Essential Elements of a Piping Reliability Program: Development and Management of Corrosion Systems and Circuits

David Hendrix, PE, The Hendrix Group
A. Boyd McKay, P.Eng., The SGS Group
Overview

• Introduction
• Piping Reliability Program: Systems and Circuits
• Systems and Circuits Model
• Criteria to Establish Systems
• Criteria to Establish Circuits
• Management of Systems and Circuits
• Summary
Definitions

• CCD – Corrosion Control Document
• CI – Continuous Improvement
• CML – Condition Monitoring Location
• IOW – Integrity Operating Window
• IP – Injection Point
• KPI – Key Performance Indicator
• MOC – Management Of Change
• MP – Mixing Point
• P&ID – Piping & Instrumentation Diagram
• PFD – Process Flow Document
• RBI – Risk Based Inspection
• RCA – Root Cause Analysis
• SAI – Soil to Air Interface
Introduction

• Notion of systems and circuits is not new
  – Referenced by industry codes
    • API 571, API 570, and API 574
  – Systems and circuits need to be created whether RBI or Non-RBI methodologies will be used

• Systems and Circuits
  – Circuits are more than an organizational tool
  – Relate to level of detail, fit with RBI, IOW, CCD, etc.
  – Start with the end in mind (investment)

• Managing systems and circuits
  – Related to CML creation/active/deactivate, etc.
  – Developed without reference to any specific software
  – Integrated with IOW and CCD
Introduction

[Bar chart showing the percent of losses for different categories: Piping Systems, Tanks, Reactors, Drums, Pumps/Compressors, Heat Exchangers, Towers, Heaters/Boilers, Others/Unknown.]

Source: Tischuk International
API 570/574 Definition

• Piping System
  – “An assembly of interconnected piping circuits that are subject to the same set or sets of design conditions and is used to convey, distribute, mix, separate, discharge, meter, control, or snub fluid flows”.

• Piping Circuit
  – “A section of piping of which all points are exposed to an environment of similar corrosivity and which is of similar design conditions and construction material”.
RIMAP\(^{(1)}\) System Definition

- Systems are generally defined based on the functions they perform.
- There are many ways of dividing a system into sub-systems.
- Sub-systems should be easily manageable and meaningful so as to allow one to concentrate on specific issues related to them, e.g. a particular damage mechanism, a certain fluid, etc.
- For every system and sub-system, it is important to clearly define its extent, i.e. to delineate the boundaries between separate systems.
- Establishment of boundaries is based on criteria specific to particular needs (i.e. safety aspects, operational requirements, process interactions, jurisdictional constraints, available data, etc.).

\(^{(1)}\) Risk based inspection and maintenance procedures for European Industry
Piping Reliability Program

• Reliability Program has Multiple Elements
  – Stakeholders (operations, technical, maintenance)
  – Taxonomy (component structure and identification)
  – Technology (RBI, condition monitoring)
  – Tools (Software, etc.)
  – Continuous Improvement (KPI, RCA, MOC, etc.)

• Systems and Circuits
  – Supported by Taxonomy, Technology and Tools, Stakeholders and CI
  – Important for enabling consistent understanding and analysis of behavior of damage mechanisms in equipment
  – Represent Industry Best Practice approach to equipment/piping inspection
  – Circuits are connected to other circuits and fixed equipment
    • Important for “connecting the dots” in understanding damage mechanisms
Piping Reliability Program

• Piping Taxonomy

Tee, strainer, Bellows, valves, etc.  Instruments

Vessel

Piping Taxonomy Boundary
Systems and Circuits Model

• **Systems**
  – A collection of connected fixed equipment (including piping) exposed to a common process fluid
  – Starting point for creating circuits
  – Usually done at the PFD level but can also be done at the P&ID level
Systems and Circuits Model

• Circuits
  – Division of systems into connected parts
  – More than just a component management tool; can be visual picture of damage
    • Show distribution of damage mechanisms in a system/unit
    • Show distribution of damage rates/susceptibilities in a system/unit
  – Contributes to the piecing together the corrosion puzzle
    • Resolution provided by circuits is driven by damage mechanisms
  – Commonly shown on color coded diagrams for visibility
System Criteria

• Criteria For Developing Systems
  – The change in stream composition (i.e. addition or deletion of a stream constituent)
  – Fluid phase not important for systems, may be important for Circuits
  – Understanding of type and duration of operating modes could impact the development of Systems and Circuits
    • For example, two train operation....
Circuits Criteria

• Circuits
  – Two methods of creating circuits observed:
    a) Create based on geometry and some process condition behavior
      a) Circuits first, Damage Mechanisms last or not at all
    b) Create based on damage mechanism behavior (preferred)
      a) Damage Mechanisms first, circuits last
Circuits Criteria

- Circuits
  - Criteria possibly unrelated to damage mechanisms drive the creation of circuits
    - Vessel flange
    - Change in Code of construction
    - Valve flange (battery Limit, isolation valve, etc.)
    - Branch connection
    - PSM/DOT delineation
    - “New”/“Old” equipment delineation
    - Instrument tubing
    - Vessel trim
    - Pipe Rack delineation
Circuits Criteria

• Circuits
  – Criteria related to damage mechanisms drive the creation of circuits (continued)
    • Temperature (internal/external) and/or pressure changes
    • Physical changes (insulation/no insulation, tracing/no tracing, liner/no liner, etc.)
    • Materials of construction
    • Physical geometry affecting flow and velocity
Circuits Criteria

• Circuits
  – Criteria related to damage mechanisms drive the creation of circuits (continued)
    • Fluid phase (e.g. slug flow, erosion)
    • Vibration (e.g. around reciprocating/rotating equipment)
    • Support system (e.g. susceptible external support design issues, etc.)
    • Inspectable/un-inspectable damage mechanisms (creep, HTHA, embrittlement, etc.)
Circuits Criteria

• Circuits
  – Circuits should provide
    • Sufficient information to support underlying inspection methodology (risk based or condition based)
    • A manageable means of providing the above information
      – Document circuit basis (CCD and management software)
    • Ability to process extent of operational changes (stream constituents, temperature, velocity, etc.)
      – “Smart” Circuit –more than an collection tool
      – Connected to CCD for consistent review
Circuits Criteria

- Circuits
  - Required data to start
    - Material of Construction
    - Diameters and thicknesses
    - Code of Construction ($T_{\text{min}}$ calculation, Optional)
    - Operating Pressure and Temperature
    - Stream constituents
    - Drawing representing process operation (P&ID)
    - Data should come from an MASTER (AS BUILT) source
Circuits Criteria

Start

>1 Material

Y - Create Circuit For Each Material

N - For Material A

IP in Circuit

Y - MAT A: Create IP Circuit

N - Manage with Inspection scheme

Mixing Point

Y - MAT A: Create Mixing Point Circuit

N - Manage with Inspection scheme

Un-Inspectable Damage

Y - MAT A: Create Circuit

N - Manage with Remaining Life Assessment

fatigue

Creep

Embrittlement
Circuits Criteria

A → SPEC Break
  Y → MAT A: Create Circuit termination point at Spec Break (Optional)
  N → SAI Break
  Y → - MAT A: Create Circuit termination point at SAI
  N → External Corrosion
  Y → Insulation Change
    Y → - MAT A: Create Circuit termination point at Insulation Change
    N → Support Design Change
      Y → - MAT A: Create Circuit termination points at ends of the Support Design Change
      N → External Corrosion
  N → B
Circuits Criteria

B

Process DeadLeg

DM: Pressure

DM: Temperature

DM: Material Condition

MAT A: Create Circuit termination point PDL Limits

DM: Pressure limits

Insulation Change

PWHT

MAT A: Create Circuit termination point at Insulation Change

MAT A: Create Circuit termination point at limits of PWHT
Circuits Criteria

1. DM: Material Condition
   - Y: MAT A: Create Circuit termination point at Solution Anneal Limits
   - N: Go to DM: Velocity

2. DM: Velocity
   - Y: MAT A: Create Circuit termination point DM velocity Limits
   - N: Go to Process Deadleg

3. Process Deadleg
   - Y: MAT A: Create circuit termination points at limits of process deadleg
   - N: Go to Other

4. Other
   - Y: MAT A: Create circuit termination points at limits of DM Criteria
   - N: MAT A: System Limits=Circuit Limits
Circuits Criteria

System 1

Termination Points for DM

DM 1

DM 2, 3

DM 4

C1 C2 C3 C4

System Limits

Example #1

DM=Damage Mechanism
C=Circuit
Circuits Criteria

System 1

DM 1

DM 2, 3

DM 4

DM 1

C1 C2 C3 C4 C5 C6

DM=Damage Mechanism
C=Circuit

Example #2
Circuits Criteria

System 1

Too Few Circuits!

Too Many Circuits!

DM 1

DM 2, 3

DM 4

DM 1

C1 C2 C3 C4 C5 C6

DM=Damage Mechanism
C=Circuit

Example #3
Summary

• Systems and Circuits are part of a Piping Reliability Best Practice
• Damage mechanisms and drivers should always drive the creation of circuits; integrate with CCD
• A defined process for creating circuits is useful; document criteria to create systems and circuits
• Start with the end in mind; Create sufficient circuits to manage piping reliability *avoid shotgun circuit blast approach*
• Significant number of failures in piping; improve circuit development efforts
Summary (cont.)

• 100 % reliability is possible!
  – With properly designed systems/circuits
  – With identification of all damage mechanisms (DM)
  – With inclusion of dead legs, injection/mixing points
  – With proper inspection techniques for all DM
  – With appropriate inspection densities

• Caveat
  – Garbage in/Garbage out!
A. Boyd McKay, P.Eng.
SGS Global AIM-RBI Leader
900 Georgia Avenue, Suite 1100
Deer Park, TX 77536
Phone:  +1 281-478-8189
Mobile:  +1 918-977-0686
anthony.mckay@sgs.com
www.sgs.com

David E. Hendrix, P.E.
The Hendrix Group Inc.
15823 N. Barkers Landing,
Houston, TX 77079
Phone:  281.556.8774
Mobile:  281-851-1262
david.hendrix@hghouston.com
www.hghouston.com