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A Work Process for Petroleum Refining Piping CML Placement and Testing Determinations

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Andeavor

About Us

Andeavor is a premier refining, marketing and logistics company with operations primarily located in the western and mid-continent United States. We operate with the highest levels of integrity and respect and with a steadfast dedication to safety and the environment.

Some Numbers

- **Number of Refineries:** 10
- **Refining Capacity:** Approximately 1.2 million bpd
- **Employee Count:** More than 13,000
- **Retail Sites:** Approximately 3,000
- **Barrels of Storage Capacity:** More than 46 million
- **Miles of Pipelines:** More than 4,800
- **Marine, Rail and Storage Terminals:** 39
- **Natural Gas Processing Complexes:** 6
- **States Where We Operate:** 18

Topics

- Current Issues with Piping CMLs
- The Piping CML Review Process
- Output
  - Emerging Piping CML Inspection Guidelines
    - Low Corroding or Non-corrosion Systems
    - Certain General Corrosive Services
    - Certain Specific Potentially Problematic Services (in the unit of interest)
  - CML Examination Point Selection Guidelines
  - Piping CML Inspection Programming

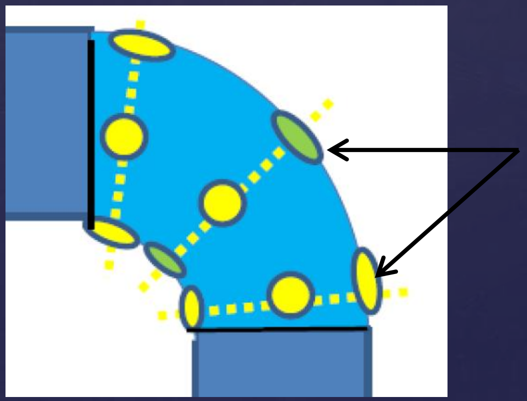
- Many refinery sites with different heritage practices. The result is:
  - Broad range of CML placement and density practices
  - Broad range of examination point location placement practices within each CML
- Scant application specific guidance with any site (or heritage practice).
- Current RBI programming calling for % testing based on risk. Which ones do you look at this time?
- A very small amount (about 4% on average) of current Piping CMLs enterprise-wide have ever shown corrosion activity.
- Far too much data in existing thickness measurement databases telling the inspector very little and generating distracting and unproductive testing work and analyses.

Current Issues

Some Terminology

- Condition Monitoring Location (CML): Designated areas on equipment or piping systems where periodic examinations are conducted. CMLs may contain one or more examination points and utilize multiple NDE techniques to make wall thickness determinations based on predicted damage mechanisms.

- Examination Point: A unique isolated location on equipment or a piping system where thickness measurement tests are taken. CML's may contain one or more examination points.



One CML with Multiple Examination Points

The Piping CML Review Process

Pre-work

- Facilitators: : (1) Assemble and review current Corrosion Review Documents, (2) Review related Company and Industry incidents (3) Assemble and scrutinize existing NDE data, and (4) Assemble Network Meeting Presentation Material
- Inspectors and Corrosion Engineers: Review Inspection records to come armed with knowledge on where corrosion has occurred and what it looked like.

Network Meeting

- Bring all responsible unit inspectors and corrosion engineers together to a face to face meeting.
- Discuss the following: Typical Operating processes and practices for units under review, typical degradation mechanisms, where corrosion has actually been observed in operating units, where corrosion has not been observed, related incidents, current CML and testing point placement practices.
- Come to consensus on: Appropriate CML and examination point placement practices, appropriate testing methodologies, appropriate inspection programming to monitor selected CMLs.

Follow-up

- Prepare Detailed Meeting Minutes
- Review decisions collectively by telecom and come to a consensus
- Incorporate into an enterprise Piping CML Guidance Document

Piping CML Meeting Agenda

1. Process Review
2. Damage Mechanism Review
3. IDMS Database Review
4. Inspector/Engineer Survey of Problem areas
5. Company and AFPM Incident Database Review
6. Compile Lists of 4 and 5
7. A nice dinner
8. Presentation By Outside NDE Expert Consultant focused on the challenges of the 6 list.
9. Discuss current and optimized Inspection Strategies for the 6 list and other services.
10. Discuss Examination Point placement requirements within each CML type.
11. Discuss Implementation challenges and needs.

Key resources for the facilitator are:

- API 571: For use in discussing application degradation mechanisms
- Existing corrosion study documents identifying applicable degradation mechanisms and expert determined expected corrosions rates
- IDMS database: Used to identify all CMLs where corrosion has and has not been observed by piping circuit and location and methods used historically to monitor.
- AFPM Incident and Company Incident database systems: Can provide helpful information on significant loss of containment events involving piping in units of interest.

Key resources for the Inspectors and corrosion engineers are:

- IDMS database
- Detailed NDE reports
- Repair and replacement histories
- Failure analyses
- Historical temporary repair lists

Notes on Pre-work

Participation:

- Typically involves facilitators (corporate SMEs or equal) and all responsible unit inspectors and corrosion engineers. Helpful to get Process SME involvement too.
- Most helpful to have all together for a face-to-face meeting but participation can be accommodated otherwise.
- Often we bring in an outside NDE expert to discuss typically utilized latest NDE technologies.

Notes on Network Meeting

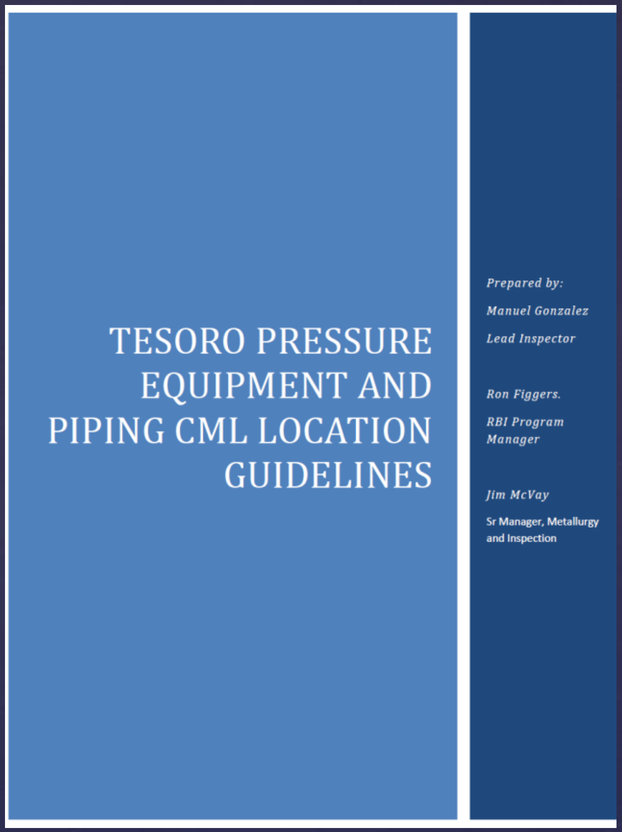
Expectations:

- Lists are compiled by system/piping circuit of where corrosion has been observed
- Appropriate CML placements within piping circuits of concern are discussed.
- Appropriate placement of examination points within CMLs are discussed.
- Appropriate testing methods of examination points within CMLs are discussed.
- What to do with the rest (the low and no corroding systems) is discussed.
- Appropriate inspection planning for piping CML monitoring is discussed.

Notes on Network Meeting

- Detailed meeting minutes are produced and reviewed line-by-line with participants.
- Process SME input is solicited as well.
- All input at this stage is encouraged. We don’t want to miss anything.

Notes on Follow-up



TESORO PRESSURE EQUIPMENT AND PIPING CML LOCATION GUIDELINES

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It all ends up here…

Industry Follow-up

- Andeavor, Phillips, Valero and Holly Frontier are planning to have regular meetings to share best practices and work towards creating an Industry standard for Refinery Piping CML selection and testing.

- The first meeting is October 26/27 in Los Angeles at the Andeavor LA Refinery Campus Bldg (223rd St, Carson CA) where piping in Crude and Vacuum Units will be discussed.
- Contact Jim McVay at James.W.Mcvay@andeavor.com if interested in attending.

Example Output from Industry Meeting

Corrosion Loop	Tower Overhead System (Crude Tower)
Anticipated Mechanisms	**HCl Corrosion** • Aqueous corrosion occurring in environments where HCl is present. Typically associated with dewpoint corrosion, where condensing HCl vapors result in highly acidic HCl droplets that can cause aggressive corrosion. • HCl Corrosion damage in refineries most often associated with highly localized damage **Salt Deposition** • Localized corrosion (typically pitting) occurring under salt deposits that can form in the process stream **CO_2 Corrosion** • Carbon dioxide (CO_2) corrosion results when CO_2 dissolves in water to form carbonic acid. The acid may lower the pH and may promote pitting or general corrosion of carbon steel. **Organic Acid Corrosion** • Organic compounds present in some crude oils decompose in the crude furnace to form organic acids. Organic acids condense in crude tower overhead systems and may cause localized corrosion.
Observed Damage	• Corrosion found in piping from crude tower to condensers (near chemical/water injection points) • Damage found in condenser outlet piping upstream of overhead accumulator
Best Practice CML and Examination Point Guidance	1. First two elbows and connecting pipe off the top of the tower. Perform UT inspection with a UT circumferential band scrub at 3" intervals along pipe. 2. Injection point inspection at water and amine/ammonia injection points. Follow injection point strategies on other slide in this presentation. 3. Perform 3" grid inspection on elbows on and at the bottom of the vertical run down the tower. 4. 100% of other accessible elbows and components upstream of the condensers. 5. Inspect 100% of deadlegs, including injection nozzles and instrumentation fittings. 6. Install real-time corrosion monitoring, such as "Permasense", as directed by a corrosion/materials engineer.
Boundaries for Application (Process & Materials)	• This guidance is not applicable to two-drum overhead systems. Consult metallurgist for CML placement.

Example Output from Industry Meeting

For each Corrosion Loop where active corrosion is expected pictures of expected degradation would be collected and presented for reference. We would also assemble detailed guidance for examination point selection within each CML most appropriate for the Corrosion Loop in question.

Output

Emerging Piping Inspection Strategies

Three types of piping CML placement and inspection programming strategies typically emerge:

- Specific strategies for problematic areas often unique to a process (Crude unit overhead systems, debutanizer systems in CR units, Reactor effluent piping, etc.)
- More general strategies for common corrosive systems/services throughout a refinery such as sour water, blowdown systems, injection points, etc..
- General strategies for how to handle systems/services where corrosion as not been observed and corrosion experts predict low or no corrosion activity.

Draft Inspection Strategies for Low Corroding or Non-corroding Services

Definitions:	Non Corrosion Systems: ≤ 1 MPY expected and/or observed. May include services on other lists in this presentation (list for Certain General Services and Certain Specific Potentially Problematic Services) if the alloys used for those services are that the expected corrosion rates are ≤ 1mpy.
	Low Corrosion Systems: ≤ 3 MPY expected and/or observed **and not services on other lists in this presentation (list for Certain General Services and Certain Specific Potentially Problematic Services)**
Number of CMLs	Complete inspection on 6 - 10 CMLs per circuit (typical)
Locations	1. Elbows (2 Qt – see note) 2. Other Fittings (Reducers, Tees, Orifice Flanges) (1-2 Qt – see note) 3. Deadleg High Point (1 Qt) 4. Deadleg Low Point (1 Qt) 5. Piping (2 Qt – see note) (one horizontal and one vertical or one low horizontal and one high horizontal (if a vapor space may develop at the high point) 6. Material Spec breaks if present – 1 at each location on lower alloy side. Consider all branch connections.
	Note: 1 Qt if circuit has 2 or less elbows, fittings or pipe sections as applicable.
Strategy	Inspect 6-8 CMLs until wall 25% wall loss from baseline thickness (75% wall remaining) or 50% of corrosion allowance for high pressure systems. Beyond this point, CMLs should be reevaluated for to determine appropriate surveillance.

Draft Inspection Strategies for Certain General Corrosive Services

System	Inspection Strategy
Deadlegs	RT 100% of deadlegs where accelerated corrosion is possible as identified in most current corrosion studies and a percentage per standard practices for others.
Injection Points	1. Inspect per API 570 - UT Scrub circumferential bands areas every 3 inches along the length of the vulnerable pipe as identified by API-570. 2. Piping that is < 8 inches may be alternately RT'd along the length of the vulnerable pipe as identified by API-570. 3. RT Injection quill. Verify integrity and orientation.
Flare Piping	1. Complete visual inspection of the piping to identify potential "Low Points" and place two CMLs at each low point location. 2. Complete visual inspection of the piping to identify flare header tie-in points and place two CMLs at each tie in location, one at the tie in point another about 2 feet down stream. 3. Beyond that, assign one CML location for every 100 feet of piping. 4. Every CML location should be UT scrubbed (UT scan a 360 degree band around the piping).
Vapor Recovery	1. Complete visual inspection of the piping to identify potential "Low Points". Assign two CML locations to each low-point. 2. Complete visual inspection of the piping to identify flare header tie-in points and place two CMLs at each tie in location, one at the tie in point another about 2 feet down stream. 3. Beyond that, assign one CML location for every 100 feet of piping. 4. Every CML location should be UT scrubbed (UT scan a 360 degree band around the piping).
Sour Water	Double the CML locations of that required for low corroding and non-corroding piping. CML counts applied to the entire sour water piping system, rather than a single circuit.
Process Water	Double the CML locations of that required for non-corroding piping. CML counts applied to the entire process water piping system, rather than a single circuit.
Strategy	Inspect CMLs at locations as described in this table until 25% wall loss from baseline thickness is experienced (75% wall remaining) or 50% of corrosion allowance for high pressure systems. Beyond this point, CML testing should be reevaluated for to determine appropriate surveillance.

Draft Inspection Strategies for Certain Specific Potentially Problematic Services in NHT Units (An example)

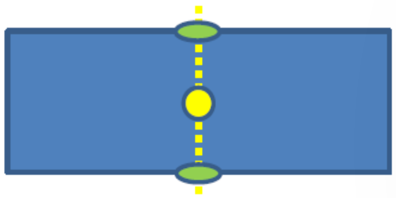
Piping System	CML Strategy
General Sulfidation or High Temp H2/H2S corrosion (>475 F) in Rx feed or effluent piping	1. inspect of 50% of the thinnest components in the system. 2. Inspect 50% of high point deadlegs. Focus on most corroded. One minimum. 3. Inspect 25% of low point deadlegs. Focus on most corroded. One minimum. 4. Inspect 100% of orifice flange locations. 4. Inspection 100% of material spec breaks (lower alloy side). Consider all branch connections. Note: For all alloys, except austenitic stainless steels which would typically render the piping systems as non-corrosive. Application of these rules for assumes that low Si carbon steel and retro-PMI survey, as applicable, have been completed.
"Boil off point" on reactor feed side at immediate outlet of HXs	1. RT 100% (or UT scrub) all nozzles and elbows on the piping just off the HX for a distance of 10 feet. 2. RT 100% of deadlegs between the tower and the first 10 feet of pipe down stream.
Rx Effluent Piping – Downstream of water inj point or last condenser to the product separator	1. inspect of 50% of the thinnest pipe sections in the system. 2. Inspect 100% of change of directions (elbows/tees). UT inspection with a UT circumferential band scrub at 3" intervals. 3. Inspect 100% of low point deadlegs. Focus on most corroded. One minimum. 4. Inspect 100% of high point deadlegs. Focus on most corroded. One minimum. 4. Inspect 100% of orifice flange or other pressure letdown locations per inspection strategies on another slide in this presentation..
Stripper Tower OVHD System (where wet/possibly wet)	1. First two elbows and connecting pipe off the top of the tower. Perform UT inspection with a UT circumferential band scrub at 3" intervals along pipe. 2. Injection point inspection at injection points if present. Follow injection point strategies on other slide in this presentation. 3. Perform 3" grid inspection on elbows on and at the bottom of the vertical run down the tower. 4. 100% of other accessible elbows and components upstream of the condensers. 5. inspect of 50% of the thinnest components in the system in HC service downstream of the condensers and through the overhead accumulator. 6. Inspect 100% of deadlegs, including injection nozzles, instrumentation fittings and level bridles throughout. 7. Inspect sour water piping off Ovh Accum iaw general sour water inj strategies with special focus at the pressure letdown location (follow general strategies for pressure letdown locations as well).
Rich/Lean Amine Piping	1. inspect of 50% of the thinnest components in the system. 2. Inspect 50% of high point deadlegs. Focus on most corroded. One minimum. 3. Inspect 50% of low point deadlegs. Focus on most corroded. One minimum. 4. Inspect 100% of orifice flange and other pressure letdown locations.
Recycle H2 downstream of compressure	1. inspect of 25% of the thinnest pipe sections in the system. 2. Inspect 100% of low point deadlegs. 3. Inspect 100% of high point deadlegs.
REAC Water Injection and Hot Hydrogen (>475F) Injection Points	Monitor per the injection point strategies on another slide in this presentation. In addition ensure testing of 4 CMLs minimum on each horizontal straight section from the injection point to the separator for intermittent water injection points and water injection points without appropriately designed quills.
Strategy	Inspect CMLs at locations as described in this table until 25% wall loss from baseline thickness is experienced (75% wall remaining) or 50% of corrosion allowance for high pressure systems. Beyond this point, CML testing should be reevaluated for to determine appropriate surveillance.

- RT all dead legs and injections points (up to 25 ft downstream) for thickness when testing is required and where practical.
- When doing RT testing for wall thickness best practice is to also get a UT measurement at a representative and field marked location in the view of the RT on the pipe for purposes of tracking corrosion rates in the IDMS system. If the location is not corroding this practice is not typically necessary or required but in those cases IDMS reading entry repeatability must be addressed by other effective means.
- RT testing for thickness is preferred on 8 inch and smaller diameter pipe where localized corrosion is possible. Not generally necessary for non-corroding and low corroding piping as defined in this presentation, at least during initial testing before pipe has lost 25% of original wall.
- For internally clad/overlaid piping which is typically very resistant to corrosion, consider conducting regular internal lining inspections per RBI inspection strategies in lieu of all but the most minimal external UT surveillance. We are looking for that “needle in a haystack”. Consider borescope inspections for this purpose.
- UT scrubs (100% coverage) for overlaid piping components highly corrosive services (in REAC systems for instance).
- Special testing for material spec break locations in piping.
- Perform thermography to detect localized salt and deposit formations where localized corrosion may develop.

Some Emerging General Piping Methodologies Considerations

Straight Pipe Sections

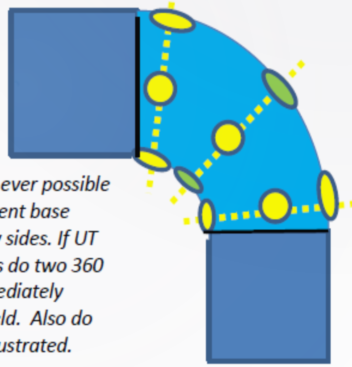
- Examination points at cardinal locations
- Examination points should be marked in the field
- Only the minimum reading along a circumferential band need be recorded.
- Only the minimum reading recorded need be logged into RBMI for tracking.
- Need to do only green filled examination points for expected low/non-corrosion services (2 total). Do both yellow and green points for others.



*In **Amine service** use RT where ever possible and center CML on weld locations. If UT must be used select CMLs at weld locations and do two 360 degree circ bands located immediately adjacent to each side of weld location at each location.*

Elbows (45/90 degree)

- Examination points at cardinal locations
- Examination points should be marked in the field
- Examination points next to welds should be about 1 inch from the weld.
- Only the minimum reading along a circumferential band need be recorded.
- Only the minimum reading recorded need be logged into RBMI for tracking.
- Need to do only green filled examination points for expected low/non-corrosion services (2 total). Do both yellow and green points for others.
- Special consideration for elbow exposed to erosives in steam air decoking loop: RT elbow to detect possibly very local impingement locations.



*In **Amine service** use RT where ever possible and view both welds and adjacent base material on the pipe and elbow sides. If UT must be used, at weld locations do two 360 degree circ bands located immediately adjacent to each side of the weld. Also do middle examination point as illustrated.*

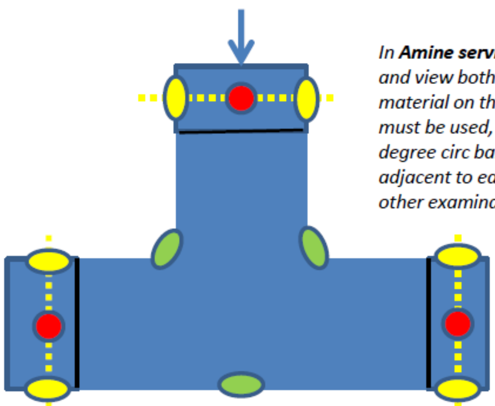
Draft CML Examination Point Selection Guidelines

Tees

- Examination points at cardinal locations, impingement points and fitting shoulders as noted below
- Examination points should be marked in the field
- Only the minimum reading along a circumferential band need be recorded.
- Only the minimum reading recorded need be logged into RBMI for tracking.
- Need to do only green filled examination points for expected low/non-corrosion services (3 total).
- Need not do red filled points if sulfidation service only. Examination points can normally be 180 degrees apart for sulfidation service only.

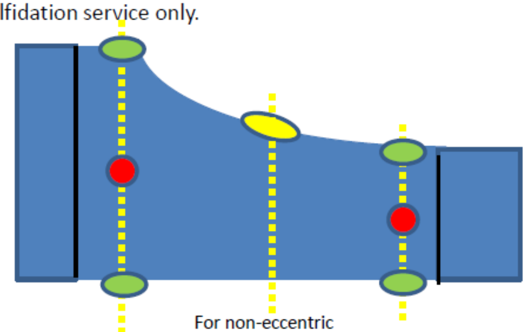
Reducers

- Examination points at cardinal locations and as noted below.
- Examination points should be marked in the field
- Only the minimum reading along a circumferential band need be recorded.
- Only the minimum reading recorded need be logged into RBMI for tracking.
- Need to do only green filled examination points for expected low/non-corrosion services (4 total).
- Need not do red filled points if sulfidation service only. Examination points can normally be 180 degrees apart for sulfidation service only.



Impingement Point

*In **Amine service** use RT where ever possible and view both welds and adjacent base material on the pipe and elbow sides. If UT must be used, at weld locations do two 360 degree circ bands located immediately adjacent to each side of the weld. Also do other examination points as illustrated.*



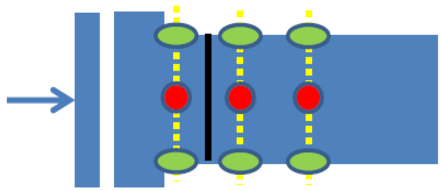
For non-eccentric reducers do mid-length readings on the reducers at all four cardinal points

Draft CML Examination Point Selection Guidelines

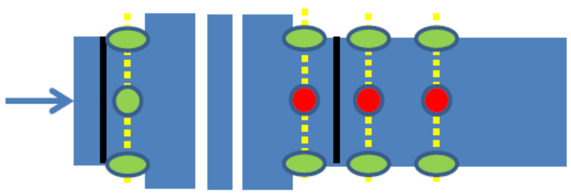
Draft CML Examination Point Selection Guidelines

- **Orifice Flange and other Pressure-Letdown Locations**
- **Pump Discharge Locations**

General



Orifice Flange Locations



General

- Examination points at cardinal locations
- Examination points should be marked in the field
- Examination points next to downstream weld should be centered within 1 inch of the weld as illustrated. RTs may be necessary to test at this location.
- Examination points on next downstream bands should be centered about 3 inches then 6 inches from the first downstream set of measurements.
- Only the minimum reading along a circumferential band need be recorded.
- Only the minimum reading recorded need be logged into RBMI for tracking.
- Need to do only green filled examination points for expected low/non-corrosion services (6 total).
- Need not do red filled points if sulfidation service only. Examination points can normally be 180 degrees apart for sulfidation service only.

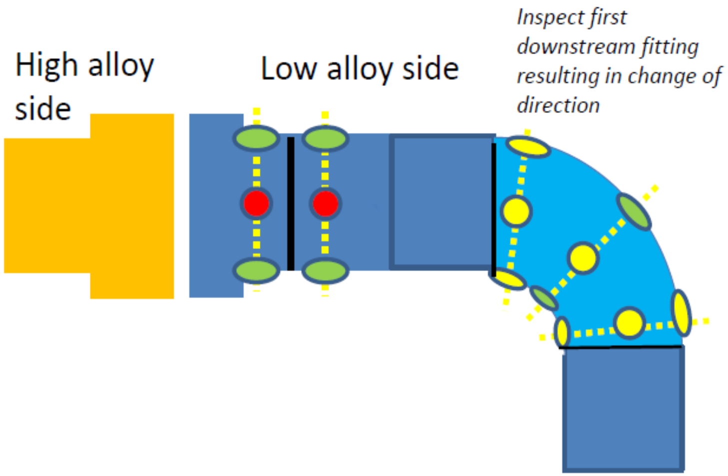
Orifice Flange Locations

In fouling service corrosive deposits may form up against the orifice on the upstream side.

- Additional examination points in a circumferential band should be test immediately upstream of the orifice flange as illustrated.

*In **Amine service** use RT where ever possible and view both welds and adjacent base material on the pipe and elbow sides. If UT must be used, at weld locations do two 360 degree circ bands located immediately adjacent to each side of the weld. Also do other examination point as illustrated.*

Material Spec Break Locations

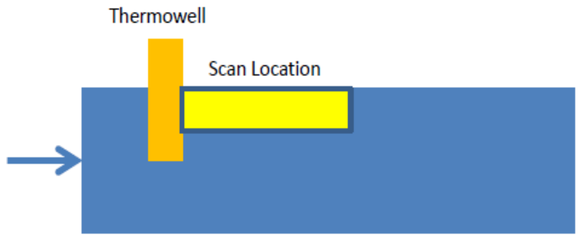


- Examination points at cardinal locations
- Examination points should be marked in the field
- Examination points next to first downstream weld on the low alloy side should be centered within 1 inch of the weld as illustrated. RTs may be necessary to test at this location.
- First downstream fitting should be examined iaw guidance provided elsewhere in this presentati0n for elbows/tees or reducers as applicable.
- Only the minimum reading along a circumferential band need be recorded.
- Only the minimum reading recorded need be logged into RBMI for tracking.
- Need to do only green filled examination points for expected low/non-corrosion services.
- Need not do red filled points if sulfidation service only. Examination points can normally be 180 degrees apart for sulfidation service only.

Consider creating separate piping circuits for these locations in RBMI, similar to how we handle/track potentially problematic dead legs.

Draft CML Examination Point Selection Guidelines

- **Thermowell locations**

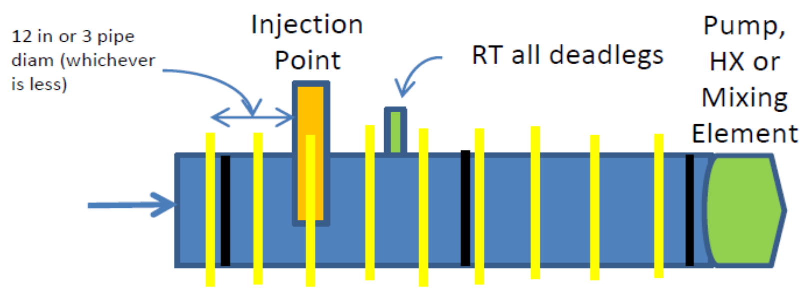


- Examination area of interest is between the 10:30 pm and 1:30 PM location starting on the downstream side of the thermowell and running 3 inches immediately downstream.
- UT scrub or Profile/Contact RT to examine.
- If RT then follow-up with UT at low point to track in database. Mark UT location in the field.
- Only the minimum reading need be recorded. Ensure minimum reading location is marked in the field.
- Only the minimum reading recorded need be logged into RBMI for tracking.
- RT Injection quill if present looking to verify integrity and acceptable orientation.

Draft CML Examination Point Selection Guidelines

Injection Points

- Examination for thickness will require 360 degree UT scrubs in bands (or RT for same coverage)
- UT Scrub bands shall be spaced at 3 inch intervals.
- 360 degree UT bands locations should be marked in the field.
- Often the surveyed location will terminate downstream at a pump (but follow API 570 for scope).
- Only the minimum reading along each circumferential band need be recorded.
- Only the minimum reading recorded need be logged into RBMI for tracking.
- RT Injection Point quills if present to verify integrity and orientation.
- RT any deadlegs present.



Draft CML Examination Point Selection Guidelines

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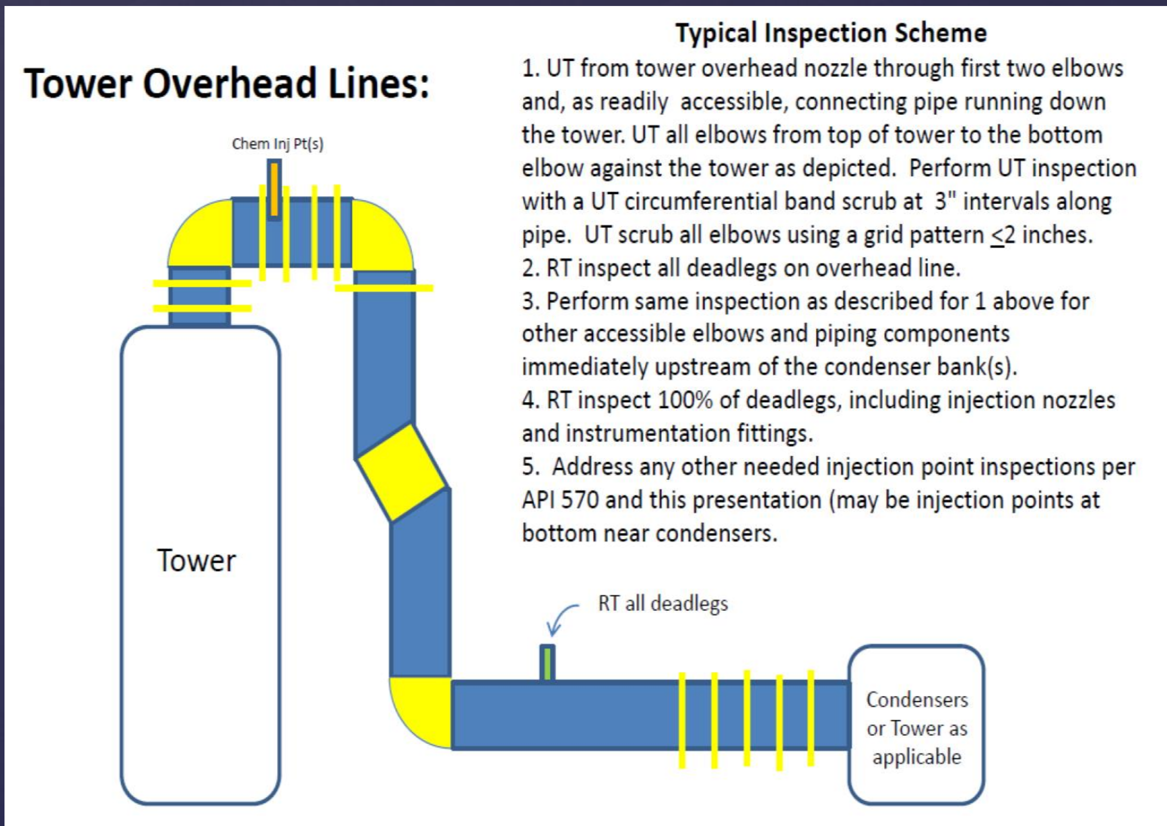

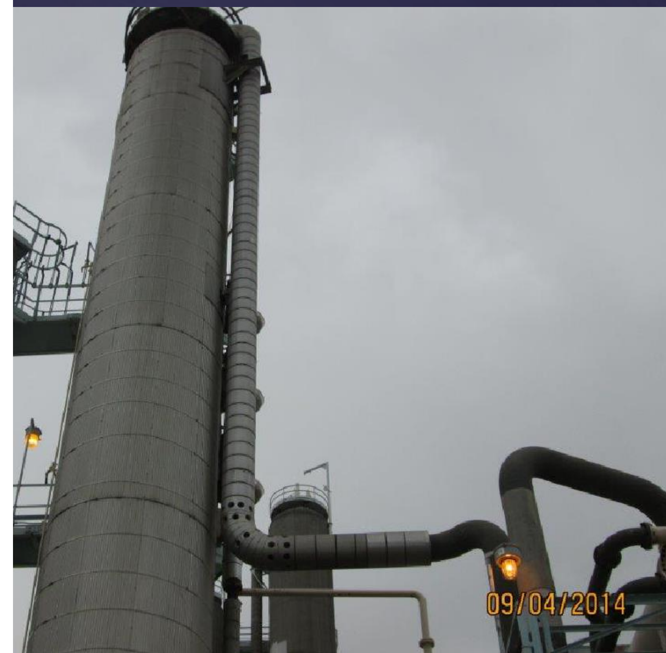

Draft Piping CML Inspection Programming

Piping Inspection: Internal Corrosion Monitoring

Piping / Internal General Corrosion / by External Thickness					
		Low	Medium	Medium-High	High
Baseline	Number of Locations per circuit [2, 3]	Greater of 2 locations or 50%	100%	100%	100%
Maximum Interval (Yr.), or ½ remaining life [3]		15 (note 3)	10(note 3)	10(note 3)	5
Inspection Confidence		Low	Medium	Medium	Medium

NOTES

1. Profile RT preferred for external thickness when NPS 2 or smaller. Recommend using RT for external thickness when piping is 8″ or less, insulated and insulation inspection port placement is a concern, otherwise use either External UT.
2. CML locations shall be in accordance with current business practices.
3. When wall loss in excess of 25% of original is observed, than the inspector shall review and re-establish the inspection plan, including CML placement to ensure the most corroded components have been detected and characterized for wall loss and that appropriate surveillance is established to manage integrity going forward acceptably.

Any Questions?