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# Addressing Hydrogen Embrittlement in the Fuel Cell Vehicle Standard SAE J2579

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DOE Hydrogen Program

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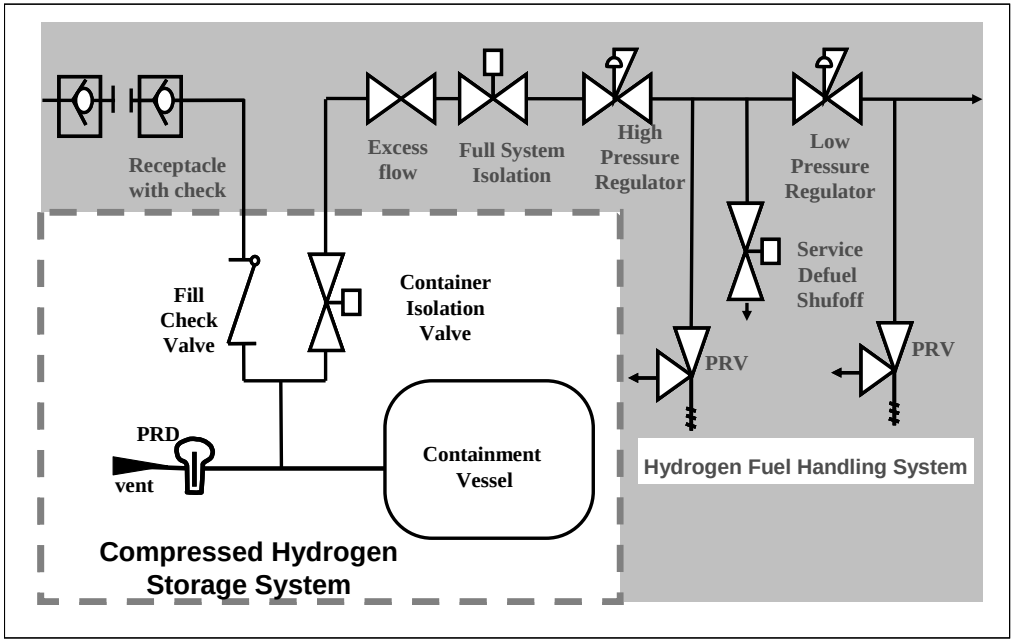
# SAE J2579 focuses on safety design qualification of Compressed Hydrogen Storage System in FCVs


- Compressed Hydrogen Storage System (CHSS) boundary defined by interfaces that isolate stored high pressure $H_2$

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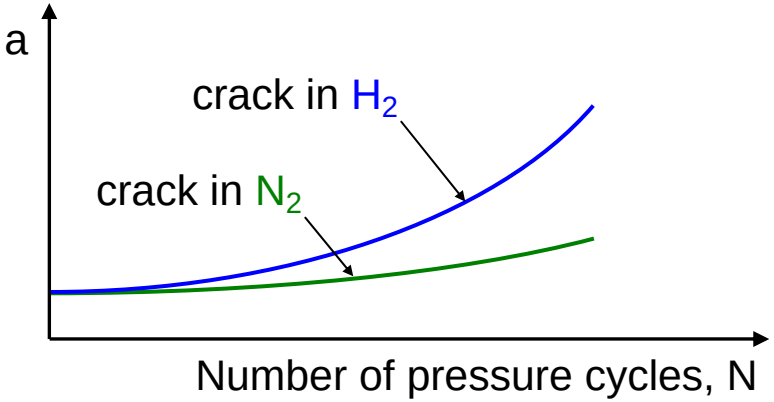
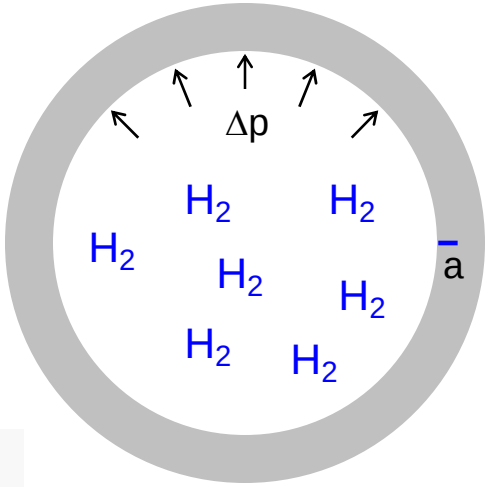
# Safety design qualification of CHSS must consider hydrogen embrittlement of metal components

## *Hydrogen embrittlement accelerates fatigue cracking*




$$N_f = N_{initiation} + N_{growth}$$




*Barthélémy, 1st ESSHS, 2006*

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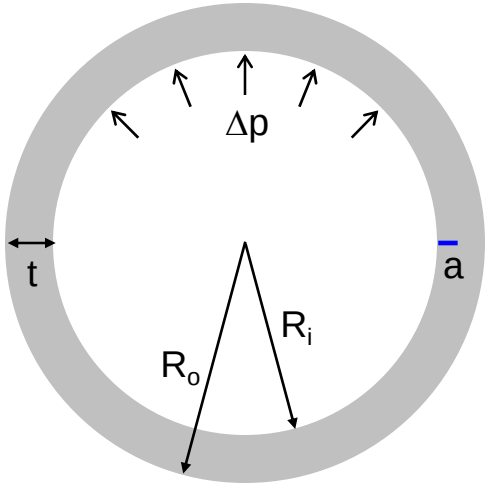
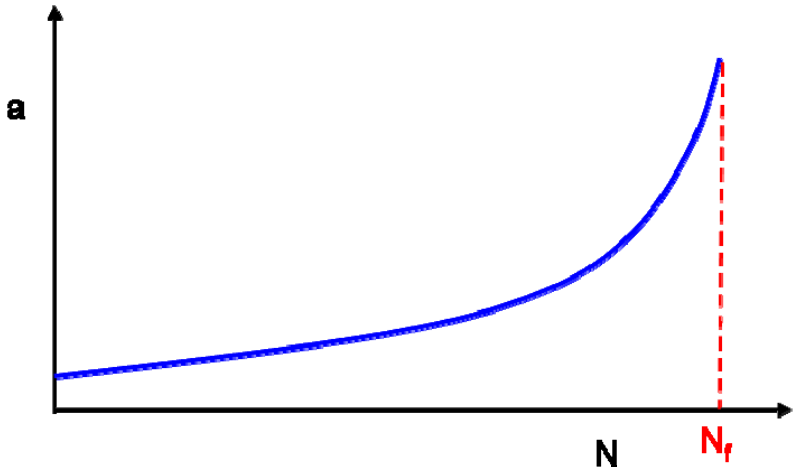
# Tank design qualification typically conducted by either engineering analysis or performance testing



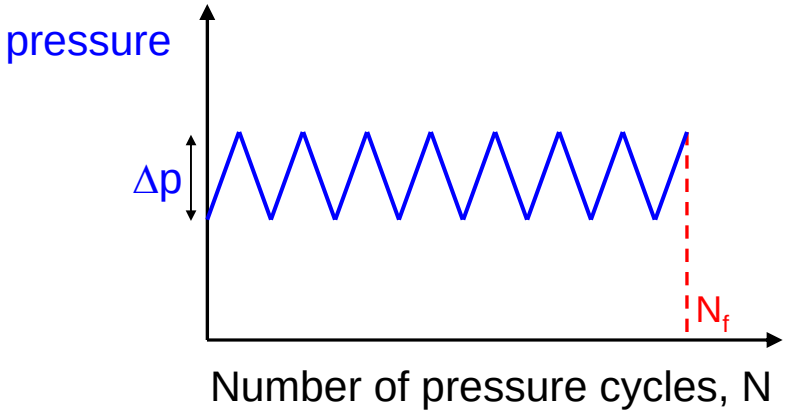

engineering analysis

stress analysis: $\Delta K = \Delta p[f(a, t, R_o, R_i)]$

crack growth law: $da/dN = C(\Delta K)^m$




performance testing




- Design qualification in SAE standards based on performance testing

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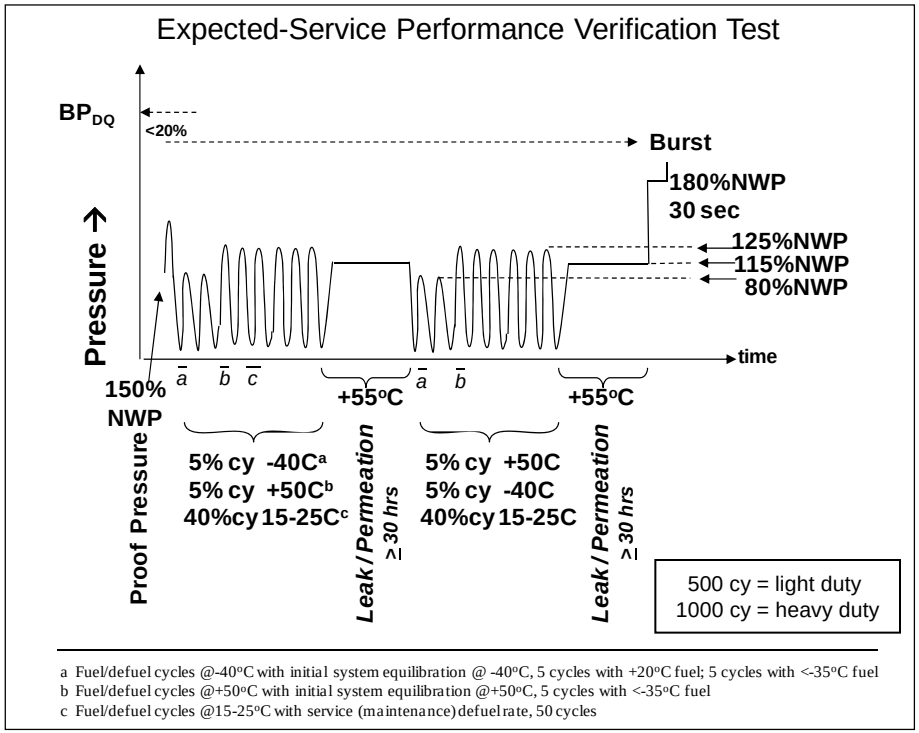
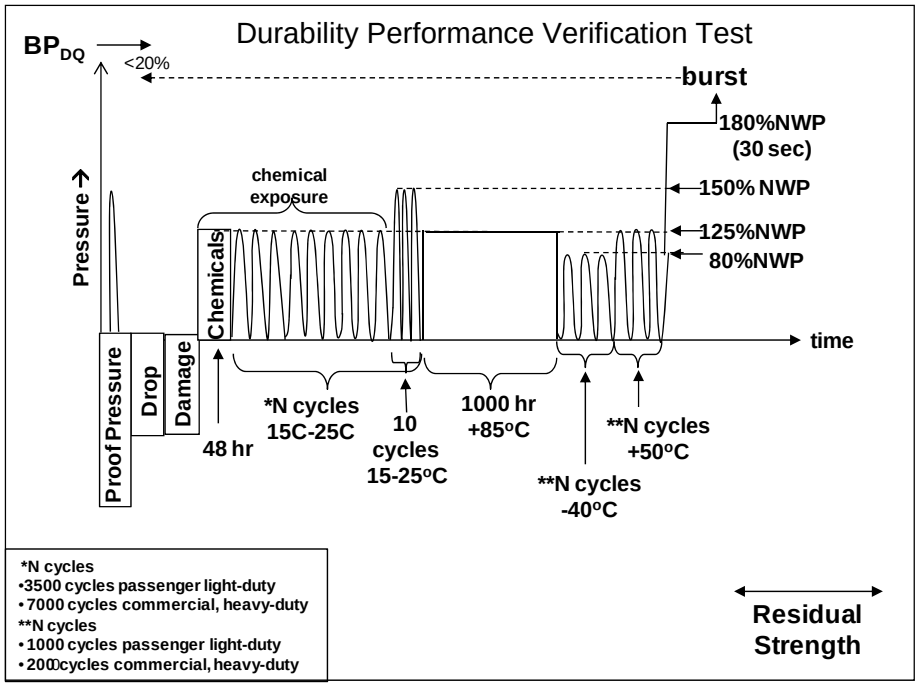
# Tank design qualification in SAE J2579 is based on performance testing

## Pneumatic test ($H_2$)




## Hydraulic test




- These performance tests do not evaluate "durability" under $H_2$ gas pressure cycling, i.e., hydrogen embrittlement

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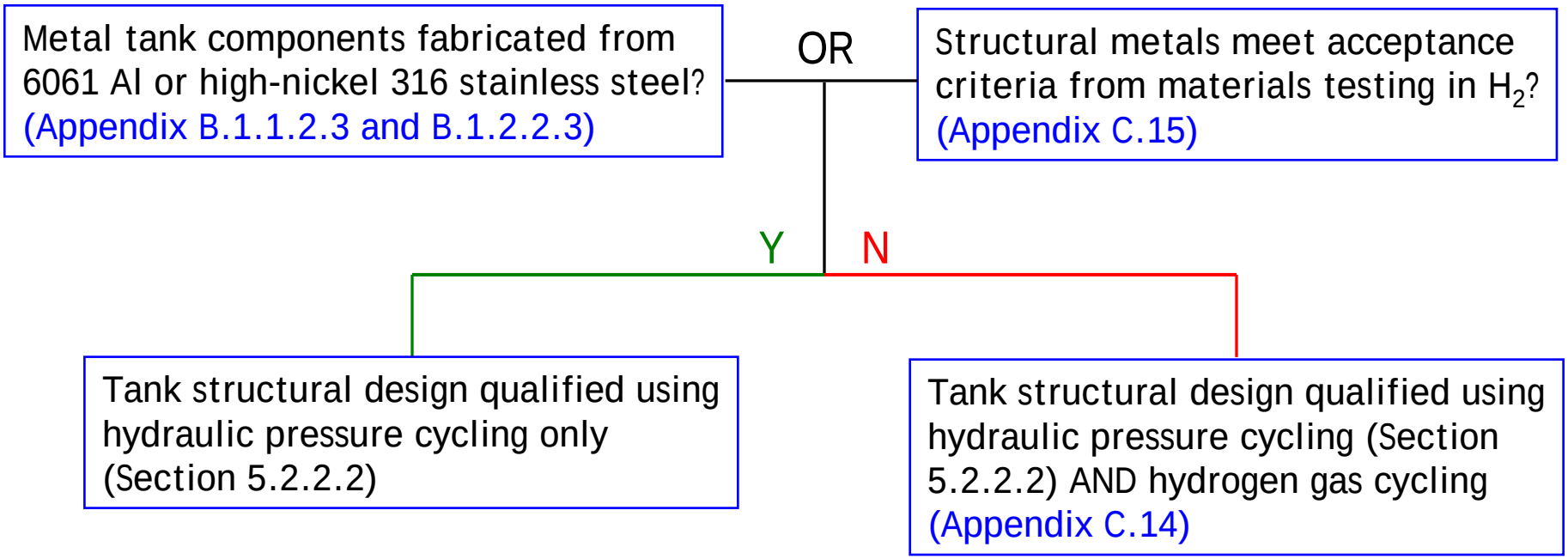
# Logic flow for addressing hydrogen embrittlement through performance testing in SAE J2579




- Recent activity focused on Appendix C.14 and Appendix C.15

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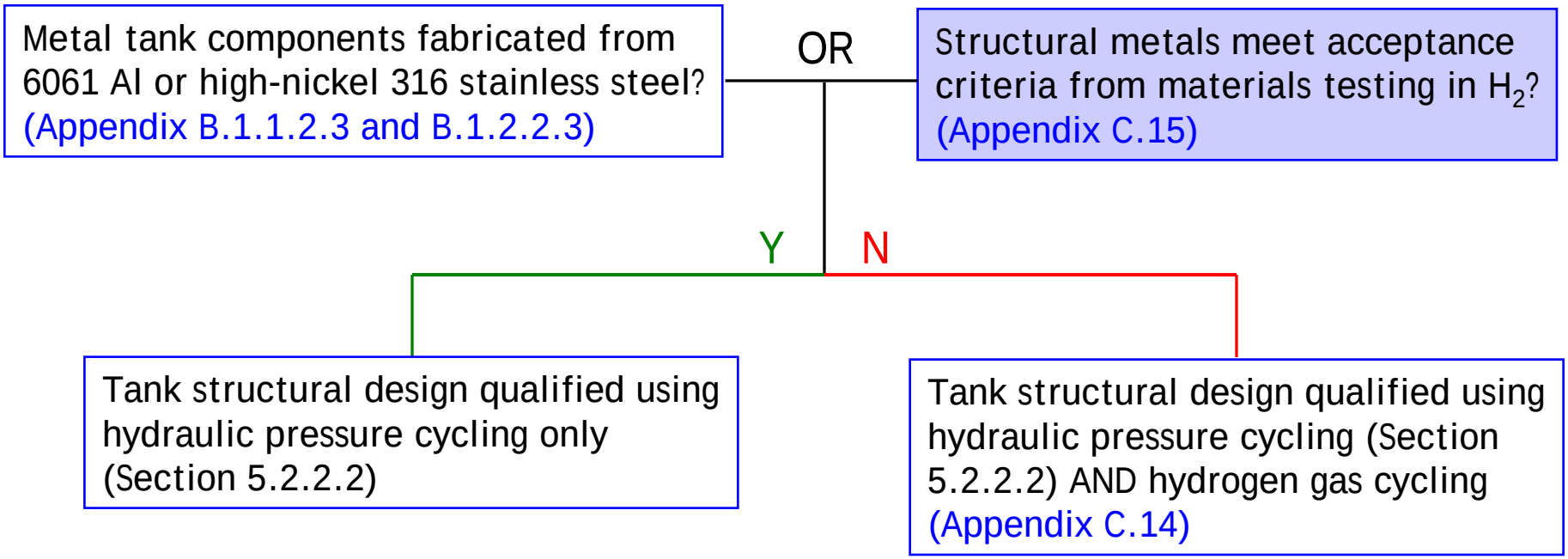
# Logic flow for addressing hydrogen embrittlement through performance testing in SAE J2579




- Materials tests in Appendix C.15 determine whether tank has unrestricted (i.e., not design specific) hydrogen compatibility

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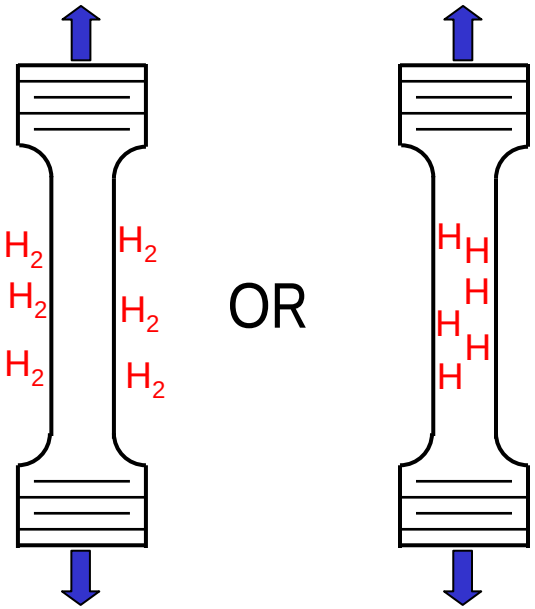
# Appendix C.15 materials test: slow strain rate tensile test




- Issues:
  - Test conducted in $H_2$ gas or with "precharged" H?
  - Test temperature(s)?
  - Acceptance criterion, e.g., $RA_{H2}/RA_{air} > 0.8$?

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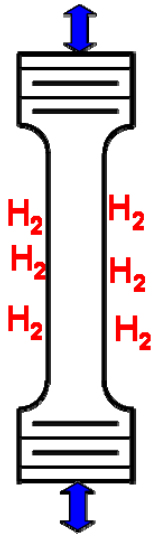
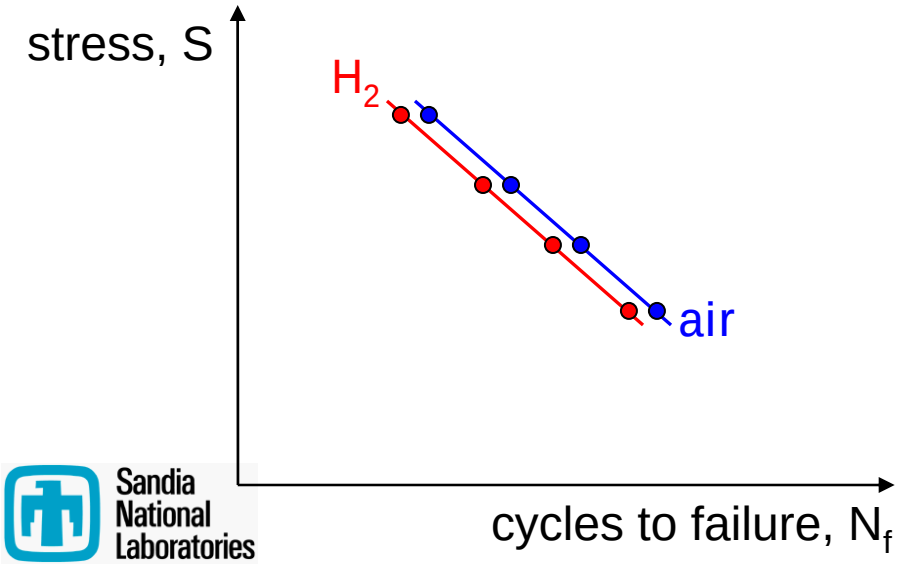
# Appendix C.15 materials test: fatigue crack initiation test




- Issues:
  - R ratio, i.e., ratio of min. stress to max. stress?
  - Stress-cycle frequency
  - Test temperature(s)?
  - Acceptance criterion, e.g., $N_{f(H2)}/N_{f(air)} > 0.8$?

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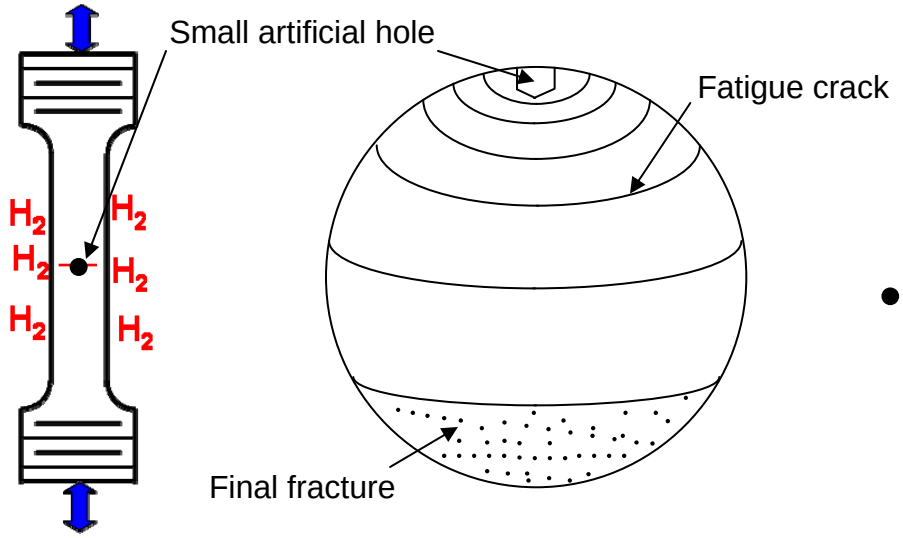
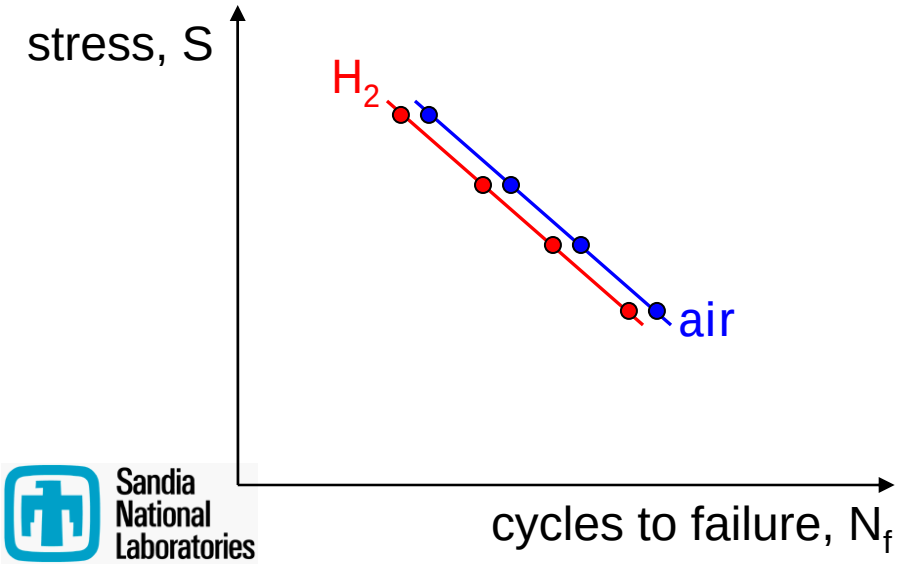
# Appendix C.15 materials test: "short crack" growth test




- Issues:
  - R ratio, i.e., ratio of min. stress to max. stress?
  - Stress-cycle frequency
  - Test temperature(s)?
  - Acceptance criterion, e.g., $N_{f(H2)}/N_{f(air)} > 0.8$?

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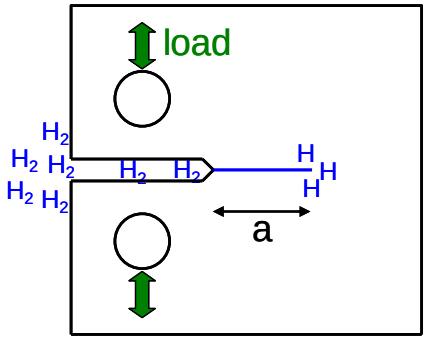
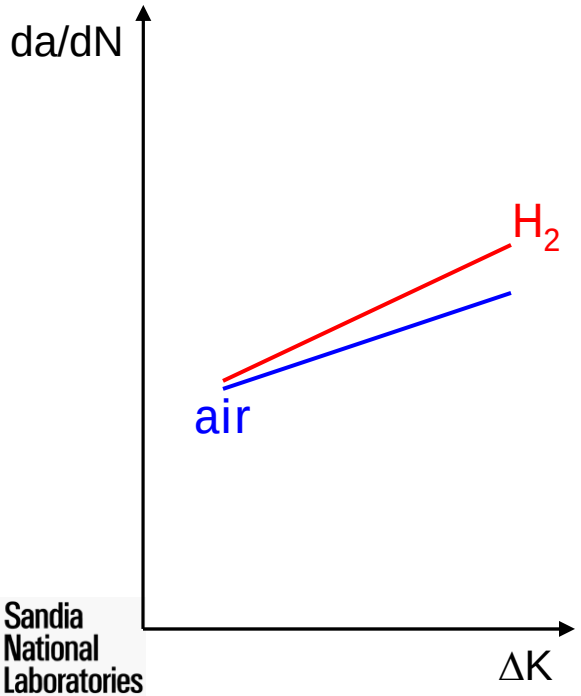
# Appendix C.15 materials test: "long crack" growth test




- Issues:
  - Load-cycle frequency
  - Test temperature(s)?

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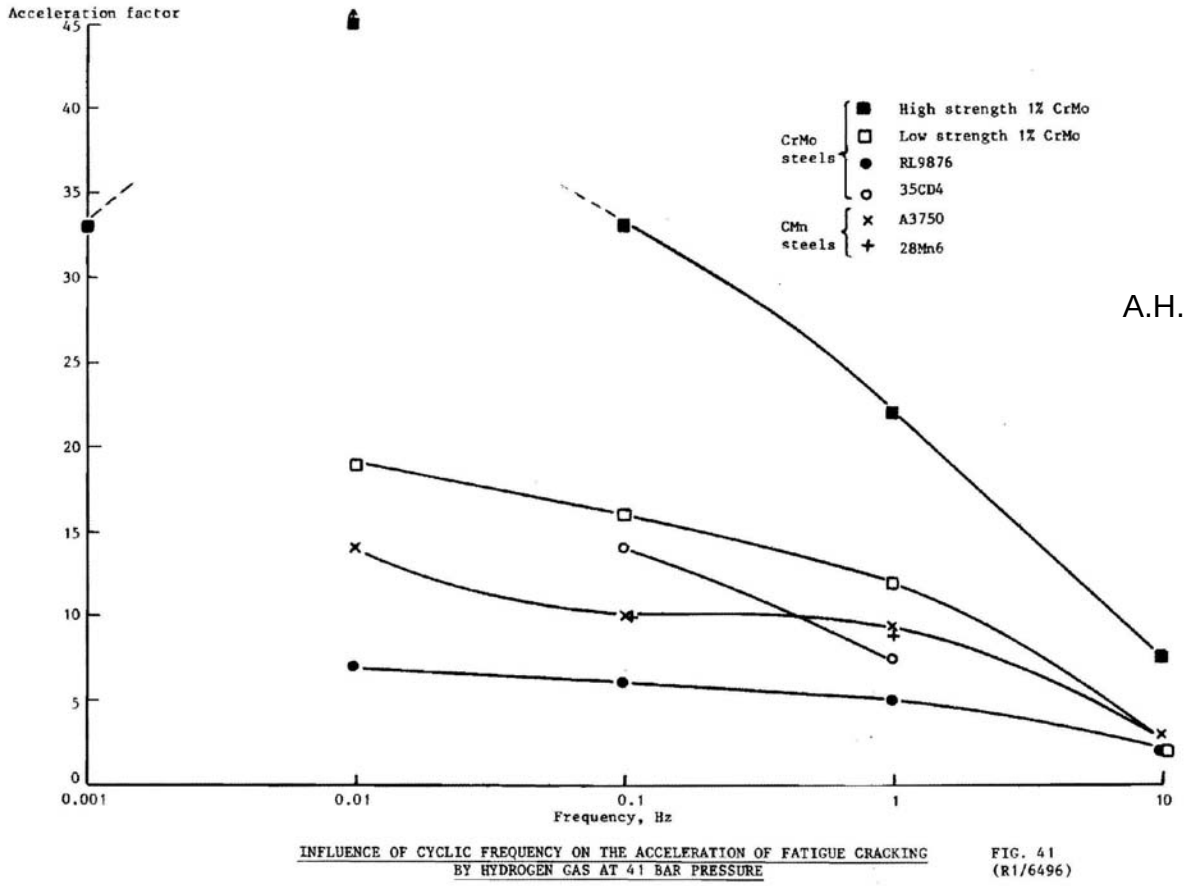
# Load-cycle frequency must be specified for fatigue tests conducted in $H_2$ gas




INFLUENCE OF CYCLIC FREQUENCY ON THE ACCELERATION OF FATIGUE CRACKING BY HYDROGEN GAS AT 41 BAR PRESSURE

FIG. 41
(R1/6496)

A.H. Priest, British Steel, 1983

Magnitude of accelerated fatigue cracking in $H_2$ gas depends on load-cycle frequency

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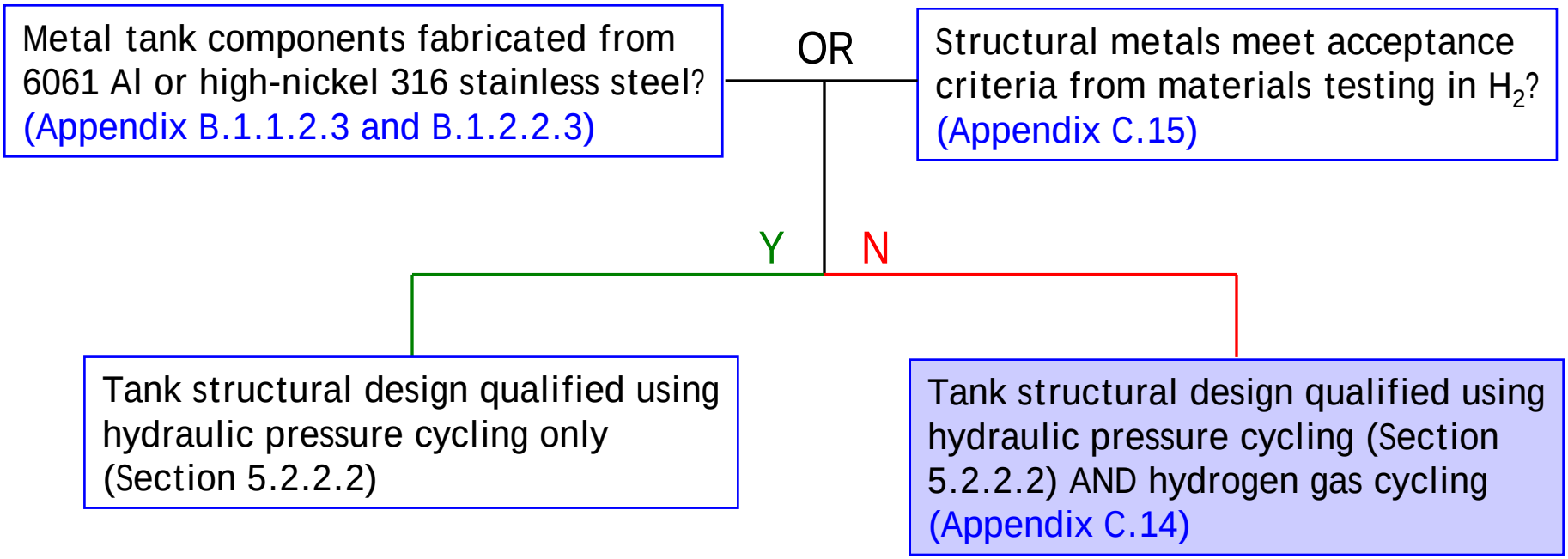
# Logic flow for addressing hydrogen embrittlement through performance testing in SAE J2579




- Performance test in Appendix C.14 evaluates design-specific hydrogen compatibility

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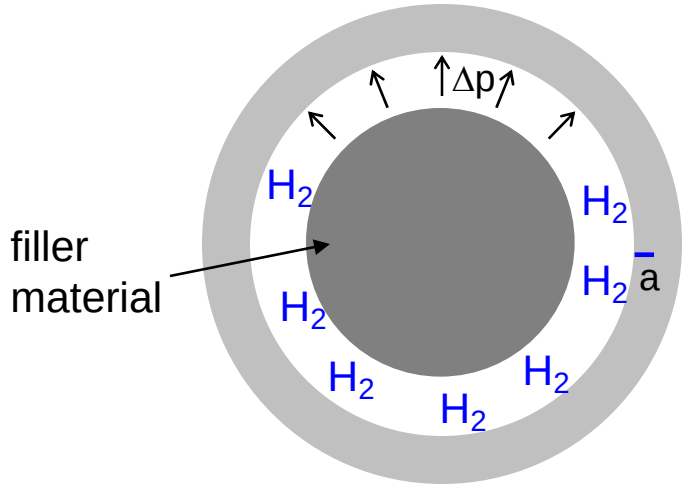
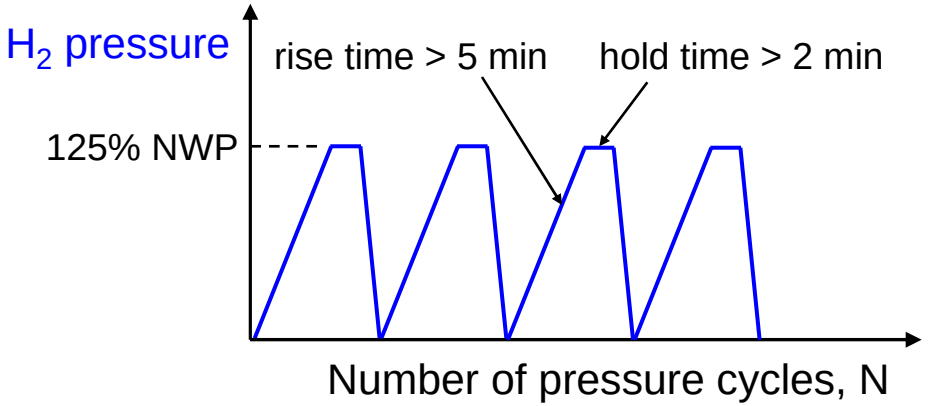
# Performance test in Appendix C.14 intended to account for $H_2$-accelerated fatigue cracking




- Issues:
  - Test temperature?
  - Number of cycles?

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# Summary

- Fuel cell vehicle standard SAE J2579 describes design qualification for Compressed Hydrogen Storage System
- Design qualification based on performance testing
  - Hydraulic long-term durability test does not account for hydrogen embrittlement
- New tests developed for SAE J2579 to evaluate hydrogen compatibility of tank designs
  - Material-level testing determines whether tank has unrestricted (i.e., not design specific) hydrogen compatibility
  - Component-level component testing evaluates design-specific hydrogen compatibility

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