GSI-191

Water Chemistry and Chemical Debris Test Plan

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Outline

- Purpose
- Recent literature review
- Recommendation from review
- Scaling considerations
- Proposed test apparatus
- Key features
- Conceptual test matrix

Purpose

- To determine the appropriate water chemistry to be used in future fuel assembly head loss testing.
  - Water chemistry in this context includes boric acid, buffer, corrosion products and their precipitates.

Recent Literature Review

- Bahn Papers (Argonne National Laboratory)
  - In-situ chemically formed precipitate head loss tests
  - In-situ corrosion formed precipitate head loss tests
  - WCAP chemical surrogate (DI water and tap water) head loss tests
- Duke Energy
  - Fiber and particulate only head loss tests
  - Tap and DI water
  - Zeta potential
- Westinghouse gravity drain column testing to evaluate Duke findings

Literature Review Summary

From Argonne Literature:

- Surrogate preparation methods were confirmed to impact size distribution of chemical precipitate.
- Chemically generated precipitates add ionic strength to the solution that may not be representative of precipitate solutions formed by the corrosion process.
- In-situ precipitates formed through a corrosion process behave differently than chemically formed precipitates in terms of screen head loss at the same fiber loading.
- SAS chemically generated precipitates are not stable (depending on the water used) and can dissolve.

Literature Review Summary

- Intermetallic corrosion products have an effect on head loss and are not represented when using surrogate or chemically generated precipitates as shown by Argonne.
- Water chemistry can impact debris bed morphology without the presence of precipitates as shown by the Duke Energy testing.
- The WEC drain column tests had some attractive features, but also had shortcomings.
  - Tests were simple, reproducible, and could be run quickly, allowing for development of good statistics.
  - However, conditions were far from those likely to be observed at the core inlet or sump screen; results cannot be scaled and the degree of relevance to plant conditions is difficult to determine.

Literature Review Summary

- The measurement of particle size and zeta-potential was useful in understanding the behavior of particle/fiber systems and the effects of dissolve water species as shown by Argonne and Duke Energy work.

CONCLUSION

- Based on the literature review, water chemistry effects on head loss cannot be decoupled from in-situ corrosion based precipitate formation.

Recommendations

- Evaluation of more appropriate chemical precipitates and water chemistry should be performed together.
- Testing should:
  - Focus on corrosion formed precipitates since they most closely represent the process that would occur in the sump.
  - Use representative water chemistry starting with DI water with the addition of appropriate chemical conditions.
  - Use representative particulates (e.g. paint chips instead of silicon carbide particles) to determine the impacts associated with particle surface chemistry.

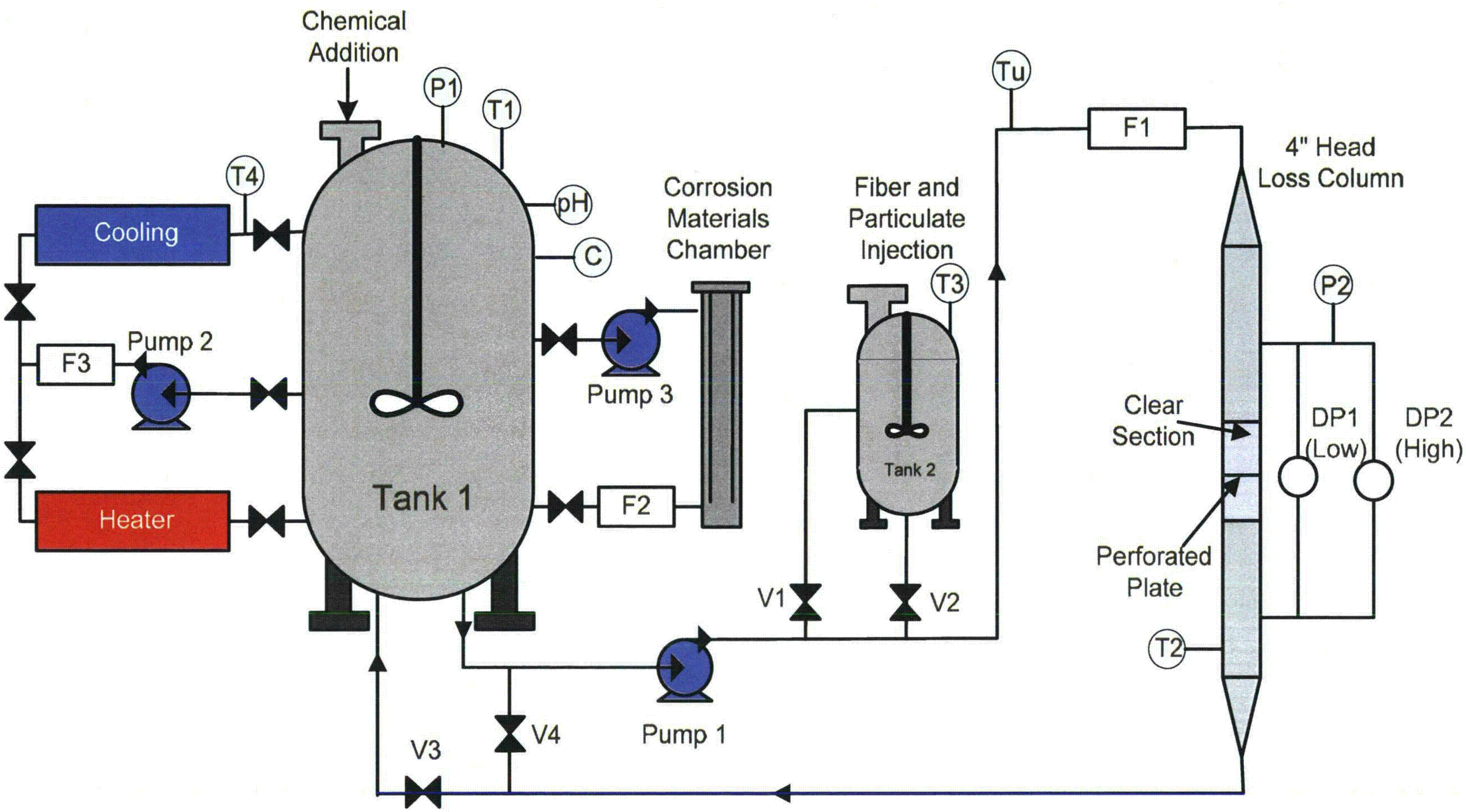
Scaling Considerations for Proposed Test Apparatus

- Debris mass scaling:
  - Fiber and particulate mass scaled to screen area.
  - Sump volume and material surface area scaled to properly represent precipitate mass (e.g. 500-600 gallons to represent the sump for a 4" diameter fuel filter area).
- 4" diameter screen area to limit edge effects and minimize required system volume.
- Debris bed entrance velocity held one to one for conserving head loss.
- Perforated plate screen with flow holes hydraulically representative of bottom nozzle.
- Fluid property similitude.

Important Aspects of Test Apparatus

- Pressure rating of 50 psi, temperature rating of 275°F.
- Corrosion product control tank:
  - Well mixed.
  - Heating and cooling loops.
  - Corrosion material chamber (controlled flow velocity).
- Fiber and particulate injection tank.
- Head loss column:
  - Borosilicate spool piece for viewing fiber bed.
- Pump controls with Variable Frequency Drives.
- Minimize locations for debris retention.

Overview of Preliminary Loop Design



Instrumentation

- Online monitoring
  - Tank level, pressure, differential pressure, temperature, conductivity, pH, flow rate, turbidity, video
- Pre-test debris characterization
  - Light microscopy and SEM for particulate and fiber size distribution
- Corrosion product measurement
  - Inductively coupled plasma mass spectroscopy (ICP-MS)
- Zeta potential and chemical debris characterization (still evaluating)
  - Precipitate size distribution and zeta potential for small chemical particulate debris (Brookhaven Instruments zeta potential analyzer)
  - Fiber and large particulate zeta potential (Anton Paar streaming potential)

Key Design Features

- Controlled, metered rate of fiber and particulate addition.
- Fiber and particulate addition at high temperature (275°F) and pressure.
- Fiber and particulate prepared and well mixed in loop water before addition.
- Ability to simulate corrosion processes at prototypic temperatures.
- Ability to simulate integrated chemical effects corrosion.
- Corrosion rates are controlled and prototypical by properly scaling the system volume and corroding surface to the debris bed.

Key Design Features

- Heat exchange and loop design allow for ~ 1 day test intervals, but allow for simulation of actual plant transients as needed.
- In-situ corrosion allows representative plant chemistry to be tested, which will impact chemical debris particulate size distribution and colloidal suspension characteristics.
- Scaling of the loop components results in reasonable system volumes and therefore provides for reasonable test durations.

Conceptual Test Matrix

- Will be finalized after receiving input from the Tiger Team, U.S. NRC and the utility survey
- Design of Experiments will be employed in defining final test matrix

Test Condition #	Material Set	pH Range	Temperature Profile	Buffering Agent
1	1	Low	1	NaOH
2				TSP
3		High	1	NaOH
4				TSP
5	2	Low	1	NaOH
6				TSP
7				NaTB
8			2	NaOH
9				TSP
10				NaTB
11		High	1	NaOH
12				TSP
13				NaTB
14			2	NaOH
15				TSP
16				NaTB
17	3	Low	1	TSP
18				TSP
19	4	Low	1	TSP
20				TSP
21		High	2	TSP
22				TSP

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QUESTIONS?