STEM-Corrosion

Integrated Flow, Internal Localized Corrosion, Microbiologically Influenced Corrosion, and Solids (iFILMS™) Software

interlace
Connect ■ Collaborate ■ Innovate
IT SOLUTION

Context
Science
Validation
Product
Application
Services

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iFILMS™ - Context

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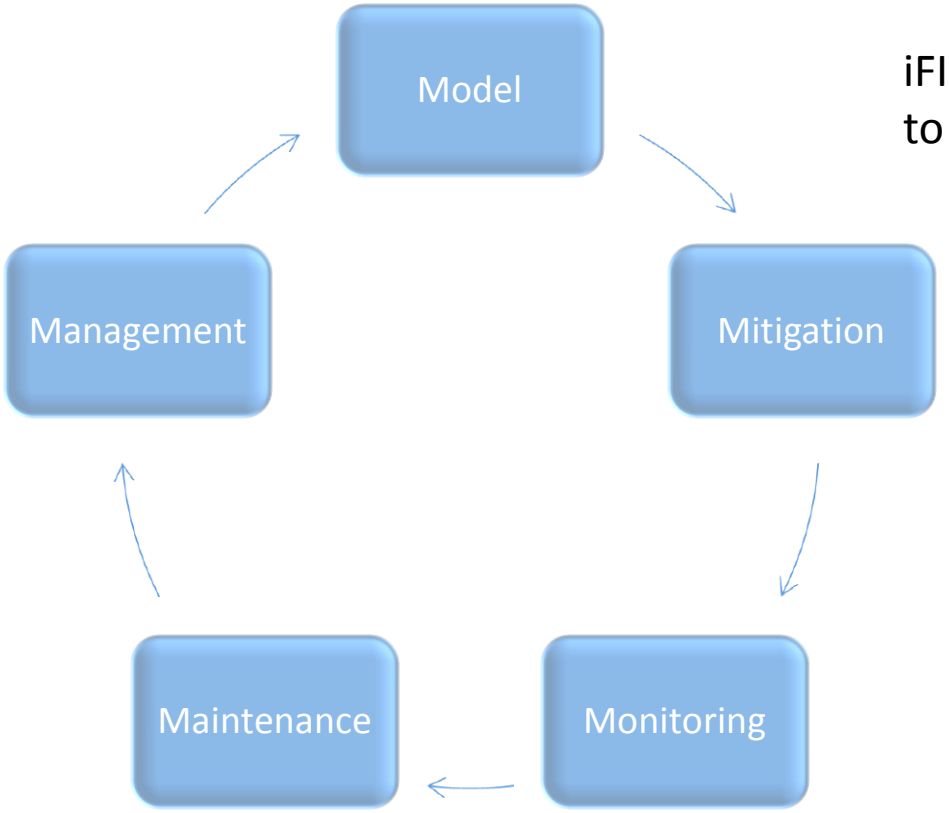

iFILMS™ integrates all 5 Ms to control internal corrosion

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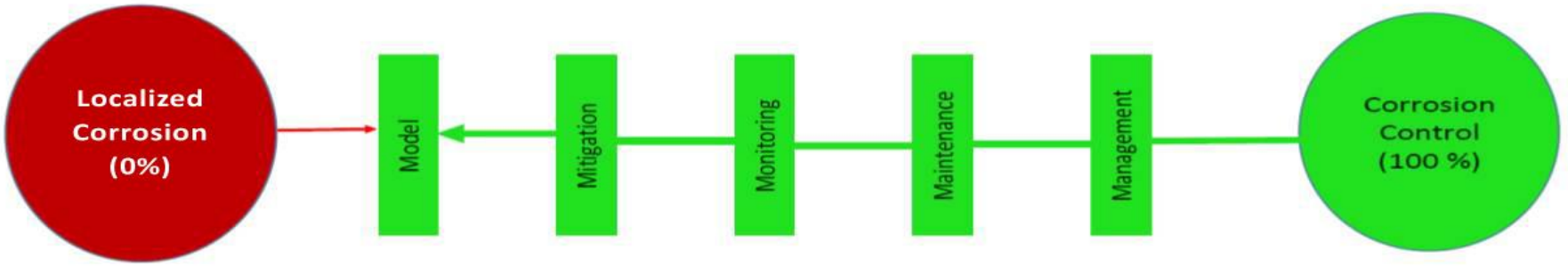

Failures/incidences do not happen due to general corrosion

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iFILMS™ – Context

(iFILMS™ addresses all aspects of localized corrosion)

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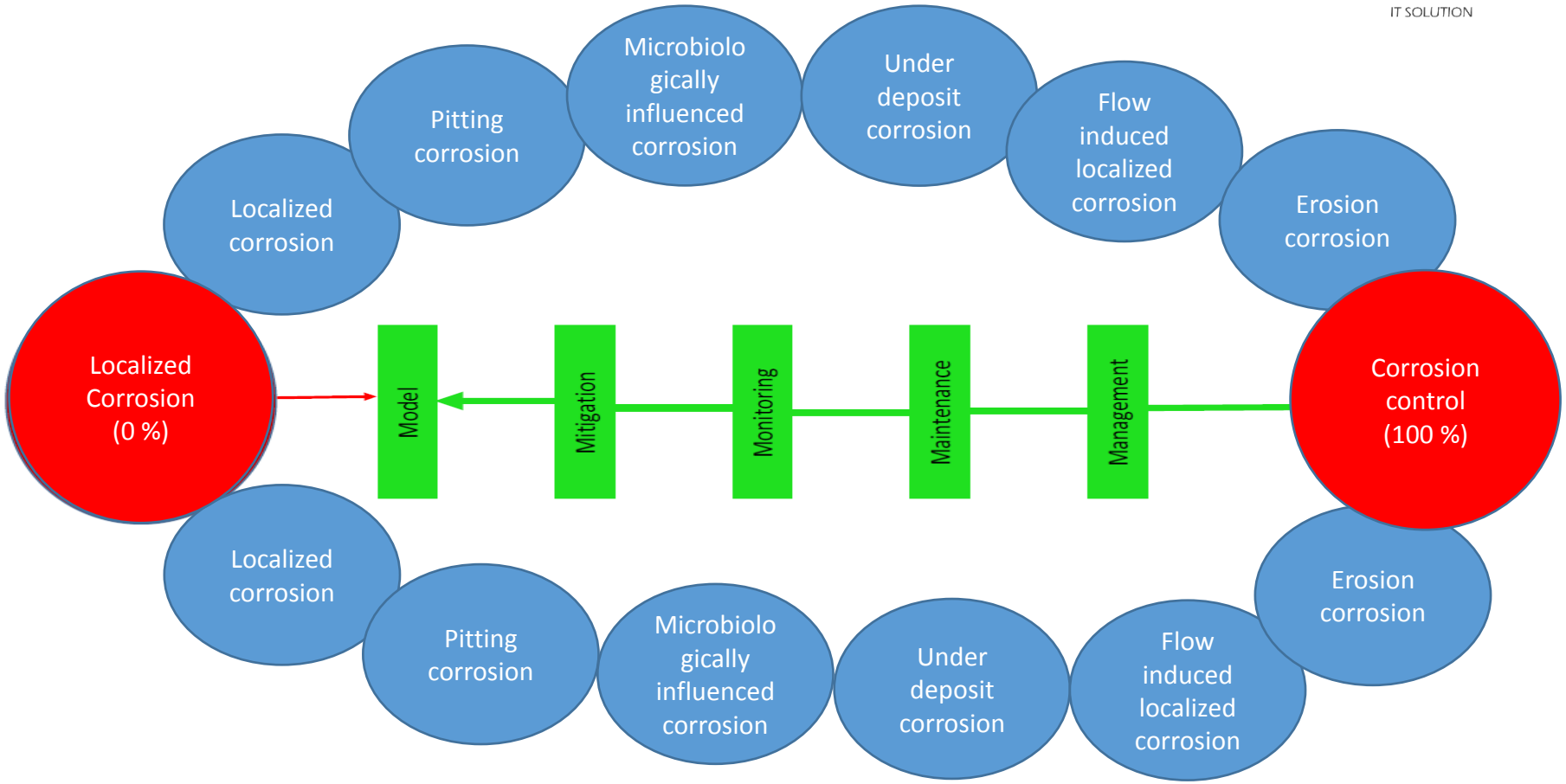

STEM-Corrosion

iFILMS™ is for both Piggable and Non-Piggable Pipelines

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- Context
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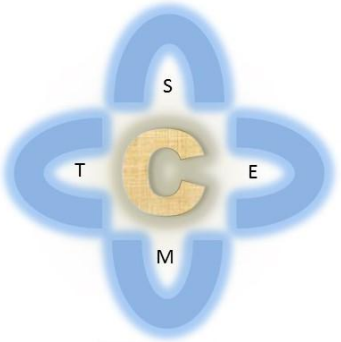
- For piggable pipelines
  - iFILMS™ is used to establish inline inspection (ILI) frequency

- For non-piggable pipelines
  - iFILMS™ is used in all four (4) NACE ICDA standards
    - SP0206: Normally dry Gas
    - SP0208: Liquids
    - SP0110: Wet Gas
    - SP0116: Multiphase



STEM-Corrosion

iFILMS™ – Context (iF = iFILMS™)

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NACE 21413, "Prediction of Internal Corrosion in Oilfield Systems from System Conditions"

- Context
- Science
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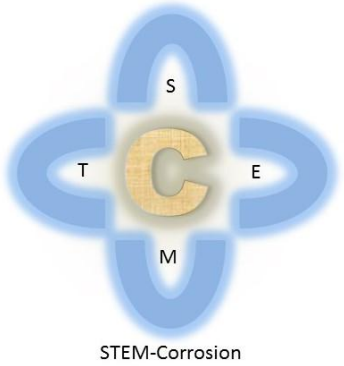
Model	DW	NO	HY	CA	CO	KS	MU	FC	EC	PR	SP	UL	OL	SR	CP	EN	SW	IF
Lab data, Field data model, Mechanistic model	L	L	M	L	F	M	M	-	L	L	M	F	M	-	L	-	L	L,F
Scale effect formation water*	N	M	N	W	W	M	M	-	W	S	S		W	-	M	-	W	S
Scale effect condensed water*	W	M	W	W	W	M	M	-	W	S	S		M	-	M	-	W	W
Effect of pH on corrosion rate*	W	M	W	W	M	M	M	-	W	S	S	S	W	-	M	-	W	M
Risk for localized attack	-	-	-	-	Y	Y		-	-	Y	-	Y	-	-	-	-	-	Y
Oil wetting effect crude oil*	S	N	M	N	M	N	S	-	S	S	N	S	N	-	M	-	N	S
Oil wetting effect condensate*	N	N	N	N	M	N	M	-	M	M	N	S	N	-	M	-	N	S
$CaCO_3$ correction for pH	-	-	-	-	Y	-	Y	-	-	-	-	-	Y	-	-	-	-	Y
Effect of organic acid on corrosion	-	-	Y	Y	Y	-	Y	-	Y	Y	-	Y	-	-	-	-	-	Y
Top of line corrosion	Y	-	Y	-	-	-	Y	-	Y	-	-	Y	-	-	-	-	-	Y
Effect of H_2S on corrosion rate*	N	N	W	N	N	N	M	-	S	S	N	W	S	-	N	-	N	S
Multiphase flow calculation**	N	P	M	N	P	N	P	-	M	P	P	M	N	-	M	-	N	M
Open, Commercial, Proprietary	O	O	P	O	O	O	P	-	C	C	P	P	C	-	P	-	P	C

Y = YES, N = NO, U = UNKNOWN
* S - strong effect, M - moderate effect, W - weak effect, N - no effect
** P - point calculation, M - multiphase profile calculation, N - no multiphase flow calculation



STEM-Corrosion

iFILMS™ - Context

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NACE 21410, Technical Report on Selection of Flow and Internal Corrosion Models

- Context
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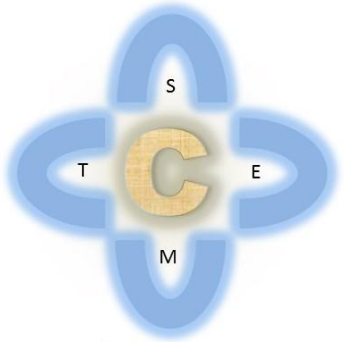
- Establish evaluation and selection criteria
- Corrosion Damage Mechanisms (CDMs)
- General corrosion vs Localized Pitting Corrosion (LPC)
  - Use of factor to convert general corrosion to LPC is **incorrect**
- Perform sensitivity analysis
- Establish boundary conditions
- Understand interim parameters



STEM-Corrosion

iFILMS™ - Science

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IT SOLUTION

- Context
- Science
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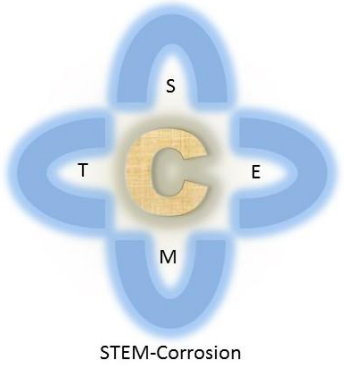
- Based on
  - Analyzing surface Layers under 40 different operating conditions
    - Iron carbonates
    - Iron sulphides
    - Iron oxides
  - Investigating pit initiation process at high temperature and high pressure
    - Electrochemical noise measurements
    - Potentiodynamic polarization tests
    - Surface profilometer analysis
  - Following pit propagation
    - 144 pits in 6 sour and sweet oil and gas operating pipelines over 4 years
- See “Literature” link for reference papers



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iFILMS™ - Science

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Pitting Corrosion Rate (mpy) ={[∑

(-0.33	θ	+	55)	+
(0.51	W	+	12)	+
(0.19	W_{ss}	+	64)	+
(25	R_{solid}	+	50)	+
(0.55	T	+	15)	+
(-0.07	P_{Total}	+	85)	+
(-0.32	P_{H2S}	+	55)	+
(-0.55	P_{CO2}	+	65)	+
(0.85	$C_{Sulphur}$	+	10)	+
(-0.013	C_{SO4}	+	57)	+
(-0.014	C_{HCO3}	+	81)	+
(0.0007	C_{Cl}	+	9)	+

)]/12}

θ	Wettability (Oil production)
W	Type of emulsion (Water Production)
W_{ss}	Wall shear stress, Pa (Gas Production)
R_{solid}	Solid production, ppm
T	Temperature, ^oC
P_{Total}	Total pressure, psi
PH_2S	Partial pressure H_2S, psi
PCO_2	Total pressure CO_2, psi
$C_{sulphur}$	Sulphur, ppm
C_{SO4}	Sulphate, ppm
P_{CO2}	Bicarbonate, ppm
C_{Cl}	Chloride, ppm

Flow of Calculations in iFILMS™ – Design Mode

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interlace
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IT SOLUTION

- Context
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Primary Drivers of Pitting corrosion

Wet | EIP | WSS | Solid | Temp. | Pressure | H_2S | CO_2 | Sulphur | Sulphate | Chloride | Bicarbonate

- $PCR_{Average} + PCR_{Std.}$
- PCR_{MIC}
- PCR_{Flow}
- PCR_{Time}
- PCR_{Oxygen}
- $PCR_{Mitigation}$ (Displayed as PCR_{iFILMS})
- Pipeline Life (Internal corrosion)

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Flow of Calculations in iFILMS™ – Operation Mode

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IT SOLUTION

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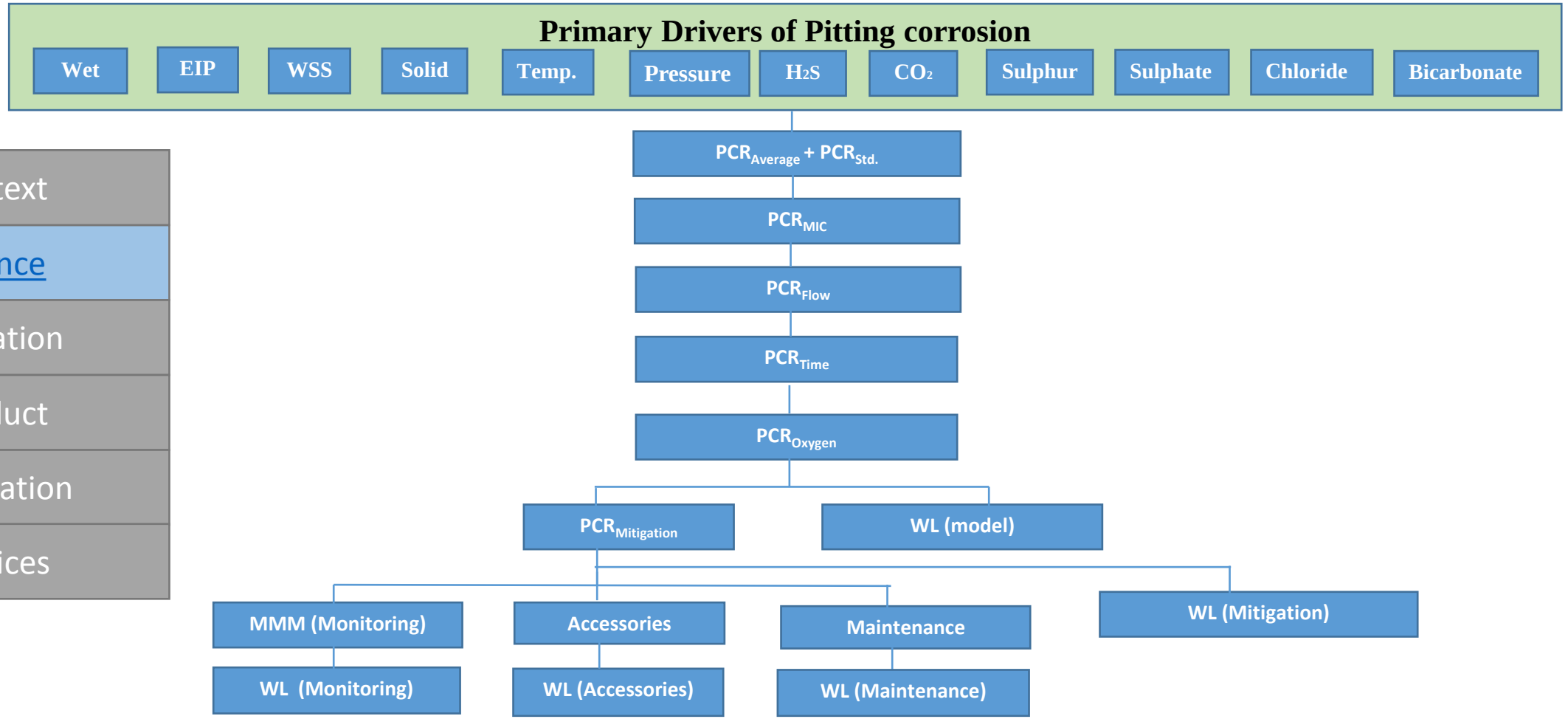

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iFILMS™ – Validation (Design Mode)

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Pitting Corrosion Rate	Low Flow		High Flow	
	mpy	mm/y	mpy	mm/y
Predicted	47 ± 24	1.2 ± 0.6	53 ± 29	1.3 ± 0.7
Actual	47 – 49	1.1 – 1.2	47 – 49	1.1 – 1.2

References:

Oil and Gas Journal, 105.44, Nov. 2007, pages 68-73.
Oil and Gas Journal, 105.45, Dec. 2007, pages 62-67.

STEM-Corrosion

iFILMS™ – Validation (Design Mode)

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IT SOLUTION

- Context
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Field*	pH_2S, psi (kPa))	pCO_2, psi (kPa)	Predicted PCR, mpy (mm/y)	Actual PCR, mpy (mm/y)
1	0.2 (1)	320 (2,206)	20 (0.45)	18 (0.45)
2	2 (14)	4 (28)	13 (0.33)	2 (0.05)
3	2 (14)	4 (28)	16 (0.40)	2 (0.05)
4	2 (14)	4 (28)	31 (0.78)	27 (0.68)
5	0.2 (1)	2 (14)	16 (0.40)	11 (0.28)
6	0.2 (1)	0.1 (1)	16 (0.40)	17 (0.43)
7	60 (414)	6 (41)	47 (1.18)	48 (1.20)
8	0 (0)	21 (145)	0.7 (0.02)	0.1 (0.00
9	0 (0)	20 (138)	1.2 (0.03)	0.1 (0.00)
10	0 (0)	21 (145)	0.5 (0.01)	0.1 (0.00)

Reference: Corrosion Conference 2016, Paper 7250

STEM-Corrosion

iFILMS™ – Validation (Operation Mode)

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- Context
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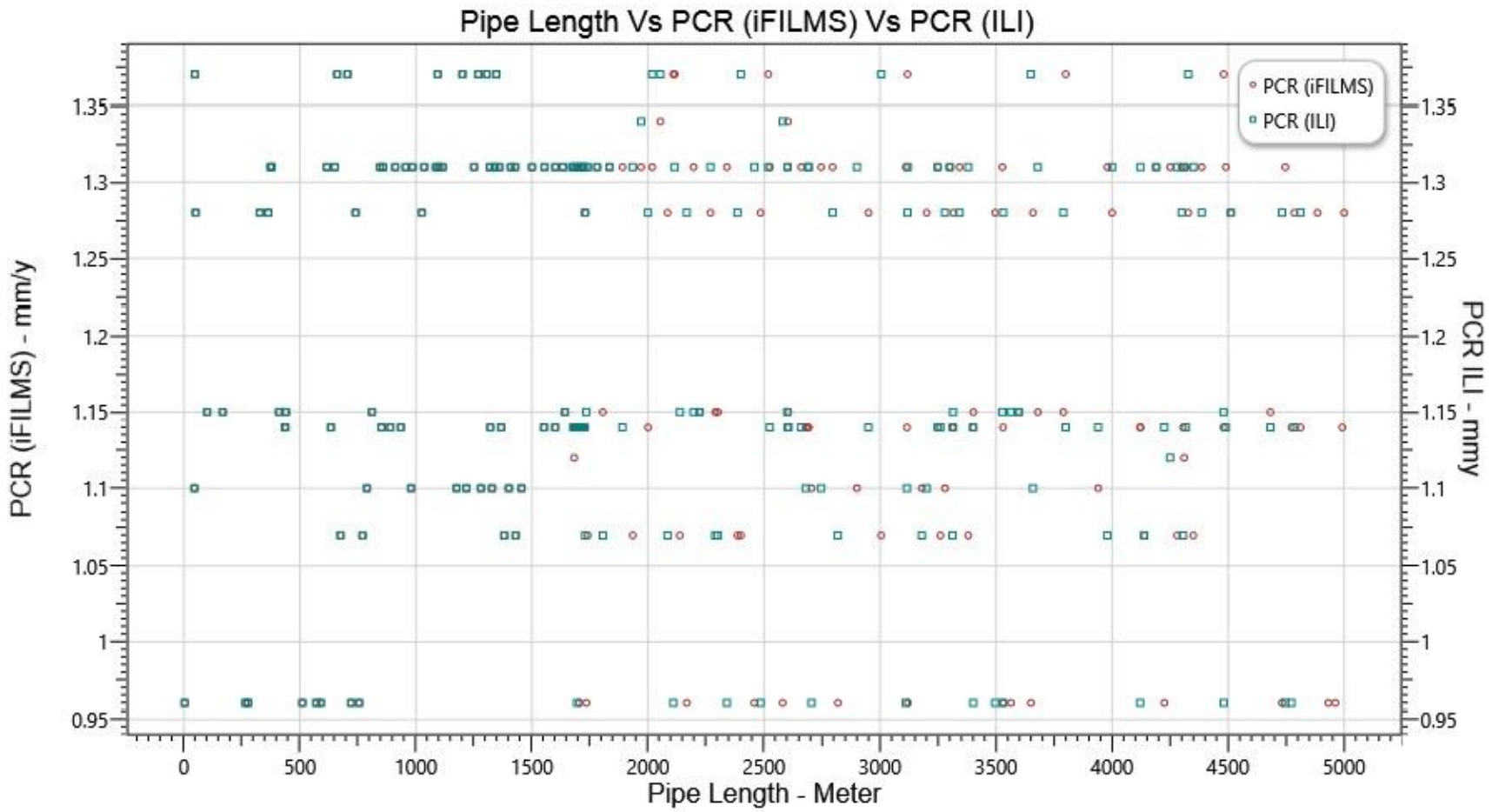

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iFILMS™ – Product

interlace
Connect ■ Collaborate ■ Innovate
IT SOLUTION

- Context
- Science
- Validation
- Product
- Application
- Services

- Design Mode
  - One screen
  - Predicts maximum localized pitting corrosion rate
  - Predicts several parameters
    - In situ pH
    - Flow regimes
    - Wall shear stress
    - Type of emulsion
    - Type of wettability

STEM-Corrosion

iFILMS™ – Product

interlace
Connect Collaborate Innovate
IT SOLUTION

- Context
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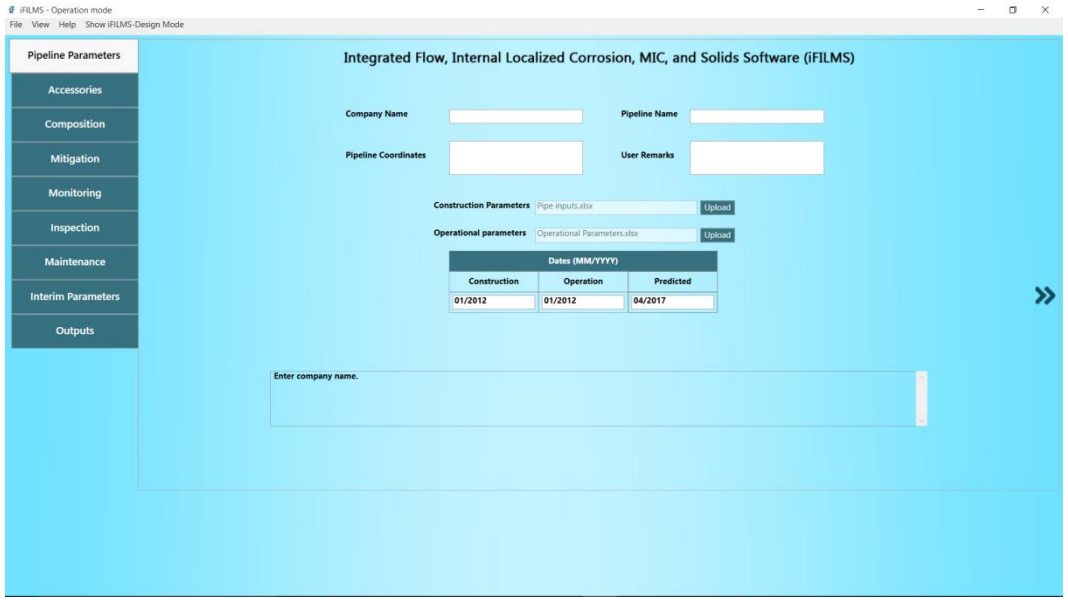
- Services

- Operation Mode
  - Several screens
  - Predicts realistic localized pitting corrosion along the length and around the circumference of the pipeline
  - Predicts several parameters
    - Corrosion Damage Mechanisms
    - Pressure Drop
    - Temperature Variation
    - pH
    - Flow Regimes



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iFILMS™ – Product

interlace
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IT SOLUTION

- Context
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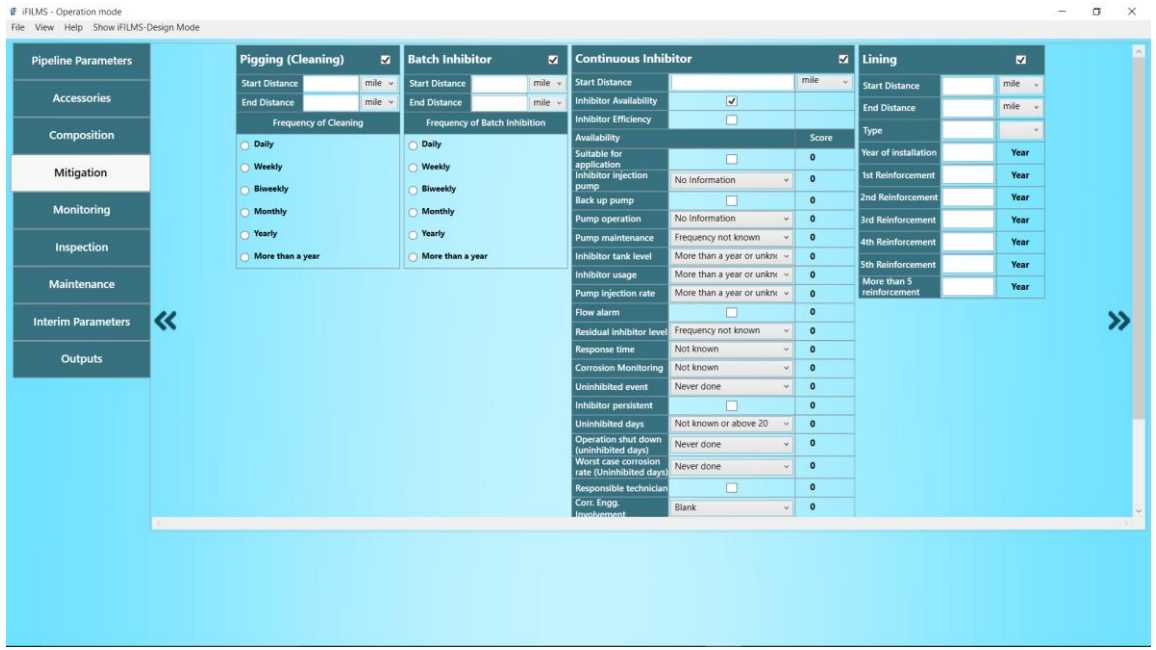
- Operation Mode
  - Vast amount of field information/data can be inputted and integrated
    - Accessories
    - Composition
    - Mitigation
    - Monitoring
    - Inspection
    - Maintenance
  - Interim parameters
    - Enable users to fine tune iFILMS™



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iFILMS™ - Application

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IT SOLUTION

- Context
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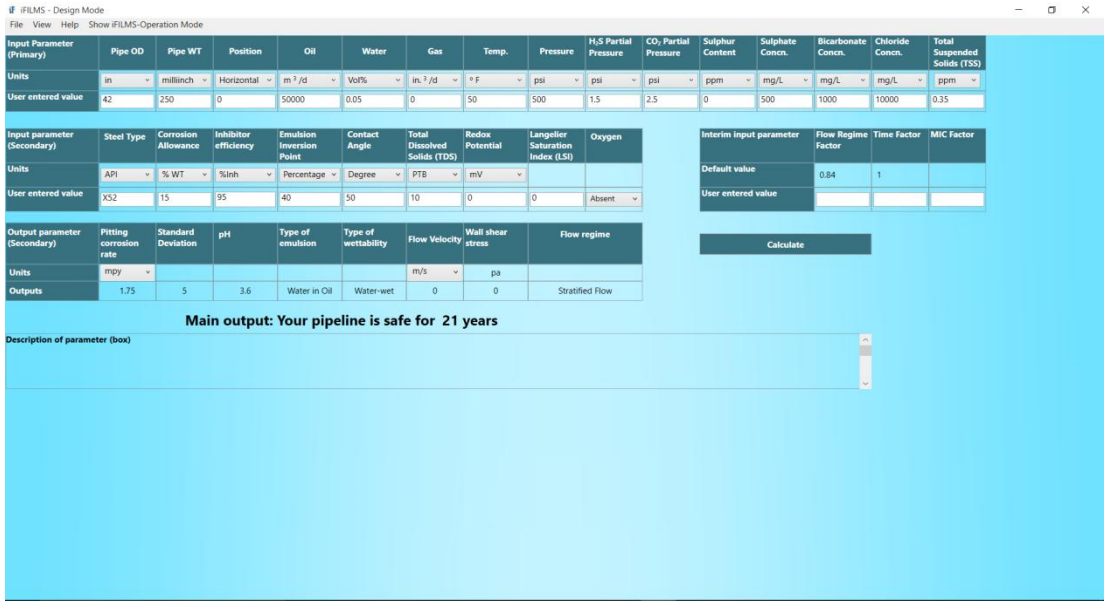
- Design Mode
  - Optimizes the corrosion allowance of carbon steel for new sour and sweet projects
  - Predicts service life in sour and sweet environments



STEM-Corrosion

iFILMS™ - Application

interlace
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IT SOLUTION

- Context
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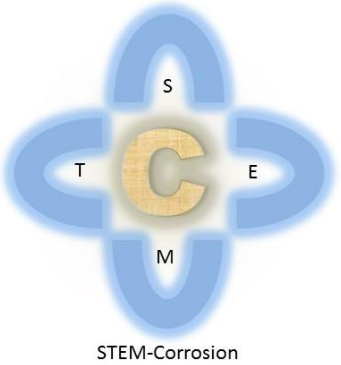
- Operation Mode
  - Piggable Pipelines
    - iFILMS™ integrates data from ILI to enhance reliability
    - Provides pitting corrosion rate from both scientific model and ILI
    - Helps to determine ILI run frequency
  - Non-Piggable Pipelines
    - NACE ICDA standards
      - SP0206, Normally Dry Gas
      - SP0208, Liquids
      - SP0110, Wet Gas
      - SP0116, Multiphase
    - Provides "pre-assessment" sites
- Exceeds the requirements of NACE 21410 technical report



STEM-Corrosion

iFILMS™ - Services (www.STEMCorrosion.com)

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- For Owner, Operator, and Inhibitor Supply Companies
  - Product downloadable from an URL link given through E-mail
- www.STEMCorrosion.com/
  - Click, “Services offered”
  - Click, “Click here to avail services”
  - Click, “Register” and “fill information”