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The Methodology for Selection of Corrosion Inhibitors for Oil and Gas Applications

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منهجية اختيار مثبط التآكل المناسب لتطبيقات النفط والغاز

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تقدم هذه الورقة مراجعة لكيفية اختيار مثبطات التآكل المستخدمة في المختبرات وحقول النفط والغاز، ولقد تم مناقشة الطرق شائعة الاستخدام في المختبرات مع التركيز بصورة خاصة على الميزات ودقة النتائج التي يتم الحصول عليها من كل طريقة. كما تم التعرض بالتفصيل إلى التطبيقات الحقلية وتقنيات المراقبة المستخدمة مع ذكر أمثلة للطرق المستخدمة حاليا وحدودها، وقورنت طريقة استخدام تقنيات الاختبار الكهروكيميائي المختلفة وكذلك العوامل الرئيسة التي يعتمد عليها في اختيار المثبط.

Abstract: *This paper reviews the laboratory and field approach in selecting corrosion inhibitors for oil and gas applications. The methods commonly employed within the laboratory environment are discussed with particular emphasis on the benefits and information each technique delivers. Field assessment and monitoring techniques are detailed with examples given on the existing methods applicability and their limitations. The electrochemical testing techniques used are compared as well as key system aspects, which influence the corrosion inhibitor selection.*

INTRODUCTION

The oil and gas industry uses corrosion inhibitors extensively for the control of corrosion to extend component lifetime as well as improving production. These products are commonly deployed in main oil export lines, subsea tiebacks and wet gas production. The treatments are usually delivered by pumping into the system continuously or as a batch treatment depending on conditions, with a typical dose rate of between 10-50 ppm based on total fluids. In the selection process, a number of test procedures must be followed before the inhibitor can be considered. This is of critical importance, as any omission or oversight in the inhibitor design can result in significant production loss from, for xample, incompatibility incompatibility of chemicals/ fluids, emulsion problems and any foaming tendency[1].

The formation and produced water generated in offshore operations can vary greatly between fields and as such has a significant effect on the corrosion rate of the pipelines. As a result, corrosion inhibitors require evaluation under conditions which simulate the field conditions as closely as possible. The water chemistry is therefore one of the first parameters to consider when selecting a suitable inhibitor. Electrochemical techniques are commonly employed for evaluating corrosion inhibitors with Linear Polarisation Resistance (LPR), the most widely used method for rapid screening[2]. Several variations exist on this method, which allows the effects of flow, temperature and pressure to be investigated. Consideration also has to be given to the persistency

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of the inhibitor. In wet gas production, the shear stresses can be relatively high creating difficulty in forming a stable film of inhibitor and accelerating its removal due to the flow regime and solids that may be in the line.

The ratio of water to crude, condensate or gas is of particular importance as this has a significant effect on whether the inhibitor recommended is water or oil soluble product and whether a continuous or batch treatment should be used[3]. The partitioning behaviour of a corrosion inhibitor between the various phases is also very important as inhibitors are normally applied on a total fluids basis and therefore need to partition into the water phase from the hydrocarbon phase to be effective. The geographical location of the production facility can play an important factor on chemical selection. Different environmental policies and restrictions can limit the options available when considering a corrosion inhibitor for deployment.

The effect corrosion inhibitors have on other production areas and chemicals in the system must also be considered. The addition of corrosion inhibitors to a hydrocarbon production system can create foaming problems particularly in turbulent conditions. In operations where low seabed temperatures are experienced, the surface-active nature of corrosion inhibitors means that they can have a negative impact on the dehydration performance of a process system, preventing chemicals added to control hydrate formation from functioning. Similarly, the stability of the inhibitor over the temperatures encountered is important as any instability could lead to precipitates and eventual blocking of the pipelines. Elastomers, used in seals, gaskets and umbilicals, can be affected by solvents causing deformation and an increase in volume or weight adversely affecting their performance.

This paper aims to identify the key inhibitor specifications and methods required to identify a corrosion inhibitor through the development of a corrosion inhibitor for a typical field application. The testing discussed in this paper details one specific application, but the methodology applied is applicable to all product development. The field monitoring options are also reviewed to identify the most suitable method for evaluating the inhibitor in the field. The main criteria for the product were as follows:

- Effective inhibition under the conditions.
- Compatibility with methanol.
- Low foaming characteristics.
- Compatibility with produced fluids.
- Compatibility with elastomers.
- High shear flow inhibition stability.

COMPATIBILITY

As part of the corrosion inhibitor design, consideration and testing is necessary for all relevant compatibility issues. These include testing for emulsion tendency, thermal stability, viscosity, foaming tendency, elastomer compatibility, compatibility of produced fluids and chemical compatibility with other production chemicals. Industry standards exist for most testing, NACE and ASTM, with operators generally setting their own protocols specific to the system in question. The methods can vary and some are more stringent than others depending on the region in question. For this application, standard test methods were employed which represented the normal practice for North Sea applications.

Water Chemistry

The brine used in this study was typical of that found in the North Sea. The composition of the brine is shown in Table 1. Sulphate and bicarbonate were replaced with NaCl to avoid any scaling interfering with corrosion measurements.

Table 1. Ionic compositions used to prepare synthetic brine.

Ion concentration	(mg/l)
Sodium	10,450
Potassium	364
Calcium	444
Magnesium	585
Barium	15
Strontium	25
Iron	12
Chloride	18,719
Sulphate	1,700
Bi-carbonate	900

Foam Tests

To evaluate the foaming tendency of the selected products, a 100 ml sample of synthetic brine was placed in a 500 ml measuring cylinder and dosed with 100 ppm inhibitor. The brine was sparged with CO_2 at a constant flow rate of 200 cm^3/min at room temperature with a sintered glass bulb used to maximise the foaming effect[4]. After 5 minutes sparging, the gas flow was stopped and the foam height and consistency observed. The time taken for the foam to collapse was then recorded.

Emulsion Tests

50 : 50 ratios of synthetic brine and standard North Sea crude were added to a graduated torpedo tube to assess the emulsion tendency with each product[5]. The inhibitors were dosed at 100 ppm under a total fluids basis and the two-phase mixture heated and held at the test temperature in a water bath for the duration of the experiments. The phases were then mixed by agitation. The colour and clarity of the interface between the hydrocarbon and brine phases were recorded at intervals of 30 seconds up to a maximum of 10 minutes.

Thermal Stability and Viscosity

A cooling bath was utilised to establish the stability of the selected products at –10°C. Each product was placed in the water bath and after 24 hours exposure removed for visual inspection. The viscosity of each product was measured at 4°C and 20°C using a Brookfield viscometer[6].

Elastomer Compatibility

Nylon 11 cylindrical coupons were immersed in each product at 115°C for a period of 21 days in accordance with ASTM D471-98 and any change in volume during that time was measured[7].

Chemical Compatibility

The compatibility of products was assessed by addition to methanol and the appearance of the solution was monitored to identify any incompatibilities. The inhibitors were dosed at rates of 0.1 %, 1%, 20 %, 50 % and 80 % on a total fluids basis.

CORROSION PERFORMANCE TESTS

Corrosion Modelling

Modelling of the field conditions was assessed before any experimental work was conducted. This was achieved by commercial software packages. This allowed the appropriate test programme to be determined by consideration of the operating minimum and maximum temperatures, partial pressure, gas ratios, water chemistry, production rates and pipe sizes to build a model of the system to be inhibited. Further information including pH, viscosity, cost and application method was then considered to assist in designing the test protocols.

Corrosion Bubble Tests

The bubble test is a CO_2 sparged beaker test used in the initial stages of an inhibitor selection programme.

The bubble test can employ a number of electrochemical techniques including Linear Polarisation Resistance (L.P.R.), Electrochemical Impedance Spectroscopy (E.I.S.) and Potentiodynamic polarization scans to assess the corrosion rate of the system. This allows rapid screening to be undertaken and identification of inhibitors that are unsuitable/incompatible with the system conditions. The effect of inhibitor concentration on performance is studied along with the time to reach maximum inhibition (adsorption kinetics) allowing the most effective candidate to be identified. Typically, bubble tests are run for 24 hours with the initial 2 hours used to establish a baseline corrosion rate for the system.

Oilfield corrosion inhibitors can take considerable time to reach maximum inhibition and an extended test period is required to determine the maximum efficiency of the inhibitor and the persistency of the film forming inhibitor. This is of particular importance in batch treatment where it may be some considerable period before the inhibitor is reapplied. The standard LPR bubble test was used to evaluate the film persistency and tenacity of the products to form an inhibiting film[8]. 1-3 hour pre-corrosion time was utilised to determine the baseline corrosion rate. The inhibitor was injected at 20 ppm and the resulting corrosion rate measured. The tests were conducted at 90°C and sparged continuously with CO_2.

Condensate from a North Sea field was also used to assess the partitioning efficiency of the inhibitor from the oil to water phase. This was conducted under differing oil to water ratios to reflect the field conditions. Other chemical additives, such as demulsifiers, scale inhibitors and hydrates, can be included to the test regime to allow assessment of their effects on the inhibitors performance. Partitioning tests were conducted at 80:20 and 20:80 brine/hydrocarbon ratios The partitioning efficiency assists in the determination of an accurate estimate of injection rate to ensure full protection in areas of water drop out or wetting. The inhibitor partitioning is based on corrosion performance rather than on an

analytical approach, although the later can also be performed. This is because the value of corrosion rate can be obtained indicating inhibitor efficiency rather than a measure of inhibitor concentration in the water which can often lead to unreliable estimates of required dosing rates.

RCE Test Method

The Rotating Cylinder Electrode test, RCE, is a standard way of performing high shear corrosion tests. For the RCE, the flow pattern changes from laminar to turbulent at high rpm speeds. The RCE enables relatively high shear stresses to be obtained in a simple cell similar to those used in bubble tests. The rotating cylinder electrode introduces turbulent flow at all but the lowest rotation speeds. With typical maximum rotation speeds of the order of 10,000 rpm, it is possible to produce shear stresses as high as 70 Pa. The RCE method is commonly employed for evaluating inhibitors in wet gas systems where high shear velocities can be expected to exist. The RCE was used to investigate the influence of flow on the inhibitors performance[9], with a rotational speed of 8000 rpm, equivalent to 52 Pa, applied. The test was sparged with CO_2 and the brine held at 80°C. 20 ppm of inhibitor was injected once a 1-2 hour pre-corrosion rate had been established.

Autoclave Test Method

For situations which demand inhibitor testing at high temperatures and pressures, greater an autoclave is used. Weight loss coupons are used to investigate general corrosion of carbon steel and stainless steel in the presence of O_2, CO_2 and H_2S. This method is also used for long term testing of the efficiency of corrosion inhibitors and allows tests at high temperature and pressure. The effects of other products, such as scale inhibitors, can be evaluated to assess change in the corrosion rate.

This apparatus allows pressures up to 200 bara and 150°C to be used in testing. Inhibitor addition can be made during a test without loss of pressure or temperature allowing a baseline corrosion rate to be established before inhibitor addition. This testing at higher pressure results in high partial pressures of carbon dioxide in solution, thus a more severe corrosion condition. A stirring facility in the autoclave enables a shear force to be applied to both weight loss coupons and electrochemical measurement electrodes. However, because of the unknown effect of the rotation of the stirring paddle on the velocity of the fluid, it is not possible to accurately quantify the wall shear stress for any given rate of stirring. This test is also able to demonstrate the ability of the inhibitor to withstand long exposure to high temperatures.

In this test the brine was pre-sparged with 100% CO_2 gas before being transferred to the autoclave and dosed with inhibitor. Coupons were cleaned with a non-abrasive cleaning liquid, rinsed with xylene and acetone, allowed to dry, weighed, and mounted on a rotating wheel inside the autoclave. At the end of the test, the coupons were removed, cleaned, weighed, and the corrosion rate calculated from the weight loss and original surface area. The testing was conducted over 48 hours at 115°C with inhibitor added at 20 and 50 ppm.

Jet Impingement

For applications where the shear stress in the system exceeds that which can be achieved by the RCE method, jet impingement testing is conducted. This method involves firing high velocity fluids through a jet to a target containing the electrodes. A series of pumps circulates the system brine through a heater which raises the brine to the field temperature before firing the brine as a fine jet onto the target. The target is fitted into a pressurised vessel which can be continuously sparged with CO_2 and/or H_2S. Inhibitors can then be assessed to determine their efficiency at extremely high shear stress. This method also allows higher temperatures and pressures to be considered when developing a corrosion inhibitor. Different electrode assemblies can be employed to establish the effects of orientation on inhibitor efficiency to simulate bends.

This technique commonly employs the LPR method for calculating corrosion and as such is not suitable in oil/brine testing. In this particular application, the shear stresses in the system were insufficient to warrant this type of testing and were therefore not conducted.

Weld Testing

Preferential weld corrosion testing can be conducted under both CO_2 and H_2S conditions. The equipment used for this testing allows the weld, heat affected zone and parent alloy to be monitored for corrosion and preferential corrosion individually. The test methods employed include LPR, galvanic current

measurements, potential measurements and EIS in low salinity brines. The evaluation of inhibitors is assessed after a pre-corrosion time varying from a few hours to several days. The test method is based on the bubble test but with far more sophisticated hardware allowing greater latitude in evaluating corrosion inhibitors. The products tested in this study were not designed for weld inhibition and therefore were not tested under this method.

RESULTS

Compatibility with Methanol

The results of compatibility tests with methanol are shown in Table 2. Products A, D, H, I J and N were found to be compatible with methanol at all levels. Products B and C were stable up to 50% with methanol but at higher concentrations clear droplets were observed to form. Product L was found to form droplets at greater concentrations than 0.1% and at higher concentrations phase separation was noted. Product M was unstable with greater than 1% corrosion inhibitor with a milky appearance observed.

Foaming Tests

The results of the foam tests are shown in Table 3. Products D, I and M were found to produce no foaming tendency. Products A, B, C, H, K, and L were found to cause an unstable flaky foam which dissipated with time, however, the height of the foam varied for each product. Product J and product N failed the test as a stable creamy foam was produced.

Table 2. Compatibility test with methanol.

Inhibitor	MeOH/CI	MeOH/CI	MeOH/CI	MeOH/CI	MeOH/CI
	99.9 : 0.1	99.1	80:20	50:50	20:80
Product A	ok	ok	ok	ok	ok
Product B	ok	ok	ok	Clear, droplets	Clear, droplets
Product C	ok	ok	ok	Clear, droplets	Clear, droplets
Product D	ok	ok	ok	ok	ok
Product E	Eliminated as inhibition was poor				
Product F	Eliminated as inhibition was poor				
Product G	Eliminated as inhibition was poor				
Product H	ok	ok	ok	ok	ok
Product I	ok	ok	ok	ok	ok
Product J	ok	ok	ok	ok	ok
Product K	Eliminated as inhibition was poor				
Product L	ok	droplets	Phase sep	milky	milky
Product M	ok	ok	milky	milky	milky
Product N	ok	ok	ok	ok	ok

Table 3. Foaming tendency.

Inhibitor	Foaming	Initial foam height	Time to collapse
Conditions: 5 min CO_2 at 200 ml/min, dose rate - 100ppm		(cm)	(min)
Product A	unstable flaky foam	5	1
Product B	unstable flaky foam	15	>10
Product C	unstable flaky foam	15	>10
Product D	Not foaming		
Product E	Previously eliminated		
Product F	Previously eliminated		
Product G	Previously eliminated		
Product H	unstable flaky foam	17	>10
Product I	Not foaming		
Product J	Stable creamy foam	4	>10
Product K	Stable creamy foam		
Product L	Stable creamy foam		
Product M	Not foaming		
Product N	Stable creamy foam	4	>10

Emulsification Testing

The crude selected for the testing was found to be strongly emulsifying and the untreated blank test required greater than 10 minutes for phase separation. The results are summarised in Table 4. Product A showed phase separation within 7 minutes. Inhibitor candidates B, C, H, J and N achieved phase separation within 4 to 5 minutes. All other products had a broad interface after 10 minutes.

Table 4. Emulsification tendency.

Inhibitor	50:50 synth. brine/ crude	water quality
25°C, 100ppm	Time to separate (min)	
blank	>10	Clear
Product A	7	Marginally worse than blk
Product B	5-4	Hazy
Product C	5-4	Hazy
Product D	>10	Yellow hazy
Product H	5	Marginally worse than blk
Product I	>10	Yellow hazy
Product J	5-4	Marginally worse than blk
Product M	>10	Yellow hazy
Product N	5-4	Marginally worse than blk

Thermal Stability and Viscosity Testing

The viscosity results are shown in Table 5. Candidates that passed the criteria were products B, C, D, H and I. Product M was found to be cloudy at –10°C and along with products A, J and N had a viscosity outside the acceptable profile.

Table 5. Low temperature stability and viscosity.

Inhibitor	Stability @ -10°C	Viscosity@ 20°C (cP)	Viscosity@ 20°C (cP)
Product A	ok	45.8	108.3
Product B	ok	63.6	67.3
Product C	ok	36.4	79.0
Product D	ok	NA	37.0
Product H	ok	35.6	80.8
Product I	ok	38.4	86.4
Product J	slightly cloudy	52.5	118.8
Product M	ok	87.0	201.0
Product N	ok	35.0	121.0

Elastomer Compatibility

The results from the elastomer compatibility are shown in Table 6. The increase in volume for Nylon 11 with inhibitors A, D, H and I were found to be between 7- 8%. A similar result was found for the weight, with an increase of between 10-14 %. The remaining products were not tested.

Table 6. Compatibility with Nylon 11.

Inhibitor	Increase in weight	Increase in volume
Conditions: 21 days, 115°C	%	%
Product A	10.90	7.07
	11.16	6.45
	11.63	6.65
Product D	13.73	7.48
	13.06	7.89
	13.86	7.89
Product H	13.08	7.68
	12.98	7.89
	13.05	7.68
Product I	11.90	6.86
	11.58	7.07
	12.03	6.65

Corrosivity Testing

All inhibitor candidates except C and L were passed on for aqueous bubble tests. The results are summarised in Table 7. The best performing inhibitors in these tests were A, B, H and M with 98 to 99% performance and good or satisfactory film persistency. D, I and J showed good corrosion inhibition but the film persistency was limited.

Partition Bubble Tests

The results of the partition bubble tests are shown in Table 8. The results demonstrate that at a water cut of 80% product A gave a corrosion rate of 7 mpy whilst product H reduced the corrosion rate to 0.9 mpy. At the lower water cut of 20%, the performance of product A had improved, reducing the corrosion rate to 0.6 mpy. Product H had a slightly poorer performance with a corrosion rate of 1.2 mpy.

RCE Testing

RCE tests were evaluated under maximum shear rate in an aqueous test at 20 ppm. Results of the

Table 7. Corrosion bubble tests.

Corrosion inhibitor	Pre-corrosion rate	Inhibited corrosion rate	Performance	Film persistency
20ppm, 90°C	(mpy)	(mpy)	%	(mpy)
Product A	205	2	99	7 stable
Product B	193	4	98	32 stable
Product C	- not tested			
Product D	175	8	95	95 raising
Product E	215	19	91	108 raising
Product F	227	77	66	201stable
Product G	216	49	77	158 stable
Product H	252	1	99	20 stable
Product I	196	3	99	85 raising
Product J	187	4	98	85 raising
Product K	217	62	71	NA
Product L	not tested			
Product M	145	2	99	14 stable
Product N	not tested			

Table 8. Partition bubble tests.

Corrosion inhibitor	Ratio brine/hydrocarbon	Pre-corrosion rate (mpy)	Inhibited corrosion rate (mpy)	% Protection
Product H	80:20	212	7	97
Product H	20:80	NA	0.6	NA
Product A	80:20	222	0.9	100
Product A	20:80	NA	1.2	NA

Table 9. RCE tests at 52Pa.

Corrosion inhibitor	Pre-corrosion rate (mpy)	Inhibited corrosion rate(mpy)	% Protection
Product A	193	7	96
Product H	204	8	96

RCE testing are shown in Table 9. Product H afforded the same level of inhibition as product A with corrosion protection of 96%.

Autoclave Testing

Table 10 shows the corrosion protection provided by product A and H in high temperature/ pressure weight loss tests. At a dose rate of 20 ppm, product H achieved around 80% corrosion protection whereas product A gave only 64% protection.

Table 10. Autoclave coupon tests.

Tests corrosion inhibitor	Pre-corrosion rate (mpy)	Inhibited corrosion rate (mpy)	% Protection
Uninhibited baseline	112.48	N/A	N/A
Product A (20 ppm)	N/A	40.72	63.80
Product H (20 ppm)	N/A	22.26	80.21
Product H (50 ppm)	N/A	22.61	79.90

SUMMARY OF RESULTS AND DISCUSSION

The pass/ fail matrix used in the Table 11 allowed rapid identification of suitable products with two strong possible candidates identified. Methanol compatibility and corrosion inhibition efficiency removed a number of potential inhibitors from the final selection process. Products E, F, G and K were found to produce insufficient inhibition while methanol incompatibility of products B, C, L and M further reduced the number. The number of possible

Table 11. Summary of the results.

Prod.	Inhibition > 90%	Persist	Methanol compatib.	Foaming	Emulsif	Thermal stability	Viscosity	Elastomer compatibility
A	Pass	Pass	Pass	Pass	Pass	Pass	Fail	Pass
B	Pass	Pass	Fail	Pass	Pass	Pass	NA	NA
C	NA	NA	Fail	Pass	Pass	Pass	Pass	NA
D	Pass	Fail	Pass	Pass	Fail	Pass	NA	Pass
E	Pass	Fail	NA	NA	NA	NA	NA	NA
F	Fail	Fail	NA	NA	NA	NA	NA	NA
G	Fail	Fail	NA	NA	NA	NA	NA	NA
H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
I	Pass	Fail	Pass	Pass	Fail	Pass	Pass	Pass
J	Pass	Fail	Pass	Fail	Pass	Pass	Fail	NA
K	Fail	NA	NA	NA	NA	NA	NA	NA
L	NA	NA	Fail	NA	NA	NA	NA	NA
M	Pass	Pass	Fail	Pass	Fail	Fail	Fail	NA
N	NA	NA	Pass	Fail	Pass	Pass	Fail	NA

candidates was still further reduced when film persistency, foaming tendency and elastomer compatibility were considered, discounting products D, I, J and N. This effectively left two possible candidates, products A and H. With the exception of viscosity, there was very little difference between products A and H in terms of performance. However, two further test techniques allowed a clear difference to be identified between the products. The RCE results for products A and H demonstrated that both inhibitors gave excellent inhibition at a shear stress of 52 Pa, Table 9. There was little difference between the performance, with each achieving 96 % inhibition. It was only when the autoclave results were considered that a clear difference was noted, Table 10. At the high temperature used, 115°C, product H had a superior performance. This suggests that product H would also be suitable for high temperature applications, with a dose rate of only 20 ppm affording an inhibition of 80 % in the weight loss coupons.

After careful consideration of all the key design parameters only product H fulfilled the requirements for an inhibitor for application into multiple systems. This effectively demonstrates the need for a wide ranging laboratory evaluation and the importance of non-performance testing when selecting an inhibitor for a particular system.

Field Capabilities

The assessment of a corrosion inhibitor in the field is critical to confirm the laboratory selection and performance of a corrosion inhibitor. In-situ performance in the field can be assessed by a variety of techniques. Field assessment and monitoring can be carried out by a number of methods both in-situ and back in the laboratory to allow the optimum treatment and injection rate to be established. These methods include:

- Sidestream testing
- In-line monitoring
- Electrochemical noise monitoring
- Electrical resistance based technology (ER)
- Corrosivity measurements of produced water
- Weight loss coupons
- Residual inhibitor analysis in produced water

Sidestream equipment can be used to assess the effectiveness of corrosion inhibitors in the field. The system fluids under evaluation are bypassed through the sidestream allowing varying corrosion measurement techniques to be employed including, LPR, EIS and ER probes depending on the fluids in the system. This also allows the system pressure to be monitored as well as measurement of additional relevant parameters such as temperature and concentration of dissolved oxygen in the brine. However, the flow dynamics are completely different in the sidestream as compared to the flowline or pipeline and therefore do not represent a true reflection of the system conditions.

Multiphase flow, where oil is present, limits the options for monitoring but fast response ER

technology allows multiphase systems to be evaluated in a matter of hours. This technology is routinely used to optimise inhibitor injection rates.

On line monitoring has the advantages that the actual system conditions are being assessed. However, in cases where oil is present this can often lead to fouling of electrodes making electrochemical analysis by LPR impossible. Only the longer term testing of weight loss and ER measurements are feasible in this situation. This is another application where fast response ER techniques have an advantage.

Corrosivity measurement can give good information if the rates can be measured with and without inhibitor although the system conditions of temperature and pressure are not reproduced. This method, like the analysis of residual inhibitor, is influenced by residual oil in water samples collected in the field, but can be measured quickly and easily both in the field and back in the laboratory. Samples are collected from relevant locations and then assessed in the laboratory using bubble tests. This data is compared with that originally collected during the inhibitor selection process and any anomalies noted. This test establishes that the correct dose of corrosion inhibitor is being injected into the system.

Residual corrosion inhibitor measurements are conducted in the laboratory from produced water samples from the appropriate locations. Varying analytical methods are employed to determine the concentration of corrosion inhibitor present in the produced water dependent on the type of corrosion inhibitor that has been deployed. This allows the inhibitor concentration within the water phase to be monitored and any corrective action to be taken to keep the inhibition optimised and is a secondary check on the effectiveness of the corrosion inhibitors performance.

Electrochemical noise is the natural fluctuation in potential and current occurring at an electrode interface. The processes resulting in the noise signals are related to electrode kinetics, thus for a corroding system this may be related to the corrosion rate mechanisms. Electrochemical noise is a passive monitoring technique, which means that measurements are taken from the freely corroding electrodes and do not require an externally applied signal, i.e. potential, to make the measurement. This overcomes some of the problems associated with the techniques of linear polarisation resistance and electrochemical impedance spectroscopy where the conductivity of the electrolyte, organic films, and surface scales influence the accuracy of the measurement.

Oil and water measurements are also commonly measured to determine any effect the deployed corrosion inhibitor has on the system efficiency. Any drop in hydrocyclone efficiency, due to the application of the corrosion inhibitor, could result in an increase in oil discharged overboard and violate the local environmental legislation and company policy. Compatibility of live fluids under system conditions can be also assessed in the field, allowing greater assurance of the compatibility of the corrosion inhibitor with the system.

CONCLUSIONS

- An extensive laboratory evaluation identified product H as the best performing corrosion inhibitor for the application discussed in this paper.
- The evaluation included inhibition performance testing, methanol compatibility tests, foam and emulsion tests, low temperature stability and viscosity tests.
- The importance of field data has been established in relation to optimising dose rate and ensuring the corrosion inhibitor in question is functioning as required.
- A number of field techniques have been discussed with the suitability of a particular technique identified as being dependent on the system in question.
- Of the techniques available for field assessment the most commonly employed methods are weight loss coupons, ER probes and LPR probes.

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