U.S. Department of Transportation

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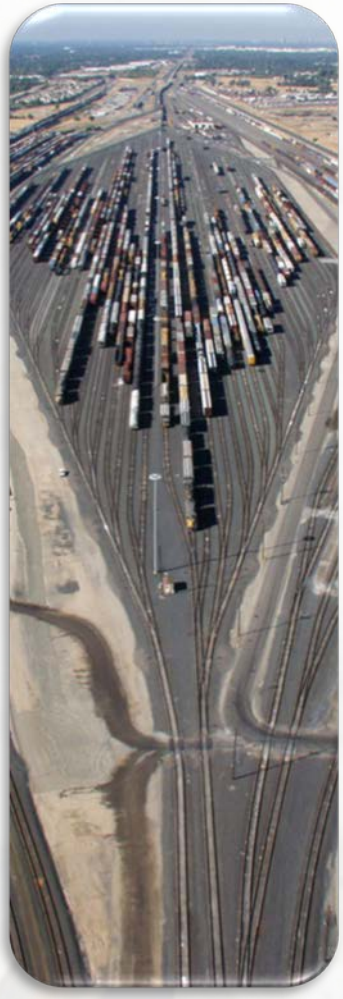

Reliability for Qualification and Maintenance

TOPICS

- Objective
- The Need for Reliability
- Subchapter C HM Regulations
- Definitions
- Qualification and Maintenance Duties
- Reliability Basics
- Reliability Program Development

OBJECTIVE

"To teach reliability principles for setting valid qualification intervals and managing fleet risk."

THE NEED FOR RELIABILITY

THE NEED FOR RELIABILITY

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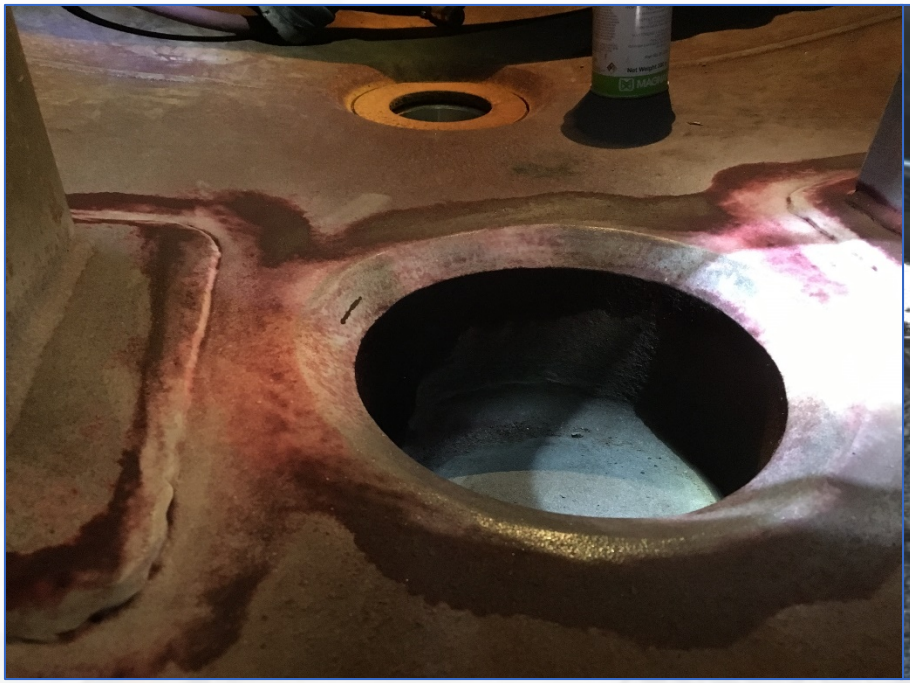

THE NEED FOR RELIABILITY

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THE NEED FOR RELIABILITY

SUBCHAPTER C HM REGS.

- 49 CFR § 171 – GENERAL INFORMATION, REGULATIONS, AND DEFINITIONS
- 49 CFR § 179 – SPECIFICATIONS FOR TANK CARS
  - SUBPART A – INTRODUCTION, APPROVALS, AND REPORTS
- 49 CFR § 180 – CONTINUING QUALIFICATION AND MAINTENANCE OF PACKAGINGS
  - SUBPART F – QUALIFICATION AND MAINTENANCE OF TANK CARS

SUBCHAPTER C HM REGS.

- 49 CFR § 179.7(a)(1) – The facility quality assurance program shall ensure that the tank car and components conform to the applicable specification and regulations of Subchapter C.
- 49 CFR § 179.7(b)(4) – Procedures to ensure that the construction materials received are properly identified and documented.

SUBCHAPTER C HM REGS.

- 49 CFR § 180.501(b) – This subpart establishes the minimum acceptable framework for an owner's qualification program for tank cars and components.
- 49 CFR § 180.501(b) – The owner's qualification program . . . must identify where to inspect, how to inspect, and the acceptance criteria.

SUBCHAPTER C HM REGS.

- 49 CFR § 180.509(k)(1) – The tank car owner must analyze the service equipment inspection and test results for any given lading and adjust the inspection and test frequency to ensure the design level of reliability and safety is met.
- 49 CFR § 180.509(k)(1) – The owner must maintain all documentation used to make such inspection and test frequency adjustment and provide to FRA.

SUBCHAPTER C HM REGS.

- 49 CFR § 180.513(b)(1) – A tank car facility must obtain the equipment owner's permission prior to starting work and use the owner's approved procedures.
- 49 CFR § 180.513(b)(1) – A tank car facility must report all work performed to the owner and all damage, deterioration, defects, failed components, and noncompliant parts to the owner.

DEFINITIONS

- Packaging – A receptacle and any other components or materials necessary to perform the containment function in conformance with requirements of Subchapter C.
- Package – A packaging plus its contents.
- Receptacle – A containment vessel for receiving and holding materials, including any means of closing.

DEFINITIONS

- Packaging (from previous definition) –

  "A containment vessel for receiving and holding materials, including any means of closing, and any other components or materials necessary to perform the containment function in conformance with requirements of Subchapter C."

DEFINITIONS

- Tank, T/C (AAR)– The shell, heads, nozzles, sumps, interior heater coils, all welds joining them, and all components welded thereto to contain the lading.
- Tank, T/C (FRA) – The shell, heads, tank shell and head weld joints, attachment welds, sumps, nozzles, flanges, and all components welded thereto that are in contact with or contain the lading.

DEFINITIONS

- Service Equipment (AAR) – PRDs, valves, closures, fittings, loading / unloading devices, sampling, venting, vacuum relief, lading temperature / amount measurement, and flow restriction.
- Service Equipment (FRA) – PRDs, loading / unloading equipment, interior heating systems, sampling, venting, vacuum relief, lading temperature / amount measurement.

DEFINITIONS

- Closure (AAR) – A device that closes an opening into the tank, service equipment, or fitting.
- Closure (FRA) – A device (primary / secondary) that prevents release of the lading (M/W covers, plugs, flanges, washouts, etc.).
- Fitting (AAR) – A part in contact with the lading with no operating components, joining service equipment to the tank or multiple parts together.

DEFINITIONS

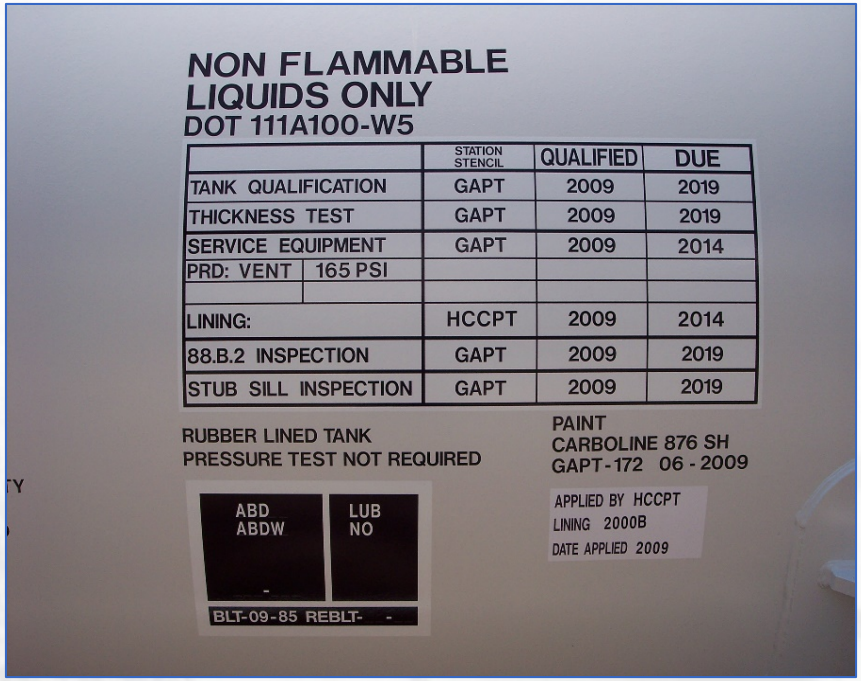
- Pressure Retaining Component (AAR) – An item integral to the tank (shell, head, nozzle, flange, saddle, and all components welded thereto) that contain the lading excluding service equipment and valves / fittings.

DEFINITIONS

- Defect – Abrasions, corrosion, cracks, dents, distortions, erosion, damaged / leaking / loose / missing components, weld flaws, or other conditions that make the tank car unrailworthy.
- Failure – A defect or potential defect that makes or could make the tank car unrailworthy.
- Failure must be defined for reliability analysis.

DEFINITIONS

- Railworthy / Railworthiness – The tank, service equipment, interior coatings / linings, safety systems, and all other Subpart F covered components conform to the HMR and the design function.



QUAL. / MAINT. DUTIES

- Qualification (FRA) – Inspections / tests to ensure the tank car and components conform to the specification to which they were designed, manufactured, or modified, and to the owner's acceptance criteria.
- Maintenance (FRA) – Preservation / upkeep / repair to ensure the tank car and components conform to the specification during the interval.

QUAL. / MAINT. DUTIES

- Owners must have Qualification and Maintenance Programs (QMPs) to qualify / maintain tank cars (TC), service equipment (SE), interior coatings / linings (IC/L) to meet design level of reliability and safety.
- Owners may use 3rd party-developed QMPs by agreement with the developer.
- Owners must ensure facilities (TCF) conform to QMPs.

QUAL. / MAINT. DUTIES

- TCF must obtain owner permission BEFORE working on equipment.
- TCF must follow owner-designated QMP to qualify / maintain equipment.
- TCF must report to owner all deterioration, failed components, damage, noncompliant parts, work performed and components / material applied.

QUAL. / MAINT. DUTIES

- Owners must have procedures to collect and analyze inspection and test (Qualification) results, set / adjust intervals to maintain DRS.
- Owners may use maximum qualification intervals (180.509(c)(3)) *only if* validated through analysis.
- Representation that a tank car is qualified and railworthy is a Federal action **subject to civil and criminal penalties if falsified**.

RELIABILITY BASICS

IF

- Quality = "Conformance to Requirements" Crosby

AND

- Reliability = "Quality Over Time"

THEN

- Reliability = "Conformance to Requirements Over Time"

RELIABILITY BASICS

- Reliability – The quantified ability of a tank car or component to perform its design function, without failure, for the specified design life or qualification interval in a given environment.
- Design Level of Reliability & Safety (DRS)– The quantified level of reliability & safety built into a tank car or component due to it's specification, design, and manufacture.

RELIABILITY BASICS

- Reliability means –
  - *Having the quantified ability to:*
  - *Perform design function without failure -*
  - *For a specified time -*
  - *In a given environment.*
- Need specific descriptions for failure, function, time, environment!

RELIABILITY BASICS

- Questions To Be Answered:
  - What is the design (expected) life of the item?
  - How will failure be defined?
  - How will failure be discovered?
  - What are the consequences of failure?
  - How many failures expected in next interval?
  - How much time is the item available (uptime)?
  - How much time/difficulty to repair (downtime)?

RELIABILITY BASICS

- Non-repairable System – An item, service, or process that, once it fails, is not repaired and put back into service. Reliability analysis is performed on initial failure data.
- Repairable System – An item, service, or process that, once it fails, is repaired and put back into service. Reliability analysis is performed on initial failure and repaired system data.

RELIABILITY BASICS

- Measures of Reliability

  1. For random failures in non-repairable systems, MTTF usually decreases as components age.

  2. For repairable systems, MTTF can increase or decrease.

MTTF lacks sufficient selectivity to determine when items can fail and how many can fail based on age / usage.

RELIABILITY BASICS

- Measures of Reliability

Is there another way ???

- Weibull Analysis:
  - Uses experimental or in-service data to estimate item life;
  - Provides probabilities item will fail given it has operated for a specific time;
  - Provides system estimates for number of failures and replacements needed over time.

RELIABILITY BASICS

Failure for Tank Integrity = Crack Detection / Sizing?

RELIABILITY BASICS

Failure for Tank Integrity = Crack Growth / Leakage?

RELIABILITY BASICS

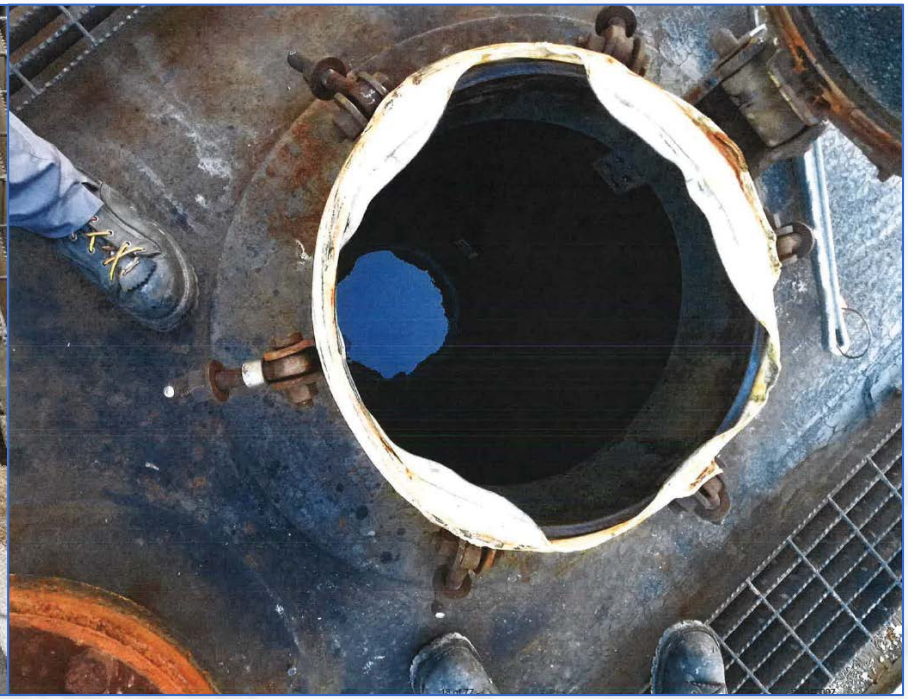
Failure for Rule 88.B.2 / Draft Sills – Cracks / Damage?

RELIABILITY BASICS

Failure for Service Equipment = Leakage / Corrosion?

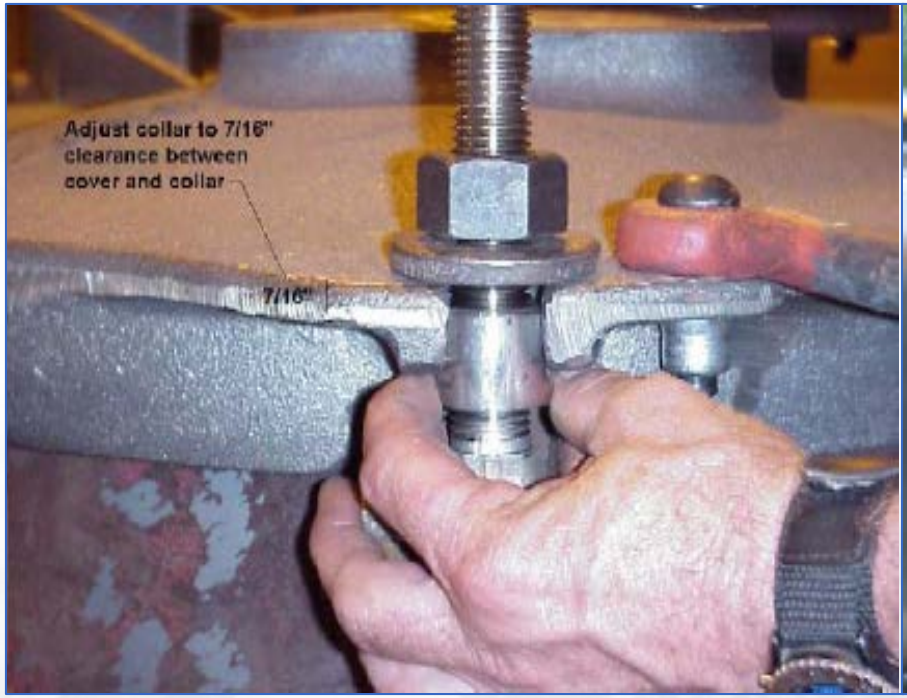
RELIABILITY BASICS

Failure for Service Equipment = Leakage / Corrosion?



RELIABILITY BASICS

Failure for Service Equipment = Leakage / Safety?



RELIABILITY BASICS

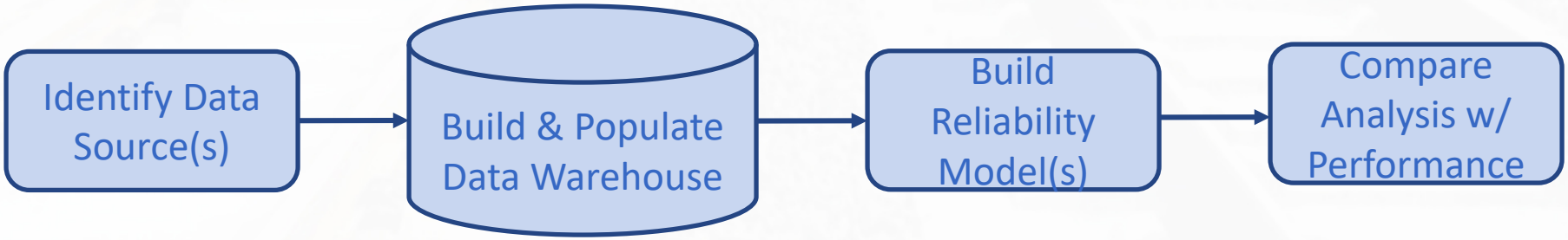
Failure for Service Equipment = Leakage / Corrosion?

RELIABILITY PROGRAM DEVELOPMENT (RPD)

- Collect / Analyze Data
- Develop Data Collection Structure
- Build & Populate Data Warehouse
- Develop Reliability Model(s)
- Compare Analysis with Performance

RPD

Collect / Analyze Data



- 5800s
- OTMAs
- QMP Results
- NCRs
- Other Sources

- Identify Item(s)
- Populate With Source Data
- Clean & Prepare
- Stratify

- Identify Covered Assemblies & S/As
- FMEA Review
- Assign Assembly & S/A Systems

- Run Algorithm
- Non-repairable Systems
- Compare “Fit” To Performance

RPD

Develop Data Collection Structure

- Identify Data Source(s)

RPD

Develop Data Collection Structure

- Build Connectivity

RPD

Develop Data Collection Structure

- Develop Data Format – NITL BRC-style Format?

Date	SS	Mark	Car #	Loc	Qty	Cond Code App	JC App	Qual App	Desc App	Ser # App	WM	JC Rem	Qual Rem	Desc Rem	Ser # Rem
5/6/17	LSNI	FRAX	1234	B	1	1	9100	06	NJV 6FRF 3600 MT	123 ABC	15	9100	03	NJV 6FRF 2236 MT	456 XYZ
5/6/17	LSNI	FRAX	1234	B	1	9	9042	04	NJV 6FRF 3600 MT	123 LHS	11	9042	04	NJV 6FRF 3600 MT	123 LHS

RPD

Develop Data Collection Structure

- Develop Data Format – NITL BRC-style Format?

SS – Station Stencil Doing the Work

Mark – Car Mark

Car #

Loc – Location on Car

Qty – Quantity Involved

Cond Code – 1 (New Material Applied)
9 (Remove/Replace Same Part)

JC App – 9100 (Siphon pipe valve, ball type)
9042 (Air inlet valve, flange type)

Qual App – 06 (3 inch Stainless steel)
04 (1 inch Stainless steel)

Desc App – Manufacturer Description

RPD

Develop Data Collection Structure

- Develop Data Format – NITL BRC-style Format?

Ser. # - Serial Number (after 7/1/2013)

WM – Why Made – 15 (Leaking)
- 11 (Removed in good condition)

JC Rem – 9100 (Siphon pipe valve, ball type)
9042 (Air inlet valve, flange type)

Qual Rem – 03 (3 inch Carbon steel)
04 (1 inch Stainless steel)

JC App – 9100 (Siphon pipe valve, ball type)
9042 (Air inlet valve, flange type)

Desc Rem – Manufacturer Description

RPD

Build Reliability Model(s)

1. Identify assemblies and subassemblies to be analyzed – these are the ones that are critical to T/C function:
   a. Structural welds
   b. Service equipment
   c. Interior coatings / linings
   d. Closures and gasketed joints

RPD

Structural Welds – Identify / Code All Welds Covered

RPD

Structural Welds – Identify / Code All Welds Covered

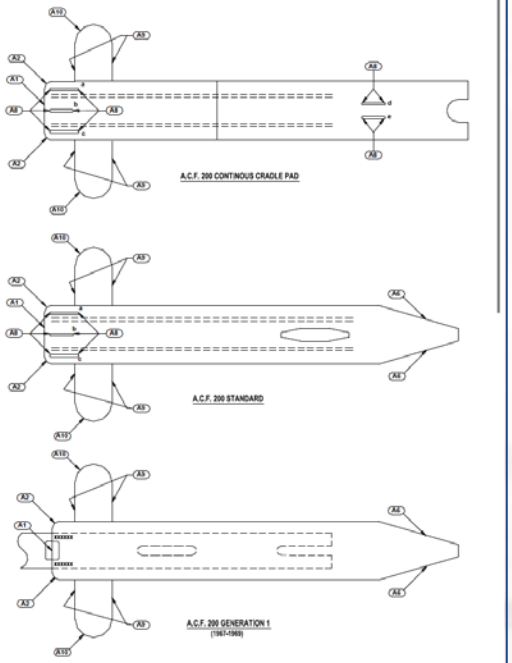
CODE	MEETS	DESCRIP	LOC	INSPECT
A1	180/SS3/88	7” TRANS	A/B	FULL
A2	180/SS3/88	OUTER TERMS	A/B/L/R	FULL
A6	180/88	INNER TERMS	A/B/L/R	6”
A8	180	PAD SLOT	A/B	IN/OUT
A9	180/88	BOLST.	A/B/L/R	NCNI
A10	180	BOLST. HORN	A/B/L/R	NCNI

Work Instruction:

1. **Pad-to-Tank** (Designated by ‘A’ codes)

Code	Meets	Description	Location	Inspect
A1[1,2]	HM-201 SS-2 88.B.2	7” Transverse weld.	A- & B-Ends	Full length of weld.
A2[3,4]	HM-201 SS-2 88.B.2	Outboard termination of longitudinal pad-to-tank weld.	AR, AL, BR, BL	Full length of weld to termination at bolster pad.
A6[5]	HM-201 88.B.2	Inboard termination of cradle pad longitudinal welds.	AR, AL, BR, BL	Last 6” of weld to termination.
A8[6]	HM-201	Cradle pad-to-tank slot welds.	A- & B-Ends (42 to 106 places per car)	Inboard and outboard slot welds. See Note 7. See Note 7
A9[7]	HM-201 88.B.2	Bolster pad-to-tank transverse weld.	AR, AL, BR, BL	See Note 7NI Cars Only
A10	HM-201	Top of Body BBolster Cradle Pad. pad-to-tank longitudinal weld.	AR, AL, BR, BL	See Note 7NI Cars Only

Sketch/Description:



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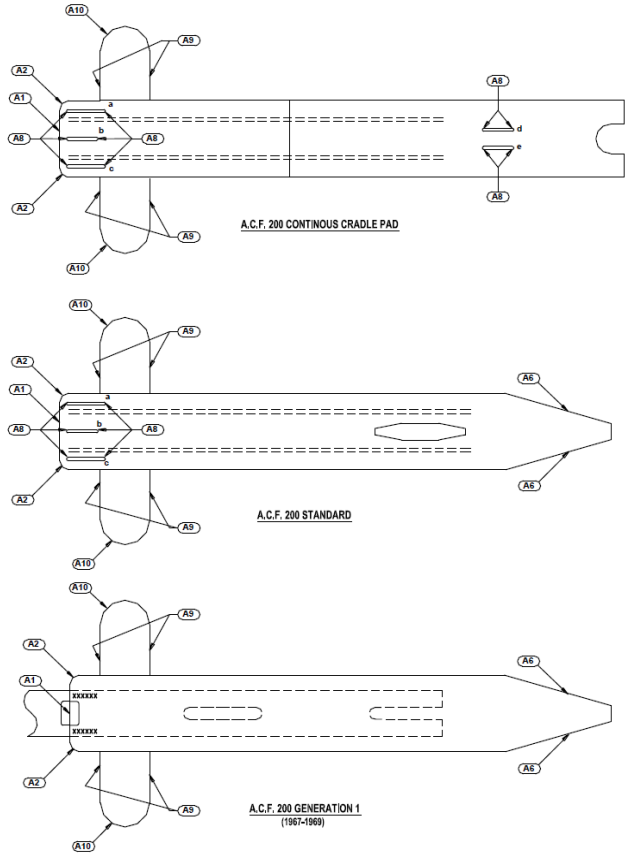
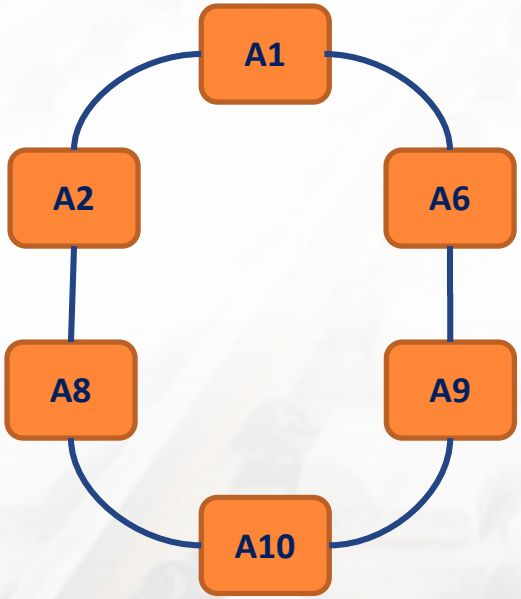


RPD

Structural Welds – Build Reliability Models



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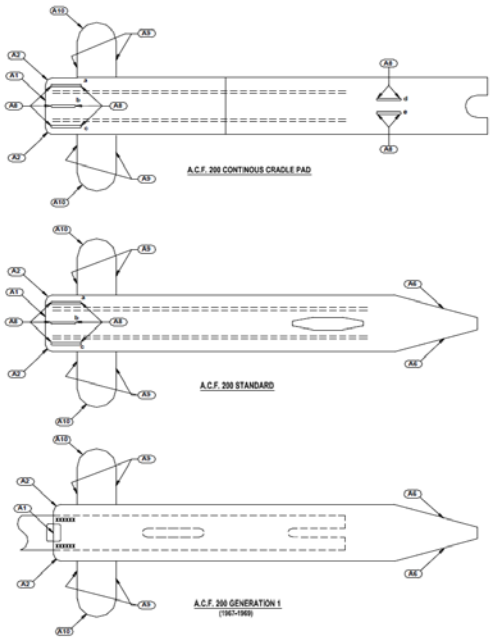

RPD

Structural Welds – Quantify Inspection Reliability

RPD

Structural Welds – Usage / Inspection Results

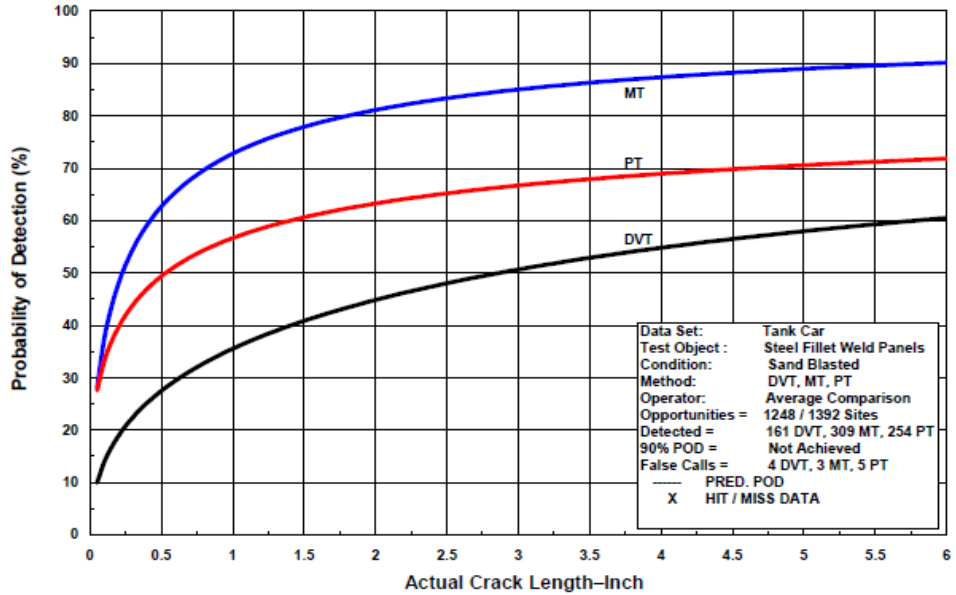

Figure 33. Combined Average POD Comparison for the DVT, MT, and PT Methods

Usage / Inspection Results

• 202,134	• A1/A2/A6	• 3/0/0
• 312,560	• A1/A2/A6	• 0/1/0
• 183,023	• A1/A2/A6	• 1/1/0
• 286,212	• A1/A2/A6	• 1/2/0
• 401,233	• A1/A2/A6	• 3/3/3
• 89,567	• A1/A2/A6	• 0/1/0
• 301,444	• A1/A2/A6	• 0/1/1
• 222,086	• A1/A2/A6	• 1/1/1
• 156,444	• A1/A2/A6	• 0/1/1
• 333,188	• A1/A2/A6	• 2/1/1
• 201,433	• A1/A2/A6	• 1/1/0
• 199,310	• A1/A2/A6	• 2/0/1
• 252,666	• A1/A2/A6	• 1/2/2
• 179,286	• A1/A2/A6	• 0/0/0
• 111,338	• A1/A2/A6	• 3/2/2

RPD

Service Equipment – Identify / Code Components

RPD

Service Equipment – Build Reliability Model(s)

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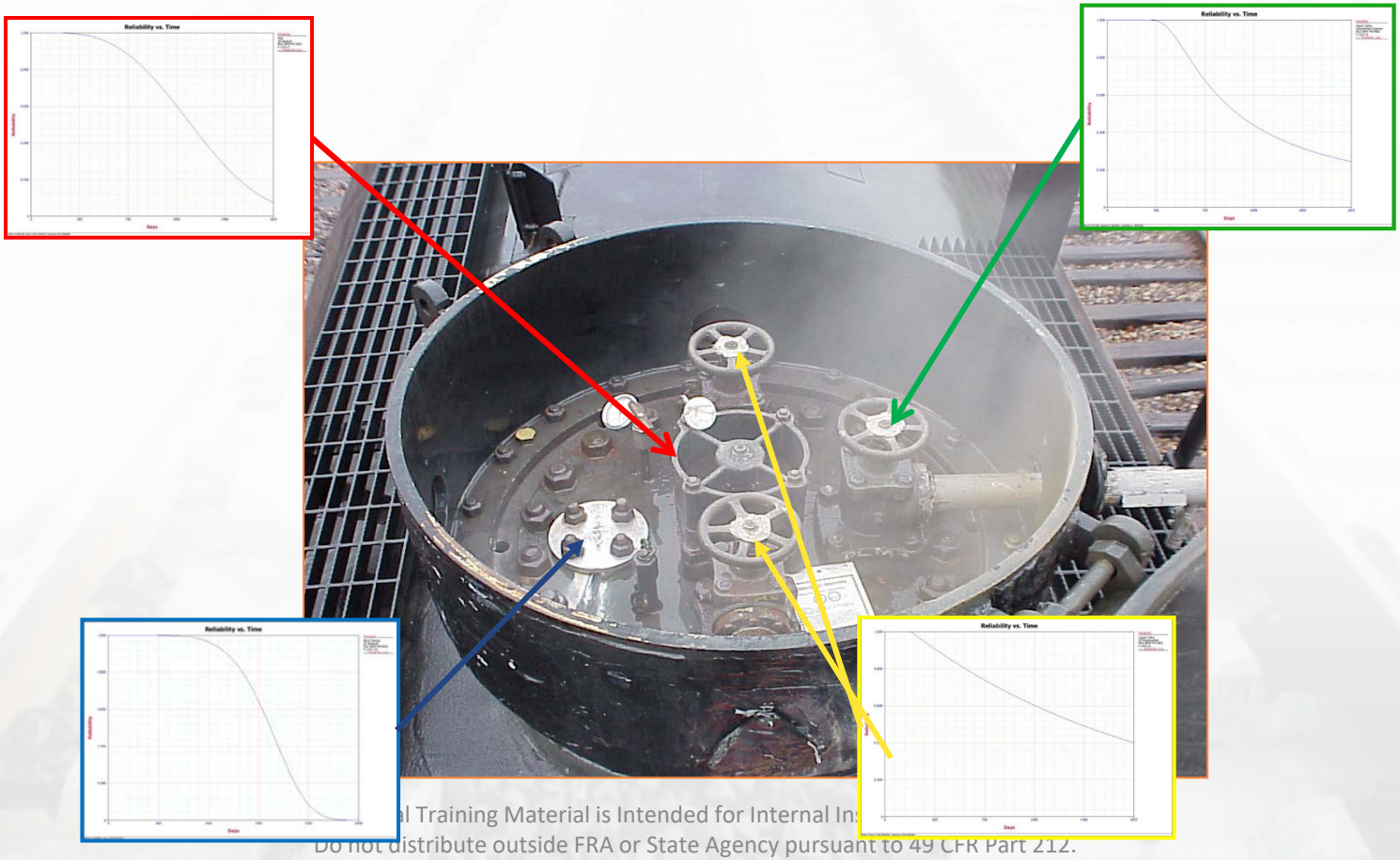
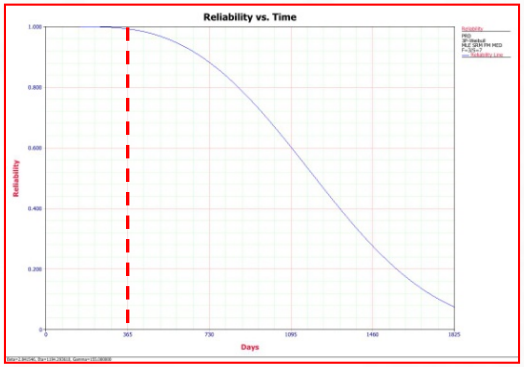
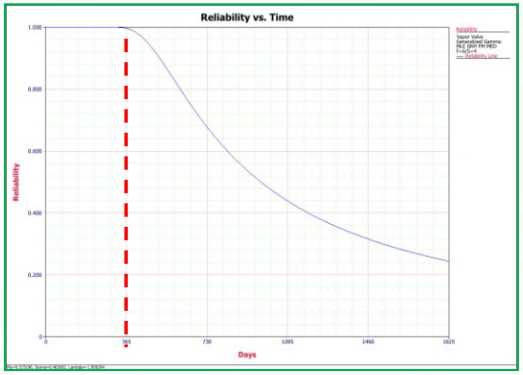
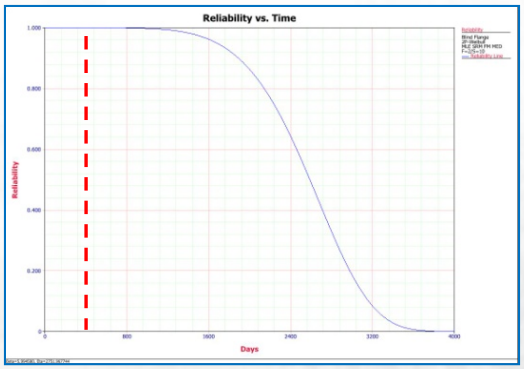
RPD Multi-Component Reliability System Analysis



RPD Multi-Component Reliability System Analysis







1 Year Valve Set Reliability = 0.99*0.99*1.00*0.90*100 = 88%

RPD

Service Equipment – Identify Failure Mode(s)

RPD

Multi-Component Reliability System Analysis

1. For T/C DRS most components are organized in series, i.e., if any component fails the entire T/C is unavailable. For example, if one vapor valve fails, T/C must be cleaned, valve R&R, leak tested.

2. For T/C, loss of DRS is any failure to meet any FRA regulation / AAR specification / or owner criteria.

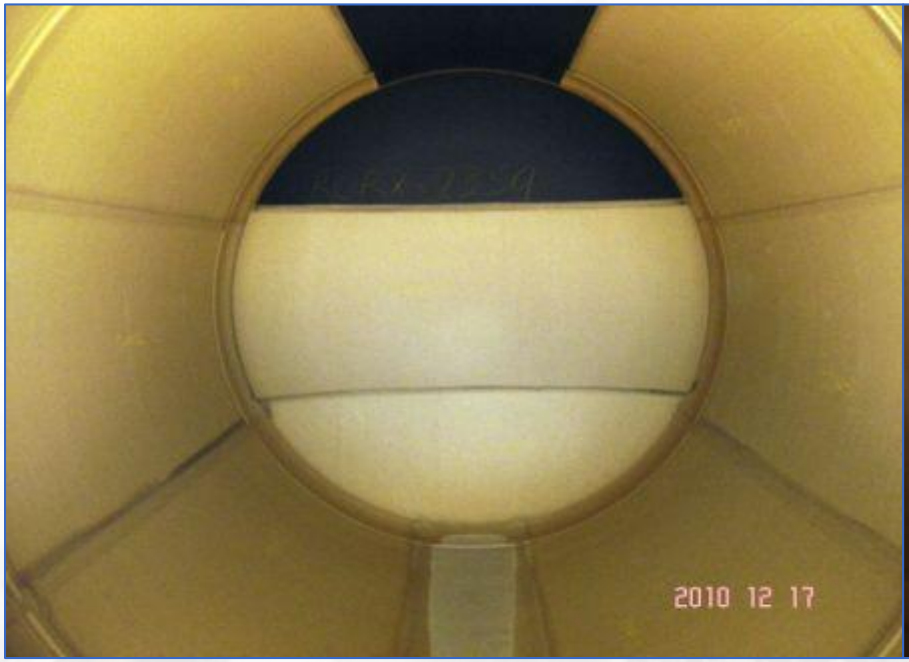
RPD

More Complex Analyses Possible Covering:

- Gasket Connections
- Fastening Systems
- Competing Failure Modes
- Component / Commodity Compatibilities
- Corrosion / Fracture Interactions

RPD

Coatings / Linings – Identify / Code Components



RPD

Coatings / Linings – Build Reliability Model(s)

RPD

Coatings / Linings – Identify Failure Mode(s)

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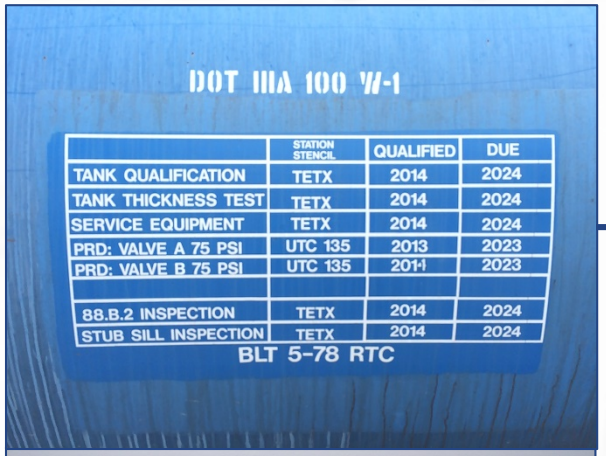
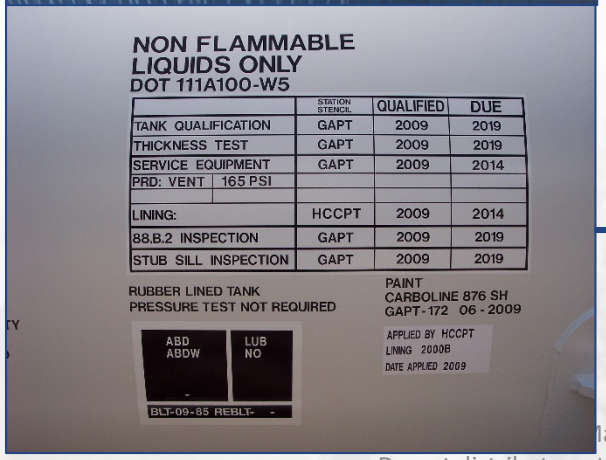
ANALYSIS v. PERFORMANCE



VS.



VS.

IN SUMMARY

Reliability principles promote an improved continuous operational methodology by incorporating a data-driven, risk-based approach to hazardous tank car safety assurance and risk management.

THOUGHTS???