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Prediction, Performance Assurance, Failure Analysis: Staehle Method: Corrosion Based Design Approach (CBDA)

The CBDA:

- Provides a clear basis for communication between the materials and design communities.
- Provides a stepwise check-off list that guides materials and design communities in developing credible predictions and assuring reliable performance.
- Is applicable to all materials and components exposed to any kind of environment.
- Provides a framework to failure analysis.

The ten steps and principal features of the CBDA are as follows:

Action 1. Environmental definition

- Environments on surfaces rather than bulk.
- Multiple critical local environments.
- Environments under deposits, inside crevices, at anodic (acid) and cathodic (alkaline) sites.
- Impurities from system sources.
- Environments change with time.
- Prior history.
- Transformations in valence and pH.
- Microbial species.
- Environments include: chemical, stress, thermal, flow, radiation.

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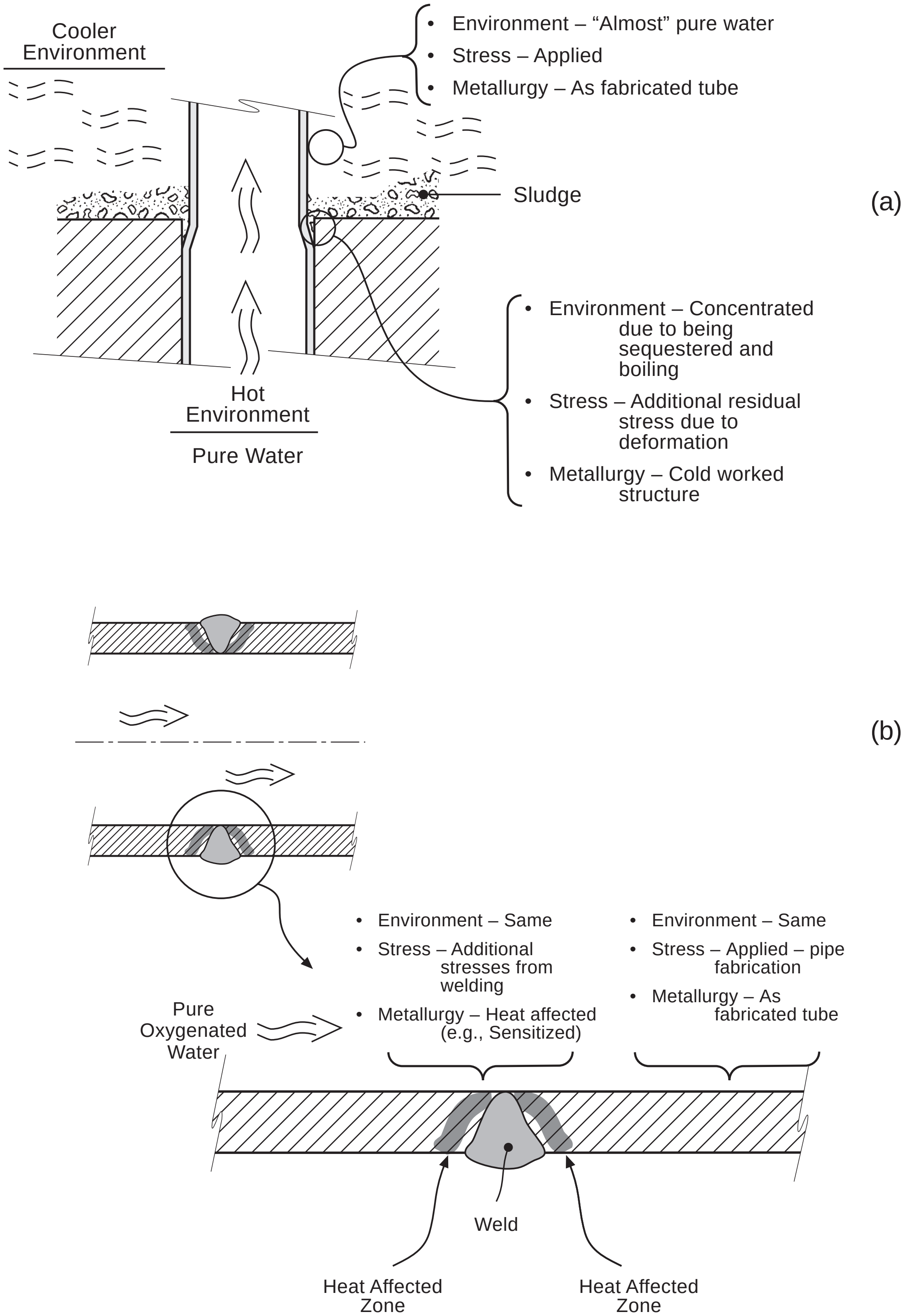

Figure 1 (a) Local environments at a tubesheet with hot fluid inside and cooler aqueous boiling fluid on outside showing similarities and differences in local conditions. (b) Pipe with weld showing similarities in environment but differences in stresses and metallurgy (Schematic illustration from Staehle)

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Action 2. Material definition

- Specifications not adequate to define resistance to corrosion.
- Cold work and heat treatment exert large influences.
- Surface condition affects initiation and rate.
- Grain boundary composition influences initiation and propagation of localized corrosion.

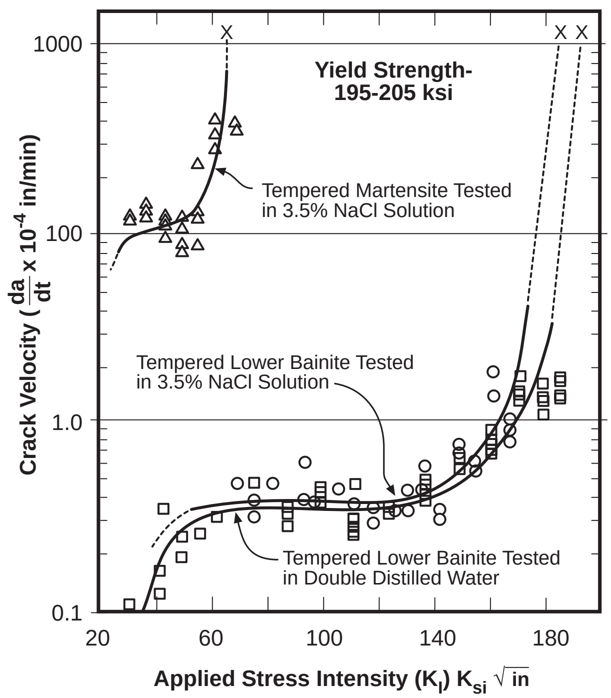

Figure 2 Crack velocity versus stress intensity for a 4340 steel heat treated to produce different structures but with same strength and exposed to room temperature aqueous solutions. (From Staehle and Wang)

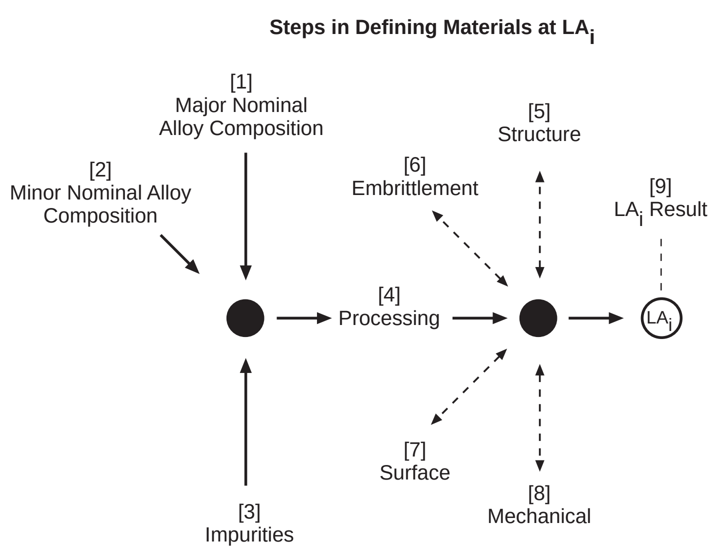

Figure 3 Analysis sequence for defining materials at a location for analysis, LA_i.

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Action 3. Mode definition

- Morphology of corrosion modes.
- Multiple submodes of the same mode occur. *(See Figure 1, for example, of array of submodes of SCC)*
- Determine dependencies of modes and submodes.

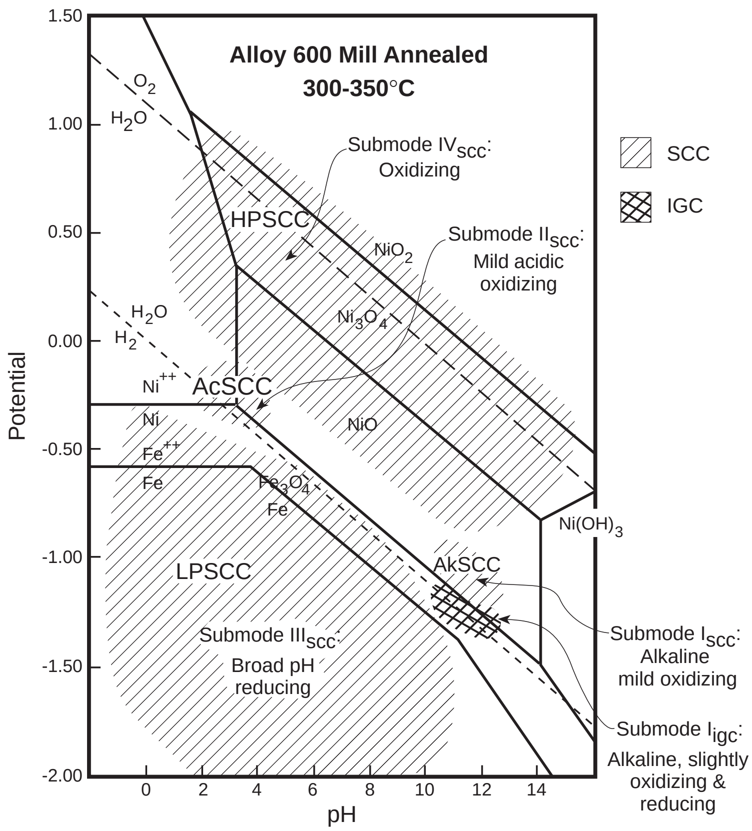

Figure 4 Distribution of submodes of stress corrosion cracking for mill annealed Alloy 600 in high temperature water as a function of electrochemical potential and pH. (From Staehle)

Action 4. Superposition

- Compare environments with the occurrences of the modes to determine whether corrosion is expected.

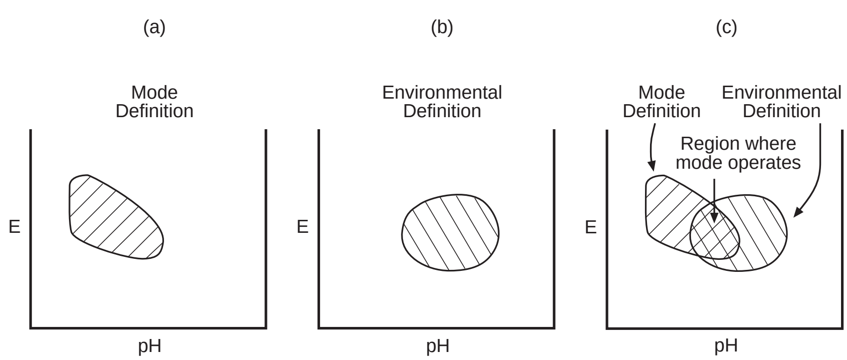

Figure 5 Comparison of mode definition (a) with environmental definition (b) to determine intersection and region for failure (c). (From Staehle)

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Action 5. Failure definition

- Definition of failure depends on the industry and the component.
- Defining failure defines the objective of design life.
- Failure varies among industries and components.
- Sometimes the first failure of many is not permitted; other times some percentage of units failed is acceptable.

Action 6. Statistical definition

• A statistical framework is required for assessing failure and conducting accelerated experiments.

Action 7. Accelerated testing

- Accelerated tests are conducted to determine whether life-time objectives can be met as compared with objective of avoiding failure.
- Accelerated tests must assure that the modes which produce failure at the end of design life are those that are the subject of accelerated tests.
- In accelerated testing it is necessary to compare both the central value and dispersion for the expected field experience and the accelerated testing as illustrated in Figure 6.

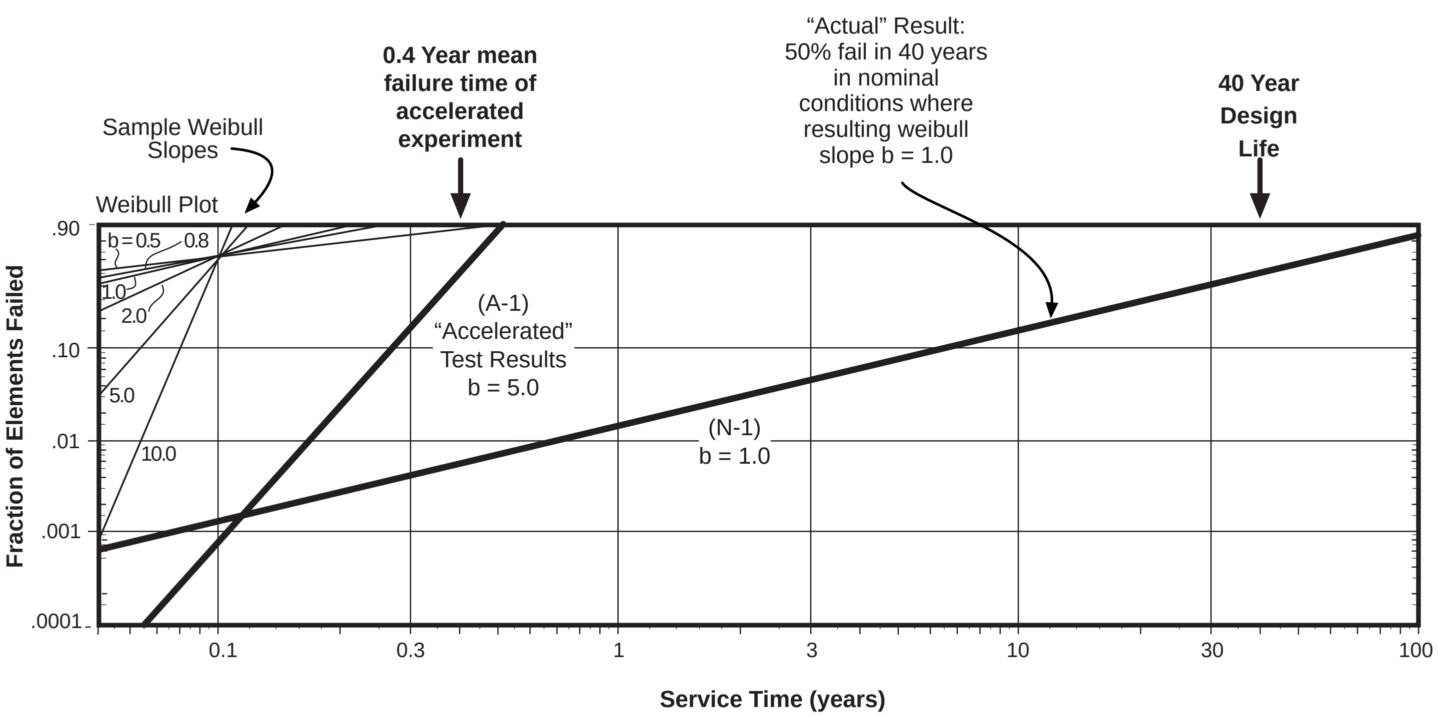

Figure 6 Fraction failed versus time for schematic field experience compared with schematic accelerated testing using Weibull coordinates. Accelerated testing generally shows less dispersion than from the field. (From Staehle)

Action 8. Prediction
- Use definition of "failure," results from accelerated tests, and analysis to determine life and to assure performance.

Action 9. Feedback
- Operation of equipment can be monitored and inspected to provide feedback to operators and designers.
- Monitoring and inspection should be related to expected modes of failure and to the seriousness of failure.

Action 10. Fix
- Modify design materials, and operation based on information from operating equipment.

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