main filtration trains and two concentrate filtration train. The safety margins were respected at the 3 x 50% design of the plant regarding the nominal throughput. The whole plant is accessible to CIP cleaning, each filtration train independently. All the loops can be emptied completely avoiding cross-contamination of the different liquids used in operation and rinsing. The rinsing and cleaning volumes are provided at the skid in nearby tanks.
The whole plant is constructed as a stand alone unit. All the pumps, piping, membrane arrangement and the CIP-station are fitted into one unit. The unit is sheltered and equipped with HVAC-system avoiding overheating of the unit or freezing of rinsing pipes in winter time.

Partial view of the full scale plant Envopur® MFI of EnviroChemie GmbH

Duplex is the preferred steel quality in the liquid containing loop. All other materials were decided to be not stable enough in this corrosive environment. Carbon steel with a suitable corrosion allowance was not indicated because of the corrosion products removing intention of the membrane filtration plant.

A fully automated plant was demanded by STATOIL and Linde, the executing engineering company in charge in this project. All process relevant switches and pumps were executed in automatic version. The signals coming from the field measurement equipment were all routed to the main control room. The CIP-procedure still remains with a manual starter, to be activated in the control room.

Summary

The MEG recycling is an important feature in the production natural gas if the well is some hundred miles offshore and logistics of any utilities are difficult. In this approach EnviroChemie has developed together with STATOIL / Linde a solid removal technology in order to maintain and ease further downstream processes in terms of availability and process stability. The core process is a membrane filtration technology using symmetric polypropylene membranes. The design of the plant is based on a minimum of 50% spare capacity. The filtration and cleaning process were examined in field test using a pilot plant for oilfield purpose. The results of that test had an impact for the design and arrangement of the full scale unit.

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This very time intensive engineering and constructing were done under an extreme time critical schedule. In total, the adaptation of membrane filtration to the oilfield specification under harsh climatic conditions has succeeded, finished successfully and executed on time.

MEG feed MEG filtrate settled concentrate
Filtration results