Environmental Effects on Crack Growth in High Temperature Alloys for Advanced Energy Systems: INL/MIT LDRD Project

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H. H. Uhlig Corrosion Laboratory

Background

- NGNP Heat Exchanger Material of Choice is Alloy 617
- Backup Material Alloy 230
- NGNP Program focused on Alloy 617 @ high temperature
  - Code case
  - Creep, Creep-Fatigue
- However, actual heat exchanger will experience wide temperature range
- Alloy 617 was designed for high oxygen potential environments

Background (Cont.)

- Ni-Base Alloys are susceptible to a form of SCC (Stress Assisted Grain Boundary Oxidation) in the temperature range 600-700°C
- Strong function of Cr concentration
  - 30wt% Cr required for "immunity"
- Growth rates can be very fast (10^{-5}m/cycle)
- Need to explore Alloy 617 (and 230) to assure that a problem does not exist

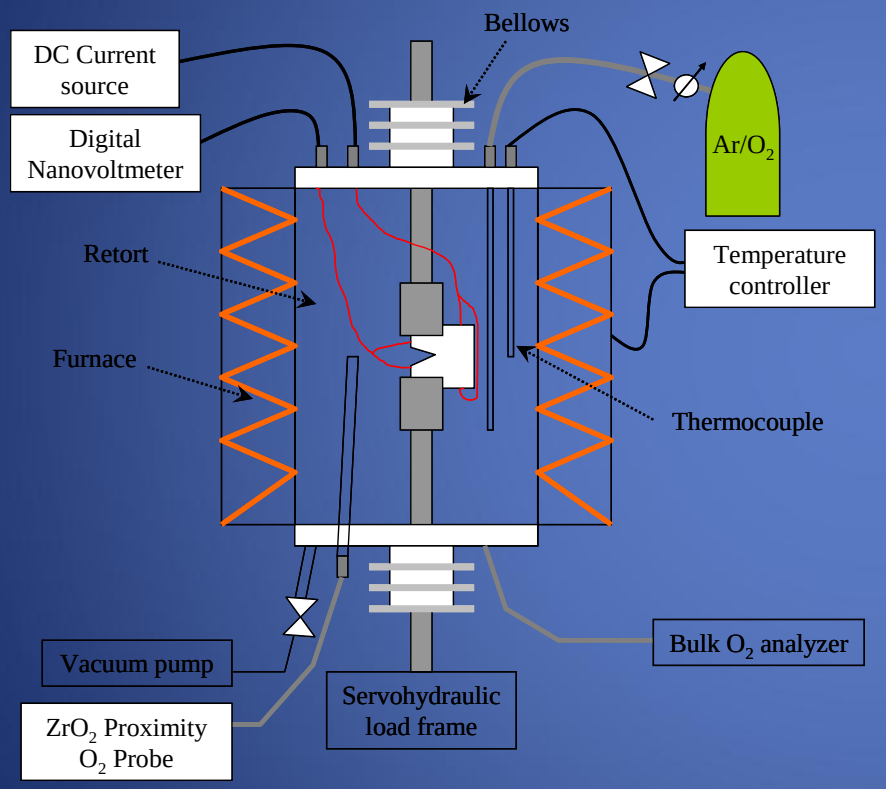
Test Program

- Fatigue & Static Crack Growth Tests as function of oxygen partial pressure.
  - Bracket NGNP Oxygen Potentials
  - Very accurate oxygen potential measurement
  - Very accurate crack length measurement (DCPD)
- Toughness measurements
- Temperature range 600-750°C
- Alloy 617 focus but with alloy 230 included
- Detailed analysis of role of oxygen
  - TEM (FIB), Nano SIMS, etc.

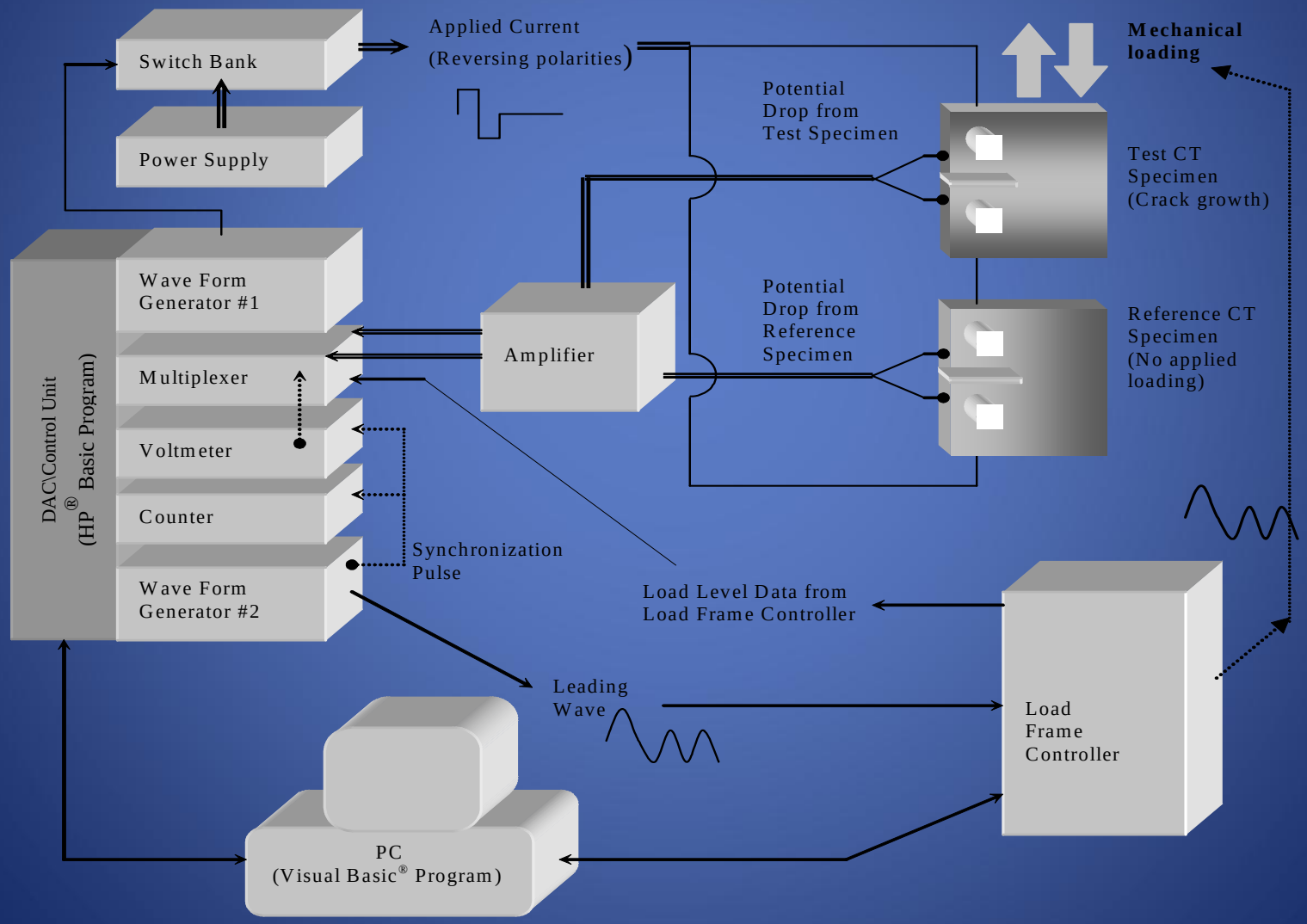
Materials

	C	Mn	Fe	S	Si	Cu	Ni	Cr	Al	Ti	Co	Mo	B	W
A617	0.08	0.11	1.69	0.001	0.12	0.04	53.55	21.91	0.96	0.34	11.42	9.78	0.002	-
H230 Base	0.11	0.53	1.34	0.002	0.37	0.04	Bal	22.43	0.29	0.01	0.215	1.34	0.004	13.91
H230 Weld	0.07	0.492	1.154	0.002	0.43	0.043	Bal	21.99	0.357	-	0.058	1.372	-	13.81
Hastelloy X	0.073	0.696	18.76	0.002	0.35	0.077	Bal	22.57	0.19	0.01	1.2	9	0.002	0.472
A718	0.06	0.25	18.13	0.002	0.11	0.03	53.75	18.15	0.47	1.02	0.37	3.04	0.003	-

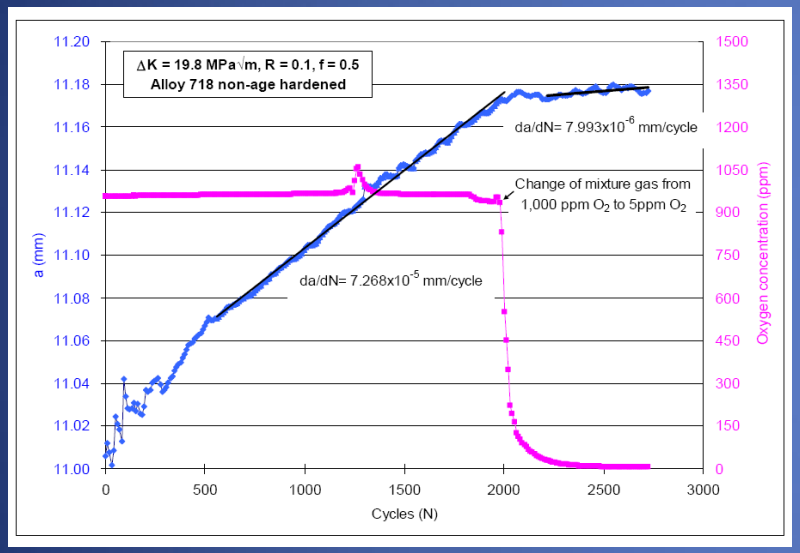
Experimental Setup



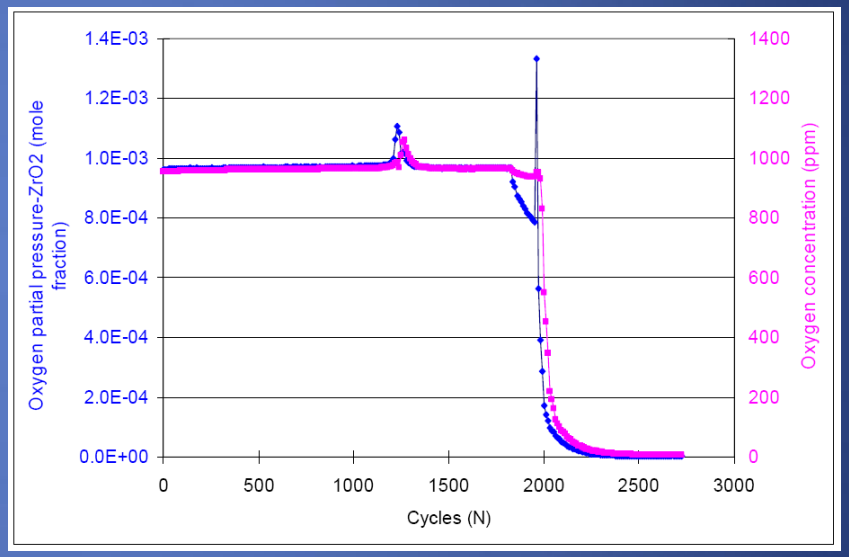
Control/DCPD Setup



Test Setup Verification

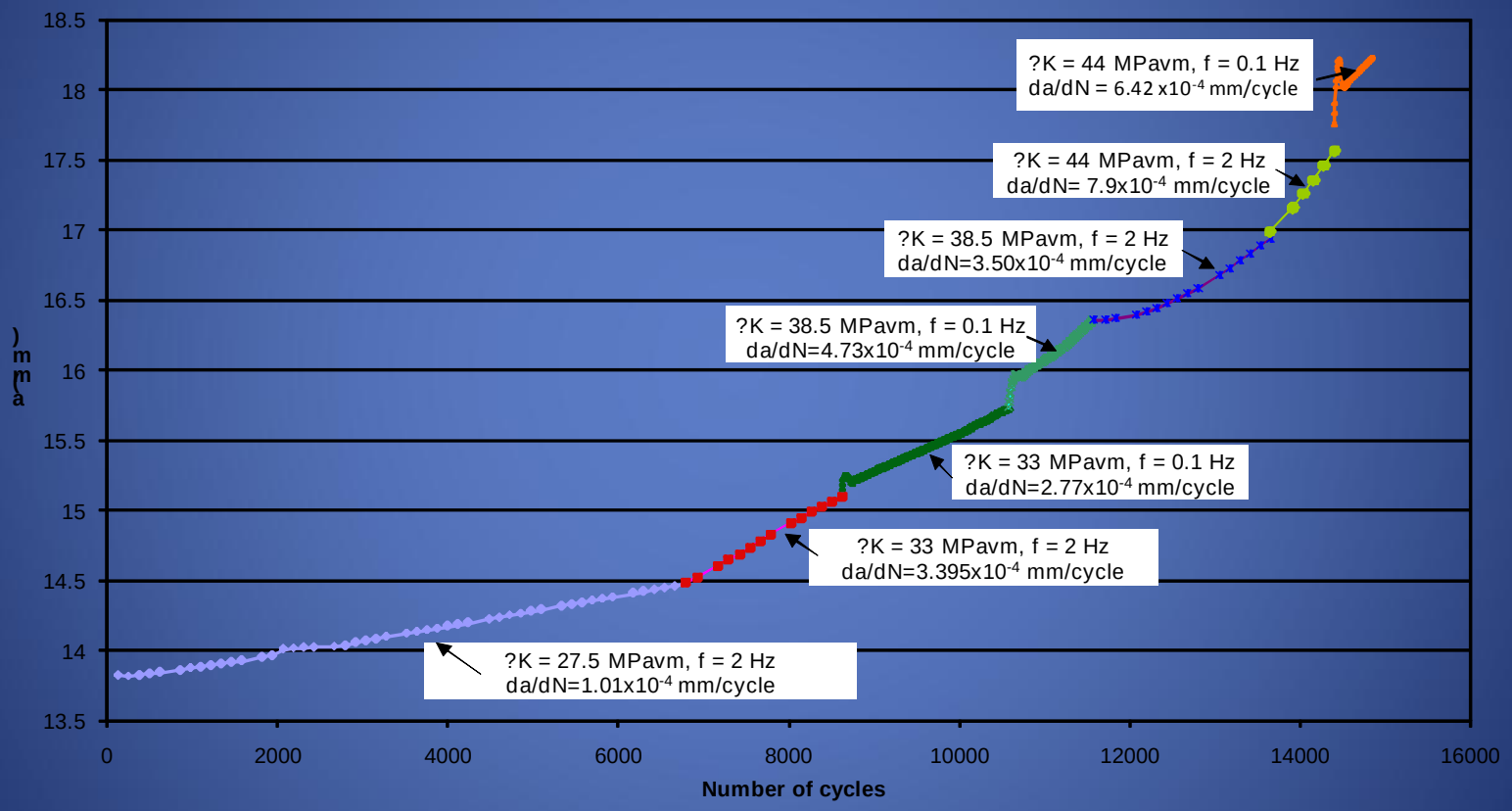


Alloy 718 fatigue crack growth benchmark data.



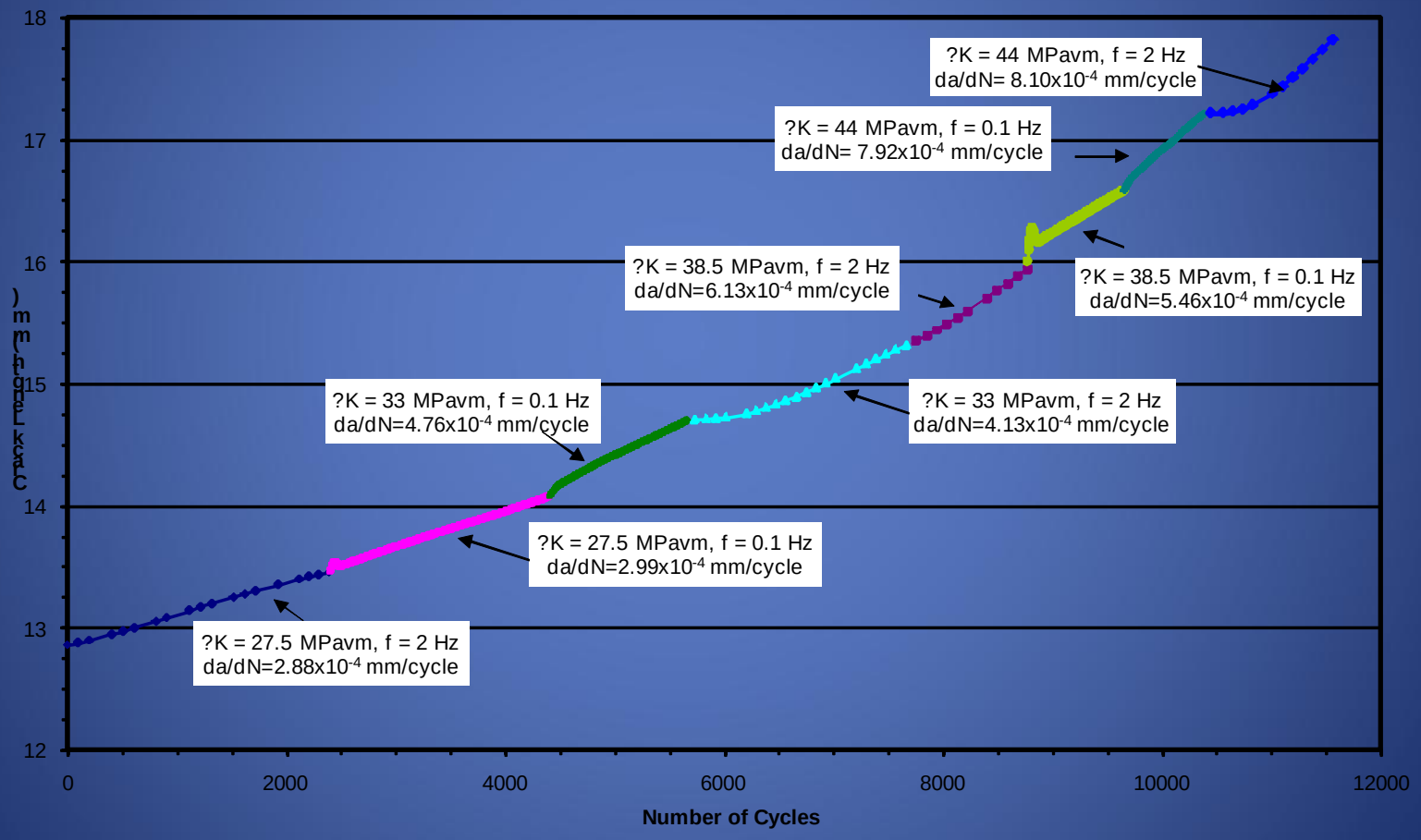
Internal (in-situ) and external oxygen concentration comparisons. In-situ (blue) and external (pink).

Results



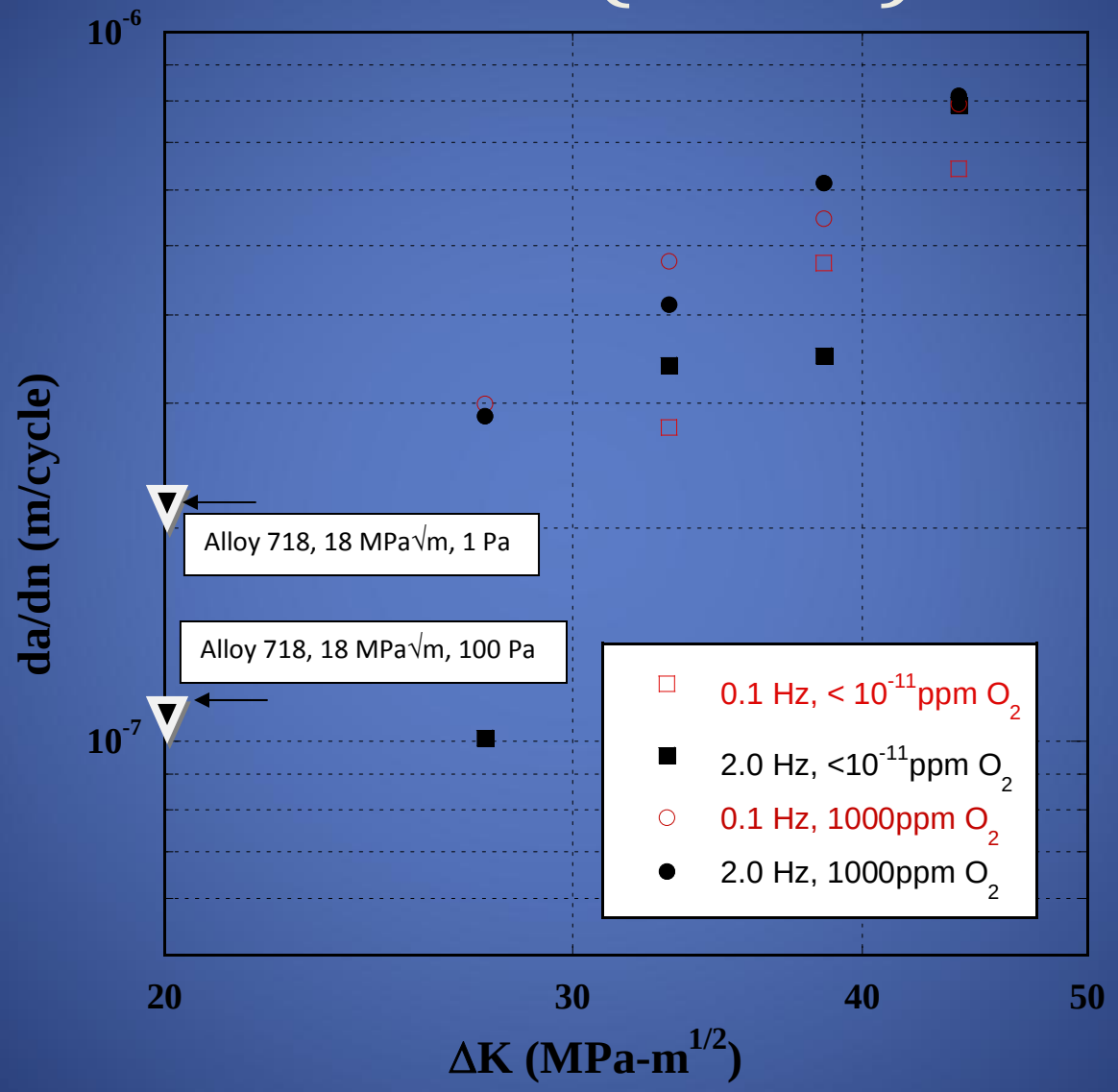
Raw data plot for Alloy 617 da/dn vs. ΔK, 650°C, R=0.1, $<10^{-11}$ ppm O_2

Results (Cont.)



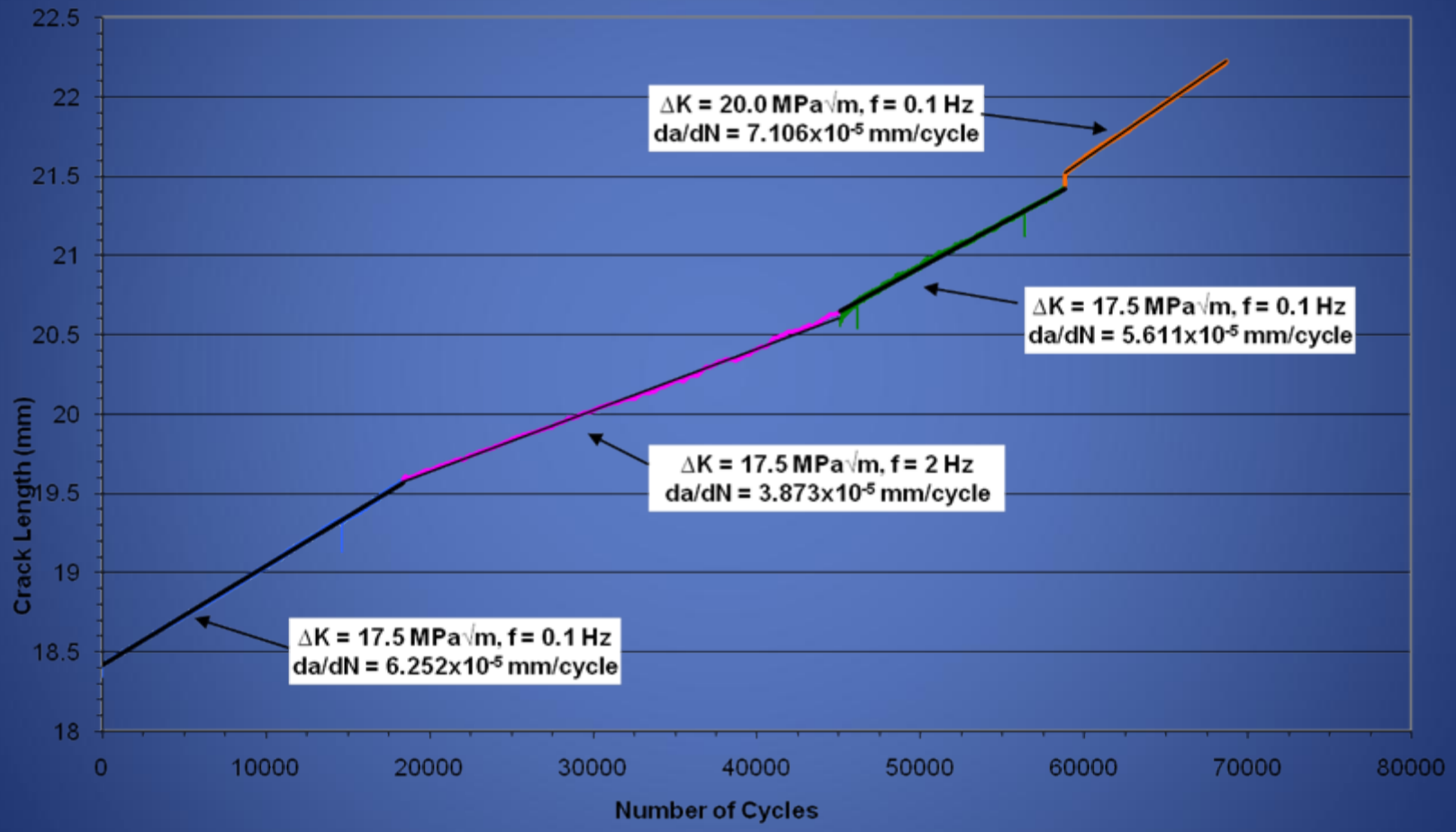
Raw Data plot for Alloy 617 da/dn vs. ΔK, R=0.1, 650°C, 1000 ppm O_2

Results (Cont.)



da/dn vs. ΔK data for R=0.1.

Results (Cont.)



Crack Growth Rates in High Purity Argon Environment (PO2 < 10^{-11} ppm O_2), Sine Wave Cyclic Loading, R = 0.5

Conclusions

- Significant effect of oxygen partial pressure in NGNP operating range

Path Forward

- Continue Testing in fatigue (function of frequency, hold time, wave shape)
- Variable Oxygen Potential
- Commission Static System
- Begin SCC Tests