Test VI – Additional Verification Testing

Public Meeting Regarding Anchor Rods
SFOBB Job Site, Pier 7, Oakland, California

Presented By:

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Dominion Engineering, Inc.in association with BAMC, Bay Area Management Consultants

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Objectives and Motivation

- Objective: Confirm that the threshold loads and stress intensity factors determined in Test IV and Test V for Pier E2 2010 rods (ID#2) remain valid for longer exposure times.
- Motivation: Time dependent processes may reduce resistance of rods to hydrogen embrittlement/stress corrosion cracking (HE/SCC). For example:
  - Hydrogen concentration may increase with time.
  - Thread root geometry may change with time as a result of corrosion.

Test Methods

- Two test methods:
  - Incremental load step test method (also called rising step load method) of Test V, but with lower rate of load increase to allow more time for hydrogen ingress.
  - Constant load tests for long durations to provide confirmation of rising step load results for threaded specimens.

Incremental Load Step Tests (1)

- Method described in ASTM –F1624.
- Load on specimen increased in steps after specified hold time at each step.
- Load increased until crack initiation indicated by decrease in load (see next slide).
- New test started with slower rate of load increase, i.e., longer hold time at each step.
- This process continued until no further decrease in final load is observed as the rate of load increase is reduced.
- The main change introduced by Test VI is to repeat the last test sequence but with halved rate of load increase (doubled time in each step) to verify that no further decrease in failure load occurs.

Test Setup for: Raymond Test (Incremental Load Step)

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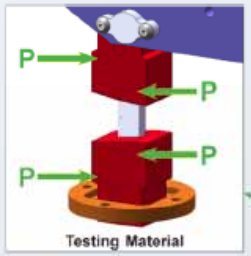

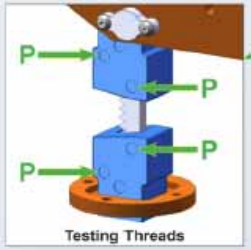

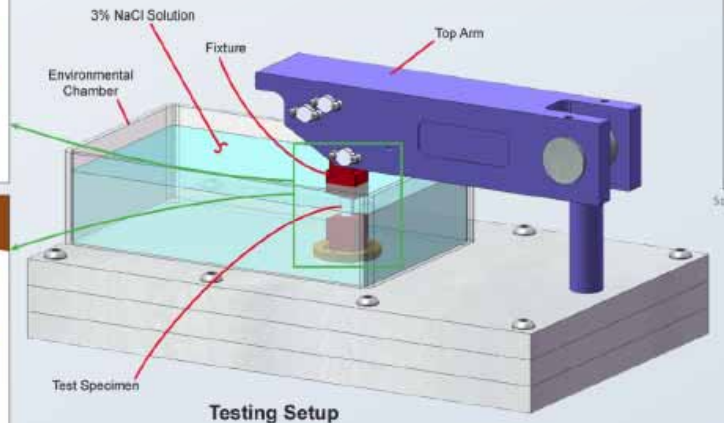

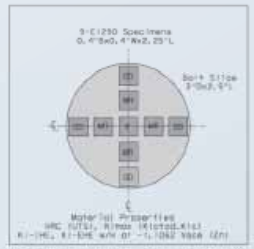

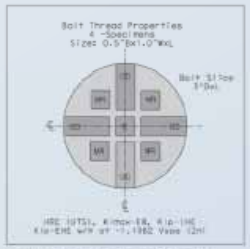

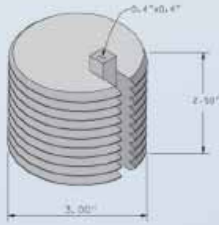

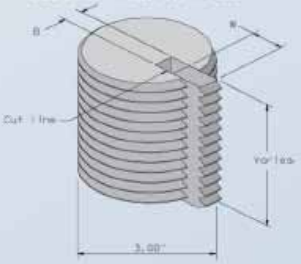

3"X2.5" SAMPLE FOR MATERIAL TEST PLAN
Scale: NTS

3"xL" SAMPLE FOR THREADS TEST PLAN
Scale: NTS

Test	Specimen with Fatigue Pre-Crack Worst Case Baseline		Threaded Specimen Beneficial Effects from Threads	
	Method	Results	Method	Results
1	Fracture Toughness (P_{max}) - Outer Diameter and Mid Radius	Kiclod-Max, Klc	Fast Fracture (P_{max}) - Outer Diameter Threads	Klp-max-ASTM E8
2	IHE -Step Load in Air - Outer Diameter and Mid Radius	KI-IHE threshold	IHE-Step Load in Air - Outer Diameter Threads	Klp-IHE threshold
3	EHE-Step Load in 3.5% NaCl @-1.1062 V_{sa} Zn - Outer Diameter and Mid Radius	KI-EHE threshold	EHE-Step Load in 3.5% NaCl @-1.1062 V_{sa} Zn - Outer Diameter Threads	Klp-EHE threshold
4	EHE/Verification Slower Loading Rate - Outer Diameter and Mid Radius	KI-EHE threshold	EHE /Verification Slower Loading Rate - Outer Diameter Threads	Klp-EHE threshold
5	Fast Fracture (P_{max}) @ Center	Klmax, Klc	—	—

IHE = Internal Hydrogen Embrittlement due to manufacturing and processing
EHE = Environmentally induced Hydrogen Embrittlement

Incremental Load Step Tests (2)

Figure from LRA

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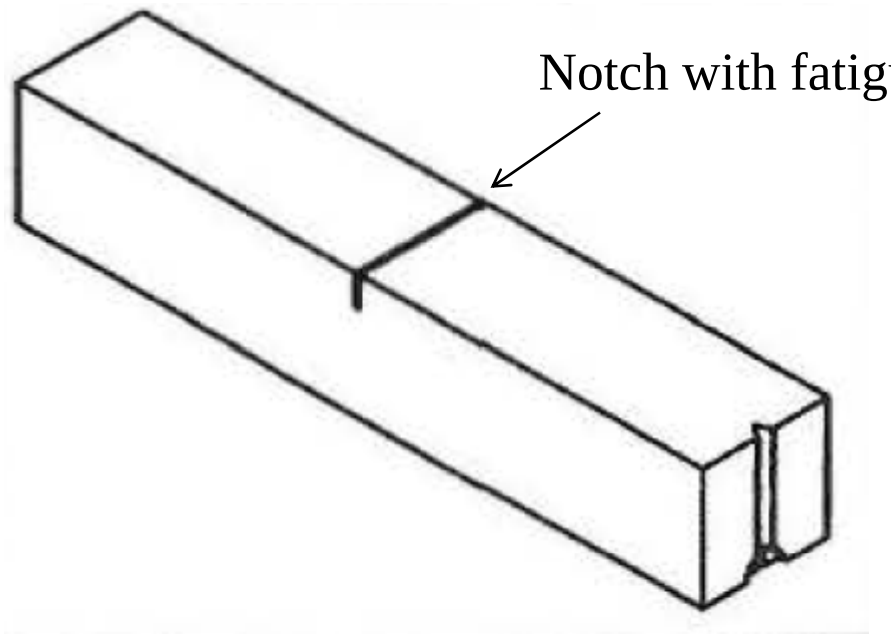
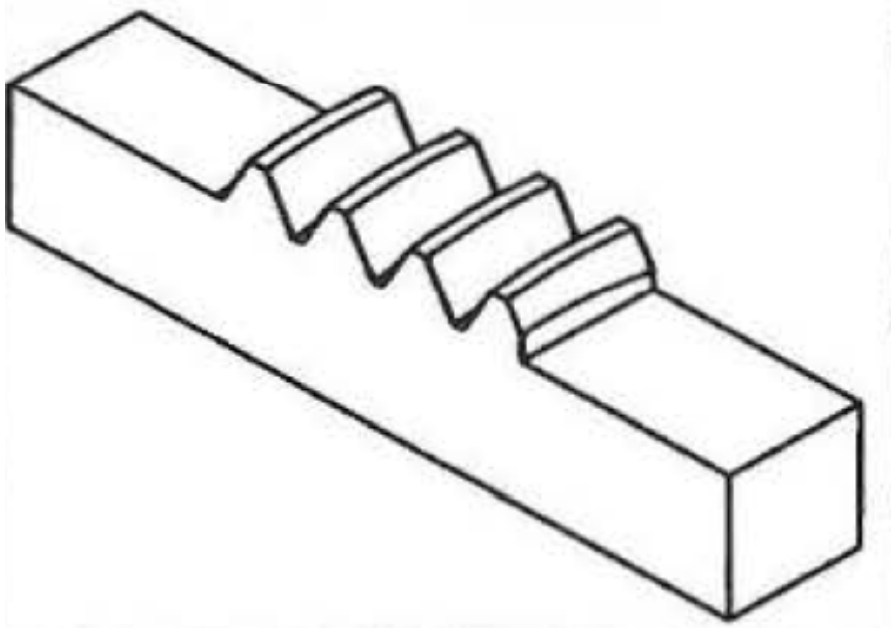
Incremental Load Step Test (3)

- Two types of specimens: (1) with pre-cracks and no threads, and (2) with threads but no pre-cracks.
- Pre-cracked specimen shown below (from LRA):



Incremental Load Step Test (4)

- Threaded specimen shown below (from LRA):



Incremental Load Step Test (5)

- Tests of precracked specimens to determine threshold stress intensity factor (K_{Iscc}).
- Characteristics of K_{Iscc}:
  - Material property.
  - Varies with material hardness and hydrogen charging conditions.
  - If applied stress intensity factor (which increases as load is increased) is less than K_{Iscc}, crack will not grow.

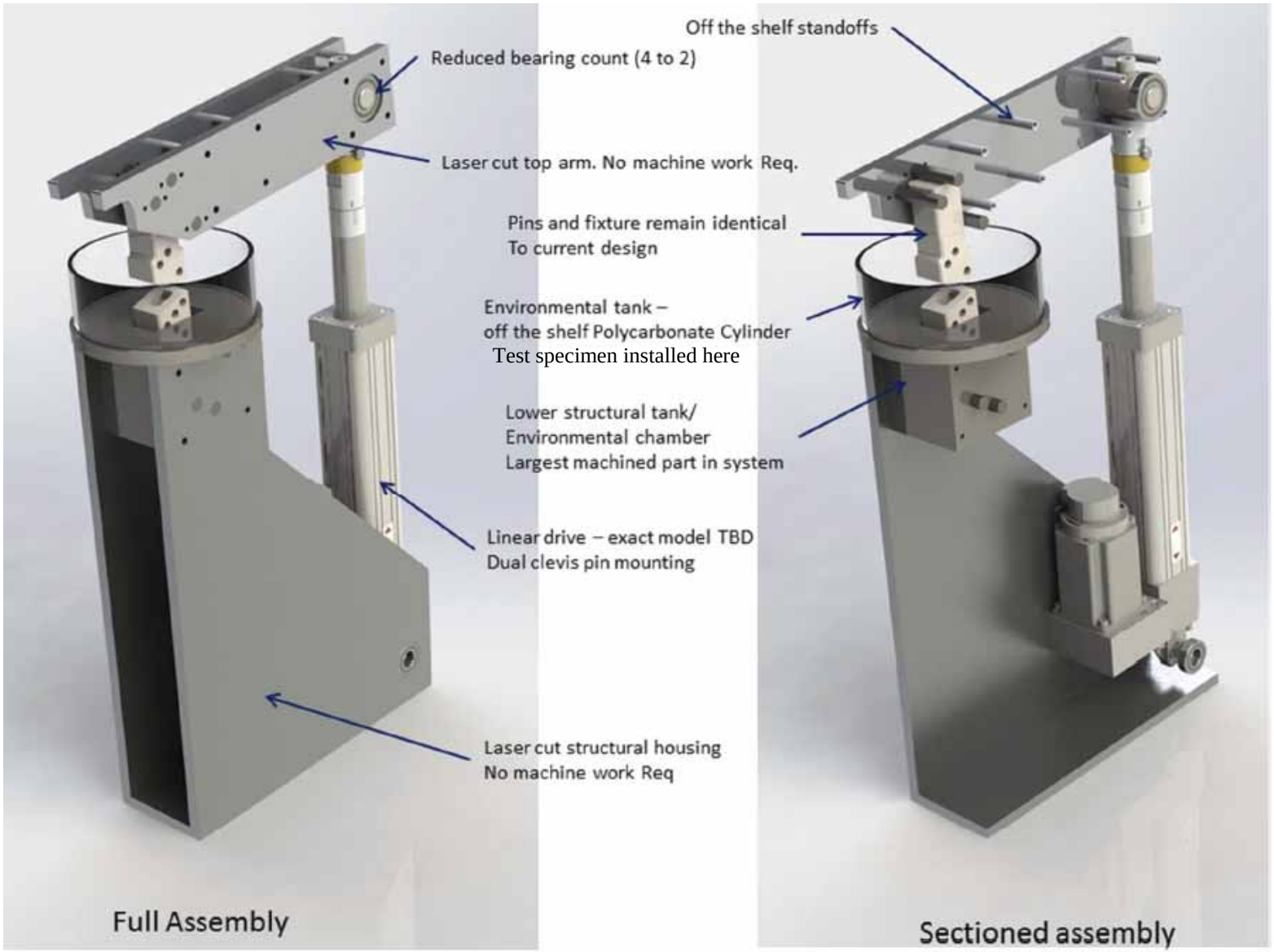
Incremental Load Step Test (6)

- Tests of threaded specimens determine threshold applied stress that will cause crack initiation at root of thread.
- Results reported as "stress intensity factor" ($K_{I\rho}$), but $K_{I\rho}$ is not solely a material property – depends on thread root geometry.
  - Ratio of $K_{I\rho}$ to K_{Iscc} indicates increase in load required to cause cracking with initial thread root geometry as compared to case with sharp crack at root of thread.
- To verify that durations in steps used in tests IV, V and VI are sufficient to reflect changes in thread root geometry caused by corrosion over time provides a reason for conducting longer term constant load tests – see next slide.

Constant Load Tests (1)

- Tests use same type of threaded specimen as used for incremental load step method, and use same salt water environment with same applied potential.
- Design of test rig shown on next slide.
- Objective is to confirm $K_{I\rho}$ values from Test V using static conditions that provide maximum opportunity for hydrogen to diffuse to high-stress regions, and that also provide opportunity for corrosion to occur.
- Tests planned at applied $K_{I\rho}$ values from 10% above to 10% below $K_{I\rho}$ value determined using incremental load step method.
- Test durations of up to 5000 hours.
- Test methods are similar to those in ASTM E1681 and F519.

Constant Load Tests (2)



Constant Load Test Rig Design (LRA)

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Status and Schedule

- Test protocol has been prepared.
- Incremental load step tests scheduled to start on March 1st.
- Constant load tests scheduled to start in the near future

Concluding Remarks

- Test VI consists of long term constant load tests and extended duration rising step load tests that are expected to verify the results of Tests IV and V.
- Tests IV, V and VI all explore the level of resistance to HE/SCC.