

Effective and Efficient Inspections through Damage Mechanism Assessment

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Presentation Outline

What is DM and DMA?

- What is a Damage Mechanism (DM)?
- What is a Failure?
- What is a Damage Mechanism Assessment (DMA)?

DMA Approach

- How to Perform a DMA?
- Data Needs
- Identify Damage Mechanisms

DMA Approach Benefits

- Detailed Review of Design and Construction
- Eased Implementation of Other Inspection/Integrity Practices
- Improved Inspection Work Processes
- Streamlined Program (DM-based CML Placement)
- Identification of Proper Inspection/Monitoring Methods
- Generate Inspection Plans
- Inspection Intervals
- Standard/Regulatory Requirements

Pulling It All Together

What is a Damage Mechanism (DM)
and
Damage Mechanism Assessment (DMA)?

What is a Damage Mechanism?

Damage (or deterioration) mechanism:

A process that induces **micro and/or macro material changes over time** that are harmful to the material condition or mechanical properties.



Manufacturing Defects

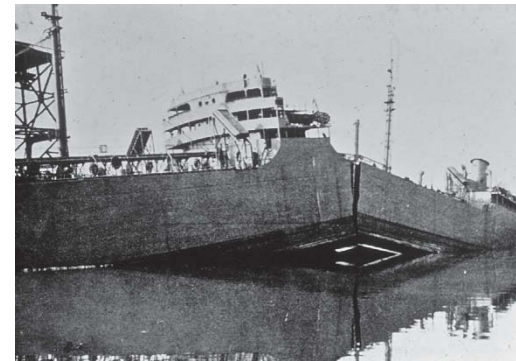


Damaged Asset

What is a Failure?

Failure is termination of the ability of a system, structure, equipment or component to perform its required function of containment of fluid (i.e. loss of containment).

The Liberty ship, which in 1943, **failed before leaving the shipyard.**



What is a Damage Mechanism Assessment (DMA)?

Systematic approach for identifying mechanical, chemical, physical, or other conditions which result in equipment or material degradation

- Designed to determine credible damage mechanism rate and susceptibilities of pressure-containing equipment/piping
- Performed circuit-by-circuit corrosion study (damage mechanism study) by a multi-disciplinary team (operations, maintenance, mechanical, materials, and inspection SMEs)
- Applicable to pressure-containing equipment – Pressure Vessels, Piping, Storage Tanks, Process Heaters
- Primarily used to help formulate inspection plans to mitigate risk of loss of containment and/or unplanned outages...

DMA Approach

How to Perform a DMA?

Obtain Data

- Process Data – PFDs, P&IDs, process description, HMB, technical specification of feeds, injectants and products
- Operating Data - Normal operating envelopes and procedure, lab analysis of feeds, injectants and products
- Equipment/Piping Design and Fabrication Data – materials of construction, heat treatment history, Inspection & Maintenance history

Develop Information

- Generate Corrosion Materials Diagram (CMD) – PFD level
- Prepare DMA worksheet
- Identify initial corrosion loops
- Identify potential damage mechanisms

How to Perform a DMA? (cont'd)

Conduct DMA

- Assemble and meet with DMA team
- Conduct process overview
- Consider operating and maintenance procedures
- Collect unit-specific process data & lessons learned (failure history, especially mechanical failures)

Identify DMs

- Identify credible damage mechanisms using API RP 571
- Finalize corrosion loops
- Determine expected rates and susceptibilities to damage mechanisms
- Identify susceptible locations
- Develop recommendations

How to Perform a DMA? (cont'd)

Document DMA

- Finalize Corrosion and Materials Diagrams
- Finalize damage mechanism worksheet
- Document recommendations
- Generate DMA report

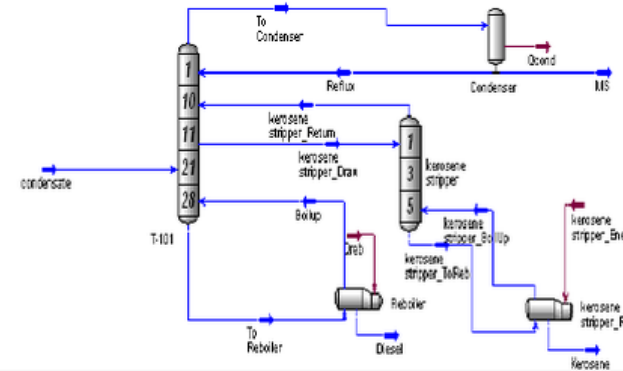
Use DMA Results

- Improved inspection work processes:
 - More technically robust inspections, efficient management through considerations to CML placement, Inspection plans, Alternatives for Internal Inspection Strategy, Identification of proper NDE methods and RBI
- Integrity Operating Windows (IOW) development
- Fitness For Service (FFS) studies
- Process Hazard Review meetings
- Management of Change reviews

Data Needs

Process Design Data

- PFDs and P&IDs,
- Process descriptions,
- Heat and material balance data including: Chemicals, Phases, Design Temperature/Pressure, Flow rate for all involved materials (feed, intermediate and final products, injectants),
- Technical specifications of all involved materials including Material Safety Data Sheets (MSDS).
- Chemical treatment programs for process/corrosion management



Material Streams												
	Reflux	To Condenser	Boilup	To Reboiler	MS	Diesel	condensate	kerosene stripper_Draw	kerosene stripper_Return	Kerosene	kerosene stripper_Boilup	kerosene stripper_ToReb
Vapour Fraction	0.0000	1.0000	1.0000	0.0000	0.0000	0.0000	0.6945	0.0000	1.0000	0.0000	1.0000	0.0000
Temperature C	35.00	119.3	250.5	272.4	35.00	280.9	200.0	180.7	184.6	200.8	200.8	195.3
Pressure psig	10.00	10.00	12.00	12.00	10.00	12.00	25.00	10.74	10.74	10.74	10.74	10.74
Molar Flow MMSCFD	1.385	2.078	1.004	1.191	0.6925	0.9870	1.104	0.4886	0.1820	0.2448	0.1933	0.4276
Mass Flow lb/hr	1.411e+004	2.117e+004	2.030e+004	2.439e+004	7095	3863	1.493e+004	5875	2190	3765	2950	8475
Liquid Volume Flow barrel/day	1240	1875	1806	1918	625.0	312.5	1280	497.4	184.8	312.5	224.1	536.6
Heat Flow Btu/hr	-1.225e+007	-1.627e+007	-1.167e+007	-1.676e+007	-8.829e+006	-2.713e+006	-1.041e+007	-4.754e+006	-1.480e+006	-2.025e+006	-1.754e+006	-6.049e+006

Data Needs (cont'd)

Actual Operating Data

- Operating envelopes and procedures for:
 - Normal, (Startup/shut down and expected upset conditions)

Lab analysis of:

- Feeds, injectants and products

Existing IOWs



Data Needs (cont'd)

- Equipment/Piping Design and Fabrication Data
- Design parameters:
 - Applicable code,
 - Design temperature and pressure
- Materials of construction and grade
- Other fabrication details (PWHT)
- Special equipment issues – re-rates, FFS evaluations, etc.



Identify Damage Mechanisms

- Mechanical and Metallurgical Failure Mechanisms
- Uniform or Localized Loss of Thickness
- High Temperature Corrosion [$>400^{\circ}\text{F}$ (204°C)]
- Environmentally – Assisted Damages

Damage Mechanisms

Identify Damage Mechanisms (cont'd)

Review

- Established corrosion/materials literature,
- Company-specific studies and
- API 571 RP

Identify damage mechanisms for

- Normal operating condition,
- Startup, shutdown condition and
- Upset condition.

Damage Mechanism No.	Description
1	Sulfidation
2	Wet H2S Damage (Blistering/HIC/SOHIC/SSC)
3	Creep / Stress Rupture
4	High temp H2/H2S Corrosion
5	Polythionic Acid Cracking
6	Naphthenic Acid Corrosion
7	Ammonium Bisulfide Corrosion
8	Ammonium Chloride Corrosion
9	HCl Corrosion
10	High Temperature Hydrogen Attack
11	Oxidation
12	Thermal Fatigue
13	Sour Water Corrosion (acidic)
14	Refractory Damage
15	Graphitization
16	Temper Embrittlement
17	Decarburization
18	Caustic Cracking
19	Caustic Corrosion
20	Erosion / Erosion-Corrosion
21	Carbonate SCC
22	Amine Cracking
23	Chloride Stress Corrosion Cracking
24	Carburization
25	Hydrogen Embrittlement
27	Thermal Shock
28	Cavitation
29	Graphitic Corrosion (see Dealloying)
30	Short term Overheating - Stress Rupture
31	Brittle Fracture
32	Sigma Phase/ Chi Embrittlement
33	885oF (475oC) Embrittlement
34	Softening (Spheroidization)
35	Reheat Cracking

Damage Mechanism No.	Description
36	Sulfuric Acid Corrosion
37	Hydrofluoric Acid Corrosion
38	Flue Gas Dew Point Corrosion
39	Dissimilar Metal Weld (DMW) Cracking
40	Hydrogen Stress Cracking in HF
41	Dealloying (Dezincification/ Denickelification)
42	CO2 Corrosion
43	Corrosion Fatigue
44	Fuel Ash Corrosion
45	Amine Corrosion
46	Corrosion Under Insulation (CUI)
47	Atmospheric Corrosion
48	Ammonia Stress Corrosion Cracking
49	Cooling Water Corrosion
50	Boiler Water / Condensate Corrosion
51	Microbiologically Induced Corrosion (MIC)
52	Liquid Metal Embrittlement
53	Galvanic Corrosion
54	Mechanical Fatigue
55	Nitriding
56	Vibration-Induced Fatigue
57	Titanium Hydriding
58	Soil Corrosion
59	Metal Dusting
60	Strain Aging
61	Steam Blanketing
62	Phosphoric Acid Corrosion
63	Phenol (carbolic acid) Corrosion
64	Uniform Corrosion
65	Pitting
66	Underdeposit Corrosion
67	None
68	Intergranular Corrosion
69	Acetic Acid/Anhydride Corrosion

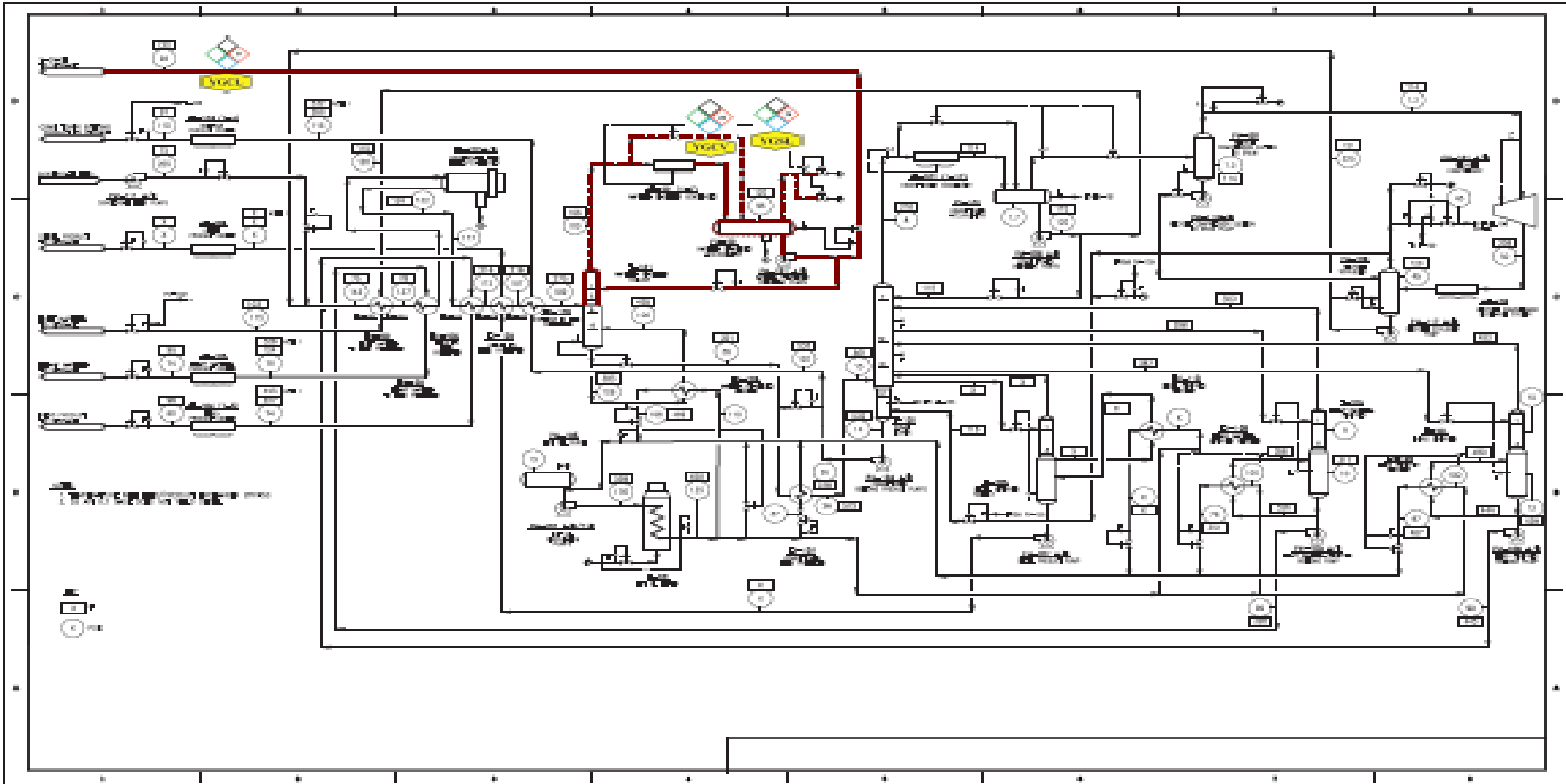
Identify Damage Mechanisms (cont'd)

Typical Gas Plant DMs By Process System / Material of Construction

Typical Damage Mechanisms	Feed HC Stream		Rich Amine		Lean Amine		CO2 Rich Stream		Mol sieve Dehydrator	Regen / Dry Gas	Refrigerant		Fuel Gas	Drain	Flare	
	CS	300 Series SS	CS	300 Series SS	CS	300 Series SS	CS	300 Series SS	CS	CS	LTCS	300 Series SS	CS	CS	CS	300 Series SS
1 - Brittle Fracture	√		√		√		√				√		√	√	√	
2 - Creep					√	√	√	√	√	√			√		√	
3 - Thermal Fatigue	√	√	√	√	√	√	√	√	√				√		√	
4 - Short Term Overheating					√	√	√	√					√		√	
5 - Dissimilar Metal Weld Cracking			√		√		√				√		√	√	√	
6 - Erosion/Erosion-Corrosion	√	[√]	√	[√]	√	[√]	√	[√]	√	√	√	[√]	√	√	√	[√]
7 - Mechanical Fatigue	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
8 - Vibration-Induced Fatigue	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
9 - Galvanic Corrosion	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
10 - Atmospheric Corrosion	√	(√)	√	(√)	√	(√)	√	(√)	√	√			√	√	√	(√)
11 - Corrosion Under Insulation	√	(√)	√	(√)	√	(√)	√	(√)	√	√			√	√	√	(√)
12 - CO2 Corrosion	√		√		√		√									
13 - Microbiologically Induced Corrosion	√	√														
14 - Soil Corrosion	√		√		√		√		√	√	√	√	√	√	√	√
15 - Amine Corrosion			√	√	√	√	√	√								
16 - Sour Water Corrosion (Acidic)	√															
17 - Sulfidation																
18 - Chloride Stress Corrosion Cracking		√		√		√		√								
19 - Wet H2S Damage	√		√		√		√	√								
20 - Hydrogen Stress Cracking-HF																

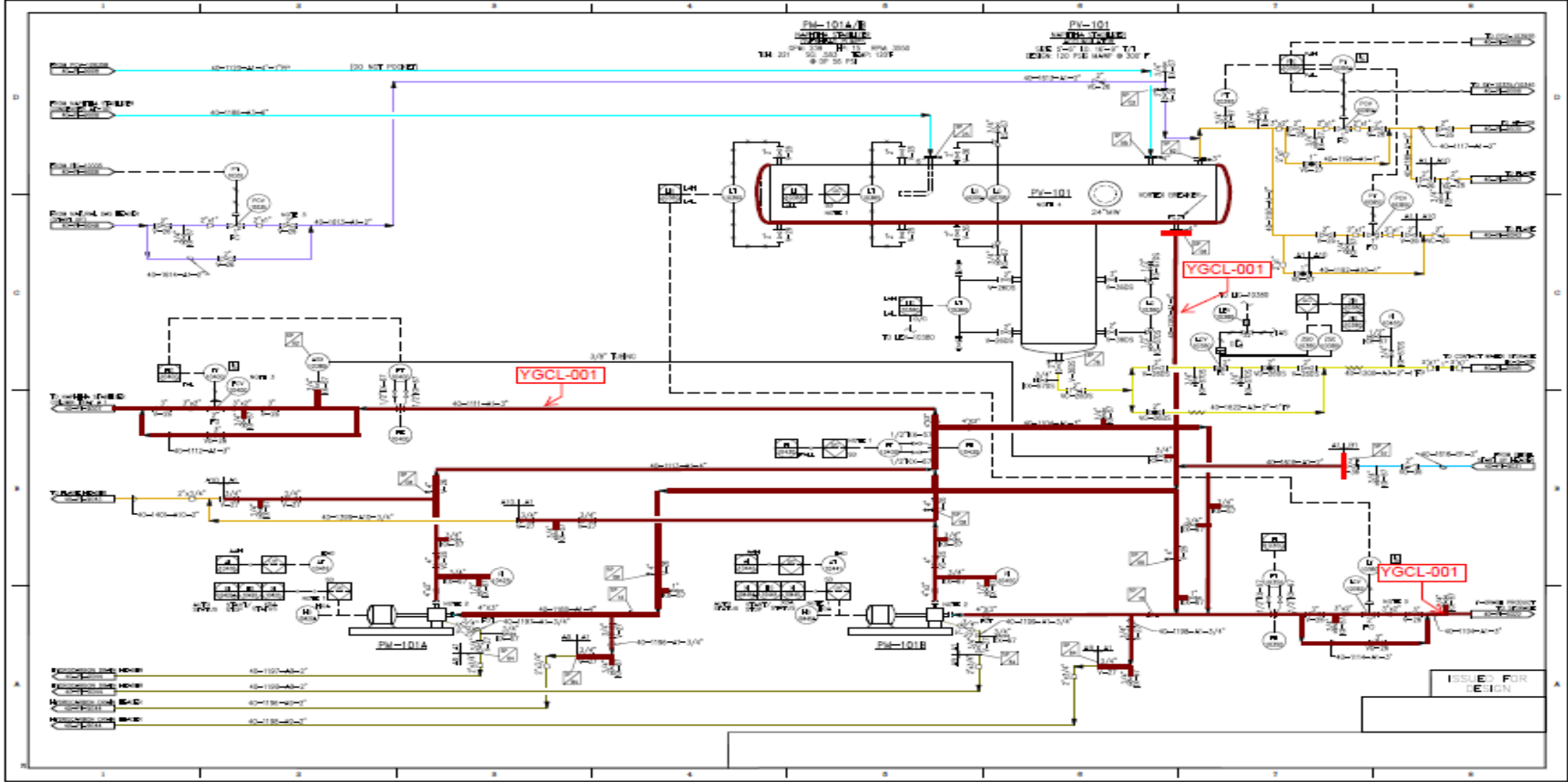
Identify Damage Mechanisms (cont'd)

Generate Corrosion Loops



Identify Damage Mechanisms (cont'd)

Generate Corrosion Loops



Identify Damage Mechanisms (cont'd)

Typical DMA Worksheet

Corrosion Loop No.	Color Code	Service & Materials ^[1]	State	Temperature	Estimated corrosion rate (mpy)	Minimum corrosion rate (mpy)	Maximum corrosion rate (mpy)	Preliminary DM ^[2]	SUSC ^[3]	Secondary DM	SUSC	Upset DM	SUSC	Startup/Shutdown DM	SUSC	Comments
CL-001		Halogenated Solvent / Hydrochloric Acid / Alkane Solvent / Caustic / Sodium Carbonate in TFE	Liquid	Ambient to 125 °C	1	1	1	None	NA	None	NA	None	NA	None	NA	_Default Corrosion Rate ^[4] .
CL-002		Alkane Solvent/ Alcohol / Halogenated Solvent in 316 SS	Liquid	Ambient to 125 °C	1	1	1	General Corrosion	Low	None	NA	Cl ⁻ SCC, Cl Pitting	Low	None	NA	_Default Corrosion Rate. _In batch type operation probability of presence of water is low to cause secondary DM.
CL-003		Halogenated Solvent / Alcohol in 316 SS	Gas/Vapor	Ambient to 125 °C	1	1	1	None	NA	None	NA	Cl ⁻ SCC, Cl Pitting	Low	None	NA	_In batch type operation probability of presence of water is low to cause secondary DM.
CL-004		Halogenated Solvent / Acetate in Carbon Steel	Gas/Vapor	Ambient to 125 °C	3	1	10	General Corrosion	Low	None	NA	HCl Corrosion	Low	None	NA	_HCl Corrosion may occur when chlorides dissociate and condensation or accumulation of vapors occurs in upset conditions
CL-005		Hydrochloric Acid /Acetate / Alkane Solvent in Lined	Liquid	Ambient to 125 °C	1	1	1	None	NA	None	NA	Thermal Shock / Alkaline Attack	Low	Thermal Stress Cracking	Low	_Default Corrosion Rate. _ Thermal stress and shock may also happen during startup/shutdown.
CL-006		Organic and Process Waste Water in 316 SS	Liquid	Ambient to 125 °C	1	1	1	General Corrosion	Low	None	NA	Cl ⁻ SCC, Cl Pitting	Low	None	NA	_Default Corrosion Rate. _Waste streams could contain Chloride ions.
CL-007		Nitrogen in 316 SS	Gas/Vapor	Ambient to 125 °C	1	1	1	None	NA	None	NA	None	NA	None	NA	_Default Corrosion Rate.
CL-008		Nitrogen / Acetate /Halogenated Solvent / Alcohol / Hydrochloric Acid Vent in TFE	Gas/Vapor	Ambient to 125 °C	1	1	1	None	NA	None	NA	None	NA	None	NA	_Default Corrosion Rate.
CL-010		Halogenated Solvent / Hydrochloric Acid / Alkane Solvent / Caustic in Hastelloy C-276	Liquid	Ambient to 125 °C	1	1	1	General Corrosion	Low	None	NA	None	NA	None	NA	_Default Corrosion Rate.
CL-011		Halogenated Solvent / Hydrochloric Acid / Alcohol Vent in Lined	Gas/Vapor	Ambient to 125 °C	1	1	1	None	NA	None	NA	Thermal Shock / Alkaline Attack	Low	Thermal Stress Cracking	Low	_Default Corrosion Rate. _ Thermal stress and shock may also happen during startup/shutdown.

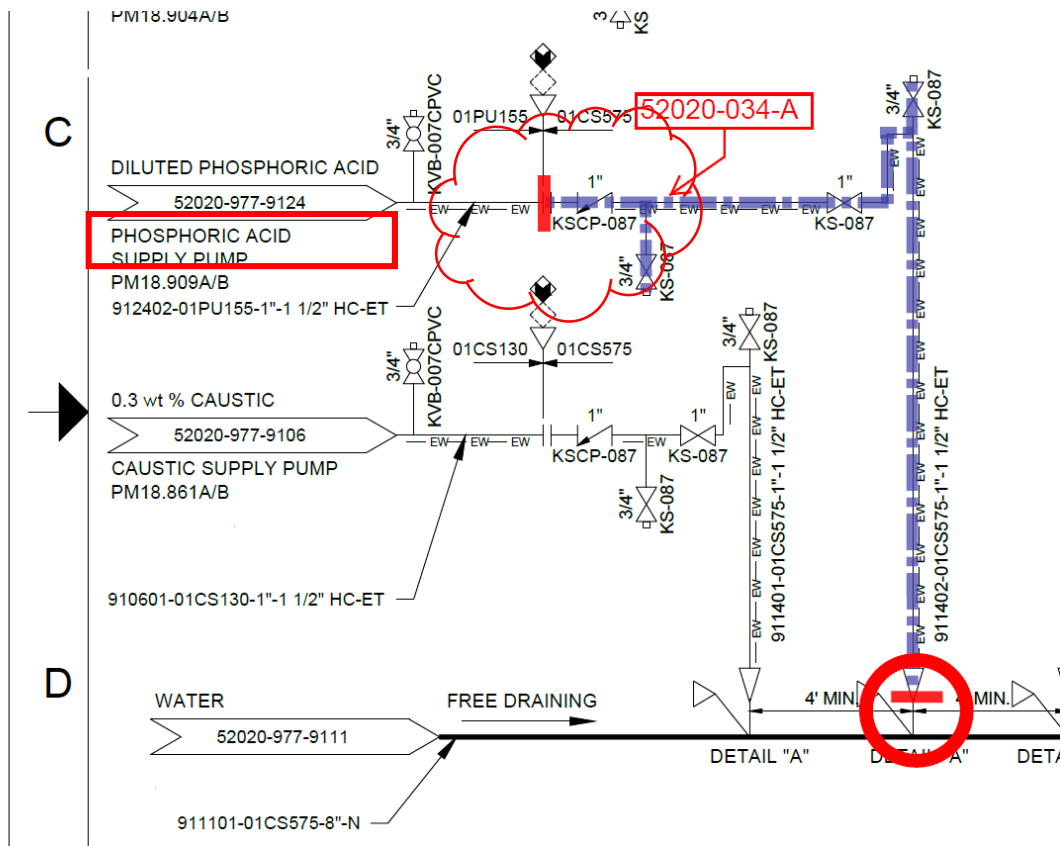
DMA Approach Benefits

DMA approach Benefits

- Detailed Review of Design and Construction
- Eased Implementation of Other Inspection/Integrity Practices
- Improved Inspection Work Processes
- Streamlined Program (DMA-based CML Placement)
- Identification of Proper Inspection/Monitoring Methods
- Inspection Intervals
- Standard/Regulatory Requirements

DMA Approach Benefits

Detailed Review of Design and Construction



Piping Material Specification

01PU155

Rev: 0.2, Date: May 2013

SERVICE:	Sodium Hypochlorite (NaOCl)	MATERIAL:	Chlorinated Polyvinyl Chloride (CPVC)
RATING:	150 LB (Note 1)	DESIGN CODE:	ASME B31.3
TEMPERATURE LIMIT:	0°F to 130°F	X-RAY:	None
CORROSION ALLOWANCE:	0.0000 in.	STRESS RELIEF:	None

PRESSURE - TEMPERATURE RATINGS (For NPS 1/2 through NPS 24)

TEMP°F	0 to 100	101 to 120	121 to 130				
psig	150	130	120				

(Full flange ratings per approved manufacturer)

ITEM	NOTES	NPS Range	SCH/RAT	ENDS	DESCRIPTION	MDMT / CODE
PIPE	2, 3	Start	End			
		3/4"	4"	80	PE	Chlorinated Polyvinyl Chloride (CPVC) ASTM F441, ASTM D1784 Class 23447-B

Piping Material Specification

01CS575

Rev: 0.0, Date: Mar 2011

SERVICE:	Water (Storm)	MATERIAL:	Carbon Steel
RATING:	150 lb ASME B16.5	DESIGN CODE:	ASME B31.3
TEMPERATURE LIMIT:	32°F to 150°F	X-RAY:	5% Random
CORROSION ALLOWANCE:	0.125 Inch	STRESS RELIEF:	Per ASME B31.3

PRESSURE - TEMPERATURE RATINGS (For NPS 1/2 through NPS 36)

TEMP°F	-20 to 100	200				
psig	285	260				

(Full flange ratings per latest approved editions of ASME B16.5 and ASME B16.47)

ITEM	NOTES	NPS Range	SCH/RAT	ENDS	DESCRIPTION	MDMT / CODE
PIPE	6	Start	End			
	5	1/2"	1"	80	T&C	CS, SMLS, ASTM A106 Gr B, Galv
						-20°F

Client was recommended to double check relevant design and construction documents as feedback of DMA.

DMA Approach Benefits

Eased Implementation of Other Inspection/Integrity Practices

DMA provide the building blocks for:

- Alternatives for Internal Inspection Strategy
 - Provides basis for on-stream in lieu of internal
 - Confirms similar service classification
- RBI and FFS
 - API-RP-571 has been published to facilitate FFS or RBI studies by classification of damage mechanisms in the refining industry as well as introducing:
 - Affected units, materials, critical factors, damage rates/susceptibilities and susceptible locations,
 - Appearance or morphology of damages,
 - Prevention/mitigation methods,
 - Inspection and monitoring methods.

DMA Approach Benefits

Eased Implementation of Other Inspection/Integrity Practices (cont'd)

DMA provide the building blocks for

- Environmentally-assisted Damage Mechanism Programs (e.g., CUI, CI- SCC)
 - Identifies potentially susceptible equipment & piping
- IOW
 - Generates information needed to identify conditions needing control via IOW
 - Assists in defining the IOW limits
- Process Hazard Review meetings
- Management of Change Reviews
 - Provides information for assessing impact of changes, especially issues related to feedstock changes, process operating condition changes, equipment/piping metallurgical changes

DMA Approach Benefits

Improved Inspection Work Processes

- More technically robust inspection plans
- Damage mechanisms were referred in API – 510/570/970 inspection codes and recommended practice as basis for developing/improving:
 - Systemization/Circuitization,
 - Selection and monitoring of CMLs,
 - Type and extent of NDE,
 - Inspection plans.

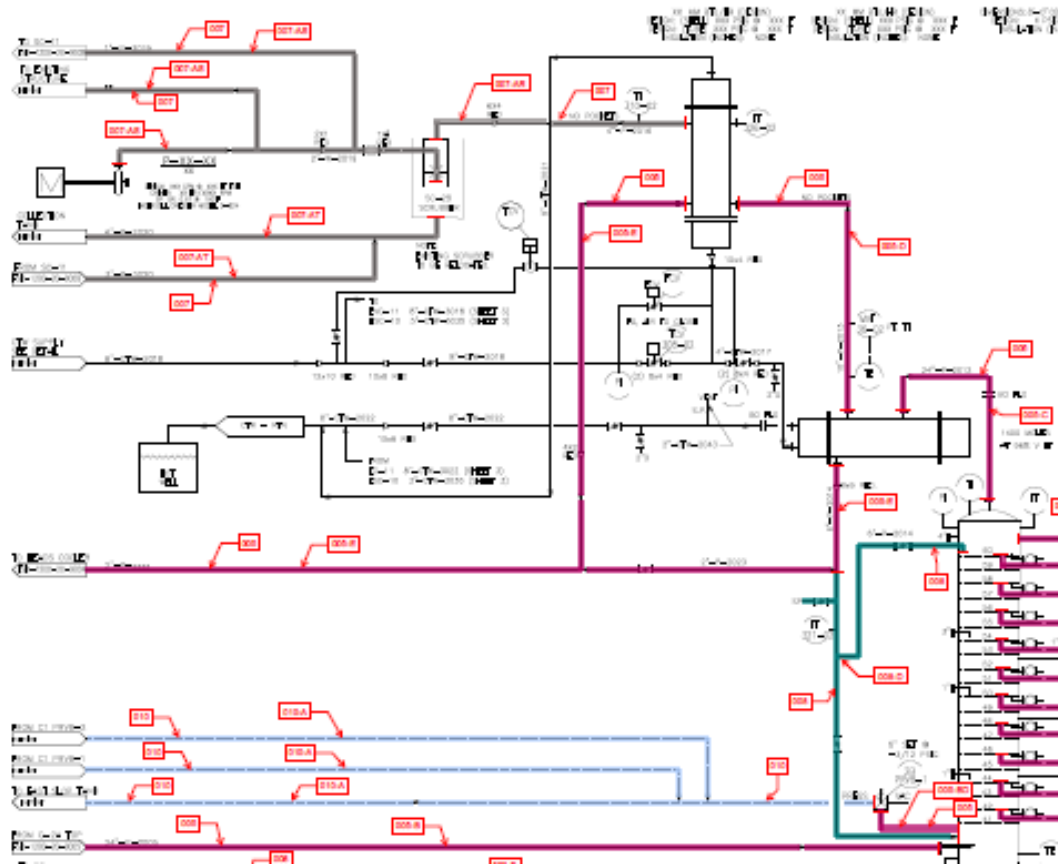
DMA Approach Benefits

Improved Inspection Work Processes (cont'd)

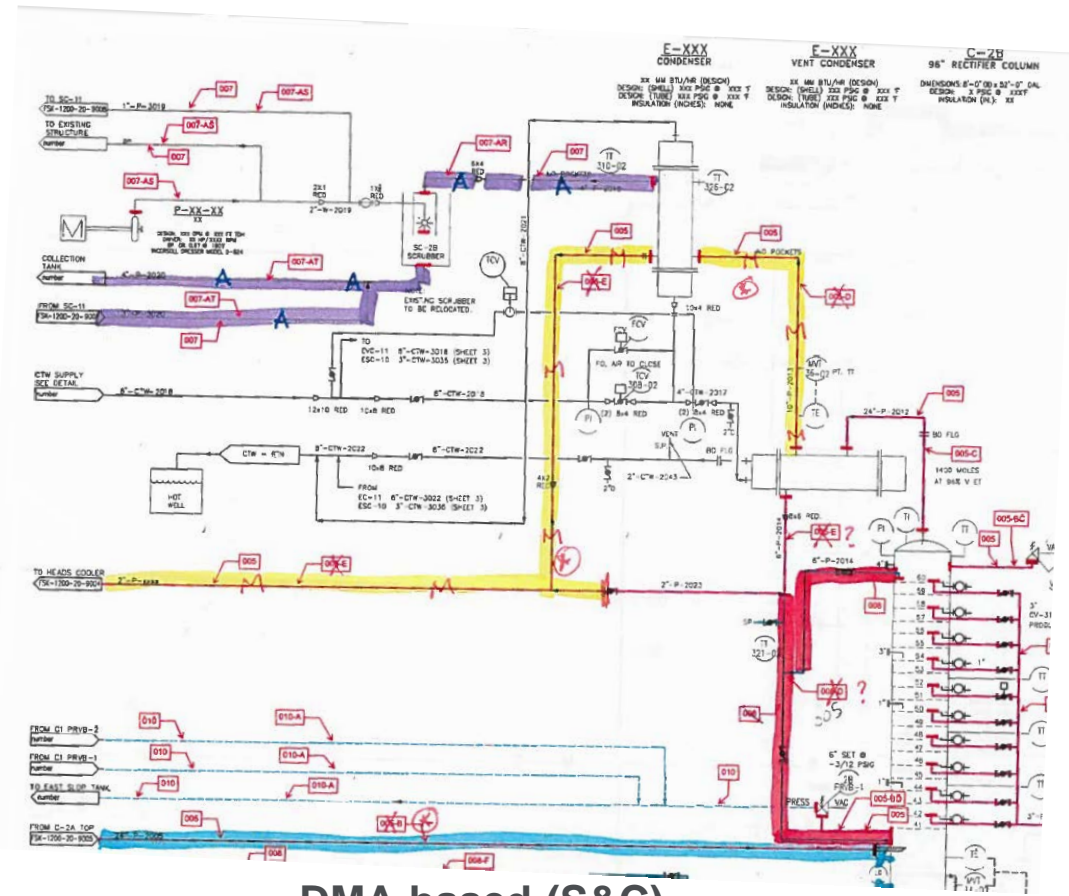
- Improved Systemization and Circuitization (S&C)
 - Fixed equipment and piping are circuitized to help manage:
 - Inspections
 - Calculations
 - Record keeping
 - Inspection circuit consists of a section of piping or fixed equipment sharing:
 - Similar materials of construction exposed to same/similar process streams/conditions
 - Common damage mechanisms
 - Similar anticipated rates of damage (e.g., anticipated corrosion rate)
 - Typically a system is divided into circuits based on major equipment items and other criteria:
 - Damage mechanism and/or anticipated damage rate changes
 - Process stream phase change
 - Significant process condition changes, such as:
 - Control valves or equipment with 50 psi differential pressure changes
 - Temperature changes greater than 200 °F
 - Flow rate changes (resulting in significant velocity changes)
 - Mixing/injection points & dead legs

DMA Approach Benefits Improved Inspection Work Processes (cont'd)

- Improved Systemization and Circuitization (S&C)



Non DMA-approach (S&C)



DMA-based (S&C)

DMA Approach Benefits

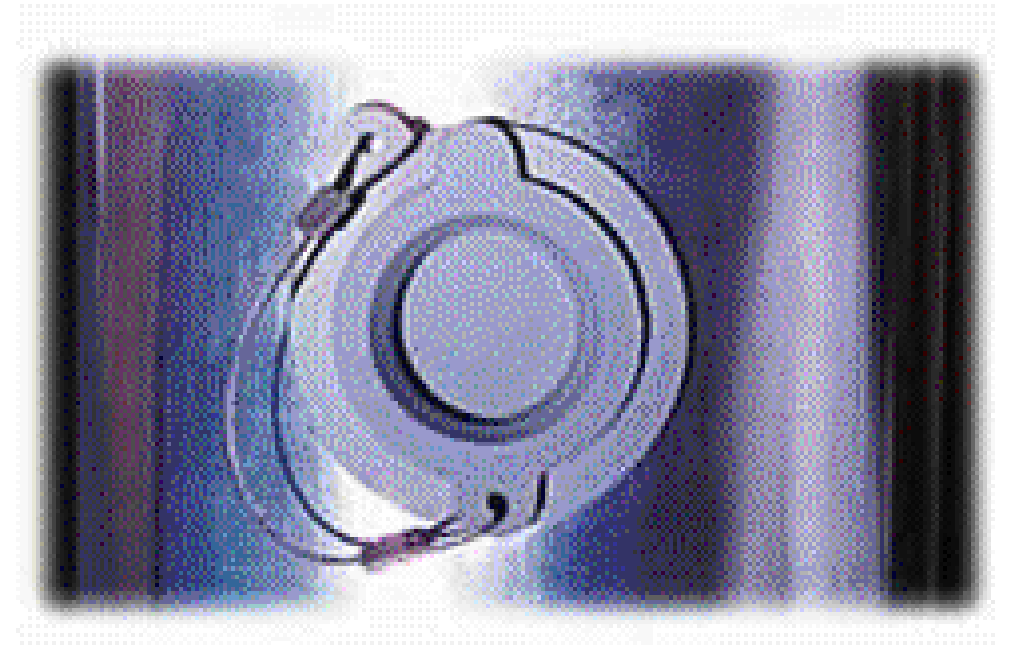
Improved Inspection Work Processes (cont'd)

- More efficient inspection management (especially for piping)
- Due to fewer number of inspected assets:
 - Fewer piping assets to establish in an Integrated Database Management System (IDMS), (reduced data entry due to grouping),
 - Less inspections to be scheduled and managed,
 - Easier performance of inspections (due to logical grouping, identification and numbering of piping),
 - Fewer inspection and NDE reports and results to manage.

DMA Approach Benefits

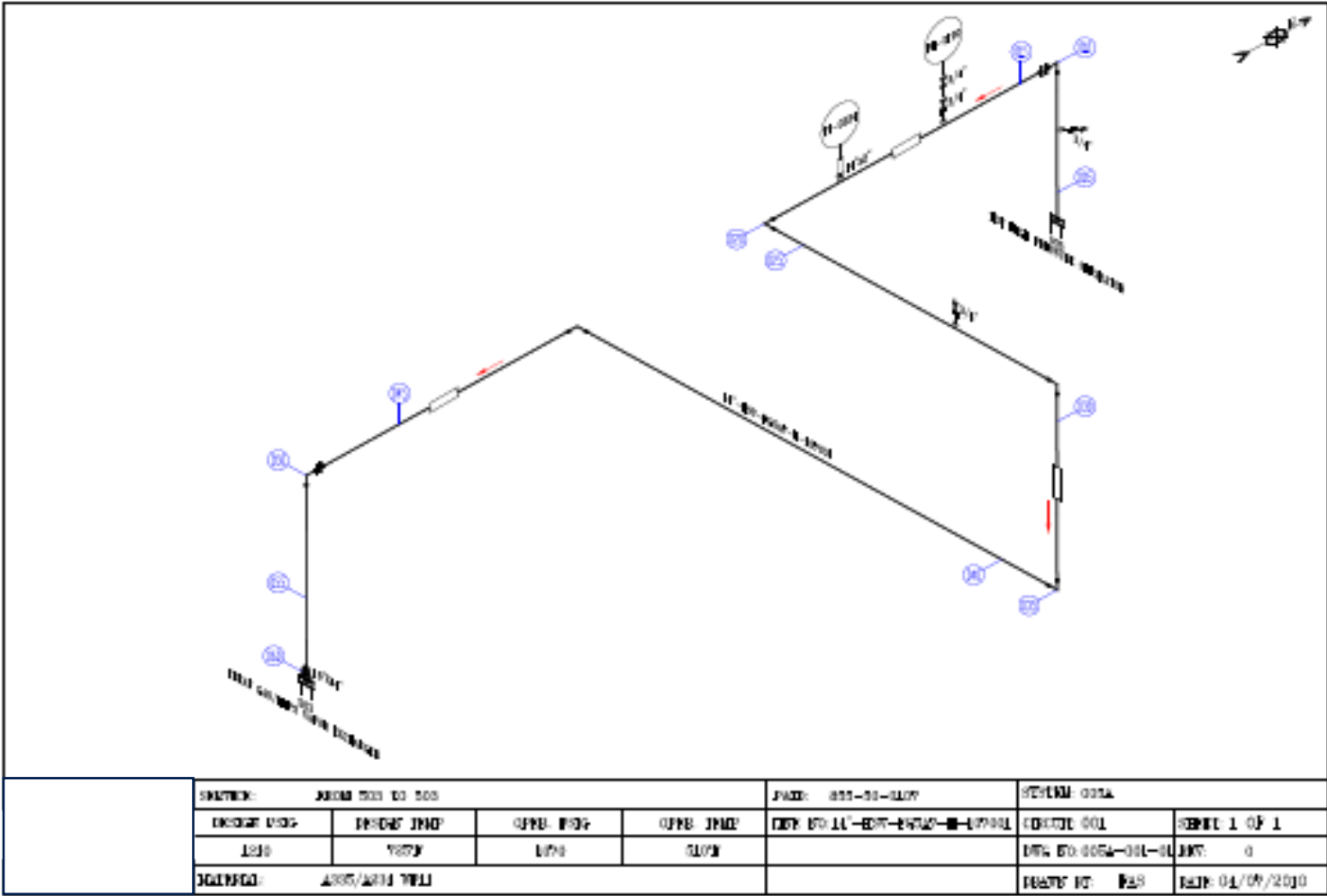
Streamlined Program (DMA-based CML Placement)

- Most common need is CML placement for thickness measurement
- DM-based Reasons for Thickness CMLs
 - Active or potential damage mechanisms
 - Uniform
 - Localized
 - Susceptibility & Predictability
 - Remaining life determination
- Other factors
 - Consequence of failure
 - Equipment/piping complexity



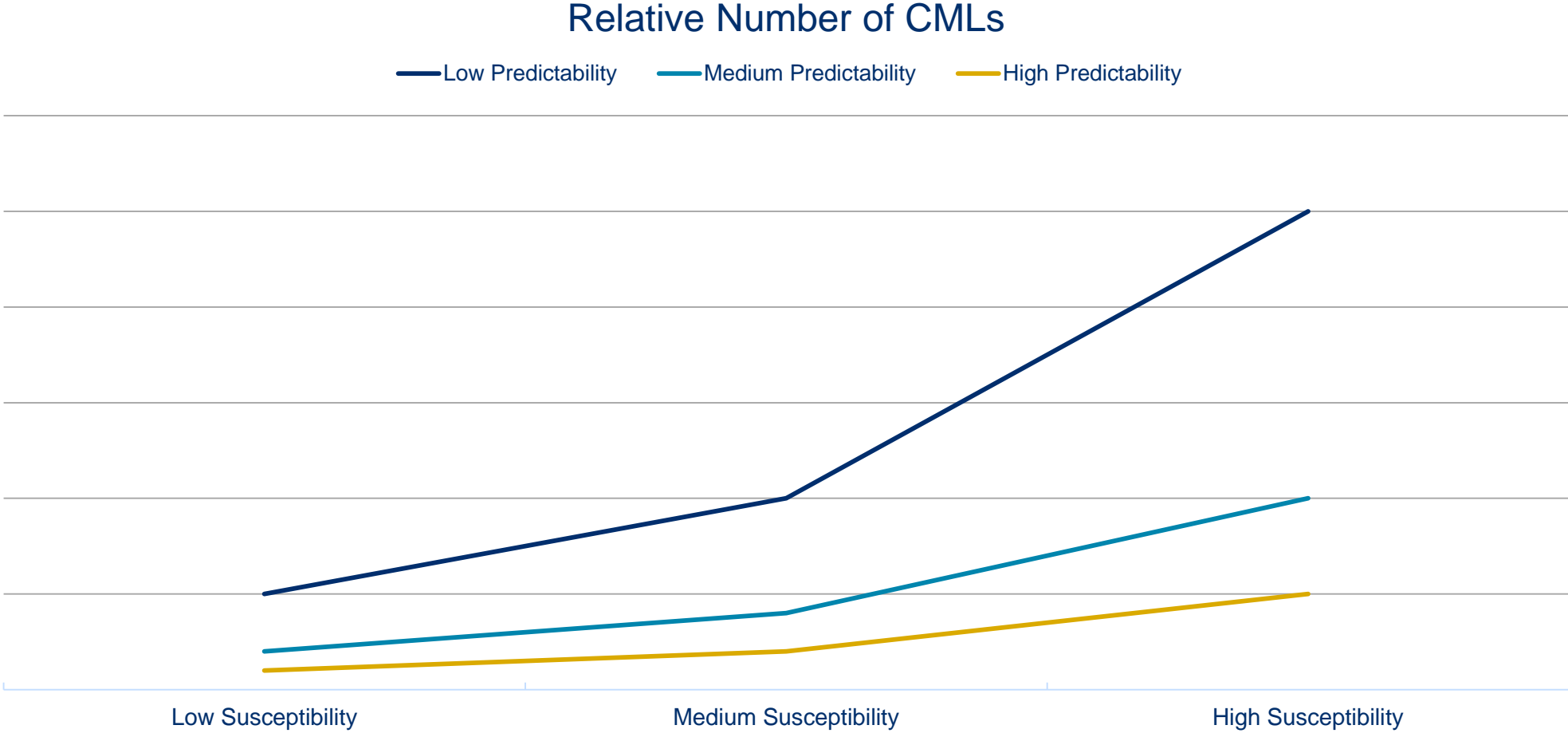
DMA Approach Benefits

Streamlined Program (DMA-based CML Placement) (cont'd)



DMA Approach Benefits

Streamlined Program (DMA-based CML Placement) (cont'd)



DMA Approach Benefits

Streamlined Program (DMA-based CML Placement) (cont'd)

- DMA & improved systemization/circuitization results in:
- More optimized CML placement – understanding potential damage mechanisms provides more knowledgeable CML placement (fewer CMLs via non-DMA approach):
 - Helps avoid the “blanketing” CML placement approach for new assets
 - Provides basis for reduction/elimination of CMLs
- Fewer assets to inspect – when combined with systemization/circuitization the end result is fewer piping circuits to manage & inspect
 - Fewer piping assets to establish & maintain in IDMS
 - Fewer CMLs
 - Less inspections to be scheduled and managed
 - Less field time
 - Less data entry and fewer inspection/NDE reports

DMA Approach Benefits

Identification of Proper Inspection/Monitoring Methods

Typical Damage Mechanisms	Visual Internal Insp. (VII)	Visual External Insp. (VEI)	Ultrasonic Thickness (UTT)	Ultrasonic Shear Wave (UTSW)	Dye Penetrant (PT)	Magnetic Particle (MT)	Wet Flour. Mag. Particle (WFMT)	Radiography Testing (RT)	Automated Ultrasonic (AUT)	Eddy Current (EC)	Pulsed Eddy Current (PEC)	Cathodic Testing (CP)	Phased Array (PA)	Guided Wave Testing (GWT)	Other Methods
Material Of Construction															
1 - Brittle Fracture															
2 - Dissimilar Metal Weld Cracking				√	√		√	√					√		PMI
3 - Erosion Corrosion	√		√					√	√		√			√	
4 - Mechanical Fatigue	√	√		√	√	√							√		Vibration Monitoring
5 - Vibration-Induced Fatigue	√	√			√	√	√								Vibration Monitoring Audible Sound Detection
6 - Localized Corrosion	√	√	√					√	√	√		√		√	
7 - Galvanic Corrosion	√	√	√					√	√		√			√	
8 - Atmospheric Corrosion		√	√					√						√	
9 - Corrosion Under Insulation		√	√		√	√	√	√			√			√	
10 - CO2 Corrosion	√		√					√	√	√	√			√	
11 - Microbiologically Induced Corrosion	√	√	√					√	√	√				√	
12 - General Corrosion	√	√	√					√	√	√	√			√	
13 - Soil Corrosion		√										√		√	EMAT
14 - Sulfidation	√	√	√					√	√	√	√			√	
15 - Chloride Stress Corrosion Cracking	√	√		√	√		√	√		√			√		
16 - Hydrogen Embrittlement				√	√	√	√						√		
17 - Amine Corrosion	√		√					√	√	√	√			√	
18 - Pitting Corrosion	√	√	√					√	√	√				√	Pit Gauge
19 - Wet H2S Damage	√			√			√	√		√			√		ACFM, AET
20 - Hydrogen Stress Cracking					√		√			√					Hardness Testing
21 - Sour Water Corrosion	√		√	√				√	√	√	√		√	√	
22 - Thermal Fatigue	√	√		√	√	√	√			√			√		
23 - Short Term Overheating															
24 - Creep	√	√	√	√	√		√	√		√					

DMA Approach Benefits

Identification of Proper Inspection/Monitoring Methods (cont'd)

ASME PCC-3-2007, INSPECTION PLANNING USING RISK-BASED METHODS
NONMANDATORY **APPENDIX C**, TABLE OF INSPECTION/MONITORING METHODS

Mechanism	Damage/Defect		Common Examination Methods Used to Identify ^[1]																
			Surface					Subsurface					Other Methods						
			Mode ^[2]	Damage Mechanism	Manufacturing Defect	Visual (Including Borescope)—VT ^[3]	Liquid Penetrant—PT ^[3]	Fluorescent Liquid Penetrant—FPT ^[3]	Magnetic Particle—MT ^[4]	Wet Fluorescent Magnetic Particle—WFMT ^[4]	Ultrasonics for Thickness—UTT	Ultrasonics—Straight Beam—UTS	Ultrasonics—Shear Wave—UTSW	Ultrasonics—Shear Wave Adv. Techniques—UTSWA	Radiography—RT	Eddy-Current—ET	Acoustic Emission—AE	Dimensional Measurements	Hardness Tests
CREEP	CRACKING	x								x	x	x			x	x		x	x

DMA Approach Benefits

Identification of Proper Inspection/Monitoring Methods (cont'd)

*ASME PCC-3–2007, INSPECTION PLANNING USING RISK-BASED METHODS
NONMANDATORY **APPENDIX C**, TABLE OF INSPECTION/MONITORING METHODS*

NOTES:

(1) Many of these examination methods depend upon proper access and surface preparation and thus will not be appropriate for all situations.

Many factors influence the detectability of imperfections, including using qualified personnel to perform the inspection.

(2) Manufacturing, weld, and casting defects can become a factor and also can lead to other damage mechanisms.

(3) These methods are capable of detecting **imperfections that are open to the surface** only.

(4) These methods are capable of detecting **imperfections that are open to the surface or slightly subsurface**.

Extra caution should be exercised for using this type of tabulated data!

DMA Approach Benefits

Identification of Proper Inspection/Monitoring Methods (cont'd)



Creep rupture of an HK40 heater tube

Fig. 2 Schematic creep curves showing the three stages of creep

Curve A, constant-load test; curve B, constant-stress test

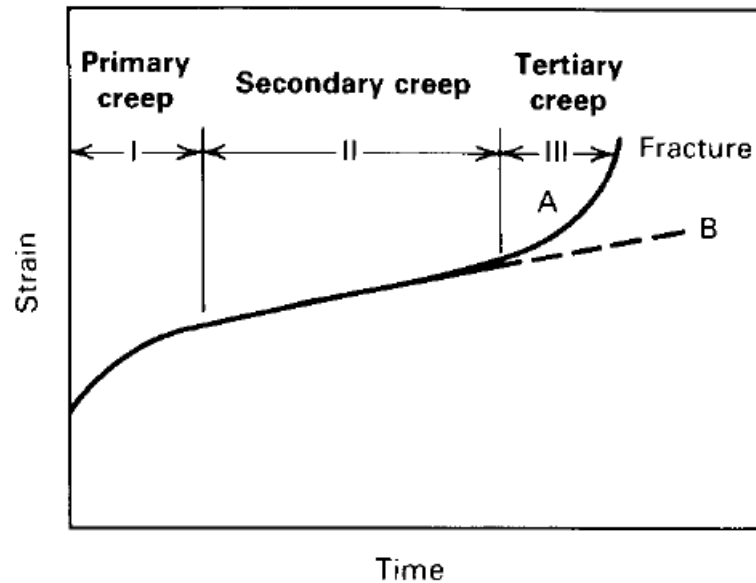
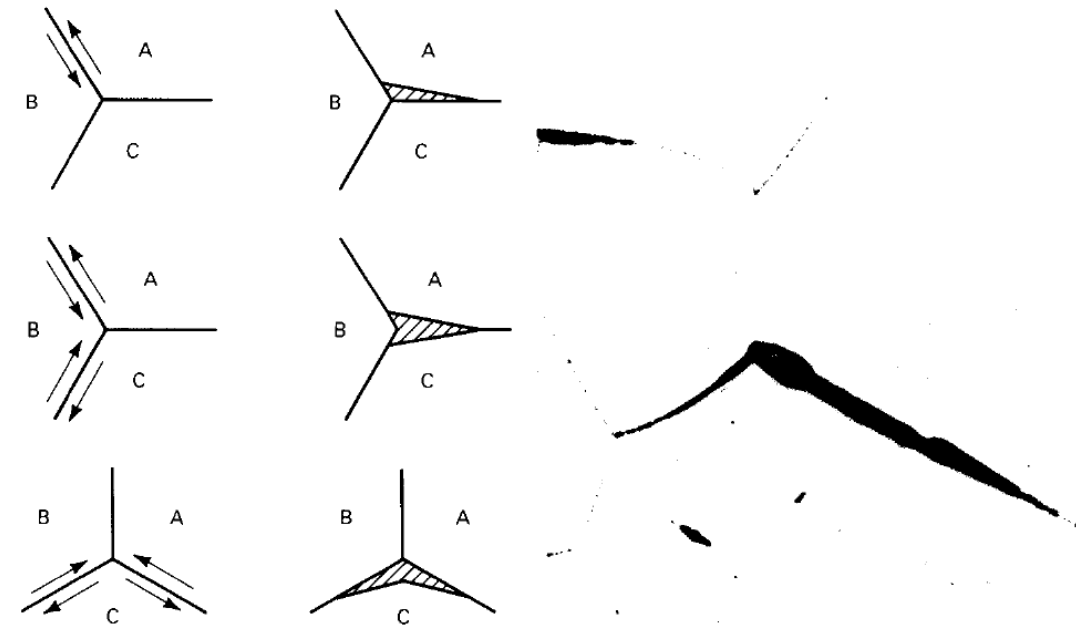


Fig. 5 Intergranular cracks in stress rupture

(a) Schematic view of cracking due to grain-boundary sliding. Arrows along a grain boundary indicate that this boundary underwent sliding. (b) Cracks and voids in Al-5.10Mg that was stress rupture tested at 260 °C (500 °F). Electrolytically polished. 60 ×



DMA Approach Benefits

Inspection Intervals

- Prescriptive – Fixed Intervals
 - API-510
 - External – Lesser of 5 yrs. or internal/on-stream inspection interval
 - Internal/on-stream – Lesser of 10 yrs. or ½ remaining life
 - API-570

Table 2—Recommended Maximum Inspection Intervals

Type of Circuit	Thickness Measurements	Visual External
Class 1	Five years	Five years
Class 2	10 years	Five years
Class 3	10 years	10years
Class 4	Optional	Optional
Injection points ^a	Three years	By class
S/A ^b	—	By class

NOTE Thickness measurements apply to systems for which CMLs have been established in accordance with 5.6.

^a Inspection intervals for potentially corrosive injection/mix points can also be established by a valid RBI analysis in accordance with API 580.

^b See API RP 574 for more information on S/A interfaces.

DMA Approach Benefits

Standard/Regulatory Requirements

- API Requirements
 - API-510 & API-570 include requirements related to damage mechanisms for managing necessary inspections as follows:
 - Identification of type and extent of NDE
 - Selection and monitoring of CMLs
 - Development of inspection plans (interval and extent)
 - API-RP-970 Corrosion Control Documents
 - Recommends circuitization for identification and assignment of damage mechanisms
- Internal Standards
 - Internal MI/engineering standards often include requirements for DMA
 - Recent OSHA document defines these types of documents as RAGAGEPs to be followed or the documentation of the bases as to why the requirements are not applicable

Pulling It All Together

- DMA provides the necessary data for:
 - Improved systems & circuits
 - Inspection planning
 - RBI
 - FFS
 - Proper IOWs
- Proper execution of these practices:
 - Enables proper implementation of IDMS
 - Helps ensure a robust, technically-sound static equipment/piping I&T program, and

IMPROVES PROCESS SAFETY



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