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CCR MEG RECLAIMING TECHNOLOGY: FROM MOBILE UNITS TO THE LARGEST RECLAIMING UNIT IN THE WORLD



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Abstract

The formation of hydrates in deep sea natural gas tie-back lines had been traditionally inhibited by injecting Triethylene Glycol (TEG) or Methanol at the subsea manifold. Unfortunately, gelling of the TEG at the manifold or in the delivery umbilical and lack of recovery of the methanol were persistent drawbacks to their continuous use. CCR Technologies Ltd. (CCR) was instrumental in moving the offshore flow assurance mindset away from TEG and Methanol and towards Monoethylene Glycol (MEG) as the hydrate inhibitor of choice for multiphase tie back production lines. CCR designed and delivered the first commercial MEG Recovery Unit (MRU), which was started up in 1999 for Shell Mensa WD-143 Offshore Project in the Gulf of Mexico, USA. At the time, Mensa was the deepest off-shore production in the world with the MRU on-line >95% since then.

Flow Assurance can be loosely defined as ensuring that production is delivered from the wells to the downstream processing facility with a high level of availability. The injection of Lean Glycol (to avoid hydrate formation) is part of that Flow Assurance Loop. Therefore, it is critical to understand the production profile and glycol needs throughout the life of the facility so that the MRU can be properly designed. The MRU may include Pre-Treatment, Regeneration, and Reclamation in several different configurations.

This paper outlines some of the information required to properly specify a MRU and follows the decision points and opportunities for optimization that arise as the design develops from initial concept to a more detailed proposal. Although the MRU is typically considered a utility within the plant, the impact it can have on flow assurance should not be overlooked.

Following an agreement signed between CCR and PROSERMAT, PROSERMAT is now the exclusive licensor of the MEG Reclaiming patented and proprietary process developed by CCR.

1. Introduction

A newly discovered field located 50 km off-shore, will be developed over the next five years with production expected to come on-line in 2019. The production will be brought onshore where it will be processed and delivered to customers and other downstream processes. Given the location of the subsea wells and the production pressure/temperature profile, glycol injection will be used to prevent the formation of hydrates. The Process Design Basis (Table 1) shows the information received from the Flow Assurance Engineer.

Rich MEG delivered to the MEG Recovery Unit typically comes from the plant slug catcher and inlet separator. This liquid feed typically contains a high level of dissolved hydrocarbons (Range 0.5-2.0 vol%), including a high concentration of CO₂. If left in solution, these hydrocarbons could accumulate in the process, leading to foaming, reduced boiling, or throughput issues with the Vacuum Compressor. In order to remove these dissolved hydrocarbons, a Rich MEG Flash Vessel will be included in the design.

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Table 1. Process Design Basis

Condensed Water Flow	2.0	m ³ /h
Formation Water Flow	12.0	m ³ /h
Formation Water TDS	50,000	mg/l
Rich MEG Concentration	35.0	wt%
MDEA in Rich MEG	1.5	wt%
Lean MEG Concentration	85.0	wt%
MEG Recovery	99.5%	
Plant Availability	95.0%	

2. MEG Recovery Unit Configuration

The Rich MEG has a salt content of 2.4 wt% and the Lean MEG specification is 85 wt% MEG on a salt-free basis. Assuming the Regenerator section of the MRU only removes water, the Lean MEG exiting the Regenerator will contain 5.82 wt% salts. At this level of salts, the Lean MEG will contain free solids which will precipitate out inside the Regenerator. This precipitation will likely occur on the outside of the tubes in the kettle reboiler, which will lead to scaling, fouling, local hot spots, and reduced throughput.

There are several different configurations and options that can be considered as part of the MEG Recovery Unit. Figure 1 provides a high level decision tree that can be used to determine which configuration and options are appropriate for any application. There is some leeway in the application of this tool which is based on experience gained during the last fifteen (15) years.

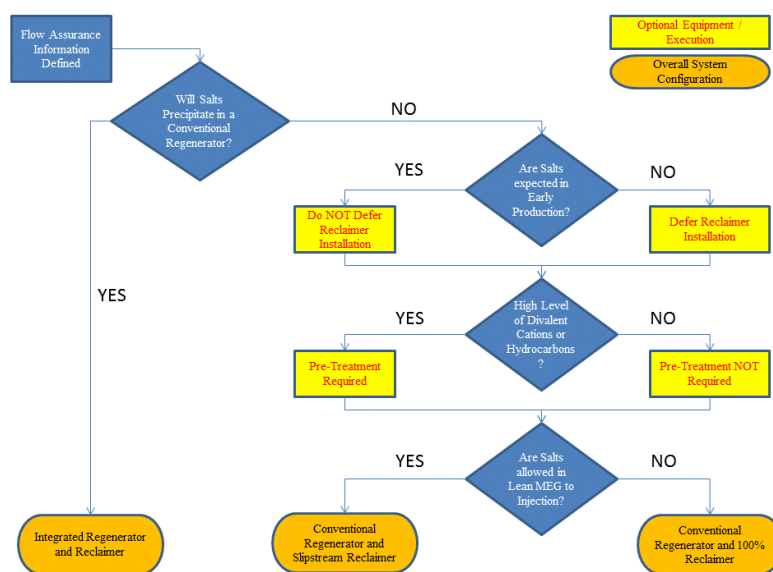


Figure 1. MEG Recovery Unit Configuration Decision Tree

It has already been determined that a conventional Regenerator will result in precipitated salts, which leads us to an Integrated Regenerator and Reclaimer design. The Integrated unit achieves the water removal (Regeneration) and salt removal (Reclamation) in a single process. It was also identified above that there would be the need for some level of Pre-Treatment due to the high level of dissolved hydrocarbons. A Process Flow Diagram of the chosen configuration is shown in Figure 2.

If the selection process above came up with a Conventional Regenerator and Slipstream Reclaimer, a detailed salt study should be carried out. This salt study investigates the individual salt species (cations and anions) and determines their accumulation, solubility, and likelihood of scaling throughout the entire Flow Assurance Loop. Using the results of this study, the optimum amount of salt removal can be determined which will result in a smaller Reclaimer Process. The study will also determine what level of Divalent Cation Removal (DCR) is necessary.

2.1. Process Description

The Rich MEG is fed to the unit from the upstream facilities and letdown across the inlet level control valve. This valve reduces the pressure of the Rich MEG, allowing some of the dissolved hydrocarbons to vapourize out of the solution. In order to promote mixing and time for chemical reactions to occur, a small amount of NaOH solution is injected into the Rich MEG before entering the Rich MEG Flash Vessel (V-1010). This caustic ensures that any calcium and magnesium ions present precipitate as calcium chloride or calcium hydroxide and magnesium hydroxide within the Reclaimer. If the pH is too low (not enough caustic injection), the calcium can form a gel with the MEG, creating issues within the process.

Sufficient residence time is included in the design of V-1010 and three product streams exit the vessel. The hydrocarbon liquids and vapours are directed off-skid to appropriate hydrocarbon handling systems such as a low pressure flare or hydrocarbon drain system. The pH-adjusted Rich MEG is directed into the Reclaimer Flash Vessel (V-1000).

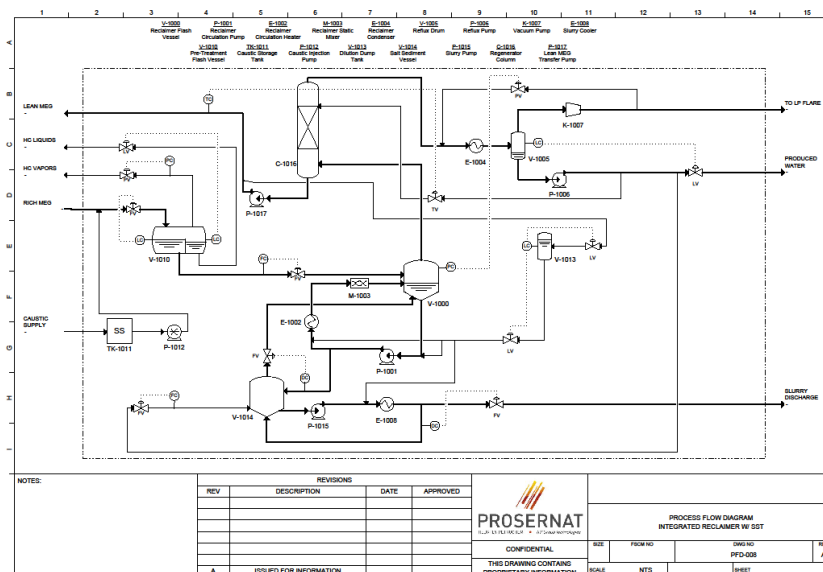


Figure 2. PFD of Integrated MEG Recovery Unit with Salt Sediment Tank

Rich MEG exits V-1010 and is injected directly into V-1000, the Reclaimer Flash Vessel. Vapours exiting V-1000 are directed into the Regenerator Column (C-1016). Both of these vessels operate at sub-atmospheric pressure. This allows the MEG/water mixture entering the vessel to vaporize at a temperature well below the degradation temperature of MEG (about 165°C). Upon flashing into the column, water and MEG will vaporize while Salts and other solids contained in the inlet stream will not vaporize and will instead become concentrated in the slurry within the Reclaimer Flash Vessel.

MEG/H₂O/salt slurry is continuously pumped from the bottom of the Reclaimer Flash Vessel through the Reclaimer Circulation Heater (E-1002) by the horizontal, centrifugal Circulation Pump (P-1001).

Boiling of the slurry circulating through the Reclaimer Circulation Heater is undesirable as it would result in solids deposition which would very rapidly foul the heat transfer surfaces. Boiling is therefore deliberately suppressed by imposing a “backpressure” on the heater using the Reclaimer Static Mixer (M-1003). In addition, a very large circulation rate is maintained through the heater to minimize the temperature rise of the slurry, the skin temperature inside the exchanger, and the time the slurry is in contact with the heat transfer surfaces. Use of these design techniques nearly eliminates the potential of fouling of the heat transfer surfaces even with divalent cations present.

Upon entering the Reclaimer Flash Vessel (V-1000), the water and MEG contained in the slurry will vaporize and flow upward through the vessel while the residual droplets of MEG/H₂O/salt slurry fall into the liquid pool in the base of the vessel. As a result, the salt and solids concentration of the liquid pool increases.

In order to maintain an acceptable level of solids in the circulation loop, a portion of the MEG/H₂O/salt slurry flowing through the recirculation loop is diverted to the Solids Handling area. A continuous “purge loop” of slurry is

pumped from the Circulation Pumps to the Solids Handling system of the plant and back to the Reclaimer. Maintaining a continuous flow ensures that solids do not settle in the lines leading to the solids handling system during low-flow, or intermittent flow conditions. In this manner, the free solids content in the recirculation loop can be maintained within a tight control band that results in optimal operating conditions for each specific application.

The purpose of the Salt Sediment Vessel (V-1014) is to allow sufficient time for the solids in the process to separate and concentrate before removal from the system. The slurry product exiting the vessel is cooled by the Slurry Cooler (E-1008). Slurry is removed from the bottom section by Slurry Pump (P-1015). The discharge from the Slurry Pump is directed into the Slurry Cooler and back to the Salt Sediment Vessel. When the solid levels increase to a pre-determined setpoint, a portion of the slurry in the bottom of the vessel is directed off-skid for disposal.

Vapors that exit the Reclaimer Flash Vessel travel upwards through a packed section within C-1016. These vapors are contacted countercurrently with reflux water which is injected at the top of the column. This results in a virtually salt-free Lean MEG product stream that exits the bottom of C-1016. A distilled water vapor stream exits through the top of C-1016.

Vapors exiting the top of C-1016 are condensed in the Condenser (E-1004). The condensed water then enters the Reflux Drum (V-1005) where liquid water is separated from any non-condensable vapors and pumped via Reflux Pumps (P-1006) either back to the tower as reflux or off-skid as a Produced Water product.

The vacuum in the Reclaimer is created by the Vacuum Compressor (K-1007). The vacuum is created as the non-condensable vapors from V-1005 and C-1016 are drawn into the Vacuum Compressor and compressed. The bulk of the vent gas stream exiting the Vacuum Compressor may then be delivered to the battery limit tie point for discharge to vent or into a LP Flare Header as required.

3. MEG Recovery Unit Optimization

The Process Design Basis (Table 1) provided by the client has established several performance criteria which must be met within the package. These criteria include MEG Recovery (>99.5%) and Process Availability (>95%).

3.1. MEG Recovery Criteria (>99.5%)

MEG Recovery is a performance criterion which is typically established by the client AND is determined by Equation 1.

$$RECOVERY = \frac{OUTLET_MEG}{INLET_MEG} \quad (1)$$

The MEG being fed into the unit has a mass flow rate of 8,724 kg/h. The MEG content in the Desalted Lean MEG product is 8,210 kg/h. Using Equation 1, the calculated MEG recovery is 94.1%. This is below the MEG Recovery dictated in the Process Design Basis and the process must be modified to improve the MEG Recovery.

Glycol is lost from the process through two main exit streams with the majority lost with the produced salts. In this configuration, the MEG lost in the Slurry Discharge is 514 kg/h. Table 2 shows the glycol losses and recovery for a few different process configurations.

In order to meet the MEG Recovery level of 99.5%, a centrifuge with water wash must be considered.

Table 2. Glycol Recovery

Configuration	Feed (kg/h)	Product (kg/h)	Waste Salt (kg/h)	MEG Recovery (%)
Salt Sediment Vessel	8,724	8,210	514	94.1%
Centrifuge	8,724	8,668	56	99.4%

Centrifuge + Water Wash	8,724	8,711	13	99.9%
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The largest source of glycol losses are through the Slurry Discharge. One method to reduce the amount of glycol losses in this stream is to consider a Centrifuge rather than a Salt Sediment Vessel. A Centrifuge is capable of producing a much drier (less glycol) salt cake stream than what the Salt Sediment Vessel can achieve. To further enhance glycol recovery, a wash step can be included in the centrifuge design. This wash step sprays the dried salt cake with Produced Water or recycled brine if it is part of the process, thereby displacing the glycol from the salt cake, reducing the glycol losses to a very low level.

3.2. Process Availability (>95%)

The Process Availability can be calculated using industry or client experience factors for each piece of equipment. Figure 4 shows a simple reliability model which determines the plant availability with no spare equipment included.

Equipment Tag	Qty	Description	Individual Availability	Combined Availability		
				Sparing	Without Sparing	With Sparing
V-1010	1	RICH MEG FLASH VESSEL	0.9920		0.9920	0.9920
P-1012	1	CAUSTIC INJECTION PUMP	0.9943	1	0.9943	1.0000
V-1000	1	RECLAIMER FLASH VESSEL	0.9920		0.9920	0.9920
P-1001	1	RECLAIMER CIRCULATION PUMP	0.9837	1	0.9837	0.9997
E-1002	1	RECLAIMER CIRCULATION HEATER	0.9980		0.9980	0.9980
V-1014	1	SALT SEDIMENT VESSEL	0.9920		0.9920	0.9920
P-1015	1	SLURRY PUMP	0.9837	1	0.9837	0.9997
E-1008	1	SLURRY COOLER	0.9980		0.9980	0.9980
C-1016	1	REGENERATOR COLUMN	0.9920		0.9920	0.9920
P-1017	1	LEAN MEG TRANSFER PUMP	0.9837	1	0.9837	0.9997
E-1004	1	RECLAIMER OVERHEAD CONDENSER	0.9991		0.9991	0.9991
V-1005	1	REFLUX DRUM	0.9920		0.9920	0.9920
P-1006	1	REFLUX PUMP	0.9837	1	0.9837	0.9997
K-1007	1	RECLAIMER VACUUM COMPRESSOR	0.9093	2	0.9093	0.9993
		Combined Reliability			0.8093	0.9542

Figure 4. MEG Recovery Unit Availability Analysis

The calculated reliability of the process is 0.8093 or 80.93%. The Design Basis dictates that plant availability must be >95% and modifications must be made to achieve this. By sparing key rotating equipment (bolded above in Figure 4), the reliability can be increased to 0.9542 (or 95.42%).

4. Other Considerations

In addition to meeting the criteria established by the client, there are other items which are reviewed and optimized as part of the technical review completed at this stage.

4.1. Heat Recovery

If a high value is placed on reducing utility consumption compared to the capital of additional heat exchangers, then heat recovery may be considered. Heat recovery is typically applied in a Lean/Rich Heat Exchanger, Slurry Cooler, and Rich MEG Pre-Treatment Heater. In this example case, the addition of a Lean/Rich Exchanger and Slurry Cooler results in a 5% reduction in heat load.

4.2. Impact of MDEA Based Corrosion Inhibitors

MDEA based corrosion inhibitors are commonly used in off-shore production facilities. One impact of including MDEA is the impact on design of the MEG Recovery Unit. There is not readily available public information on the distillation properties of glycol-amine-water systems with dissolved salts. However, CCR commissioned laboratory testing of the glycol-amine-water mixtures to obtain experimental data on these systems. From the results, proprietary software that can accurately predict the distillation properties was developed. This information enables

process engineers to predict how the system will behave, allowing more confidence in distillation design with greater accuracy for systems containing glycol and MDEA.

In this example case, using a conventional process simulator would have under predicted the operating temperature in the Reclaimer Flash Vessel by 27°C. This error in the operating temperature would have carried over into the design of the Reclaimer Circulation Heater leading to a surface area that is under sized by approximately 60%. As a result, using a conventional process simulator without the additional experimental data would have resulted in a design that would not be capable of achieving the required throughput.

5. Next Steps

With more than 130 references for glycol regeneration units (including TEG, DEG, MEG units) for both onshore and offshore application, Prosernat is today a leader in the design and supply of glycol units. As well, Prosernat has wide experience with floating supports (FPSO, semi submersibles) and has adapted its design to cope with effects of motion on equipment in particular with severe sea conditions such as in the North Sea.

Now that the preliminary design has been completed and the MRU configuration has been selected, additional details can be developed. Using the process model generated and proprietary equipment sizing procedures, a detailed Equipment List can be put together. Prosernat's team of engineers and estimators can put together a preliminary cost estimate and can inform the client about the site footprint, weight, utilities requirement and layout.

During project execution stage and at client's request, Prosernat can adopt a flexible approach including:

- either the license supply together with basic engineering and some limited proprietary items supply,
- or the complete supply of modular turn-key unit.

In both cases, Prosernat make available to its Licensee assistance at commissioning and start-up and after sales services such as regular technical assistance, analysis, training, supply of spare parts, and revamp studies.

6. References

- Offshore Reliability Data Handbook 4th Edition*, SINTEF Technology and Society, 2002.
KNETSCH, D., GROENEVELD, W.L., Alcohols as Ligands. III. Complexes of Ethylene Glycol with some Divalent Metal Halides, *Inorganica Chimica Acta* | 7:1 | March, 1973.