Planned Agenda

1. **NRC Introduction & Meeting Purpose:** *M. Srinivasan*
2. **Overview of PNNL Research Project:** *S. Bruemmer*
3. **Review of SCC Crack-Growth Test Systems:** *M. Toloczko*
4. **Test Plans and Initial Test Results:** *Bruemmer, Toloczko*
5. **Discussion of Programmatic Challenges:** *S. Bruemmer*
6. **Opportunity for Public Questions/Comments**
7. **Crack and Crack-Tip Observations on Alloy 600 and Alloy 182 CRDM Components:** *S. Bruemmer*

SCC Crack Growth System Design and Construction

Mychailo Toloczko, John Keaveney
and Steve Bruemmer
Pacific Northwest National Laboratory

Project Kick-Off Meeting
Richland, Washington

May 3, 2005

Research Supported by
U.S. Nuclear Regulatory Commission

Presentation Outline

- **CGR System Design Requirements and Decision**
- **Review and Assessment of CGR System**
  - Loadline & load control
  - Pressure & temperature control
  - Water chemistry control
  - DCPD measurement
  - System control & automation
- **Review and Assessment of Peripheral Systems**
  - Pre-cracking station
  - Ultra-high purity make-up water system
- **Construction & Assembly Status**

SCC Crack Growth System Essentials

- **Long term static loading with load control**
- **Water temperatures to 360°C (3000 psi)**
- **Circulating ultra pure water (18 Mohm-cm) with chemistry control for simulated BWR/PWR conditions**
- **In-situ, high-res. crack length measurement**
- **Active control of key system variables**
- **Continuous data acquisition**
  - load, crack length, temperature, water resistivity, oxygen content, ECP

Options for System Design

- **Design our own**
  - Lengthy design cycle
  - Unproven design
  - Finding appropriate components
- **Purchase ready-made system**
  - Few vendors
  - System limitations (expandability, repairability)
  - Potentially high cost
- **Base the design on an existing system**
  - Fast design cycle
  - Proven design
  - Cost efficient to achieve project objectives

General Electric Global Research

- World leader for quantitative SCC crack-growth-rate testing of LWR materials and they have led key international round-robin test programs.
- 25 years of development and test system evolution, unmatched experience with ECP control and DCPD, unique control and data acquisition software.
- Pioneered ultra-high-purity, make-up water system (outlet resistivity better than 15 Mohm-cm) for BWR applications and for isolation of impurity effects
- Recent PWR experience (290-360°C, B/Li water) evaluating Ni-base alloys and stainless steels
- Peter Andresen and his team have advised in the construction of SCC crack-growth systems for many laboratories over the last 10 years.

Elements of G.E. SCC CGR System

➢ CGR System

- Loadline and loading
- Water system (flow, pressure, temperature, chemistry control)
- Temperature controller
- In-situ crack length measurement (DCPD)
- System control & data acquisition

➢ Peripheral Systems

- Pre-cracking station
- Ultra-high purity make-up water system

Features of G.E. Systems

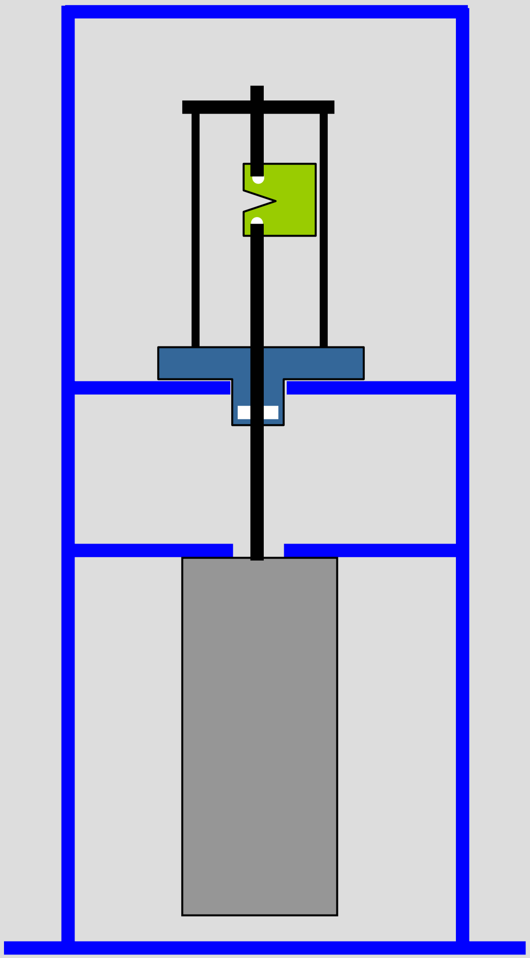
- **Many parts are "off-the-shelf"**
  - Inexpensive
  - Most items are rebuildable
- **Full control over loading system, incl. const K**
- **State-of-the-art DC potential drop for crack length measurement**
- **Low pressure loop for chemistry control**
- **High pressure loop**
- **Careful attention to seal materials**
- **Mature software package for continuous system control and data acquisition**

PNNL Approach to SCC System Design

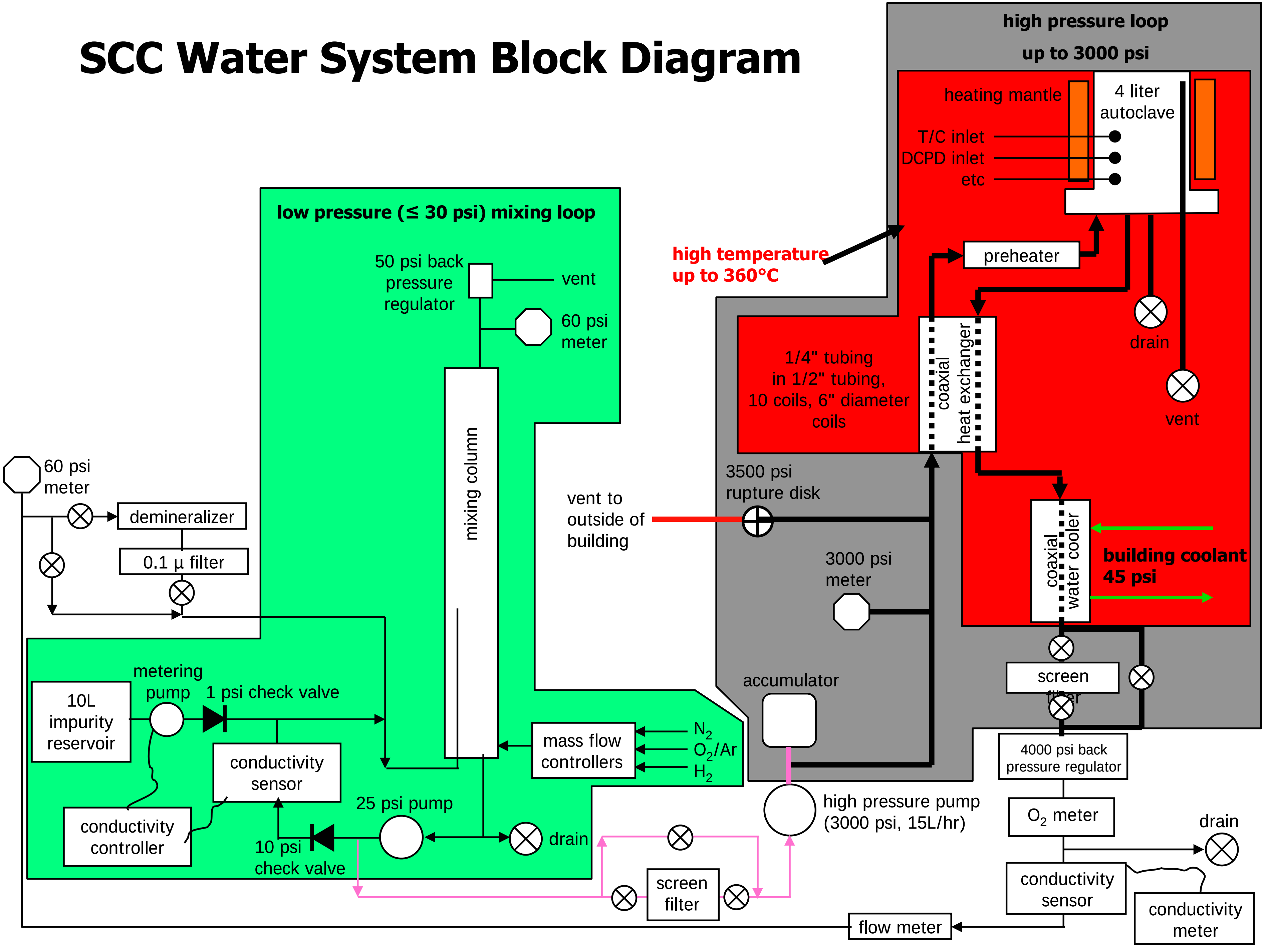
- **Subcontract with GE Global to enable rapid and cost effective construction of state-of-the-art crack-growth test systems**
- **Assess individual elements of the elements of the GE system design and components**
- **Determine where improvements are possible**
  - System layout
  - Major components
  - Wetted materials
- **Incorporate improvements into design and establish cost basis for complete system**

Evaluation of Loadline

- **Sturdy loadframe**
- **Selected servo-electric motor**
  - Excellent long term static loading & positioning
- **Four-bar cage to support upper pullrod & clevis**
- **One mechanical feed-through on autoclave base**
  - feed-through sealed with a virgin teflon seal good to ~280°C
  - water pressure applies a load on pullrod
  - pressure load factored into total specimen load
- **Sufficient room for two 0.5T specimens**
- **Components are manually aligned using a special alignment rod**



SCC Water System Block Diagram

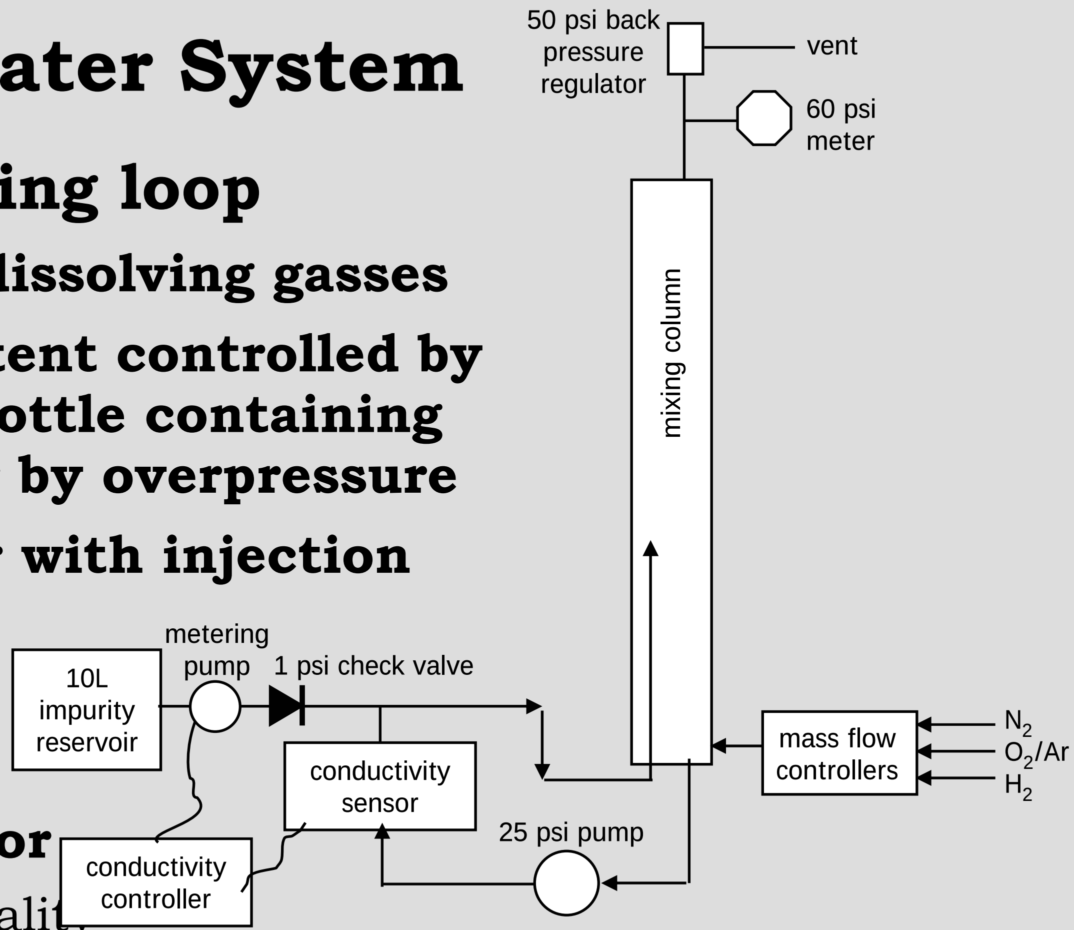


Evaluation of Water System

- **General features**
  - 316L SS tubing and compression fittings
  - Low-leaching seals (viton, virgin teflon)
  - Low pressure loop for chemistry control
  - High pressure loop
  - All water runs through a demineralizer and submicron filter

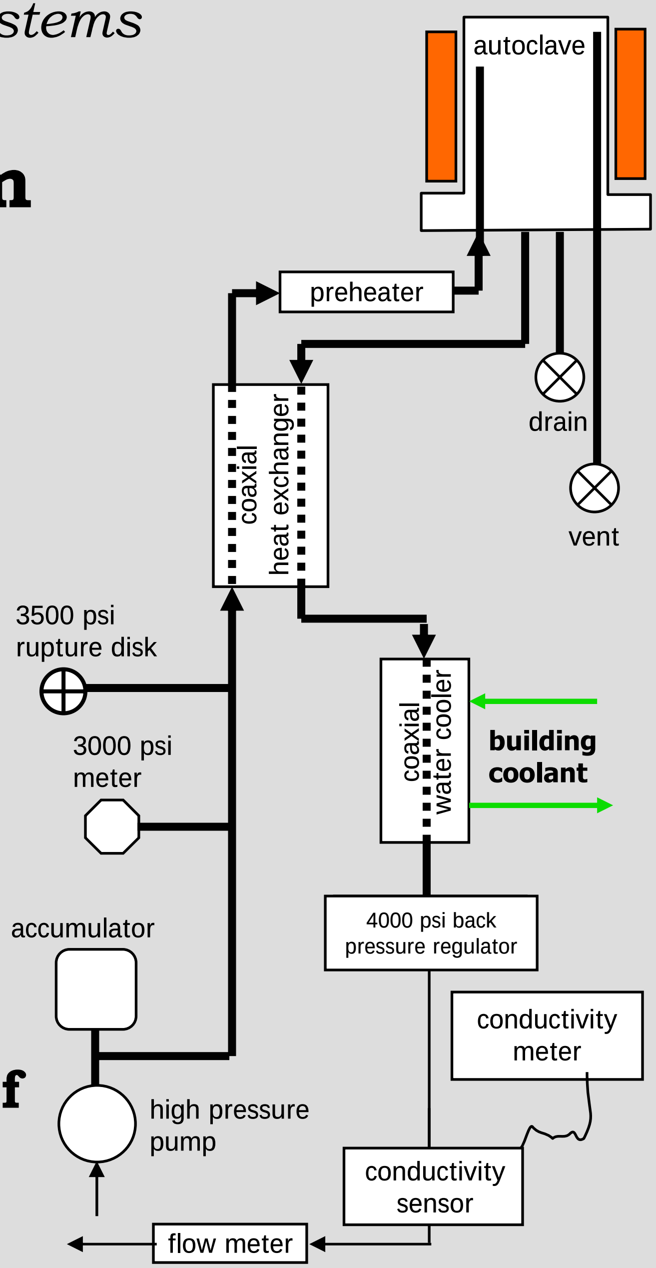
Evaluation of Water System

- **Low pressure mixing loop**
  - **Glass column for dissolving gasses**
  - **Dissolved gas content controlled by partial pressure (bottle containing target gas & Ar) or by overpressure**
  - **Impurity reservoir with injection pump**
    - boron & lithium
    - sulfates
  - **Conductivity sensor**
    - measure water quality
    - control injection pump
  - **Other sensors such as pH, dissolved oxygen will be added**



Evaluation of Water System

- **High pressure loop**
  - **Piston pump creates high pressure**
    - adjustable flow rate
  - **Back pressure regulator**
    - pressure control
  - **Pulsation damper**
    - less than 3 psi peak-to-peak
  - **Water conductivity measured at end of high pressure loop**
    - measure of water purity
  - **Water flows from top to bottom of autoclave**
    - minimizes stagnation

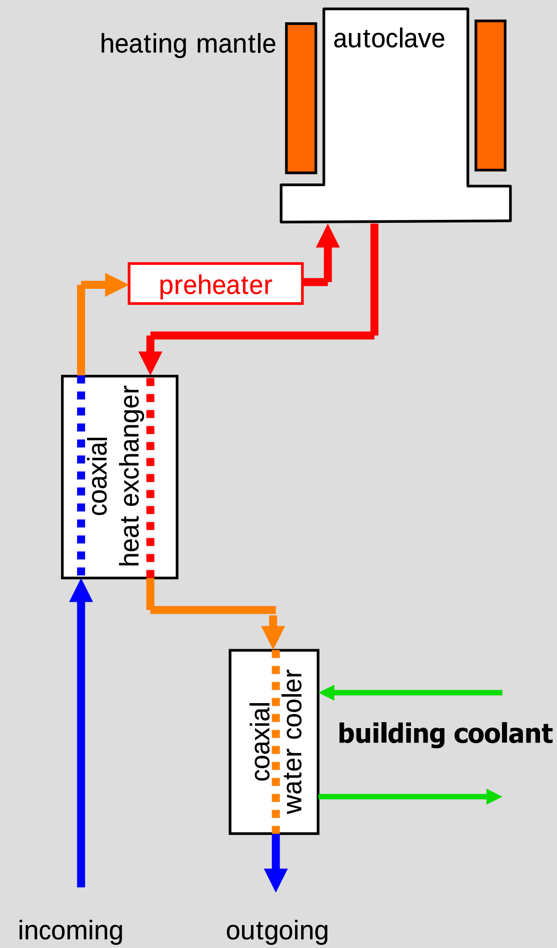


Evaluation of Water System

- **Cost effective, efficient design**
- **Very little to improve upon**
- **Upgraded conductivity sensors and meters**
  - temperature measurement, more analog outputs
- **Careful evaluation of pulsation damper specs**
- **Careful evaluation of seal materials in flow meter, back pressure regulators, pulsation damper, etc.**
- **Reduced length of heated tubing to improve purity of water entering the autoclave**

Evaluation of Temperature Control

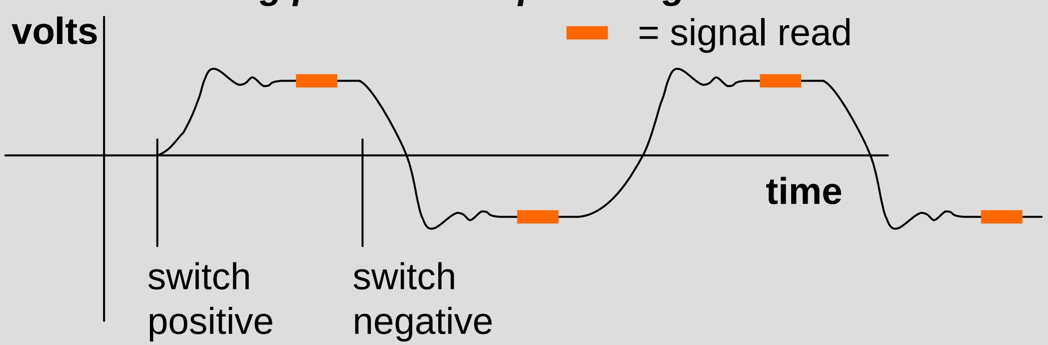
- **Heating**
  - Step 1: coaxial heat exchanger
  - Step 2: preheater
  - Step 3: autoclave heater
- **Cooling**
  - Step 1: coaxial heat exchanger with incoming water
  - Step 2: coaxial water cooler with building coolant
- **Control: Temperature controllers for preheater and autoclave heater**
- **Will evaluate magnitude of temperature gradients in autoclave**

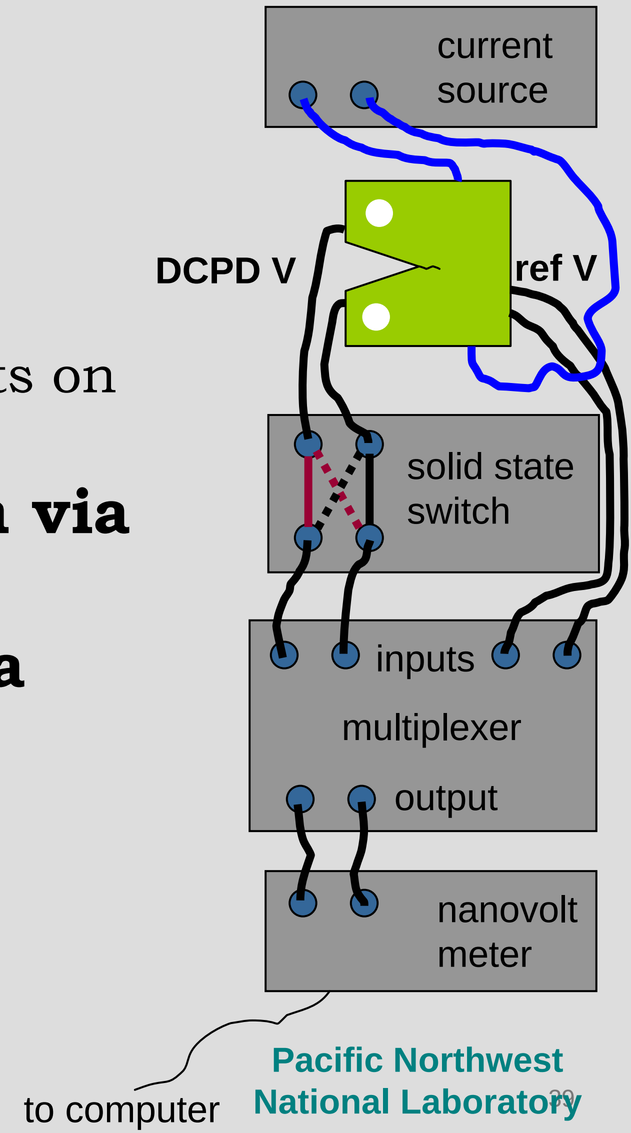


Evaluation of Crack Length

- **Reversing DC potential drop Measurement**
  - compensates for work function between dissimilar metals
  - setup to read stabilized voltage
- **Reference potential**
  - compensate for temperature effects on resistivity
- **DCPD estimates crack length via existing calibration curve**
- **All DCPD data written to data file**

reversing potential drop reading



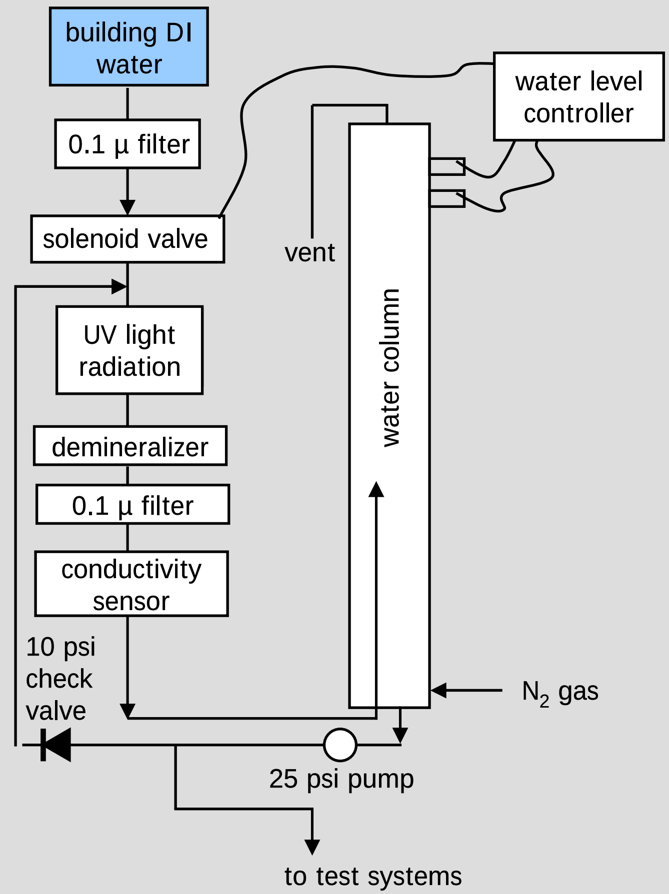


Evaluation of Data Acq. & System Control

- **Data acquisition**
  - DCPD, reference voltage, applied current, water mixing loop conductivity, water outlet conductivity, autoclave water temperature, corrosion potential, dissolved oxygen
  - May add: water pressure logging, mixing loop water temperature logging
- **PC used to control load on specimen**
  - Inputs for load control include specimen crack length from DCPD and water pressure which is entered manually
  - Constant K testing
  - Cyclic K with variable hold time
- **Automatic shutdown**
  - run-away crack
  - system overtemperature

Evaluation of Make-up Water System

- **UV light kills organics**
- **Demineralizer for ions**
- **Submicron filter for particulates**
- **N_2 gas to displace oxygen**
- **18.18 Mohm-cm is the typical water resistivity (theoretical purity)**



Pre-cracking

- **Instron servo-hydraulic used for pre-cracking**
- **Crack length measured from DCPD**
- **GE software package controls the Instron and pre-cracking routine.**

Construction & Assembly Status

- **System #1 running continuously for 60 days**
  - Simultaneously oxidizing autoclave internals and performing a shakedown test on cold-worked 316 SS sample
  - Excellent system cleanliness with outlet resistivity better than 10 Mohm-cm and still rising
  - Excellent system performance
- **System #2 is 80% complete**
  - Completion expected by end of May
  - Oxidation and shakedown test will follow
- **System #3 is 30% complete**
  - Completion next fiscal year