Elements of an Engineering-Based Integrity Management Program EB-IMP®

Fitness For Service Considerations

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Julian J. Bedoya, P.E.
Julian.Bedoya@stress.com

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Outline of Presentation

- What is Fitness for Service? When is it applicable?
- Introduction to API 579-1 / ASME FFS-1 Standard
- Introduction to the concept of EB-IMP®
- Case Study
  - "Vintage" Girth Weld Repair

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What is Fitness For Service?

- Fitness for Service is an approach that has been developed to address equipment that has been placed in service whereby flaws/defects/cracks/damage have been identified.
- Nowadays it is a standard used to aid in the justification of continued operation, repair or replacement of such equipment, whereby its integrity is threatened by in-service deterioration, or newly discovered (fabrication) flaws.
  - Run?
  - Alter?
  - Repair?
  - Monitor?
  - Retire?
  - Replace?
- Ensure the safety of the public
- Ensure consistent results
- Optimize maintenance / operation
- Enhance long-term economic viability of existing facilities

Design Codes vs. FFS

- Design Codes for Pressurized Equipment
  - Provide rules for design, fabrication, inspection, and testing
  - Do not address defects found during inspections
  - Do not address in-service degradation

- API 579-1 / ASME FFS-1 provides procedures for what design codes do not…
  - Flaws, defects, degradation, repairs, etc.

Scope

- Pressure boundary of pressure vessels, boiler components, piping, and shell courses of storage tanks (ASME, API, other codes).
- Addresses both
  - Current integrity
  - Remaining life
- Concepts may be utilized for assessment of non-pressurized equipment.
- Supplements and augments requirements of:
  - API-510 (PV Inspection Code)
  - API-570 (Piping Inspection Code)
  - API-653 (Tank Inspection, Repair, …)

API 579-1 ASME FFS-1 (2007 and 2016)

- How does API 579-1 relate to Div. 2 and other Codes?

Table 5.5
Load Case Combinations and Load Factors for an Elastic–Plastic Analysis

Criteria	Required Factored Load Combinations
Design Conditions	
Global	(1) $2.4(P + P_s + D)$
	(2) $2.1(P + P_s + D + T) + 2.7L + 0.86S_s$
	(3) $2.1(P + P_s + D) + 2.7S_s + (1.7L \text{ or } 0.86W)$
	(4) $2.1(P + P_s + D) + 1.7W + 1.7L + 0.86S_s$
	(5) $2.1(P + P_s + D) + 1.7E + 1.7L + 0.34S_s$
Local	$1.7(P + P_s + D)$
Serviceability	Per User's Design Specification, if applicable; see 5.2.4.3(b)
Hydrostatic Test Conditions	
Global and Local	$\max\left[2.3, 2.0\left(\frac{S_T}{S}\right)\right] \cdot (P + P_s + D) + W_{pe}$
Serviceability	Per User's Design Specification, if applicable
Pneumatic Test Conditions	
Global and Local	$1.8\left(\frac{S_T}{S}\right) \cdot (P + P_s + D) + W_{pe}$
Serviceability	Per User's Design Specification, if applicable

GENERAL NOTES:
(a) The parameters used in the Design Load Combination column are defined in Table 5.2.
(b) See 5.2.4.3 for descriptions of global and serviceability criteria.

Serviceability Criteria	Per Owner-user's Specification, if applicable

ment Based on Elastic-Plastic Analysis

	β
	$2.35 \cdot RSF_a$ (1)
	$2.4 \cdot RSF_a$ (1)
	$2.4 \cdot RSF_a$ (1)
n	$3.0 \cdot RSF_a$ (1)
	$3.5 \cdot RSF_a$ (1)
n	$4.0 \cdot RSF_a$ (1)
	$2.5 \cdot RSF_a$ (1)
	$3.3 \cdot RSF_a$ (1)
	$3.5 \cdot RSF_a$ (1)
	$4.0 \cdot RSF_a$ (1)
	$3.0 \cdot RSF_a$ (1)
ASME B31.4	$2.4 \cdot F \cdot RSF_a$ (2)
ASME B31.8	$2.4 \cdot f \cdot T \cdot RSF_a$ (2)
ASME B31.12	$3.0 \cdot RSF_a$ (1)

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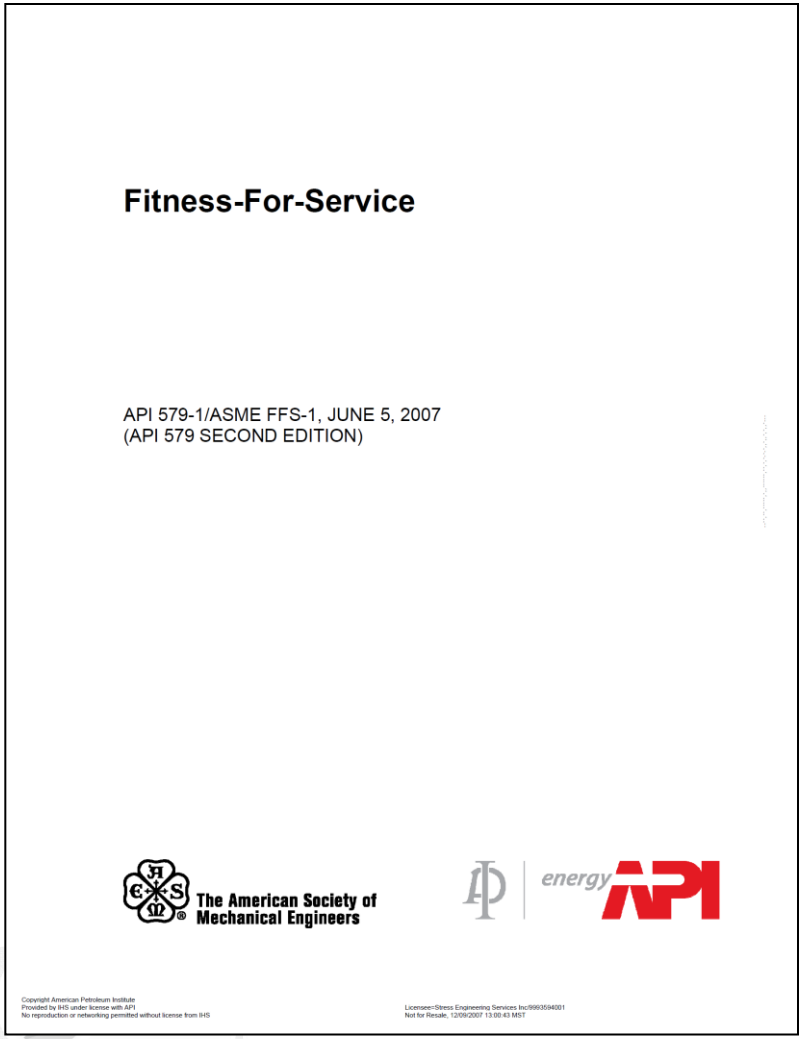
API 579-1 / ASME FFS-1 “Fitness-For-Service”


Fitness-For-Service

API 579-1/ASME FFS-1, JUNE 5, 2007
(API 579 SECOND EDITION)

The American Society of Mechanical Engineers

energy API

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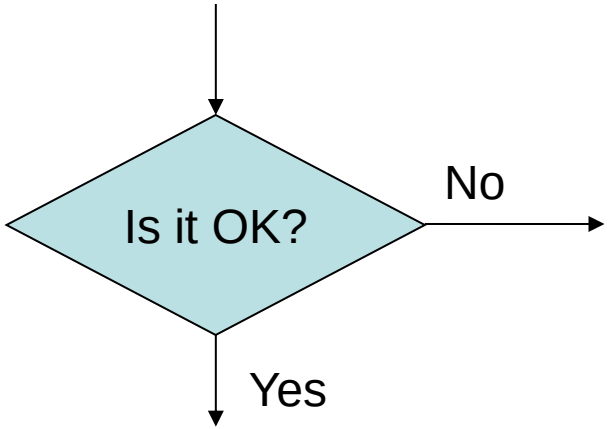
- API Recommended Practice 579, Fitness-For-Service. (Jan. 2000).
- Joint API/ASME Committee formed in 2001.
- API 579-1/ASME FFS-1 standard is based on and supersedes API RP 579.
  - Published June 2007
- API 579-2/ASME FFS-2 example manual published October 2009.

Part 1: Introduction

- Quantitative engineering evaluations.
- Performed to demonstrate/check the structural integrity of an in-service component that may contain a flaw or damage.
- Pressurized equipment.
- Goal: **Run-Repair-Replace** decisions.



Part 2: FFS Procedure

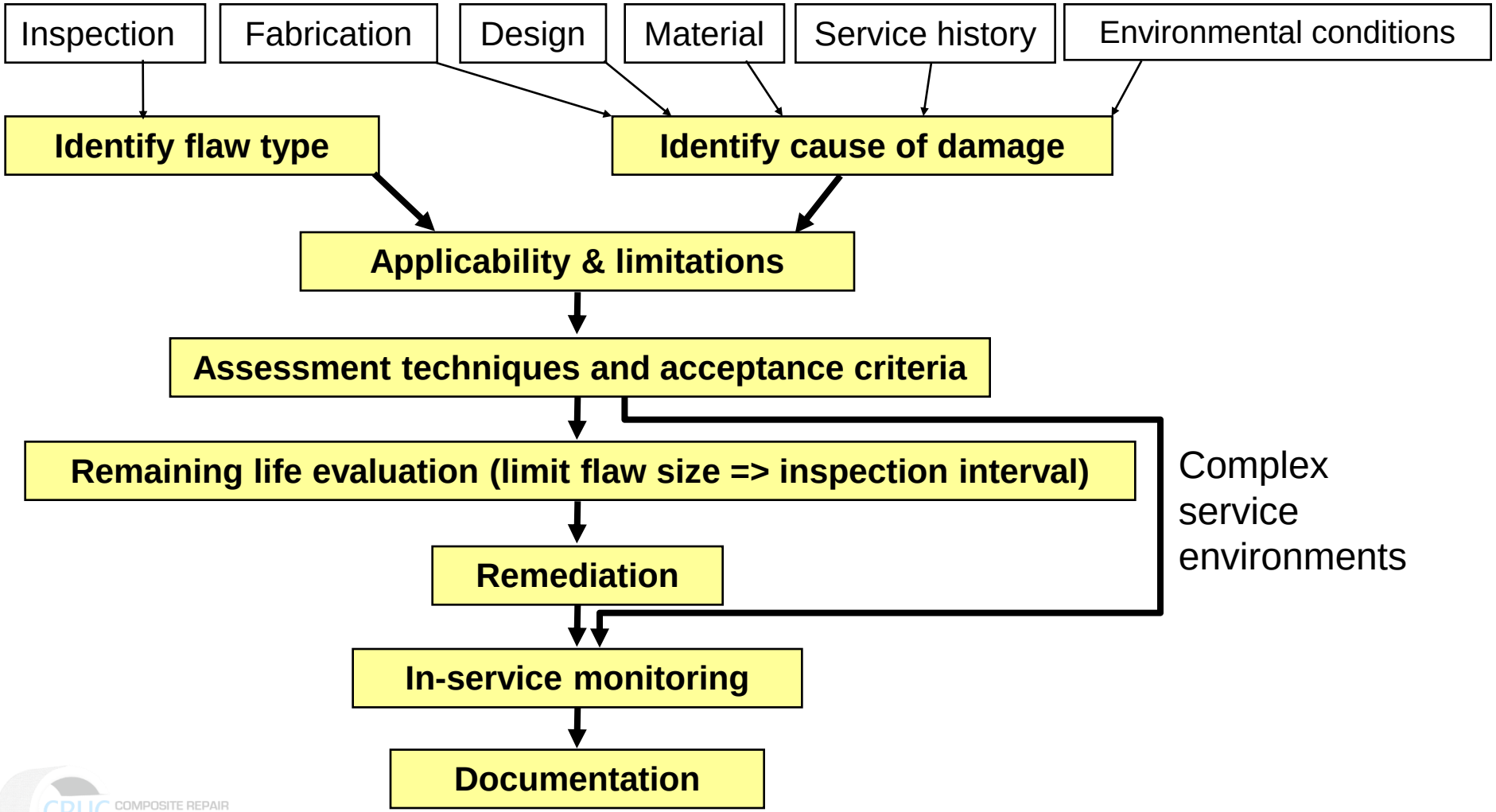
In each Part, there are three levels of assessment.

A balance between:

- Conservatism
- The amount of information required
- The skill of the analyst
- The complexity of the analysis

- Level 1: Least conservative, easiest to use.
- Level 2: More detailed, more precise.
- Level 3: Most detailed analysis.

General Procedure



Integrity Management Overview

- In 2008 SES developed what is known as the "Engineering-Based Integrity Management Program" (EB-IMP®)
- EB-IMP is a 5-step process that permits engineers to use testing, analysis, and field data to make decisions on pipeline integrity
- EB-IMP is based in-part on API 579 (Fitness for Service), but extends the capabilities of this document by adding full-scale testing and developing repair solutions

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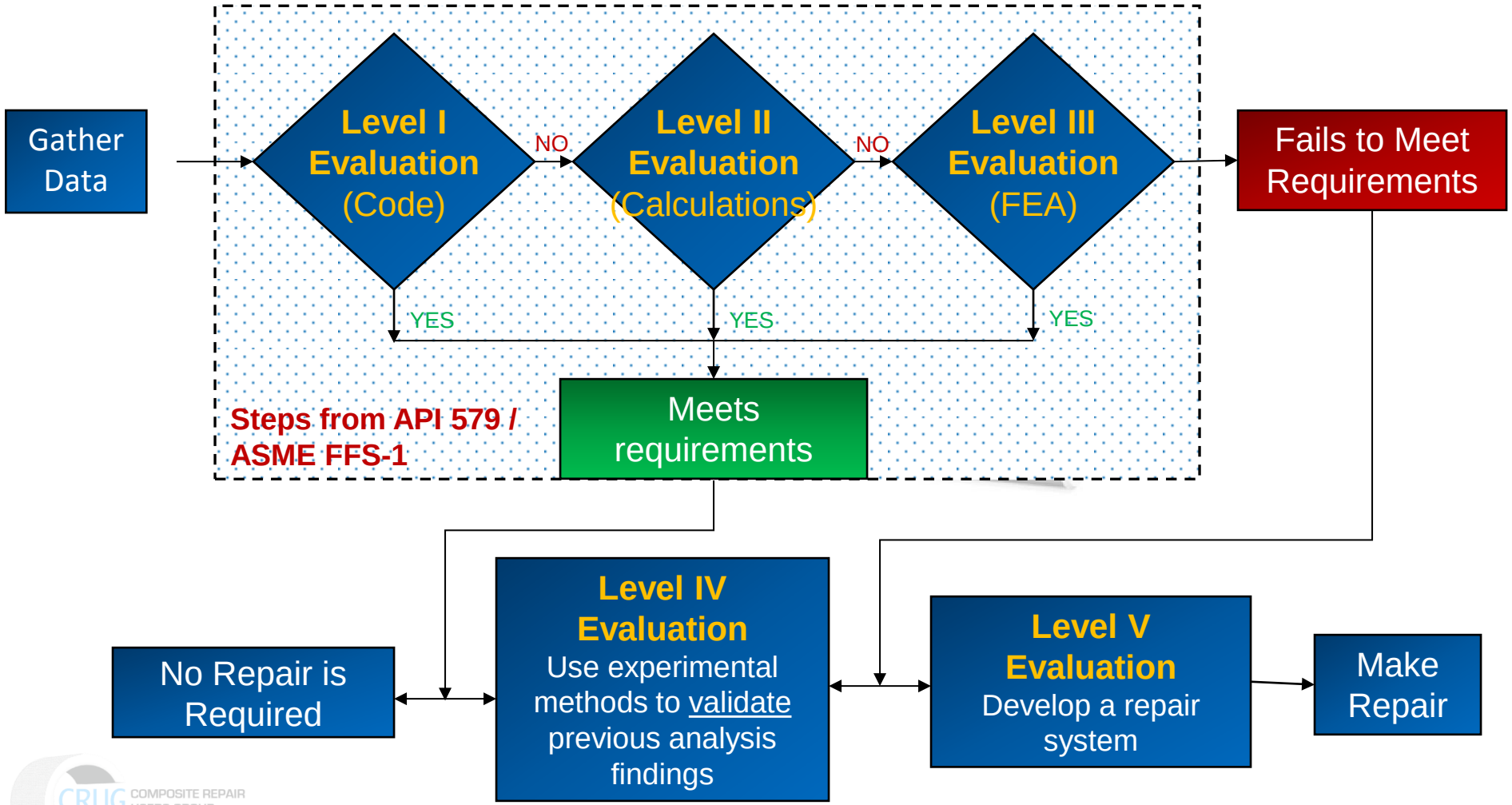
The EB-IMP® Process



Case Study – Girth Weld Reinforcement

- Focus is to evaluate the ability of composite materials to reinforce girth welds subject to axial and bending loads
- Full scale test program involving:
  - **Vintage welds (intentional defects)**
  - **Repair using composite materials (PCC-2 as guide)**
  - **Test loads: Pressure (36% SMYS, constant), axial tension and bending.**
- Five (5) composite systems participated

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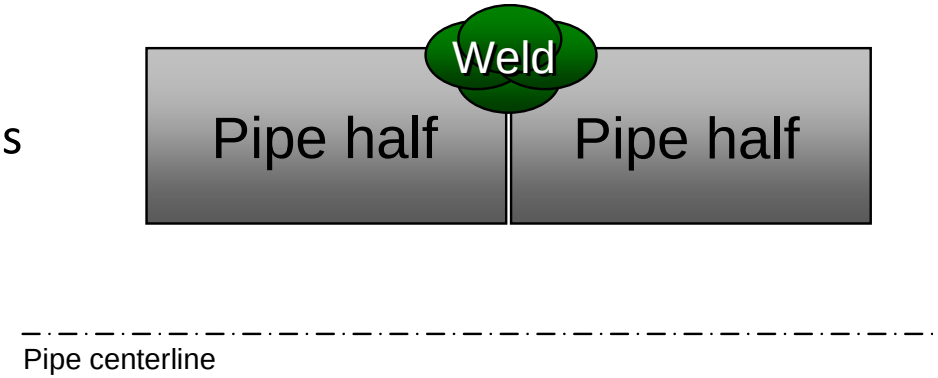
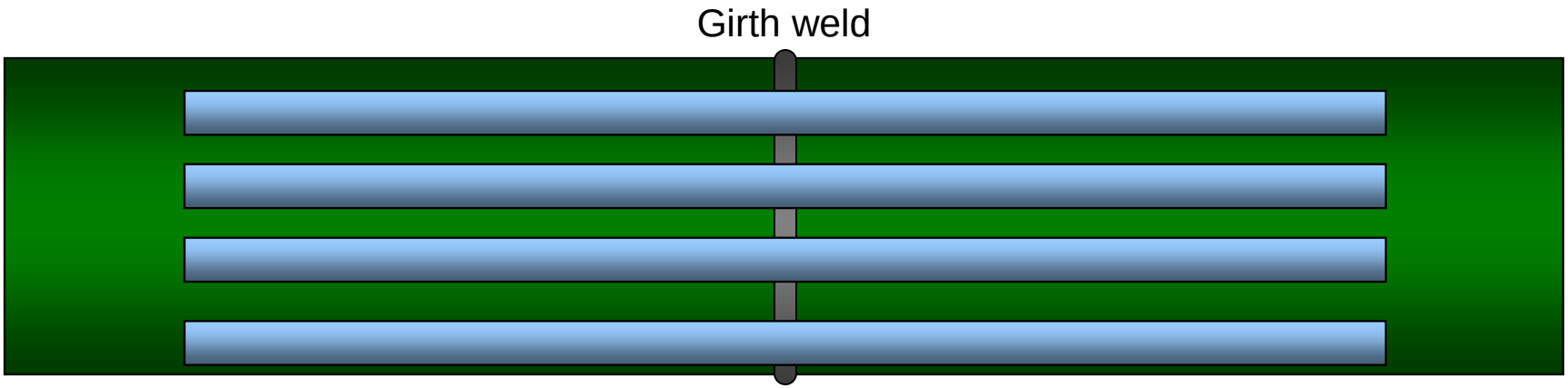
MATR-3-7 Test Plan

1. Purchase pipe material (12.75-inch x 0.188-inch, Gr. X42)
2. Perform material characterization (Chemistry, tensile, and Charpy including properties in exemplar weld)
3. Weld samples with intentional girth weld deficiencies (weld cap only) and threaded end caps
4. Sandblast
5. Install strain gages at select locations
6. Install composite repairs
7. Set-up test fixtures
8. Conduct test and record data
    1. Pressure cycles from 8% to 80% SMYS, 18,000 cycles.
    2. Pressurize sample to 36% SMYS
    3. Apply tension (or bending) loading with holds at specific load levels
    4. Apply tension (or bending) loads to failure
9. Inspect failures including photo documentation region of failure



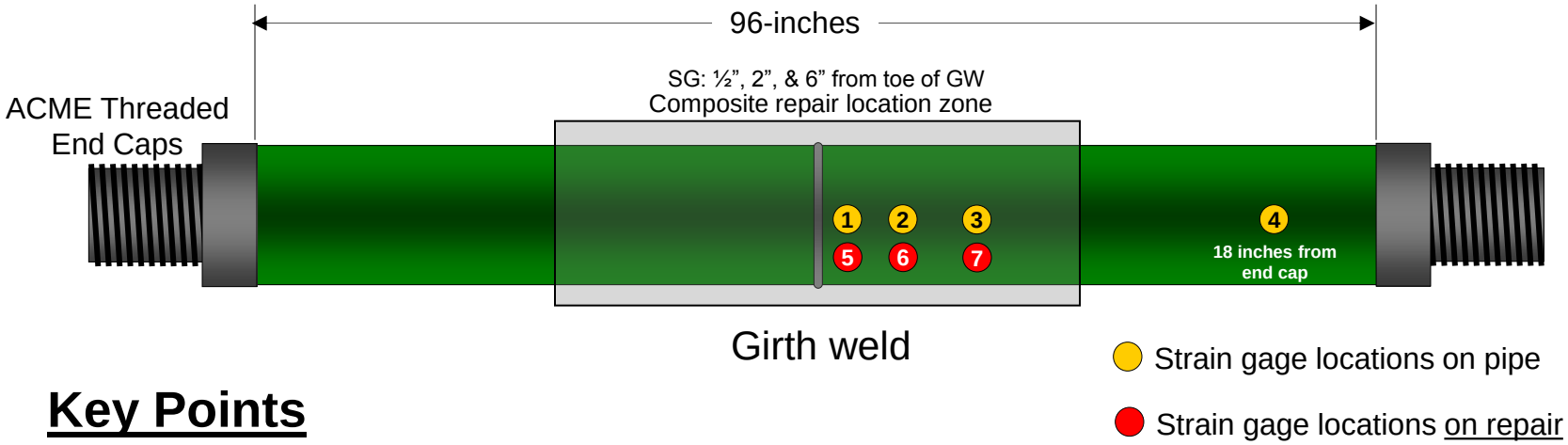
Reduced Bonding Area Sample



Sample with Mylar packing tape shown (to cover½ of the pipe's outer surface)

Configuration for 8-ft Tension Samples

Measure wall thickness at each strain gage location

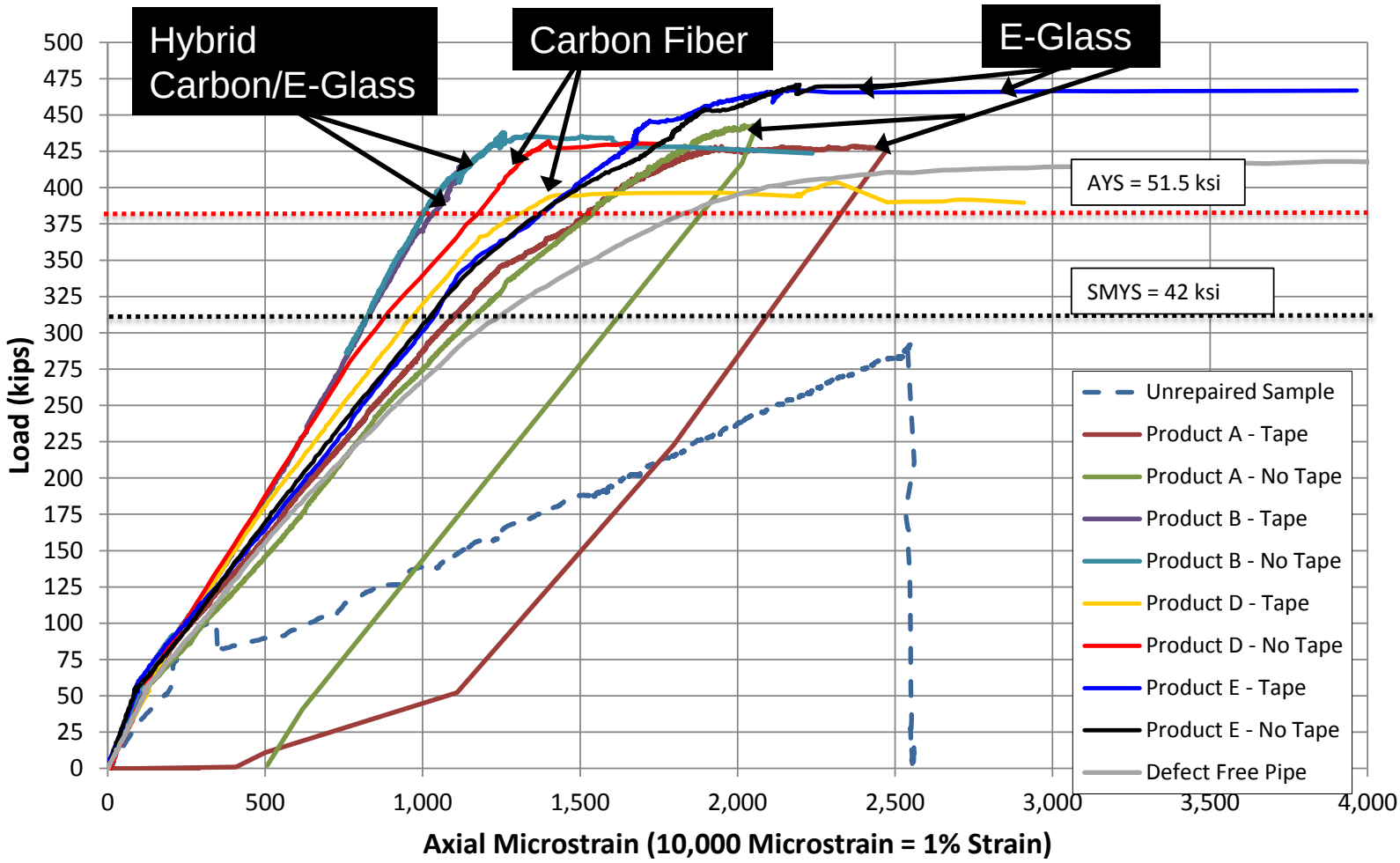


Key Points

1. Surface preparation
2. Length of reinforcement
3. Consistent girth weld fabrication
4. Instrumentation: strain gages beneath and on top of the composite
5. Generate load deflection curves for each manufacturer

Tension to Failure

Tension vs. Axial Strain for 12.75-inch OD x 0.188-inch , Grade X42 Pipe, With a "Cap Only" Girth Weld With 36% SMYS Internal Pressure



Bending to Failure