The APS 350-MHz CW RF Test Stand

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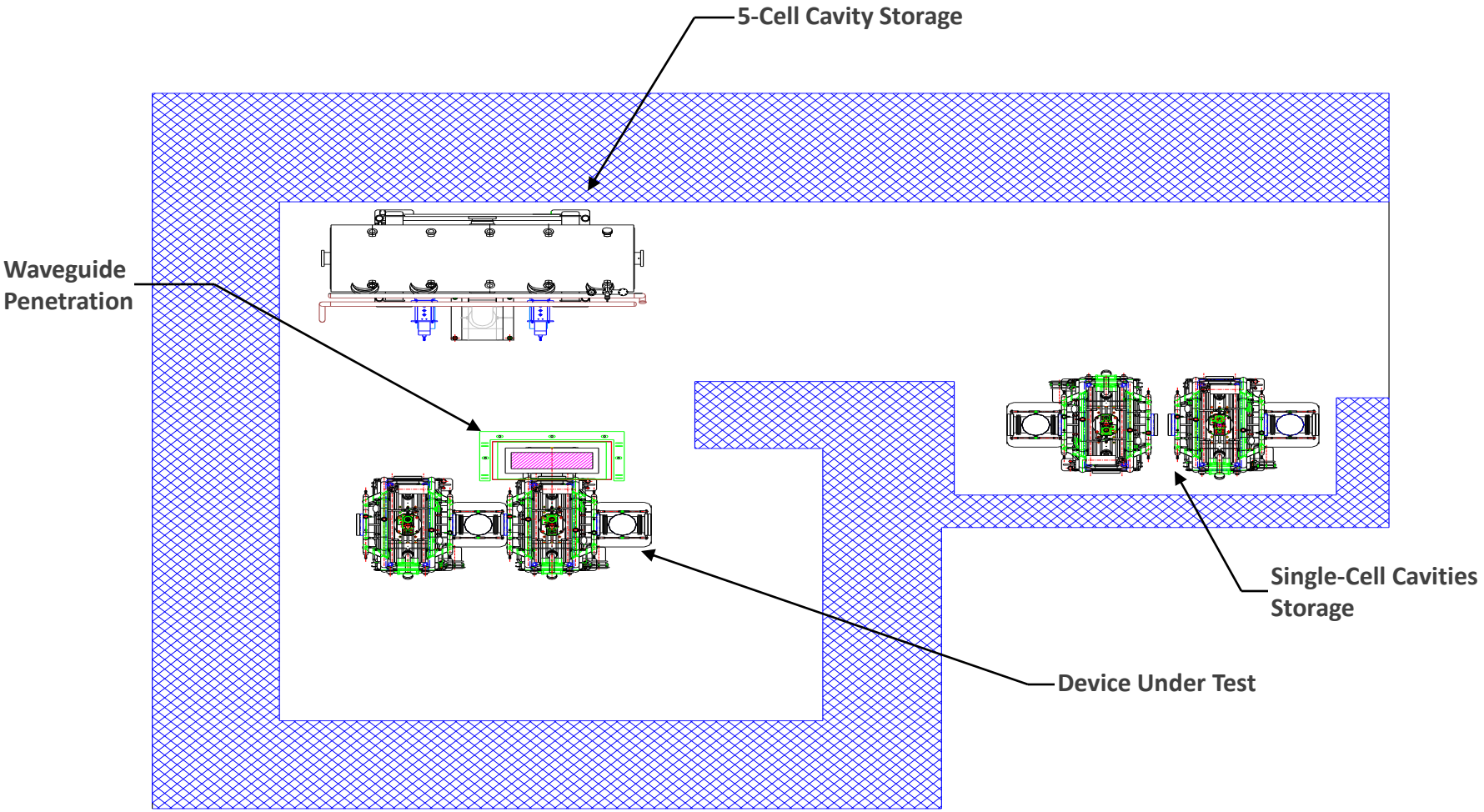
Outline

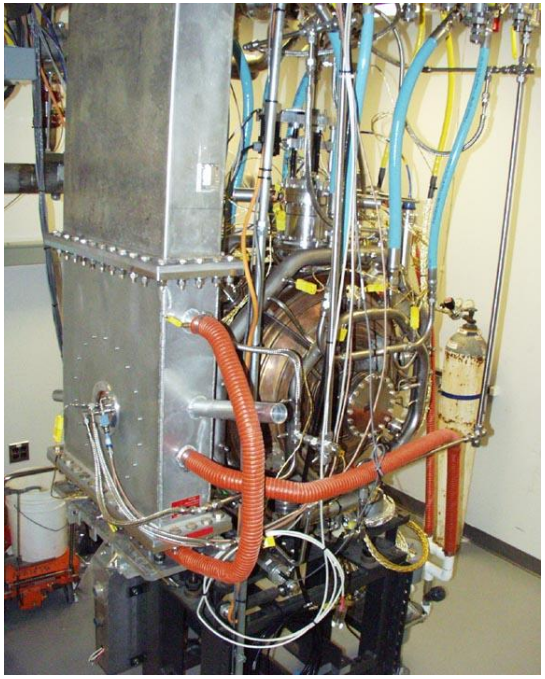
- General Description and Layout
- Recent Statistics
- Successes & Failures
- Conditioning Techniques
- Recent Improvements
- Future Plans

General Description and Layout

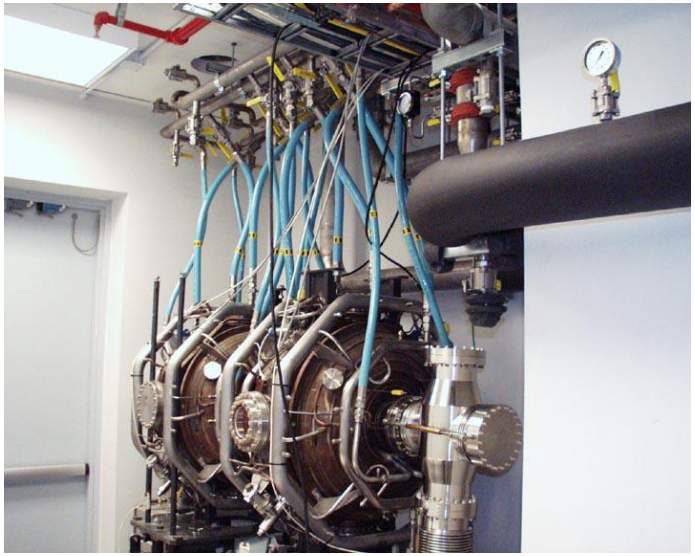
- RF source and LLRF system independent of APS operations
- Klystron and power supply (RF1), shared with operations
- Waveguide switching system and shutters
  - Switching system can direct rf power from RF1 to either the Storage Ring, the RF Test Stand, or a 1MW RF Load
  - Waveguide shutters are utilized as a personnel safety system to allow entry into the bunker with Storage Ring rf stations on-line
- Can be configured to power a single-cell cavity with one or two input couplers, or a 5-cell cavity
- Storage space for two single-cell cavities and one 5-cell cavity
  - Cavities stored under vacuum with cooling water

Test Stand Bunker Layout

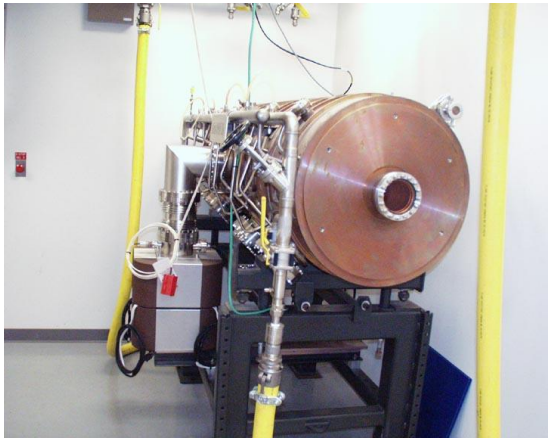




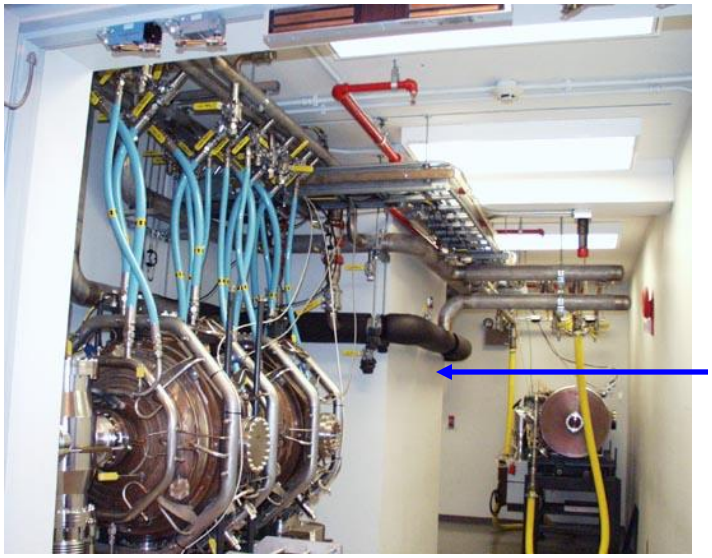
Device Under Test



Single-Cell Cavities in Storage

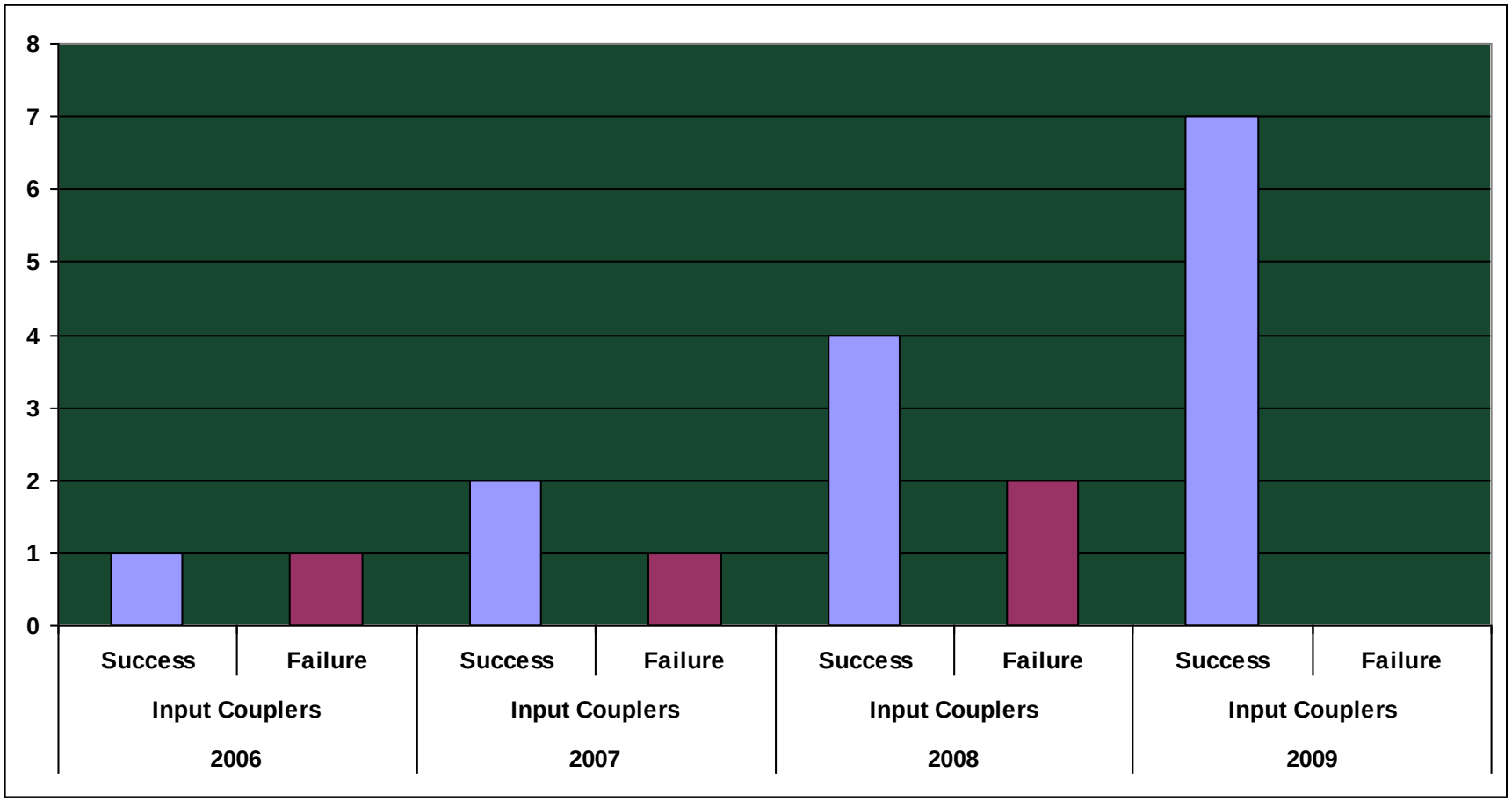


5-Cell Cavity in Storage



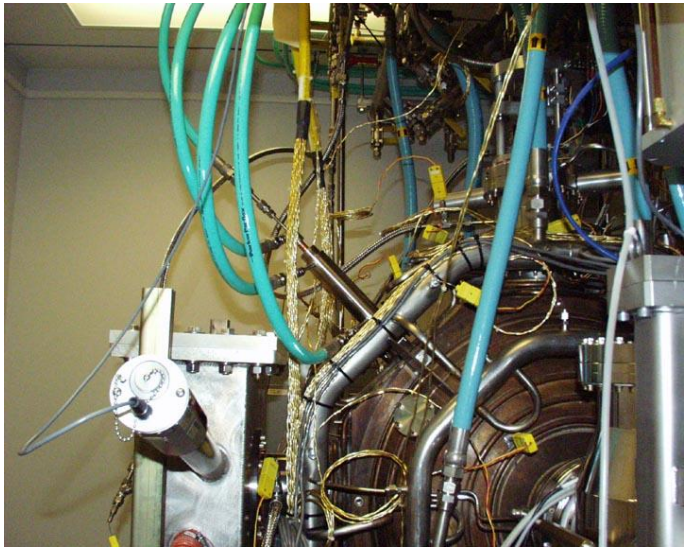
View From Test Stand Doorway

Recent Statistics



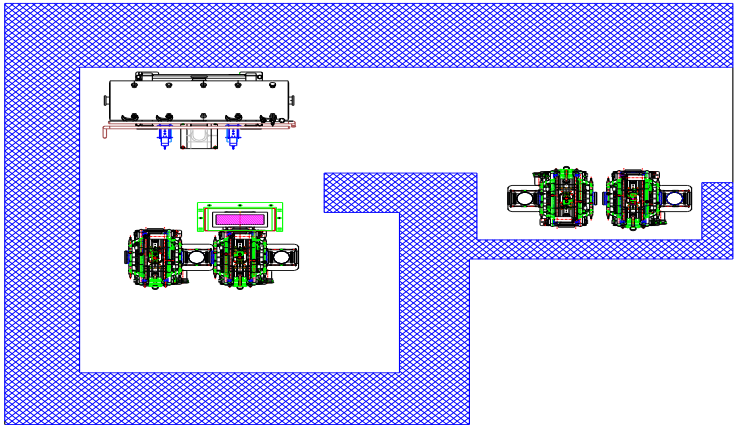
Recent Successes

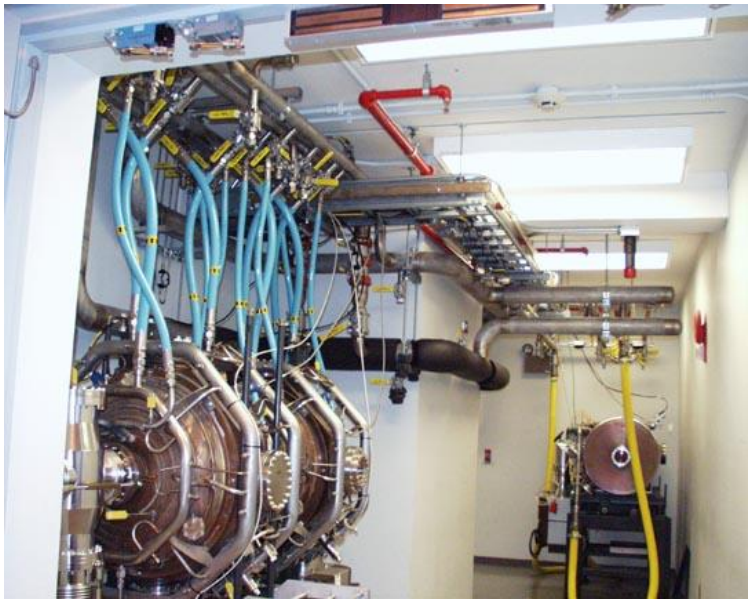
- Successfully tested and conditioned HOM dampers prior to installation on the sector 38 cavities
- We now have an adequate stock of conditioned spare SR couplers (6), SR tuners (3), and Booster couplers (3)



Recent Successes

- 200kW “Two Coupler Test”
  - A success yes, but not without some degree of difficulty
    - Original thought was to use the existing penetration and plumb the waveguide and hybrid to the 2nd coupler on the inside of the bunker. Water for the hybrid load was available, so why not?
      - Real estate was an issue
    - Needed to add a second waveguide penetration (shielding modification)
    - Once we finally began the test, other problems surfaced

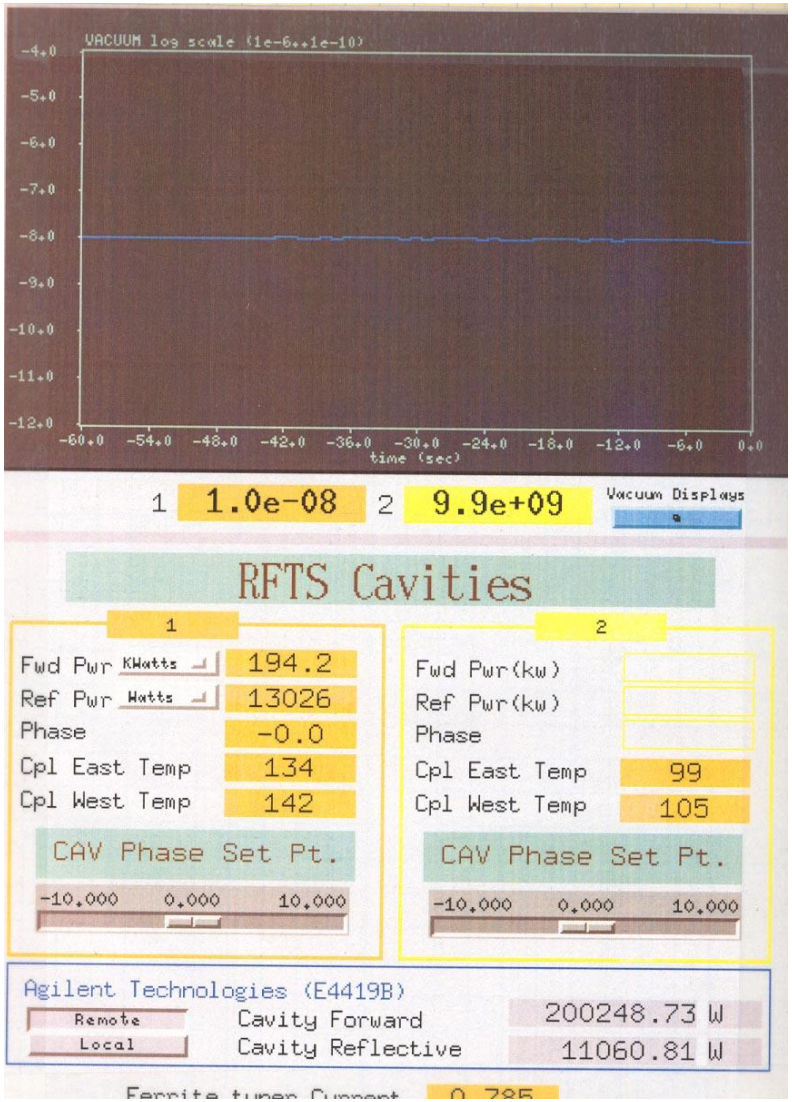




200kW “Two Coupler Test”

- Began rf operation in December 2006
- One of the couplers (ANL-14), took a hit at 60kW
  - Base pressure held at ~1E-8 torr and did not recover
    - Helium leak check revealed a pin-hole leak
- Removed the failed coupler and installed another (ANL-18)
- At ~110kW, tuner piston and cavity center temps went into alarm
- Raised these setpoints to the levels used during SR high current runs
  - Tuner Piston from 42C to 45C
  - Cavity Center from 65C to 80C
  - Also raised tuner body & tuner bellows setpoints
- Moved tuner water lines to a separate water header to increase both tuner and cavity water flow
- Regular Health Physics surveys revealed high radiation levels which had to be closely monitored. Engineering and administrative controls were put in place in some areas
- At ~190kW, the power monitor (fast interlock), began tripping on waveguide overpower
- Finally reached 200kW on 10/31/07

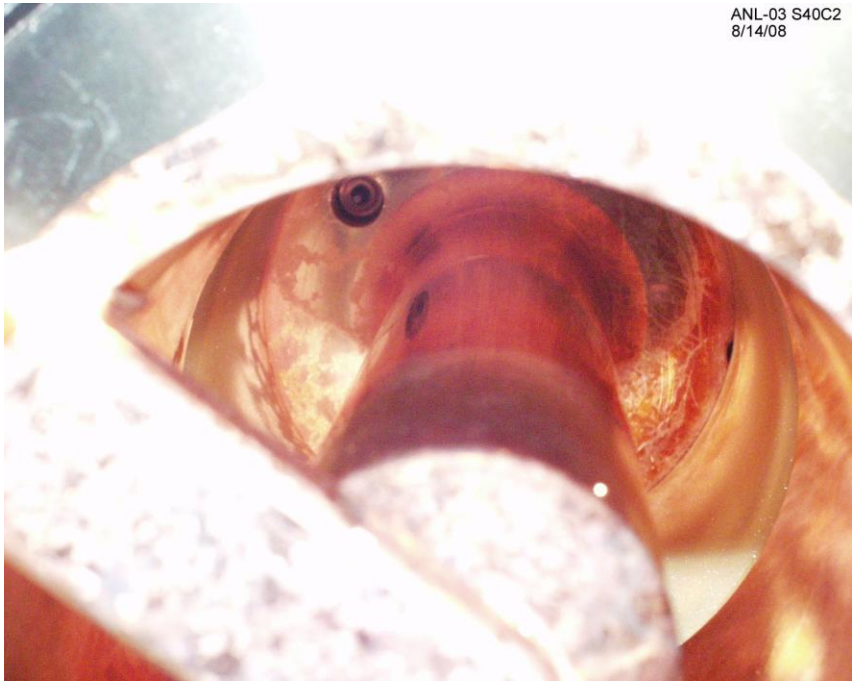
200kW “Two Coupler Test”



Ti Coated Copper Parts Coupler

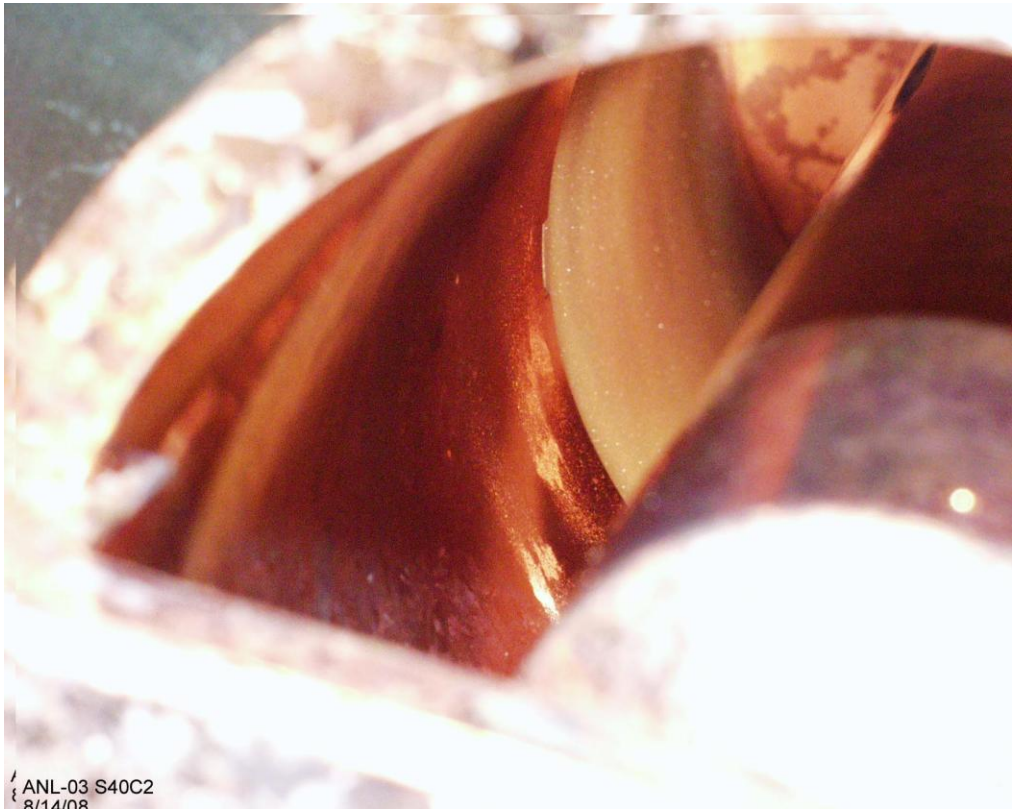
- Selected ANL-03 as the test coupler
  - ANL-03 was removed from SR Sector 40 Cavity 4 due to repeated vacuum trips and elevated window IR temps
  - Waveguide was blanked-off to stop the trips
  - Removed the following shutdown. Inspection revealed a heavy coating of copper on the vacuum side of the window, and obvious signs of arcing on the copper parts
  - This coupler was chosen to make the test as difficult as possible. The arc marks were slightly polished down and a new window installed
- Inner and outer conductors coated with >200Å titanium
- Started on 3/20/09, encountered rough spots between 10kW-20kW with 2 vacuum trips at 11kW
- Smooth with no trips up to 75kW when coupler arc detector trips began
- Recorded trips on DVD, then reviewed the trips frame by frame and determined a coupler arc was not the cause
- Adjusted arc detector sensitivity to get through the trips
- Reached 100kW on 3/31/09

Ti Coated Copper Parts Coupler

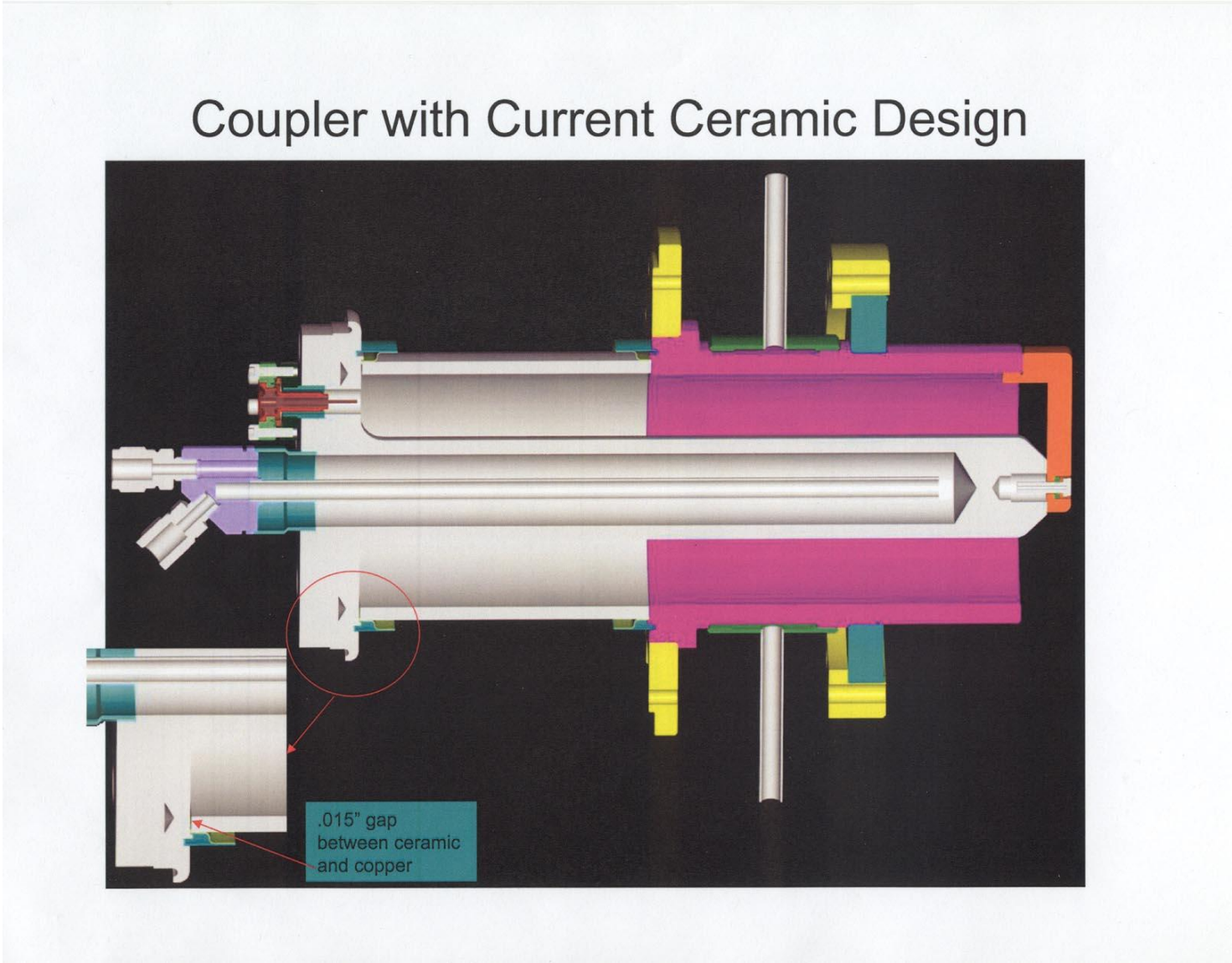


Common Failure Modes

- Ceramic window pin-hole leaks
  - High base pressure that does not recover, usually in the low E-8 torr range
- High infrared thermometer temperatures/Repeated Vacuum trips
  - Visible signs of arcing on inspection after removal
  - Vacuum side of window discolored by copper deposition, color varies with amount of deposition
    - Light Yellow
    - Green/Gray
    - Dark Gray
    - Copper

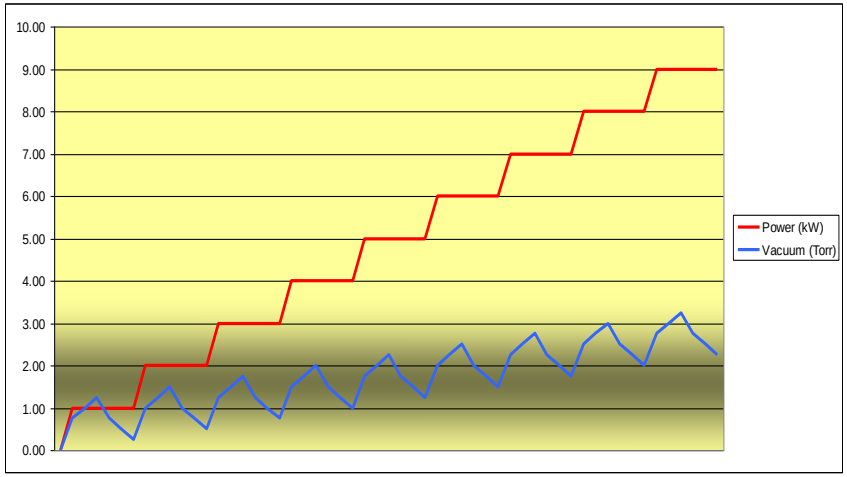


Common Failure Modes

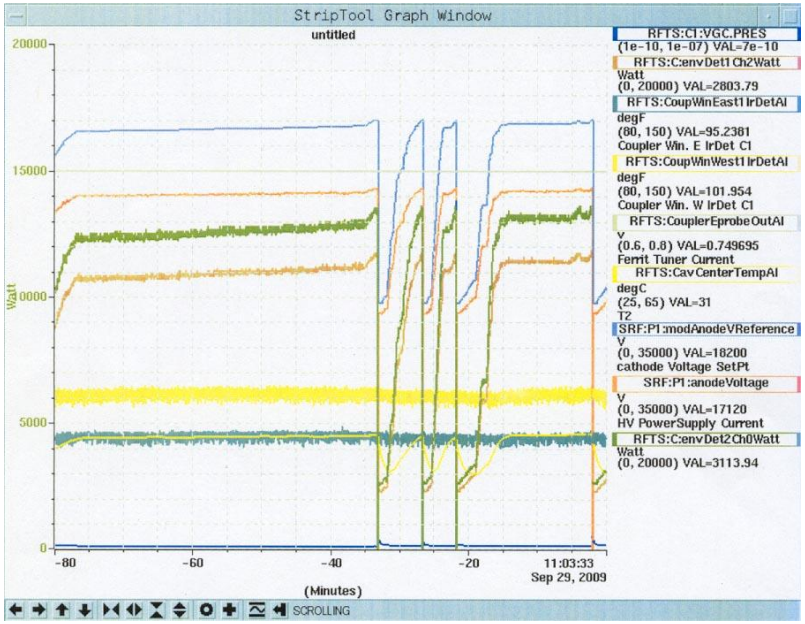


Conditioning Techniques

- Ideally conditioning would look like the chart on the top. Steady increases in power with a sawtooth vacuum waveform that has a slightly elevated base pressure with increased power.



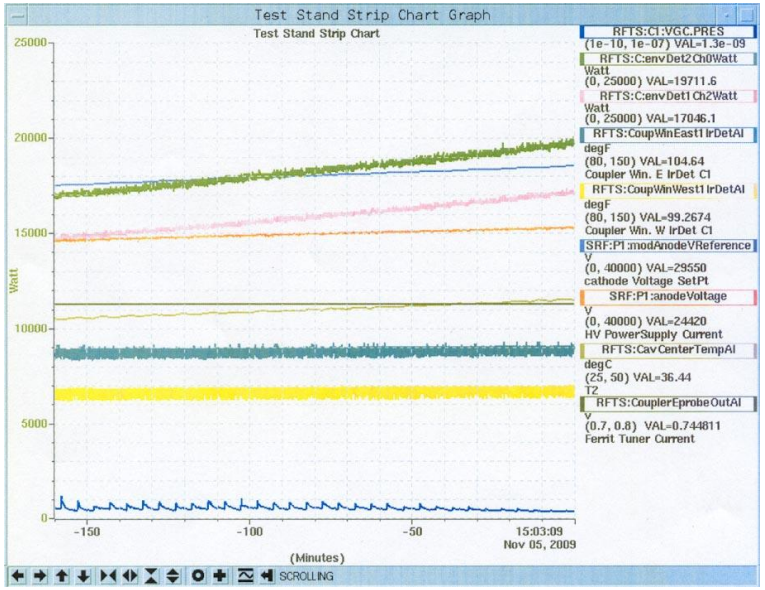
- In reality though, you're more likely to encounter something like the chart on the bottom.

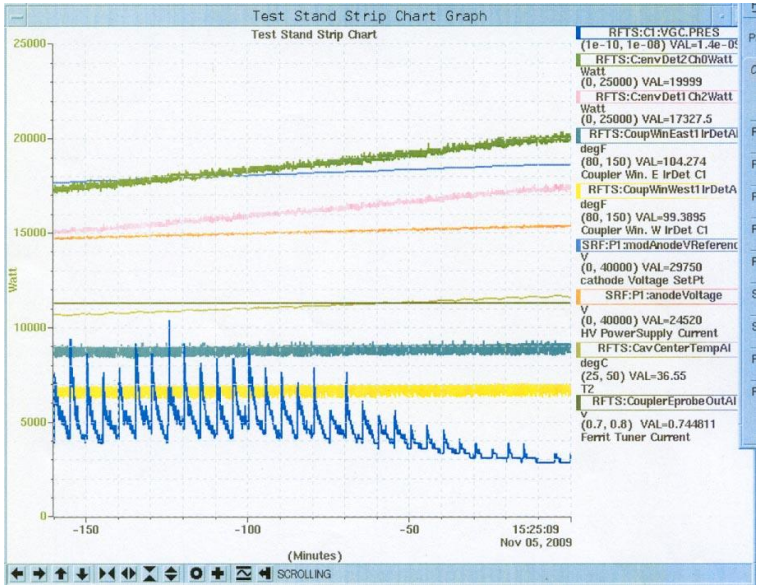


Conditioning
Slow & Steady

- Preferred method. Regular intervals of power increases. Pressure increases then settles down prior to the next power increase

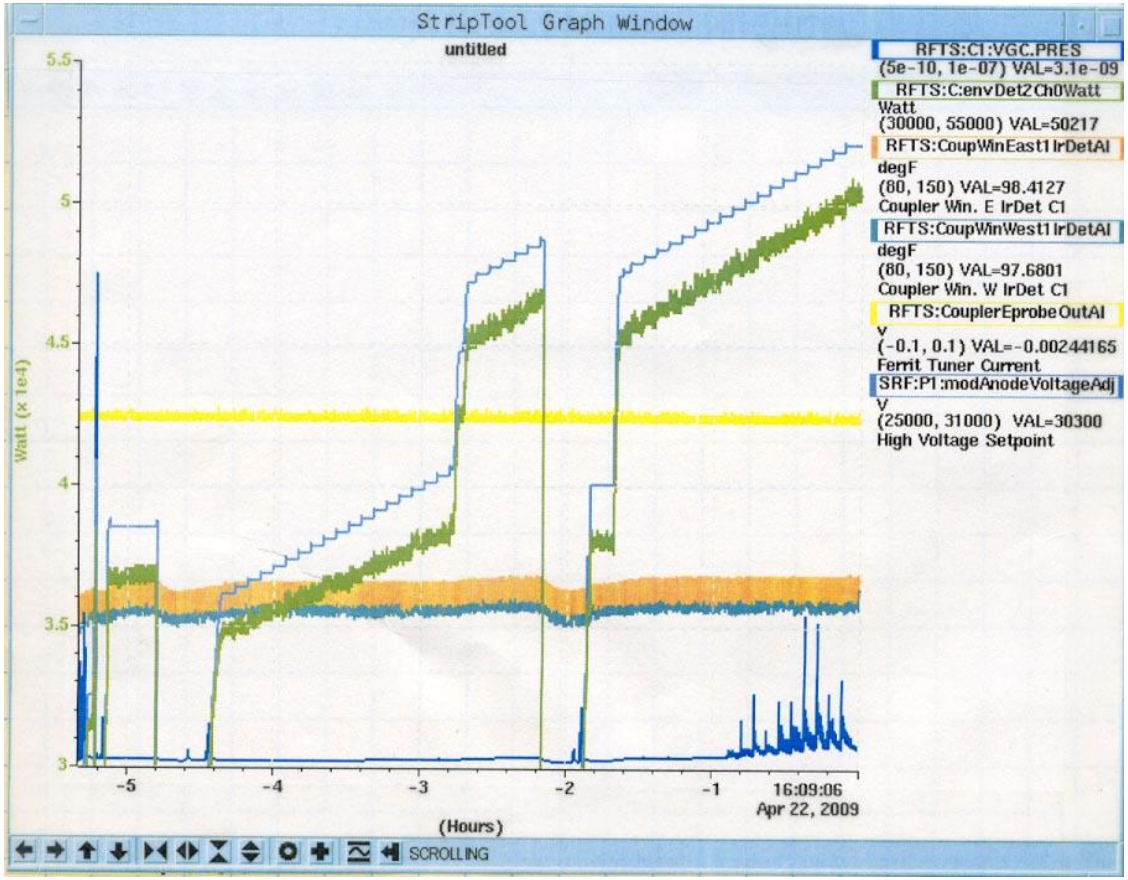
- Classic “sawtooth” vacuum waveform



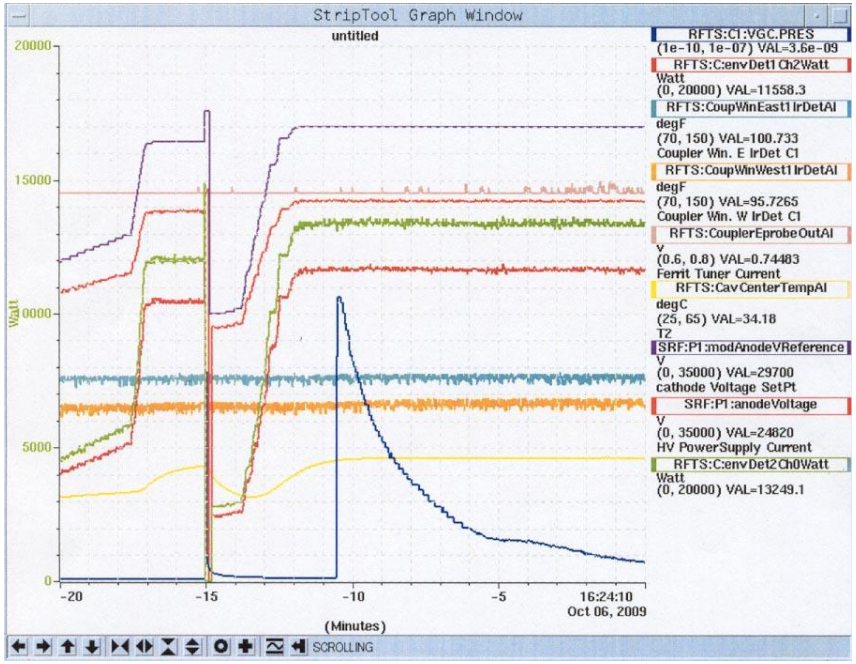


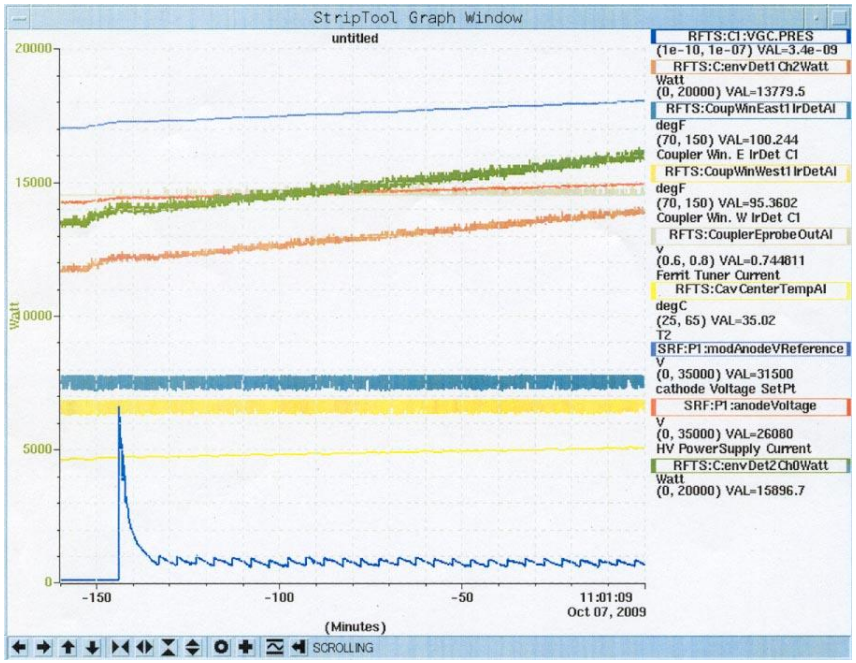
Conditioning
2 Steps Forward, One Step Back

- Effective when stuck at the same power level due to repeated vacuum trips
- Allows the cavity to momentarily see the power level you're stuck at, before it has a chance to trip
- Another effective method to use when stuck at a certain power level is to bring the power to a level just below the problem area, and just let it "cook" there for a few hours

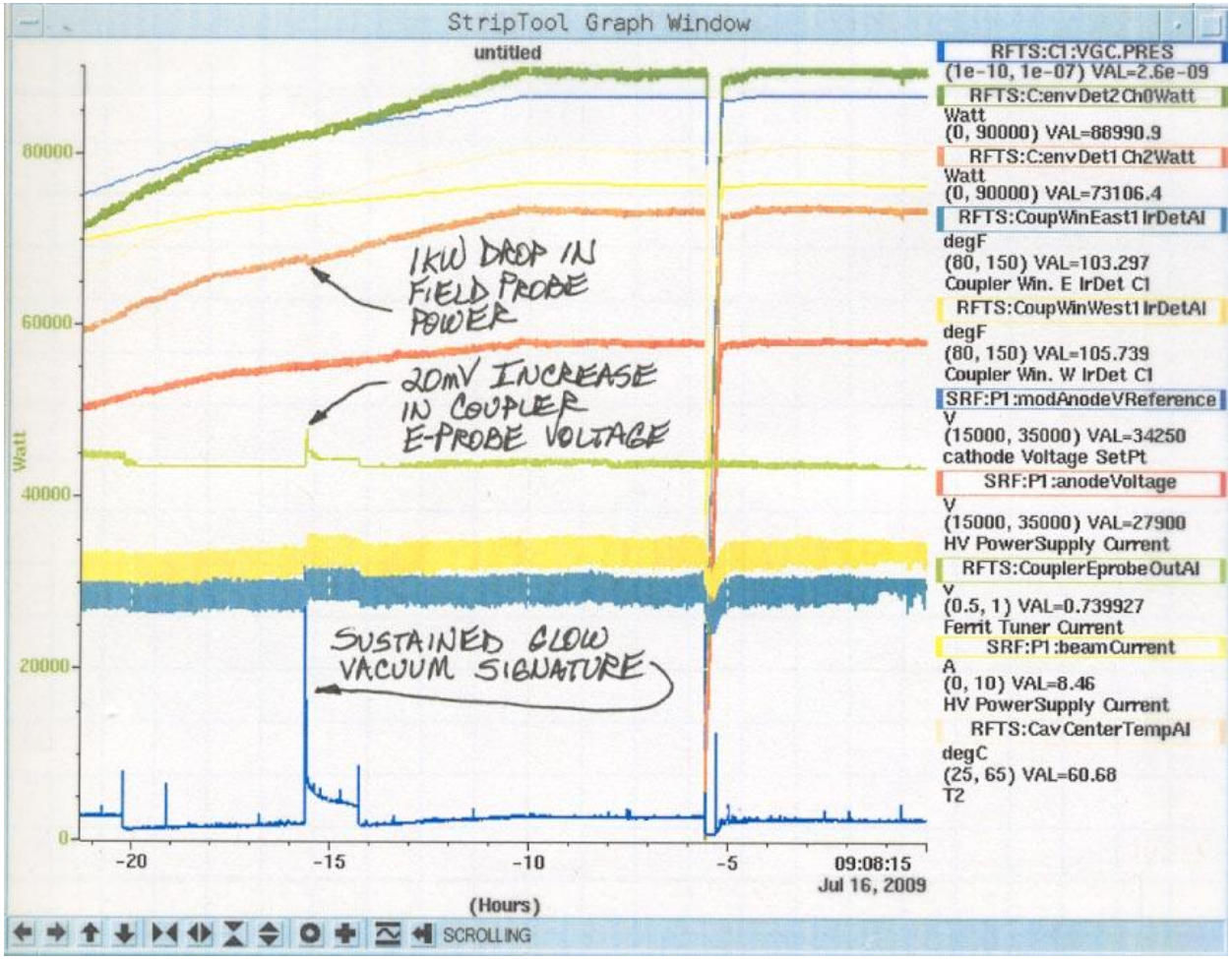


Conditioning
Blast-Thru (Last Resort)





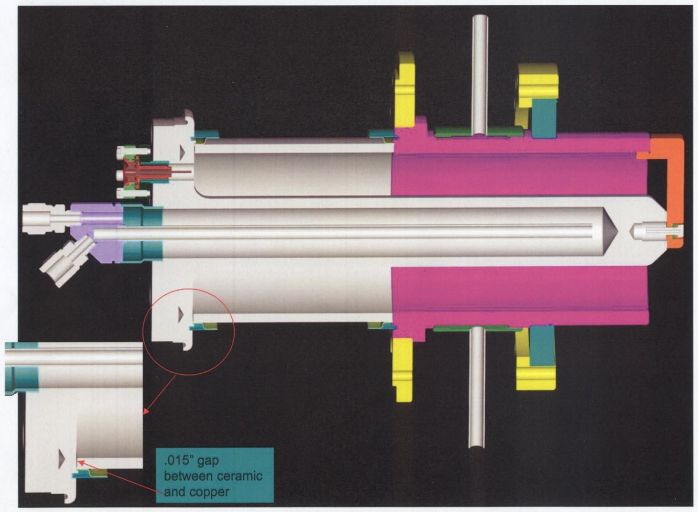
Conditioning
Another Signature Vacuum Waveform “The Glow”



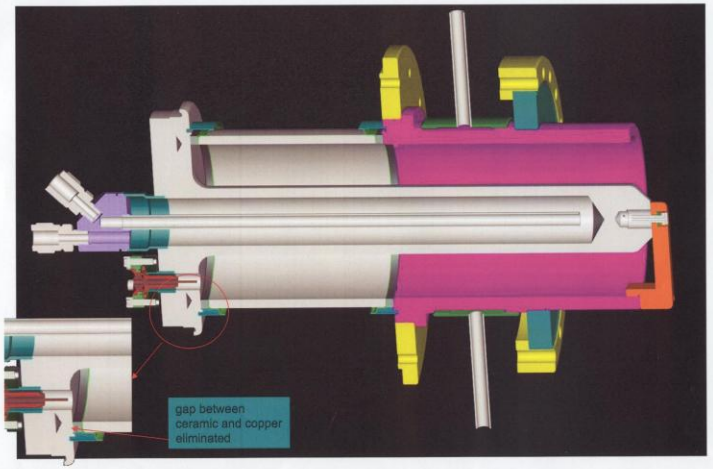
Recent Improvements

- Ti coated copper parts
- Metalized the ceramic edge gap caused by the ceramic to Kovar ring
  - 4 vacuum trips total to 100kW
- Full width Kovar ring to eliminate the gap (Yet to be tested)
- Installed an arc detector looking at the coupler through a quartz viewport
- Automated Conditioning Script
  - Several iterations with new features over the past 3 years
  - Mimics how an operator would react to events

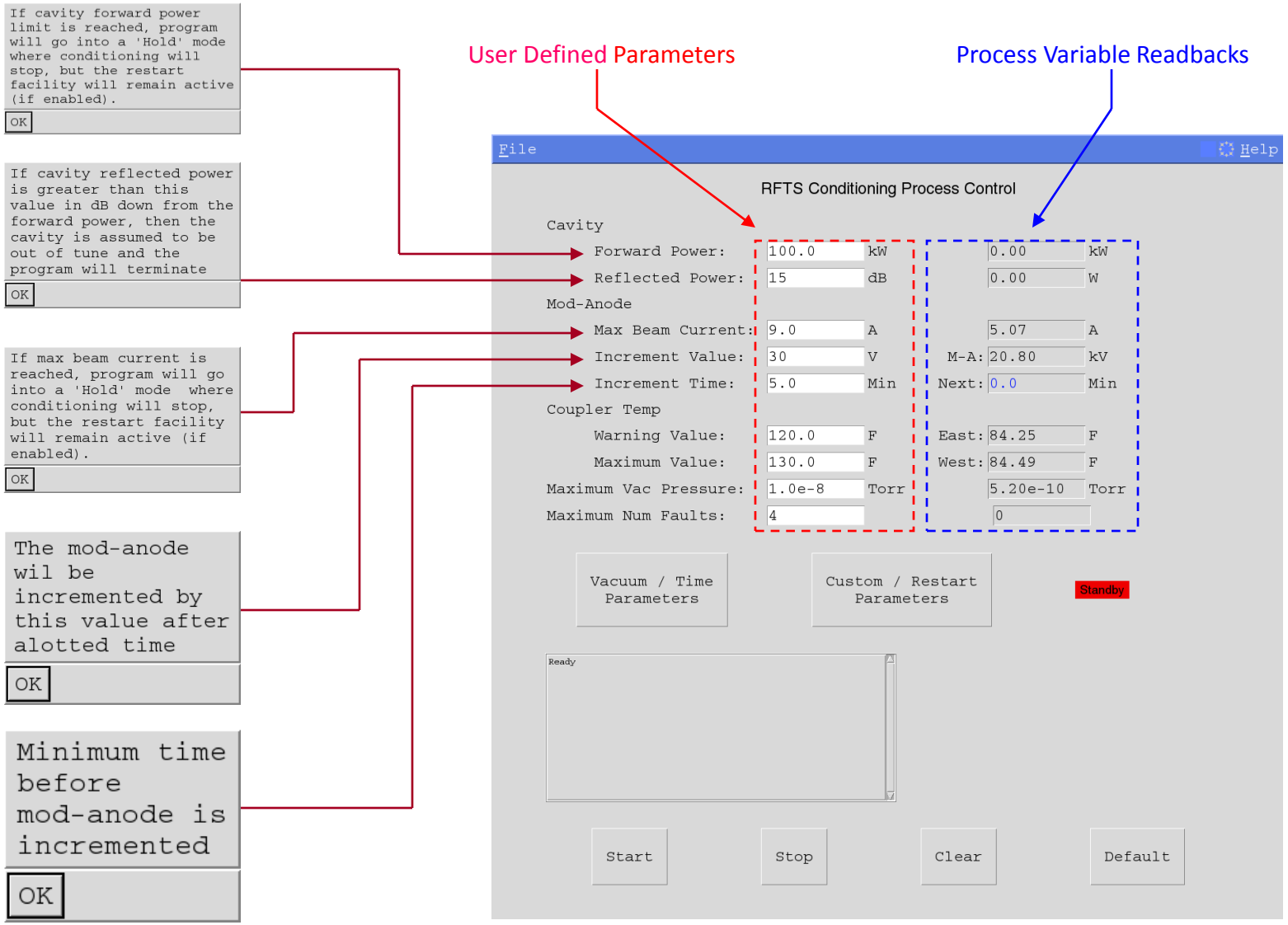
Coupler with Current Ceramic Design



Coupler with Proposed Ceramic Design



Auto-Conditioning Main Screen



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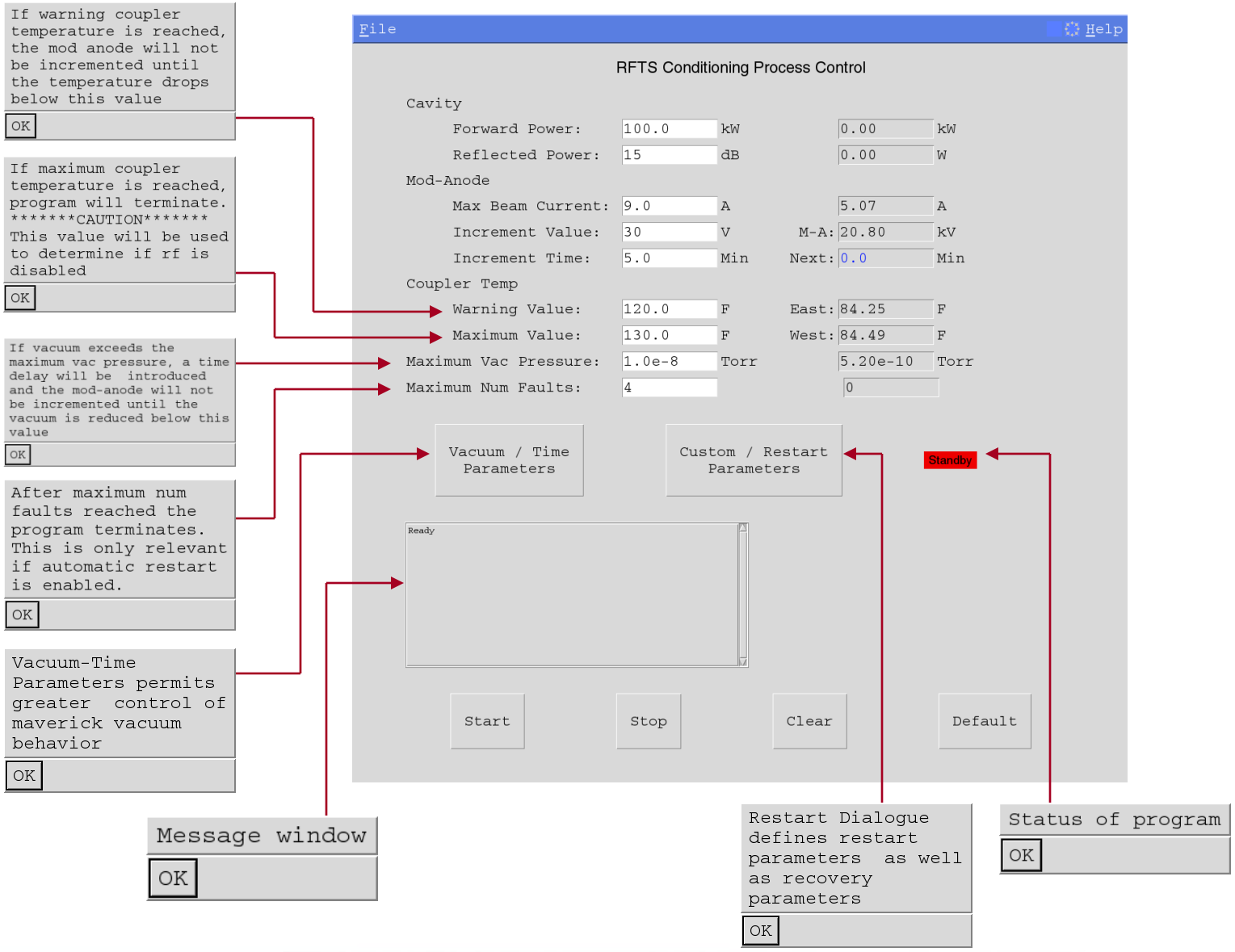
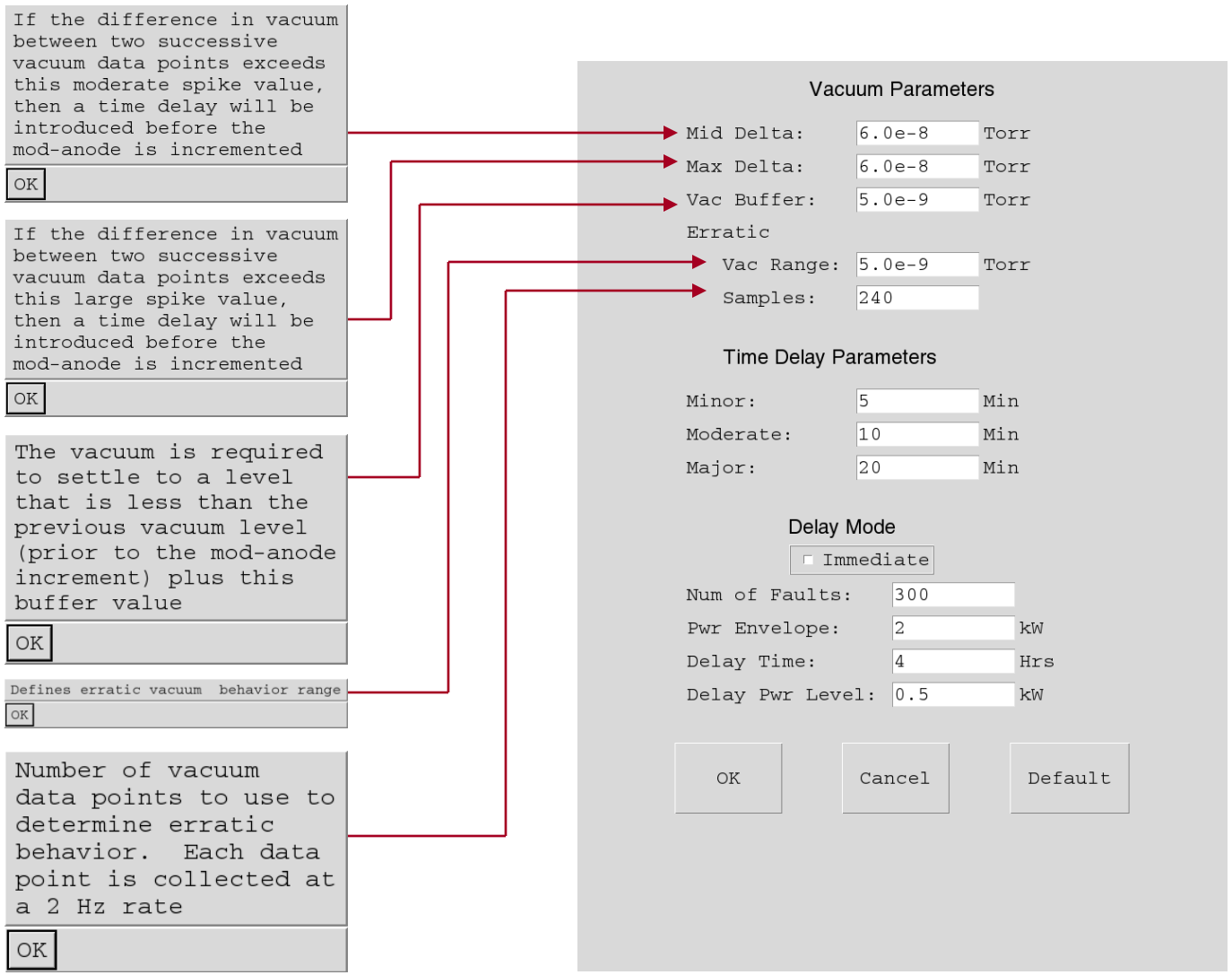
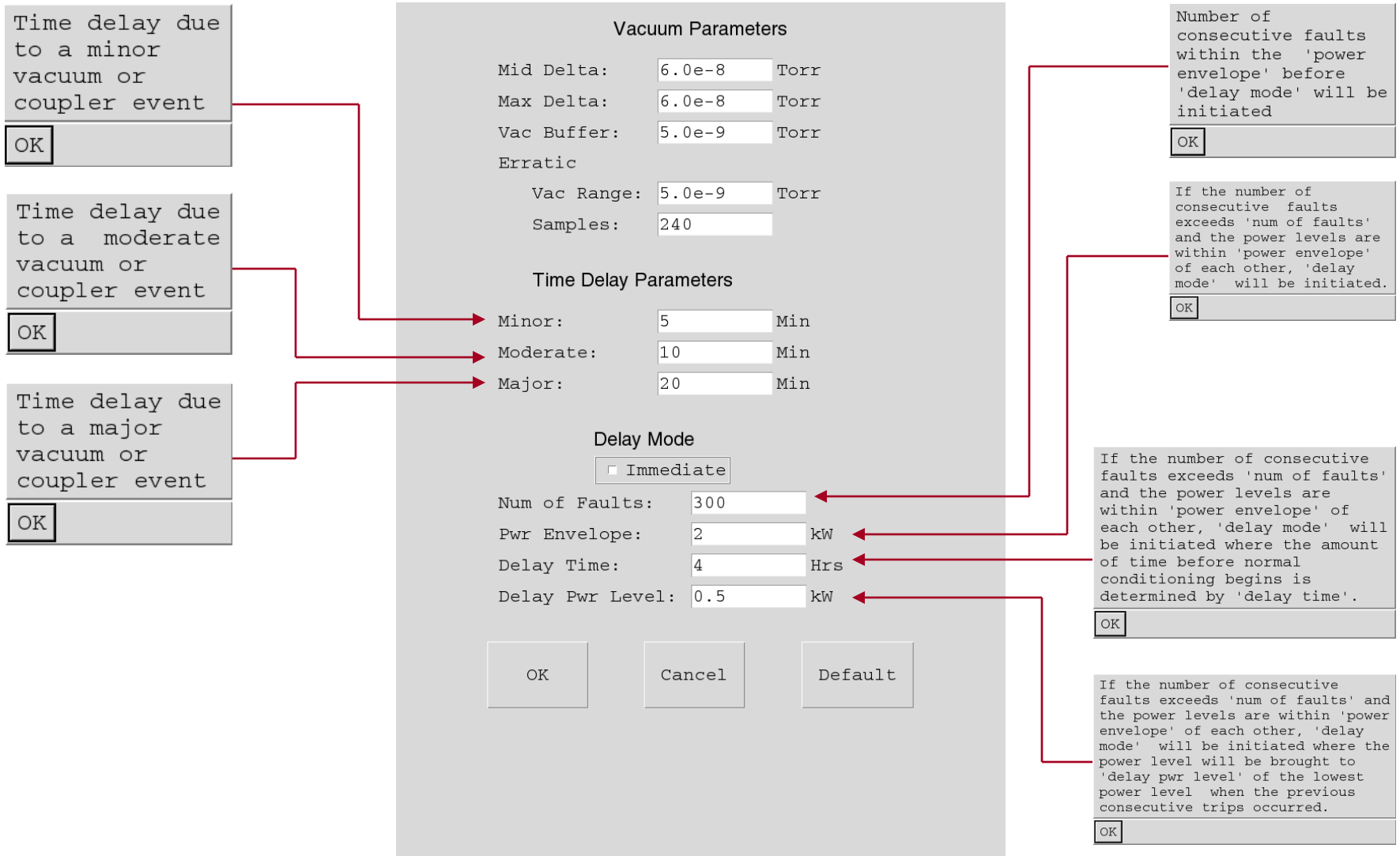


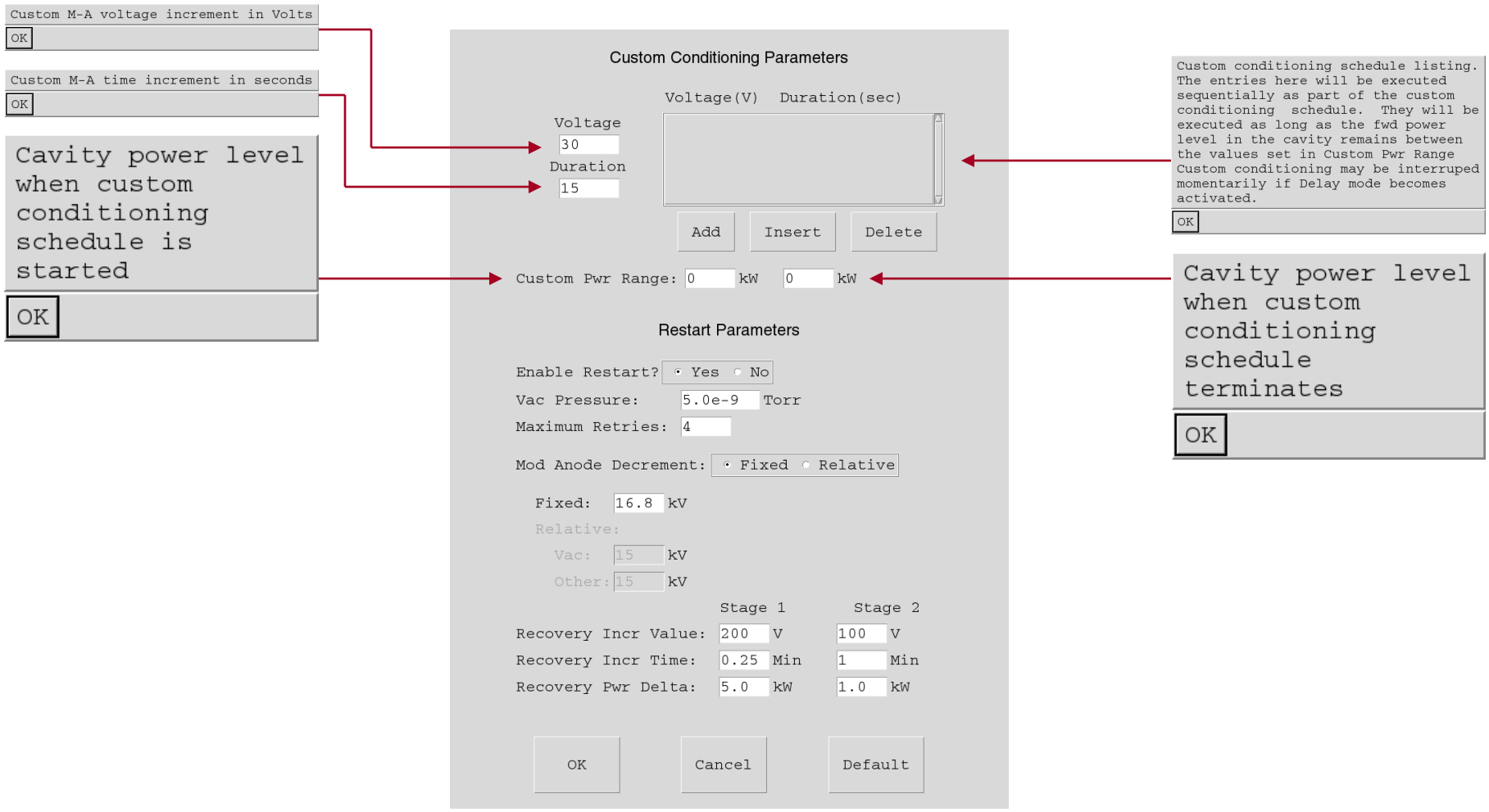
Vacuum/Time Parameters Screen



Vacuum/Time Parameters Screen



Restart and Custom Conditioning Screen



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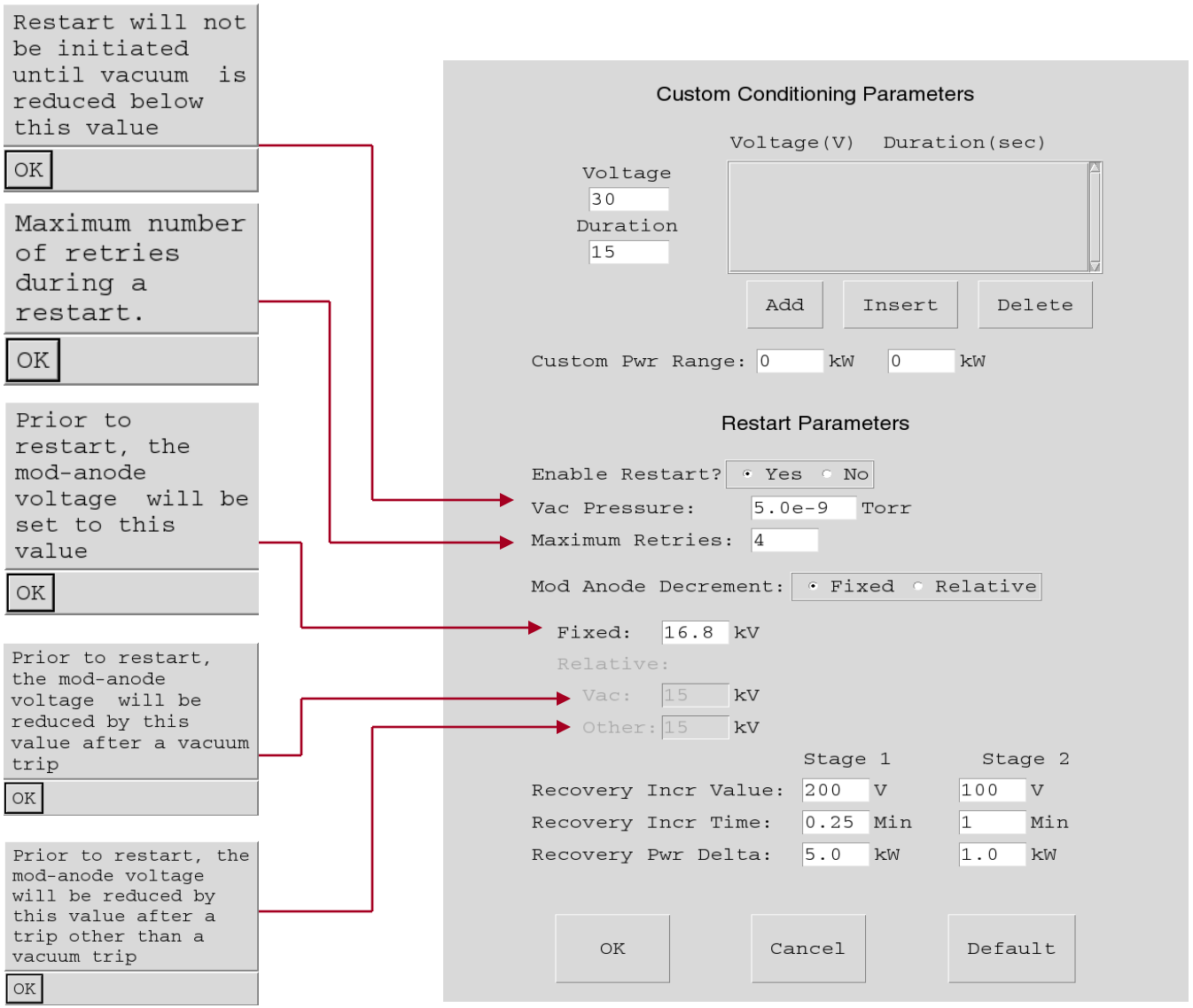

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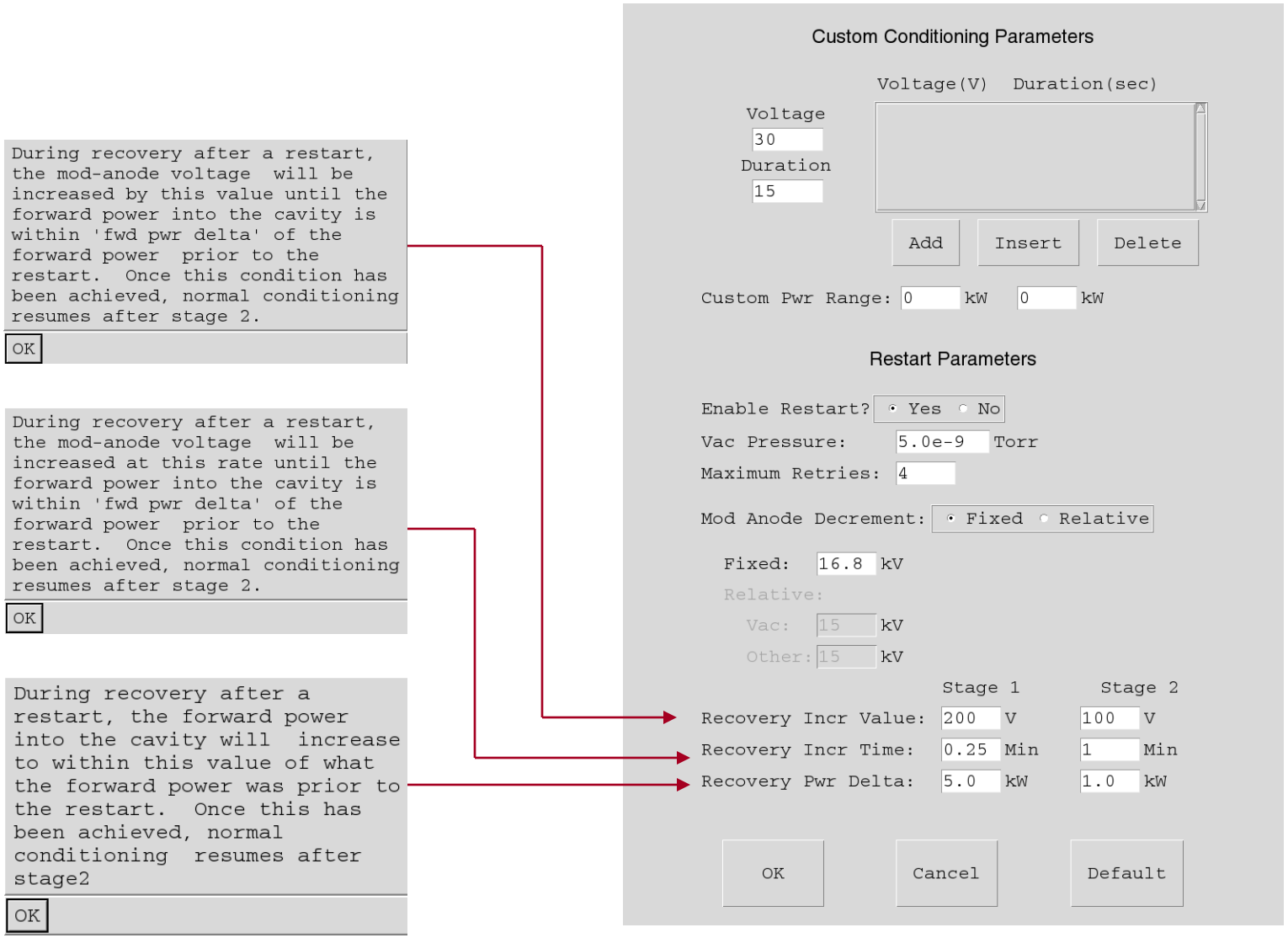

Future Plans

- Condition Booster tuners
- Test full-width Kovar ring coupler with Ti coated copper parts
- Test & condition HOM dampers
- Improve auto-conditioning script as needs arise

➢ Special thanks to Doug Horan, Geoff Waldschmidt, Dave Meyer, Leonard Morrison, John Pace, Andre McKenzie, John Hoyt, Mark Martens, Guy Harris, and Raul Mascote for their effort and support