Function-Related Dosage of Corrosion Inhibitors; The Development of An On-Site, Operator Deployable Technology

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Presentation Outline

- Who is LUX Assure?
- Background
- What are corrosion inhibitor micelles?
- Where are we now?
- What are we looking to achieve in the future?
LUX Assure Ltd

- A provider of on-site chemical detection products.
- Innovative approach; unique products; strong IP culture; POC to commercialisation
- Founded in 2001; focused on O&G industry in 2009
- Investors
  - Statoil
  - ConocoPhillips
  - Archangels
- Headquartered in the UK, with worldwide agents
- Relevant to the North Sea, and beyond

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Our mission is to establish LUX Assure as a leader in innovative technologies that enable independent, cost effective, better-informed chemical management decisions.

Value for our customers:
- Cost savings (chemicals; analysis; fines)
- Simplifying operations
- Independence of data – not from chemical and service providers
- Improved accuracy
- Improving asset integrity management
- Minimising environmental discharges

LUX’s Products:
- **Simple** to use on-site chemical detection kits
  - MMICA™ - hydrate inhibitor management
  - QMIC™ - corrosion inhibitor management
  - TRAXBiC™ - surfactant biocide mapping

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Informing Better Corrosion Inhibitor Management

Background
Timeline

- Conversation with an operator in a corridor 2008
  - Fact-checking
  - Technical evaluation (2008 POC shown)
  - Commercial evaluation
  - IP evaluation

- Decision point
  - Funding (Operator and TSB funding 2009)
  - Rapid incremental experimentation
  - Access to relevant test samples
  - Access to expertise
  - Access to fields (first field deployment 2011)
  - Further field work (2011-2013)

- Commercialisation (2013)
  - Field trials
  - Sales
  - Feedback from clients meant redevelopment 2015/16

- Idea 2008
- Proof of concept 2008
- Funding 2009
- 1st field trial 2011
- 1st sale 2013
- Last icorr presentation 2014

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Why Bother With Corrosion Inhibitor Monitoring?

- Corrosion inhibitors are an important part of corrosion management
- Their dosing needs to be monitored and managed

- Are they available at recommended dosage for the required amount of time?
- Has the system changed? Does their dosage need to change?
- Is injection equipment working?

- Good management requires good monitoring

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Corrosion Inhibitor Monitoring

- Some methods are excellent – LC-MS
  - Although sending samples to specialist labs for analysis takes time and is expensive
  - Often the only lab it can be sent to is the chemical vendor, so independence in monitoring is not possible

- Some methods can be used on-site
  - Sometimes they work OK
  - But lots and lots and lots of operators complain to us that they are inaccurate

Survey: More than 37% respondents said they strongly agreed that improving inhibitor management could have significant impact on reducing production upsets, reducing OPEX or improving long term asset integrity

There is an opportunity for a better on-site corrosion inhibitor monitoring tool

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Surfactant

- Corrosion inhibitors (quats, imidazolines, phosphate esters)
- Surfactant biocides (quats)
- Form aggregate structures above chemical specific concentrations ➔ micelles
Micelles and Critical Micelle Concentration (CMC)

- CMC is defined as the concentration of a surfactant above which micelle formation occurs.

![Diagram showing micelle formation below and above CMC](image)
PREMISE: corrosion inhibitors form micelles once all available sites for adsorption (e.g. pipe wall) are occupied.

Can these micelles be detected and used to inform corrosion inhibitor management? Not just amount but information...
**Literature: Optimal Corrosion Rate $\leq$ CMC**

BUT a review of 43 papers indicates that only ONE used formulated inhibitors, with the majority looking at single components e.g. an imidazoline and all tested in model systems, not in complex field fluids.

Does the relationship hold true with formulated chemicals and in real fluids?

“The CMC should be used as the treatment rate in the field since maximum inhibition is achieved at this concentration.”
Micelles are a relevant measure for corrosion inhibitor dosage.
A Product to Inform Corrosion Inhibitor Management

- Improve operations: fewer upsets; are pumps functioning etc
- Independent data on chemical management
- Higher throughput corrosion inhibitor evaluation
- Enhance long term asset integrity. Save future integrity costs
- Save chemical costs in overdosed systems (up to £1k/day)

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Using CoMic™

- We add nothing to the system – only take a sample from it for testing.
- Water samples analysed by on-site operators using optical analyser and detection kits in on-site lab.
- Data sent to LUX for analysis and reporting – quick turnaround.

<table>
<thead>
<tr>
<th>OPTICAL ANALYSER</th>
<th>DETECTION REAGENTS</th>
<th>DATA ANALYSIS</th>
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Since 2014 almost everything has evolved

- More work on the instrumentation; now an entirely new instrument
- More work on protocols ➔ client deployable

- More work on the science; micelle link to the corrosion rate
- More chemicals tested
- More field deployments

Development continues to enhance the product

- Looking at surfactant biocides
- How to apply to systems below the critical micelle concentration
- More fields, more conditions, influence of other production chemicals
- Automated data processing

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Evolution of CoMic™ - instrumentation and detection ‘kits’

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Feedback - examples

- We are very excited in recent results.
- Very simple to use.
- Would like clarity on treatment rates and how far below CMC they are?
- Can data be turned around quicker?

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Steps in using CoMic™

- Site identified
- Safety data sheets send to LUX ➔ reviewed
- Chemical/fluid tested @ LUX ➔ confirmation is suitable
- Pre-deployment report sent ➔ Confirmation of deployment
- Training of on-site personnel
- Equipment and kits sent to site
- Samples taken from system and taken to on-site lab
- Mixed with CoMic™ detection reagents
- Placed in instrument
- Data collected transmitted to LUX ➔ data processing
- Report provided
- Data compared with other corrosion management tools to inform decisions e.g. coupons, probes, pump information

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How to use CoMic™? How frequently?

✈️ It depends on what the asset wants to know

“We want a better residual test”

✈️ if micelles can assist us with understanding residuals then we’ll use CoMic™

✈️ Use regularly (daily, weekly, monthly... depends on stability of the system, its criticality, the level of availability required, pump reliability)

✈️ costs –£200-350 a sample; £350/day equipment hire. Lower or higher depending on frequency

“Micelles can help us understand optimal dose and that’s important to us”

✈️ We want to know if we’re protecting our infrastructure as best we can, whether we can save money if we’re overdosing, whether we can reduce production upsets

✈️ Special project. Longer in duration, but may be a one off

✈️ Costs – depend on frequency $5,000 for a client-deployed test of a few samples lasting a few days to $40,000 for a longer period using LUX staff

We’ll take CoMic™ into our labs to assist with chemical qualification and use it to inform field dosage and then use CoMic™ on-site to check this is being dosed

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The Operating Envelope

- Is an optical technique
  - Oil can be present (1-2% water cut OK) but the separated water phase must have good enough sample clarity. Tight emulsions are not suitable
  - Ideally we can have 50 mL water to test

- Production chemicals can be present. Some may interfere (surfactant biocides; scale inhibitors potentially; KHIs potentially) and we ask to screen in advance of deployment
- Need some space in an on-site lab (1m x 1m); need power source; need water

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Common questions…

- Does it provide a residual concentration value for individual chemical components?
- What if multiple chemicals are being used in different lines and the chemicals co-mingle?
- Can it determine how effective the particular inhibitor is?
  - If the client is using a bad chemical (e.g. it doesn’t form a good film on the surface), then CoMic™ can only provide information on whether they are using the optimal amount of a bad chemical.
- Can it measure where corrosion has occurred in an under-dosed system?
- What is ‘optimal’? Weld corrosion. Economics.

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applications
Example 1: Improve Operational Management e.g. is The Pump Working?

- UK offshore field
- Samples from HP Separator
- Initial results showed no chemical – reported to operations
- Corrosion inhibitor pump found to be off
- Pump switched on – micelles detected after approx. 10 hours

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Example 2: Is the Amount of Chemical at an Optimal (Functional) Dose?

- Highly sour field and production system using wetting agent required optimisation
- Chemical detected in initial sample, but not after dose reduced (as part of optimisation study)
- Reducing dosage not recommended – original dosage was optimal

- Depending on the asset cost savings of >1k/day feasible
- Enhance long term integrity
- Improve oil in water separation

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Example 3: Dosage optimisation

- North Sea
- Low water cut
- Production upsets; too much corrosion inhibitor?
- Sample taken ➔ allowed to settle ➔ water removed ➔ CoMic™

overdosing

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Example 4: Impact of Solids

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Example 4: Keeping on Top of Changing Conditions - Solids

- **Solids production, water cut changes, chemical use etc will impact inhibitor availability and so the protection offered. Systems are dynamic and should be monitored routinely.**

- Different solids → different adsorption
- Different corrosion inhibitors → different adsorption

→ **CoMic™ has a place in informing corrosion inhibitor management following system changes.**

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CoMic™

- Corrosion inhibitor detection. CoMic™ provides information on optimal amount not just data relating to concentration
- Commercialised in 2013, redeveloped 2016 to be more client friendly
- Client deployable version now in early commercialisation

What Next?

- Surfactant biocide mapping
- Automated data processing
- Online monitoring
- Feedback loop to pumps

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