

# **Scale Removal from the Condensate Stripper at Kollsnes - An Environmentally Friendly, no Shutdown, Cheap and Simple Method for Scale Removal**

*Baard Kaasa, Nichlas Marheim and Jesper Jacobsson, Statoil, Norway*

## **Introduction**

The Kollsnes gas processing plant is located on the west coast of Norway, near Bergen. It treats about 145 MSm<sup>3</sup>/d gas from the Troll, Kvitebjørn and Visund fields. In addition, there is about 4-5 000 m<sup>3</sup>/d condensate and about 90 m<sup>3</sup>/d condensed water. To prevent hydrate formation and corrosion, pH stabilised Mono Ethylene Glycol (MEG) is continuously injected into the gas phase at the offshore installations.

After startup of a second condensate-MEG separator in October 2005, a regulation valve in the condensate stripper column at Kollsnes plugged and it was necessary to reduce the production significantly and replace the valve. It turned out that the valve had been plugged with sodium bicarbonate (NaHCO<sub>3</sub>) scale, the same salt used as pH stabiliser. Shortly after the valve had been replaced, it once again showed signs of being plugged with salt.

A task force with personnel from Kollsnes and Statoil Research Centre was put together to find out why scale had formed in the condensate system, why now after several years of operation and how could it be removed and prevented without production loss?

During the last years, Statoil has done extensive research on salt precipitation in MEG containing systems and by using this knowledge it was possible to understand the mechanisms for this particular scale problem. And when the mechanism was understood, a simple treatment for both removal and future prevention was designed.

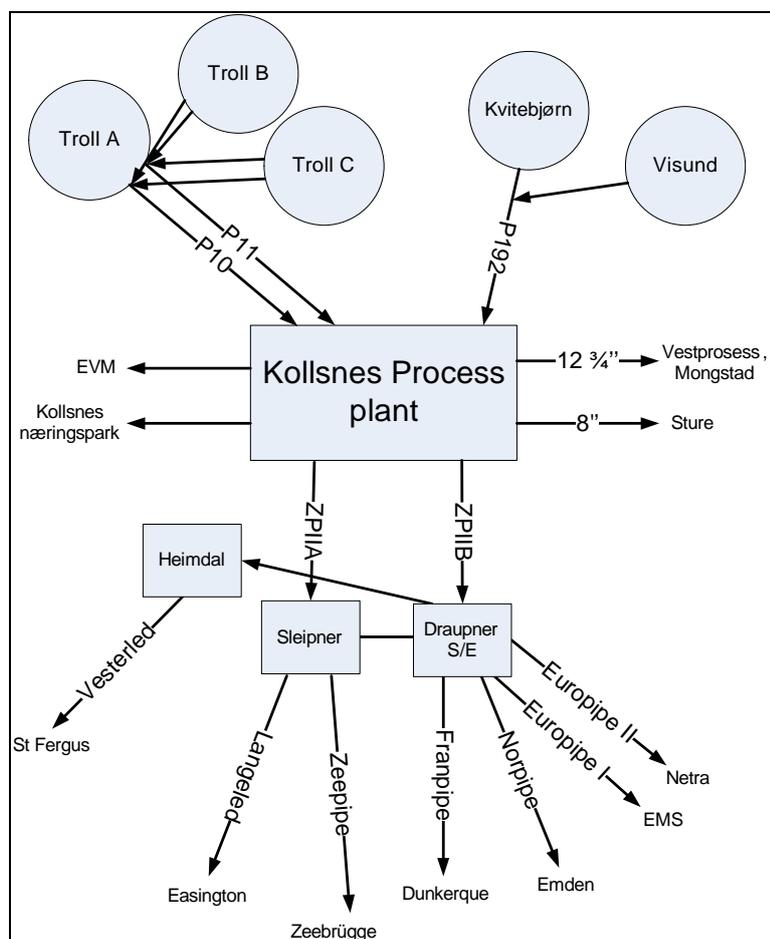
Until March 2007, 1.5 years later, Kollsnes has been able to prevent scale formation in this regulation valve by treating it about once or twice every month, and thereby avoiding several production shutdowns. This has increased the regularity of the Kollsnes plant as a shutdown to clean or replace the valve gives a production loss corresponding to 8-12 hours.

## **Troll-Kollsnes field description**

Kollsnes receives partly processed gas from Troll A-B-C, Kvitebjørn and Visund. On Troll A, gas from both Troll B and Troll C is mixed with the Troll A gas and transported 67 km via two 36" pipelines to Kollsnes. The capacity of the two Troll-Kollsnes pipelines is 124 MSm<sup>3</sup>/d.

The gas from Kvitebjørn is transported 147 km via a 30" pipeline to Kollsnes. The gas from Visund is first transported 35 km in a 20" pipe and is mixed into the Kvitebjørn gas about 2 km from Kvitebjørn. The total gas capacity from Kvitebjørn and Visund is 26 MSm<sup>3</sup>/d. A schematic overview of the field installations is shown in Figure 1.

The condensate is pumped via a 12" pipeline to the Mongstad refinery for further processing. The MEG is regenerated in three MEG regeneration trains where the water is boiled off to produce 90 wt% MEG.



**Figure 1.** Schematic overview of the Troll-Kollsnes-Kvitebjørn-Visund field installations.

## Pipeline chemistry

### *Hydrate prevention*

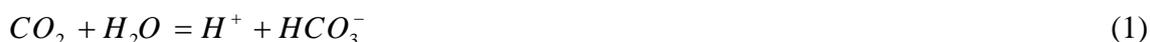
As the gas cools down in the pipeline, water will condense to liquid. With the combination of high pressure and low temperature, hydrates may form and plug the pipeline. To prevent hydrate formation, MEG (Mono Ethylene Glycol) is injected continuously at Troll, Kvitebjørn and Visund. The amount of MEG is determined by the amount of water that may condense in the pipeline, which again is a function of the gas rate and water content in the gas. Table 1 shows typical numbers for the gas production and MEG injection rates from the three facilities to Kollsnes.

**Table 1.** Gas production rates and MEG injection rates (typical values, actual values may vary).

Field/Platform	Typical Gas rate (MSm <sup>3</sup> /d)	Typical MEG injection (m <sup>3</sup> /d)
Troll (ABC)	119	200
Kvitebjørn	20	10
Visund	6	4
<b>Total</b>	<b>145</b>	<b>214</b>

### **Corrosion protection – pH stabilisation**

pH stabilisation<sup>[1,2]</sup> is used to prevent corrosion. pH stabilisation means that caustic is added to the MEG prior to injection to increase the pH in the water-MEG phase. On Kollsnes, NaHCO<sub>3</sub> (sodium bicarbonate) is used to increase the alkalinity<sup>[3]</sup> and thereby the pH. When pH is increased, the following reactions will be driven to the right:



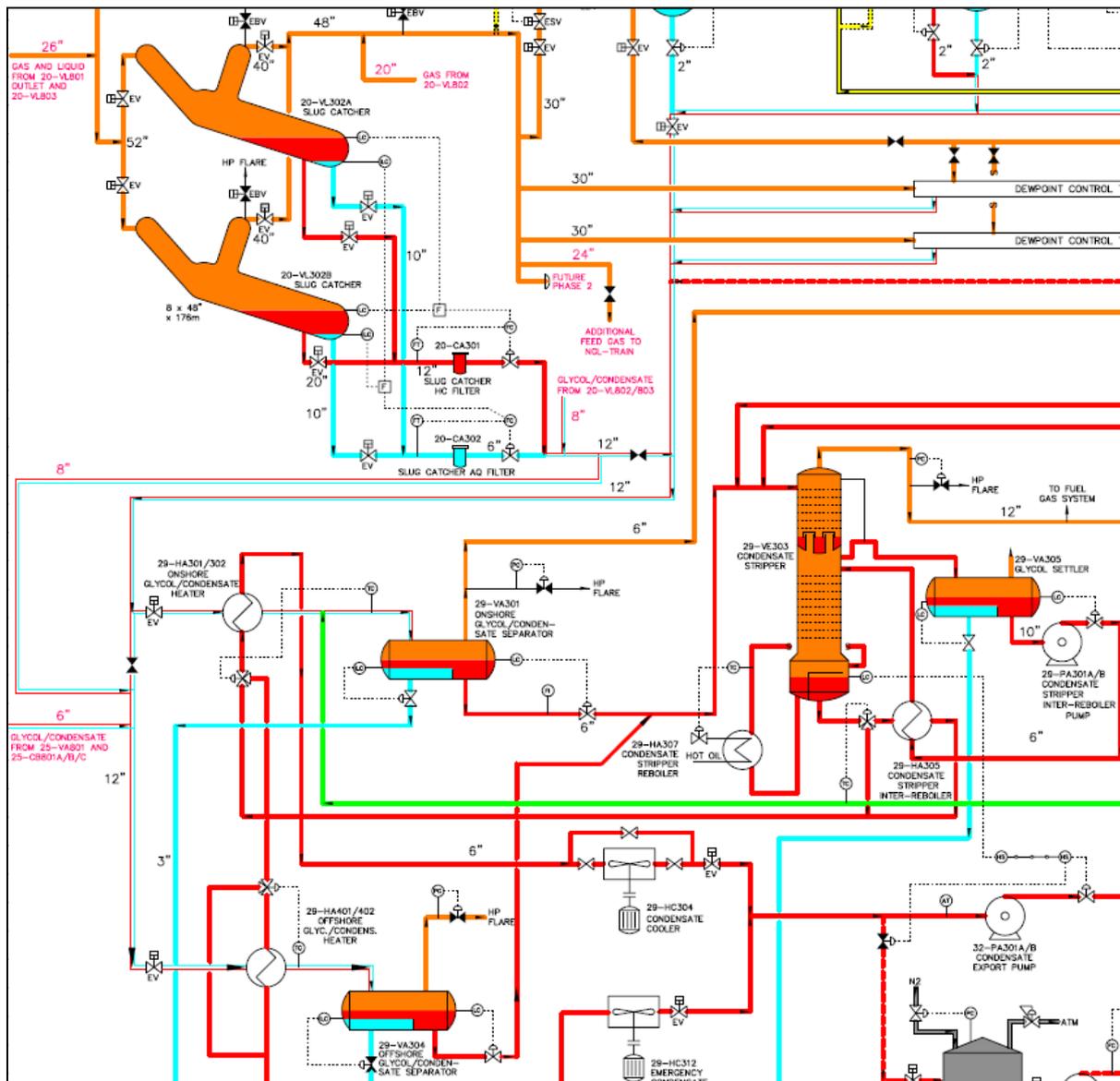
When the pH increases, the CO<sub>3</sub><sup>2-</sup> concentration will increase and iron will precipitate as iron carbonate. When iron carbonate precipitates on the pipeline wall, it creates a tight layer that prevents further corrosion or reduces the corrosion rate significantly. With the pH stabilisation technique it has been possible to keep the iron concentration in the MEG at about 5-20 mg/l.

### **Kollsnes process description**

A schematic layout of a part of the Kollsnes process is shown in Figure 2. The gas-condensate-MEG\* mixture first enters the slug catchers. They operate as 3-phase separators at ca 93 bar and 5-10°C. The condensate and the MEG phases are depressurised separately to about 26 bar before they are remixed and heated to 25°C. The condensate and MEG phases then enter the condensate-MEG separators for final separation. The MEG phase from the condensate-MEG separator is sent to MEG regeneration.

The condensate from the condensate-MEG separators is depressurized to about 7-8 bar and is fed into the top section of the condensate stripper. The condensate is heated to about 35°C by the warm gas coming up from the bottom section from the stripper and light gas components are evaporated from the condensate. The condensate is then collected in trays in the middle of the stripper and led to a glycol settling separator operating at ca 35°C. Any residual glycol (or water) is supposed to settle out in this tank. The condensate is then pumped back via a heat exchanger where it is heated to 70°C, to the bottom section of the condensate stripper. The condensate in the bottom of the condensate stripper is contentiously circulated via a hot oil heat exchanger to keep the temperature at about 122°C in the bottom section.

\* When “MEG” is used in the process description it means the water-MEG mixture with about 60-65 wt% MEG.



**Figure 2.** Schematic layout of the Kollsnes condensate process.

## Scale formation in condensate regulation valve

### *First plugging*

In October 2005, the operators had to open the regulation valve on the condensate outlet from the Glycol Settler tank (29-VA305) to 100% and still it was not possible to keep the production rate. A series of pressure measurements was initiated to locate the restriction and it was concluded that it was inside the regulation valve. Over a few days, the situation got worse and it was necessary to reduce the production rate from Troll, Kvitebjørn and Visund. At a reduced production rate, the regulation valve could be temporarily bypassed and replaced.

Figure 3 shows a picture of the internals of the regulation valve after it was taken out. The picture shows that there is a layer of salt inside the whole valve and especially in the small holes. Many of them were plugged completely.

A XRD and XRF analysis of the salt showed that it was mainly  $\text{NaHCO}_3$ , with some traces for iron probably as  $\text{FeCO}_3$  and chlorine probably as  $\text{NaCl}$ . Naturally, it was expected that the salt was the pH stabilizer added to the lean MEG, but how and why did it end up in the condensate system? And why now after several years of operation?

### ***Second plugging***

With the new valve in place, the production could be increased back to normal again. However, after only short time, the operators noticed that the setpoint of the level regulation valve had to be increased step by step to keep the production rate, indicating a slow plugging of the valve. Unless immediate actions were taken, the valve would plug within the month. Several options were considered. One service company suggested the use acids to clean the valve as the salt was a carbonate salt. However, this would require an isolation of the valve to avoid getting acid into the condensate as this would reduce the condensate quality. Isolation of the valve meant shutting down Kollsnes and thereby the production from Troll (A-B-C), Kvitebjørn and Visund. At this point, the Kollsnes operators contacted the Statoil R&D Centre and a task force was put together to understand the plugging mechanism and find a treatment to dissolve and prevent it.



**Figure 3.** Level control valve on condensate outlet from Glycol settler. The salt is  $\text{NaHCO}_3$ .

## **System analysis and simulations**

### ***Process analysis***

As the condensate does not contain any salt, the precipitation must be due to presence of MEG in the condensate. The separation of condensate and MEG is therefore not perfect and there is some carryover of MEG to the condensate. Earlier, Kollsnes had only one separator for condensate-MEG separation. Recently, a second separator was started up to split the MEG system into two separate systems, off-shore and on-shore, with and without pH stabilisation. Samples of the condensate feed to the stripper column before the second condensate-MEG separator was started showed a content of up to 600 ppm MEG in the condensate. After the second condensate-MEG separator was started, the MEG content in the condensate dropped to about 30-40 ppm.

It is easy to think that a 20-fold reduction in MEG content in the condensate should *reduce* salt precipitation in the condensate system. It is correct that the amount of salt (in kg/d as dissolved ions) is reduced when the MEG content is reduced, but the *potential* for salt precipitation due to MEG evaporation increases exponentially when the amount of MEG is reduced. (NB! Remember that “MEG” in this context means the 66 wt% MEG-water mixture with dissolved pH stabiliser and some other ions.)

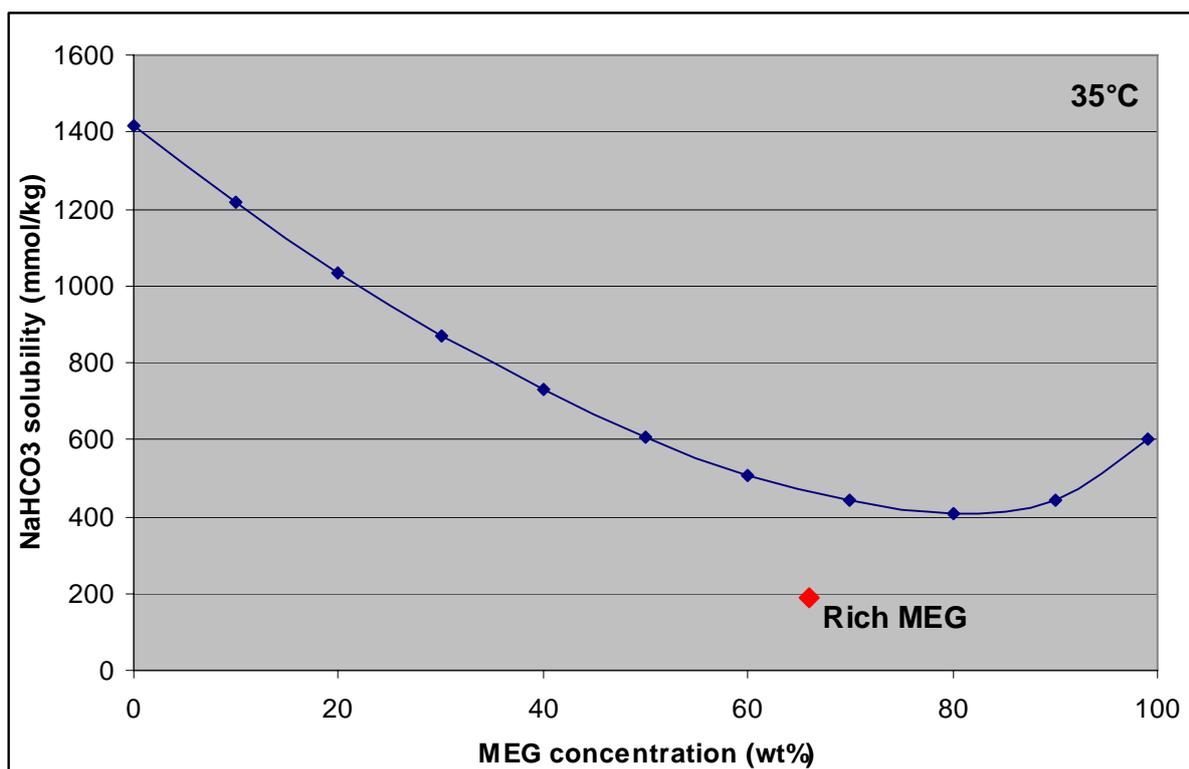
#### ***Water evaporation and salt precipitation in condensate stripper***

When the condensate enters the top section of the condensate stripper, it is heated from about 20 to 35°C and the pressure is reduced from about 25 to 7 bar. This causes gas to evaporate from the condensate. In addition, it is mixed with hot gas from the bottom section of the stripper (it is the hot gas that heats the condensate to 35°C). This causes MEG (and water) to evaporate to saturate the gas phase with water and MEG. Both the pressure reduction and the temperature increase causes and increase of water/MEG solubility in the gas. The amount of water and MEG dissolved in the gas is, however, very small, but when there is only very little water/MEG present this will increase the ion concentrations significantly or even cause complete evaporation. The hypothesis is therefore that when the water-MEG content dropped from 600 to 30-40 ppm, the carry over is not longer large enough to saturate the gas phase with water and MEG at 35°C and this leads to complete evaporation of the solvent and complete salt precipitation. This theory is supported by the fact that before the separator modification, there was some buildup of MEG-phase in the glycol settler (29-VA305), but not after the modification, indicating complete evaporation.

#### **Solubility data and simulation model for MEG systems**

Over the last years, water-MEG-salt systems have been studied by several research projects, both in-house projects and in cooperation with Hydro, NTNU and Ife, and a large database for salt solubility in water-MEG mixtures is available. Most of these data have been incorporated into a MEG module and coupled with the MultiScale software<sup>[4,5]</sup>.

The solubility of NaHCO<sub>3</sub> in water-MEG mixtures at 35°C is shown in Figure 4. The composition of the Rich MEG (pipeline water-MEG mixture) is also shown in the figure indicating that the Rich MEG is actually 50% saturated with respect to NaHCO<sub>3</sub>. This means that if more than 50% of the solvent (water+MEG) evaporates, NaHCO<sub>3</sub> may precipitate.



**Figure 4.** Solubility of NaHCO<sub>3</sub> at 35°C as function of MEG concentration. The red point shows the composition of the Rich MEG. Solubility curve is calculated by MultiScale<sup>[4-5]</sup>.

#### *Fluid analyses and simulations*

A typical composition of the Rich MEG (water-MEG phase coming out of pipeline) is given in Table 2. The composition of the Troll Gas is given in Table 3.

**Table 2.** Average composition of Rich MEG (water-MEG phase from pipeline).

Component	Concentration (mg/l)
Na <sup>+</sup>	5 032
K <sup>+</sup>	44
Mg <sup>2+</sup>	NA
Ca <sup>2+</sup>	5
Ba <sup>2+</sup>	Na
Sr <sup>2+</sup>	Na
Fe <sup>2+</sup>	16
Cl <sup>-</sup>	1 000
Br <sup>-</sup>	Na
SO <sub>4</sub> <sup>2-</sup>	Na
Alkalinity (mmol/l)	191
Alkalinity (mg/l as HCO <sub>3</sub> <sup>-</sup> )	11 600
MEG concentration (wt%)	66

**Table 3.** Composition of Troll gas.

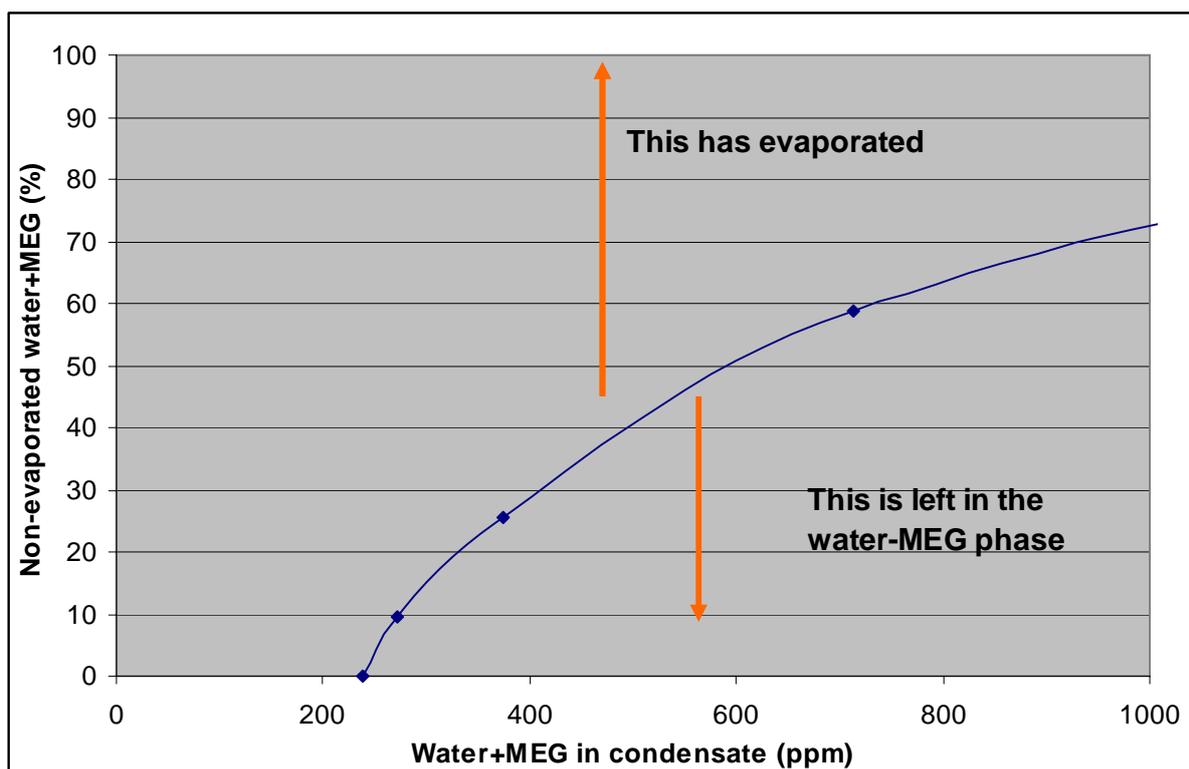
Component	Composition (mol%)	Moleweight (g/mole)	Density (kg/m <sup>3</sup> )
N <sub>2</sub>	1.749	28.01	
CO <sub>2</sub>	0.226	44.01	
C1	92.815	16.04	
C2	3.265	30.07	
C3	0.585	44.10	
iC4	0.331	58.12	
nC4	0.090	58.12	
iC5	0.081	72.15	
nC5	0.330	72.15	
C6	0.110	86.18	664.0
C7	0.185	96.00	738.0
C8	0.118	107.00	765.0
C9	0.051	121.00	781.0
C10+	0.064	160.13	811.5

The above fluid analyses were entered into the scale prediction software MultiScale<sup>[5]</sup>. The following simulations were performed:

- 1) Composition of phases in slug catcher at 93bar, 5°C
- 2) The liquid phases were saved and used in the next calculation at 25 bar, 25°C. The condensate phase and the water-MEG phase were stored as separate streams.

If the condensate-MEG separators had worked 100% perfect, only the condensate phase should continue to the stripper column, and there would be no scale formation.

To study the effect of MEG-water carry over in the condensate-MEG separator, various amounts of the water-MEG phase were included together with the condensate and flashed to 7 bar 35°C. Figure 5 shows how much MEG that is left in the MEG phase after flash to 7 bar 35°C as function of the ppm of MEG in the condensate feed. In the situation with only one condensate-MEG separator, the amount of water-MEG was about 600 ppm in the feed. In this case, about 50% of the MEG evaporates, leaving 50% in the water-MEG phase. When the MEG content in the condensate is reduced, the fraction that will evaporate increases. Figure 5 shows that when the amount of MEG in the condensate gets below 200-300 ppm, all the MEG will evaporate, precipitating all the dissolved salts. The measured MEG content in the condensate was only 30-40 ppm, i.e. well below the limit where everything will evaporate and all salts will precipitate.



**Figure 5.** The graph shows how much of the MEG that is still in liquid phase after flash to 7 bar, 35°C. x-axis shows the amount of MEG in the condensate feed to the stripper column.

### *Amounts of salt*

Scaling in an oil production systems normally means precipitation of the low soluble salts like  $\text{CaCO}_3$ ,  $\text{FeCO}_3$ ,  $\text{BaSO}_4$ ,  $\text{CaSO}_4$  etc. The concentration of these salts is normally low so the amount of salt per litre of water is normally in the mg range. But, in the situation with complete evaporation, also the very soluble salts like  $\text{NaCl}$ ,  $\text{NaHCO}_3$  etc will precipitate. As the concentration of these salts is much higher, the amount of salt can be dramatic.

To illustrate this: The rich MEG on Kollsnes contains about 16 mg iron. During the pressure reduction to the condensate-MEG separator, the theoretical amount of  $\text{FeCO}_3$  that can precipitate from the 300 m<sup>3</sup>/d rich MEG is about 0.0013 kg/d. The 30-40 ppm water-MEG in corresponds to only 0.13 m<sup>3</sup>/d but it will precipitate as much as 0.5 kg/d salt if all the solvent evaporates. The reason is that the concentration of the pH stabiliser ( $\text{NaHCO}_3$ ) is much larger than the concentration of other ions.

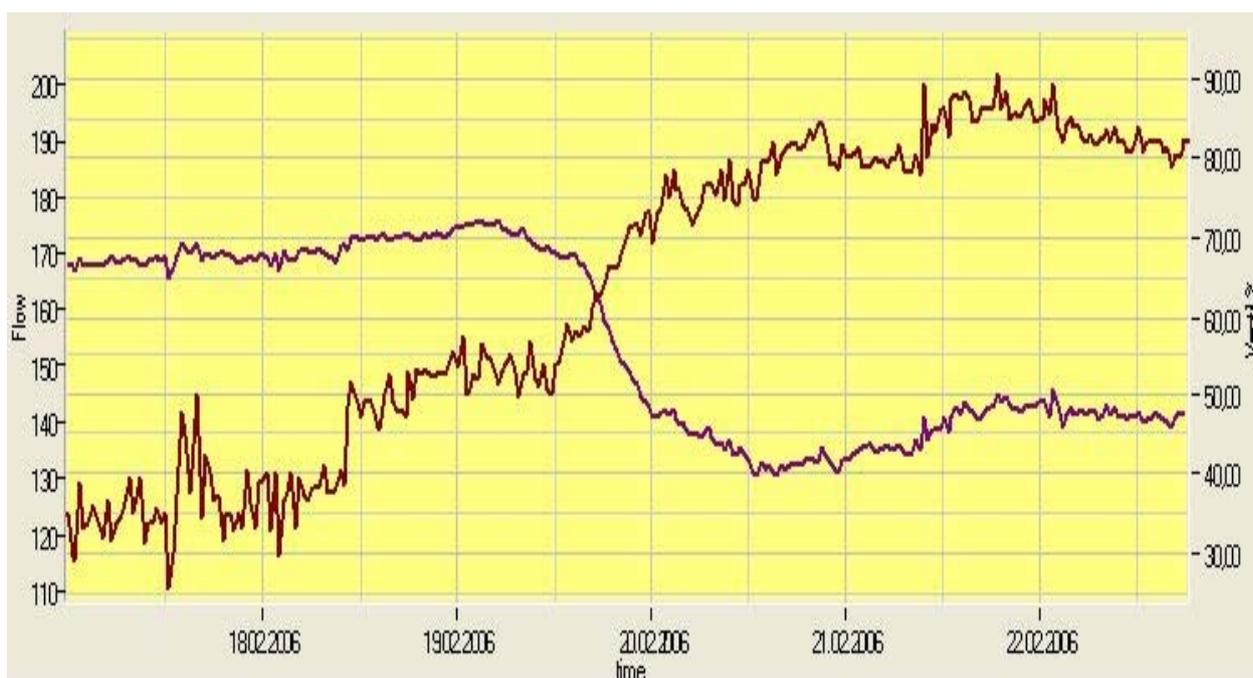
### **Scale removal and future prevention**

Based on the samples taken from the system and simulations, the mechanism for scale formation in the condensate stripper column is known. But how can it be removed and is it possible to do it without shutting down the production?

The obvious answer on how to remove a carbonate scale is of course to use an acid to dissolve it. Unfortunately, there is no possibility for separating out any acid downstream the stripper column and acid would contaminate the condensate. Using an acid to dissolve the carbonate scale would therefore require a full production shut-down.

The best way would be to inject a chemical that can dissolve the scale without contaminating the condensate. And MEG is such a chemical! Figure 4 shows that the solubility of  $\text{NaHCO}_3$  is high in both water and MEG and the condensate is already saturated with respect to MEG, i.e. no new chemical is introduced.

It was therefore suggested to inject MEG into the condensate upstream the stripper column. This was done, and the result came immediately. The MEG injection rate was adjusted so that the MEG accumulated in the glycol settler. This was to ensure that excess MEG compared to evaporation was injected. Figure 6 shows a typical trend during MEG injection. The condensate rate is increasing, showing that a restriction is removed and the valve opening can be reduced back to its normal setting at about 50% opening.



**Figure 6.** Variation in condensate flow and valve position during MEG injection. The valve opening is reduced from 70 to 50% while the condensate rate increases from 120-190  $\text{m}^3/\text{h}$ .

An analysis of the MEG injected to the condensate sampled from the glycol settler showed concentrations of  $\text{NaHCO}_3$  round 200  $\text{mmol/l}$ , proving that  $\text{NaHCO}_3$  salt had been dissolved. In addition, there were chlorine, bromine, sulphate and potassium. (The injected MEG was of course salt free.)

During the 1.5 year since the first time this MEG was injected to remove scale, Kollsnes has injected MEG into the condensate systems about once or twice every month, in periods every week, at full production. It has not been necessary to reduce the production due to scaling.

## Summary and conclusions

After starting up a second condensate-MEG separator, Kollsnes experienced blocking of a regulation valve in the condensate stripper column. The valve was opened and the salt was analysed and found to be  $\text{NaHCO}_3$ . The source to  $\text{NaHCO}_3$  was the pH stabilizer injected to the MEG to prevent corrosion in the pipeline. The reason why the salt was formed in the condensate stripper was due to complete evaporation of MEG carry over from the condensate-

MEG separator. Earlier, with only one condensate-MEG separator, this was not a problem because the amount of MEG carry over was much higher, about 600 ppm. With the second condensate-MEG separator, the amount of carry over was as low as 30-40 ppm. When the condensate is depressurised and heated in the stripper column, water and MEG will evaporate and with only 30-40 ppm present, everything evaporates leaving all the salt (pH stabilizer) inside the stripper column and circulation loop.

To dissolve the scale, acid was not an option because it would contaminate the condensate and would therefore require a full production shut down. MEG however, was already present in the system and it can dissolve significant amounts of  $\text{NaHCO}_3$ . MEG was therefore injected to the condensate upstream the stripper, and the effect was immediate. The condensate rate increased and the valve could be closed back to its normal setting.

During the 1.5 year since the first time this MEG was injected to remove scale, Kollsnes has injected MEG into the condensate systems about once or twice every month to prevent plugging of this regulation valve. This has increased the regularity of the Kollsnes plant as a shutdown to clean or replace the valve gives a production loss corresponding to 8-12 hours.

## References

1. A. Dugstad and PE Dørnen, "Efficient Corrosion Control of Gas condensate Pipelines by pH-stabilization", CORROSION/99, Paper No. 20, NACE 1999.
2. S. Olsen, O. Lunde and A. Dugstad, "pH-Stabilization in the Troll Gas-Condensate Pipelines", CORROSION/99, Paper No. 19, NACE 1999.
3. B. Kaasa and T. Østvol, "What Alkalinity is and How it is Measured", *Int. Symp. Oilfield Chemistry*, SPE 37277, Houston, 18-21 Feb, 1997.
4. K. Sandengen, "Prediction of Mineral Scale Formation in Wet Gas Condensate Pipelines and in MEG Regeneration Plants", Ph.D. Thesis, NTNU, 2006:137.
5. MultiScale with MEGscale module, Petreotech.