

CLS Thales TH2161B system issues 2003-2024

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CLS system overview

- 52 kV V_k at 10.0 A
- Mod-anode bias
- 320 kW CW saturated power, 250 kW CW nominal system power (TH2161B)
- Thales ICS and Siemens PLC control system
- AFT 350kW ferrite loads
- AFT 350kW circulator
- CESR-B SC cavity



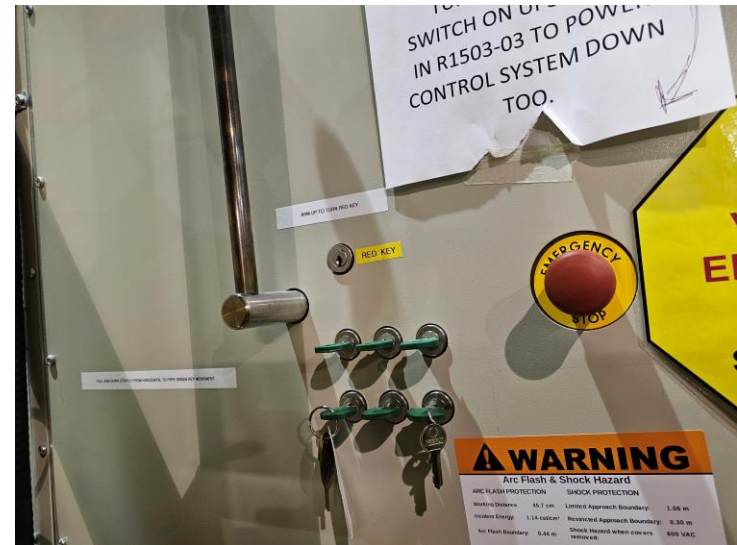
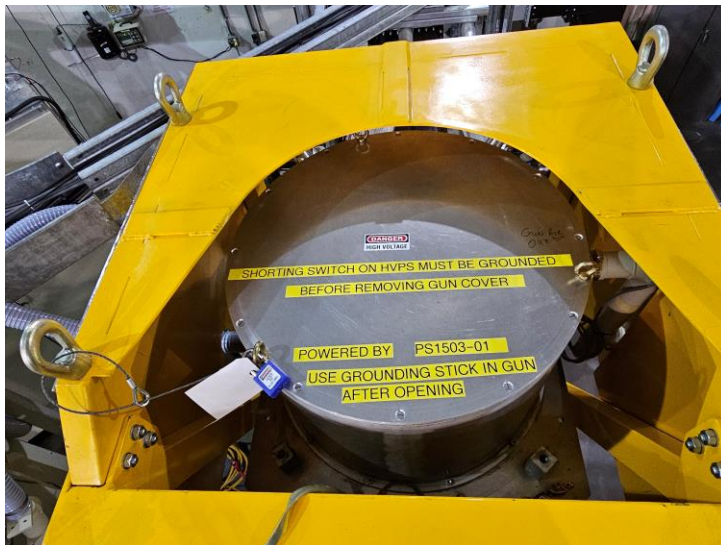
A note for safety

- Disconnected HV cables will self-charge to high potential and should be left shorted in storage and discharged whenever an open-circuit cable is to be worked on. Signage is recommended



A note for safety

- No interlocking/prevention of klystron gun tank cover removal to HV cable and HVPS short-circuit mechanism activated status exists. Lock and cable to cover were added with the key attached to another safety key in the HVPS switch bank



List of issues with PSU

- Cathode HV power supply High Voltage divider resistor and capacitor failures
- FuG IOP and Modulating Anode power supply AC Mains switches
- HV switching module fiberoptic Rx and Tx connector block covers falling off/light leakage
- HV Switching module 3 phase AC mains input connectors burning up



List of issues with PSU

- HV switching module contactor failure
- HV switching module electrolytic capacitor replacements as routine maintenance
- HV switching module discharge resistor replacements- insulators crumbling
- Main contactor “engaged” auxiliary switches intermittently
- Transient “Emergency Button” interlock relay in step-start cabinet



List of issues with HV cables

- Filament cable resistance variations
- Recall the safety note about discharging HV cables



List of issues with klystrons

- Early klystrons' collector input/output water connections labelled backwards
- Klystron 161004 RF output power and modulating anode current exhibit low frequency oscillation
- Intermittent Thales klystron window box and waveguide arc detectors tripping
- Ionization issues in klystron gun tank



List of issues with klystrons

- HVPS fast over-voltage trips after restarts



List of issues with support systems

- Klystron Focus Coil panel terminal strip connection faults
- Klystron Gun and Window blower cabinet issues
- Sorenson focus PS failures
- AFT circulator issues: high surface temperatures
- AFT arc detector issues
- AFT RF load water leakage
- Intermittent control system issues



Cathode HV power supply High Voltage divider resistor and capacitor failures



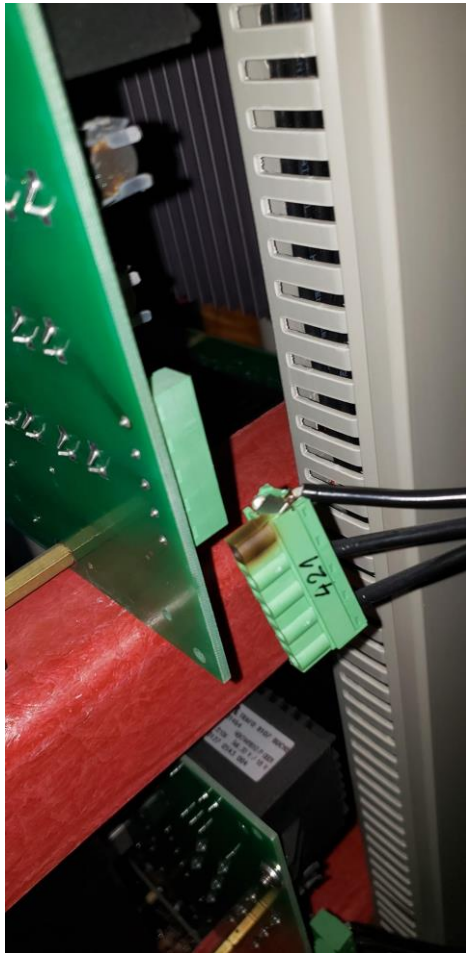
- This was the temporary replacement
- Breakdown of HV coating on resistors in HV deck filter tank caused unequal voltage on series capacitors exceeding cap breakdown voltage



HV switching module fibreoptic Rx and Tx connector block covers falling off/light leakage



HV Switching module 3 phase AC mains input connectors burning up

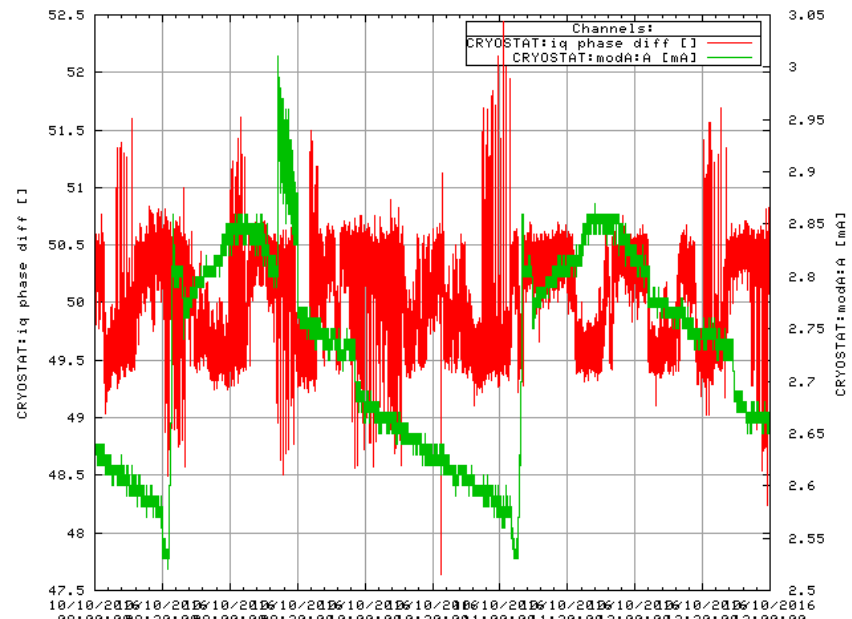
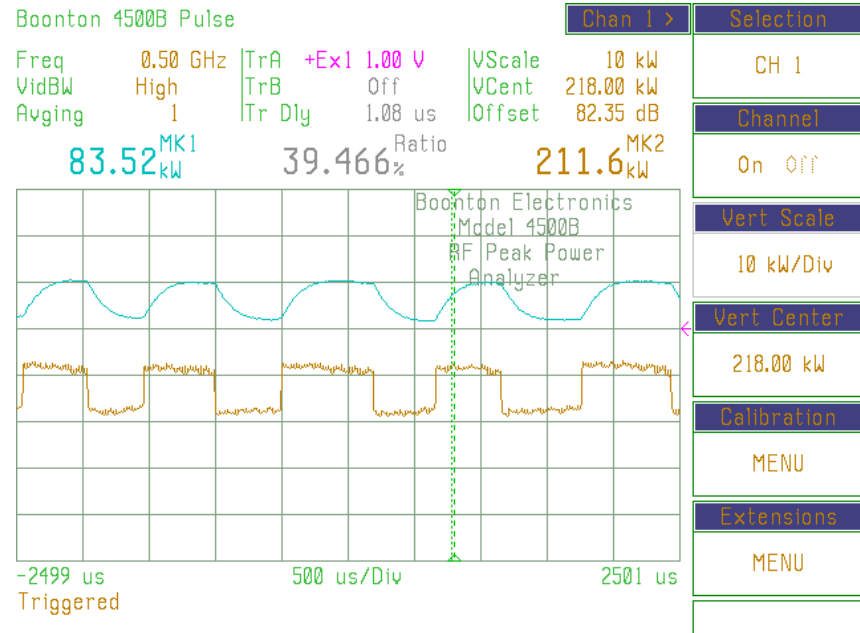


- Was found before any symptoms were noticed.
- Replaced with higher current version



Klystron 161004
RF output power
and modulating
anode current
exhibit low
frequency
oscillation

RF output power
 and modulating
 anode current
 exhibit low
 frequency oscillation
 when operating in
 intermediate RF
 power range



Klystron 161004 RF output power and modulating anode current exhibit low frequency oscillation

- 47K hours on tube.
- Possible collector damage due to water system issues?
- Or effect of reflection magnitude and phase angle on effect observed.
- See paper references for 2 causes of similar effects. (last slide)
- Klystron kept as emergency spare for use outside affected RF output power range.
- Will try spotknocking tests on this tube initially



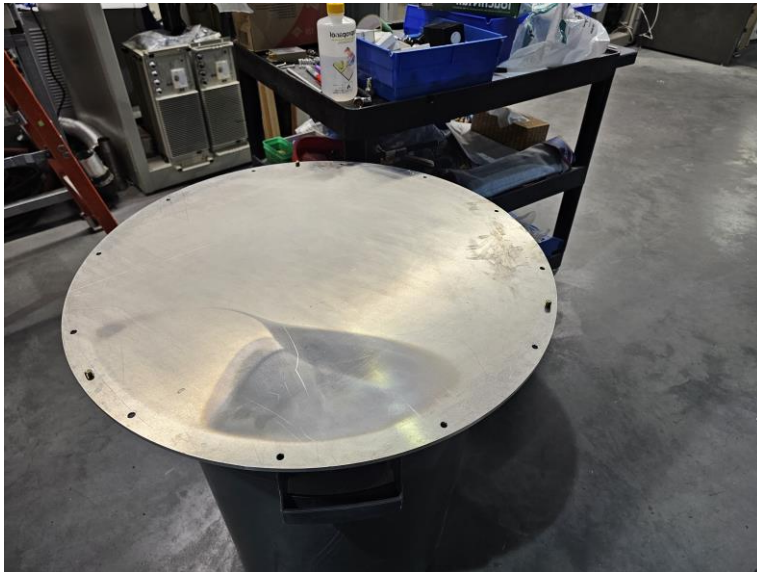
Intermittent Thales klystron window box and waveguide arc detectors tripping

- no apparent reason/even with no RF.
- Window box area clean.
- Removed PLC "test" lamp feed from detectors and issue went away. Reconnecting test function resulted in more trips within minutes. Test functions still disconnected during operations for now; to be addressed at some point.



Ionization issues in klystron gun tank

- Routing of flexible Pantak to gun wires too close to cover (161003 and 161004)
- Internal mounting of sharp-edged klystron lifting blocks inside tank instead of outside



Ionization issues in klystron gun tank

Installation of
internal lead
shielding with
resultant lead
ion shower on
ceramics
(161033)



Klystron Gun and Window blower cabinet issues

- Shedding filter cloth material from locally sourced replacement internal blower cabinet filter caused mess in gun tank and RF window arcs.
- HEPA post-filtration to be installed as part of blower cabinet redesign

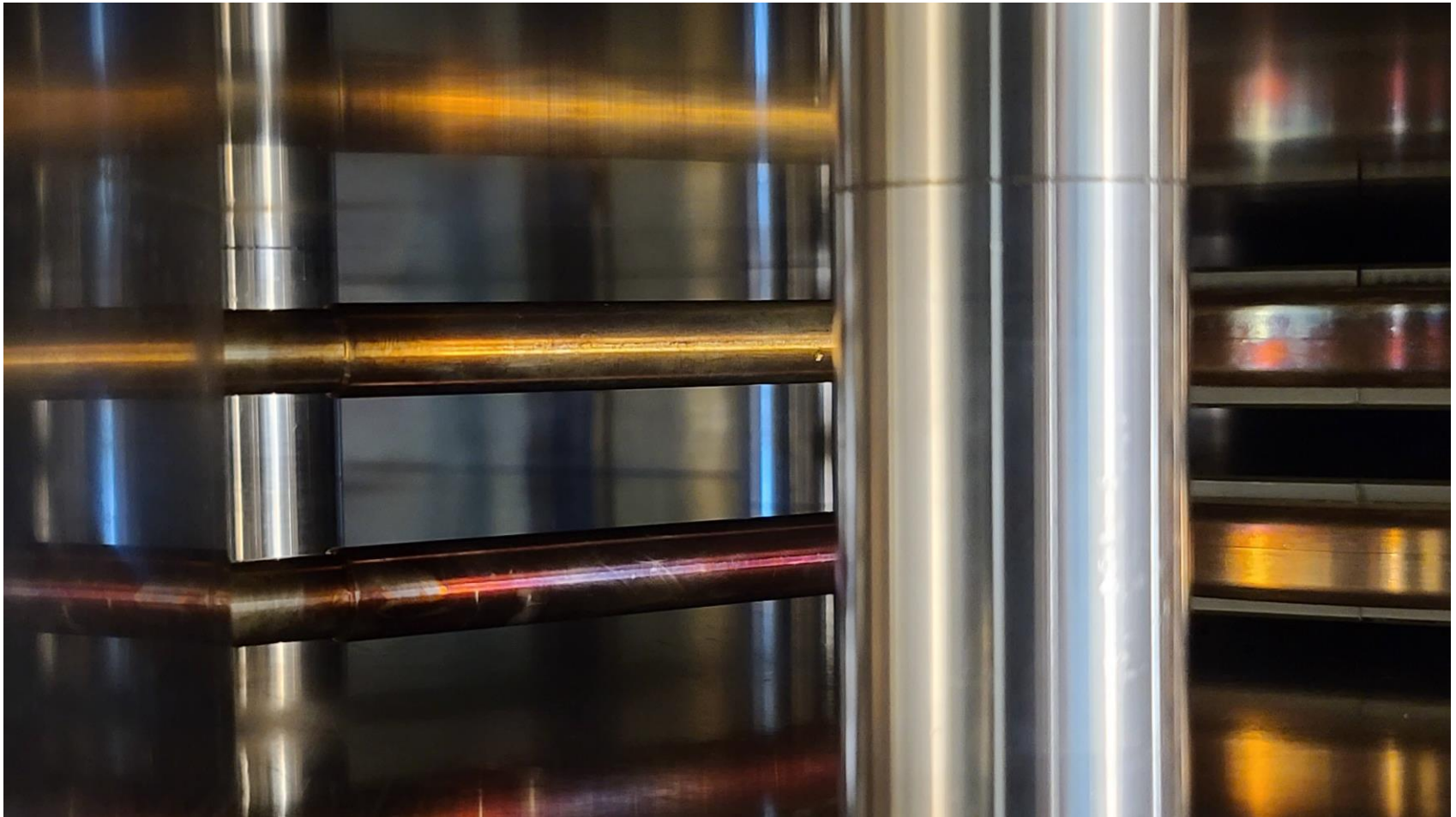


AFT circulator issues: high surface temperatures

- Temperatures (130 deg. C) on early unit at high H field standing wave phase.
- Port 1 cooling channel surfaces showing plating delamination and deep pitting of surface. Unit replaced to prevent potential klystron shower,
- Newer circulators have different cooling design and higher water flow specs. Ports still showing heating effects though.
- Amplifier power now limited to 250 kW CW.
- Poor “real world” measured power isolation of 19 dB at our cavity waveguide reflection phase on our initial unit.
- OK at low power. Better/good enough “real world” measured high power RF return loss seen on newer circulators, though some effects of later cavity iris Qext retuning may also be involved.
- Potential to extend cavity waveguide to move H max/E max standing wave longitudinal location relative to circulator ferrites, spacers machined but not fitted.



AFT circulator issues: high surface temperatures



AFT arc detector issues

- Scintillation induced trips from poorly shielded glass fibres addressed by substituting new AFT plastic fibres

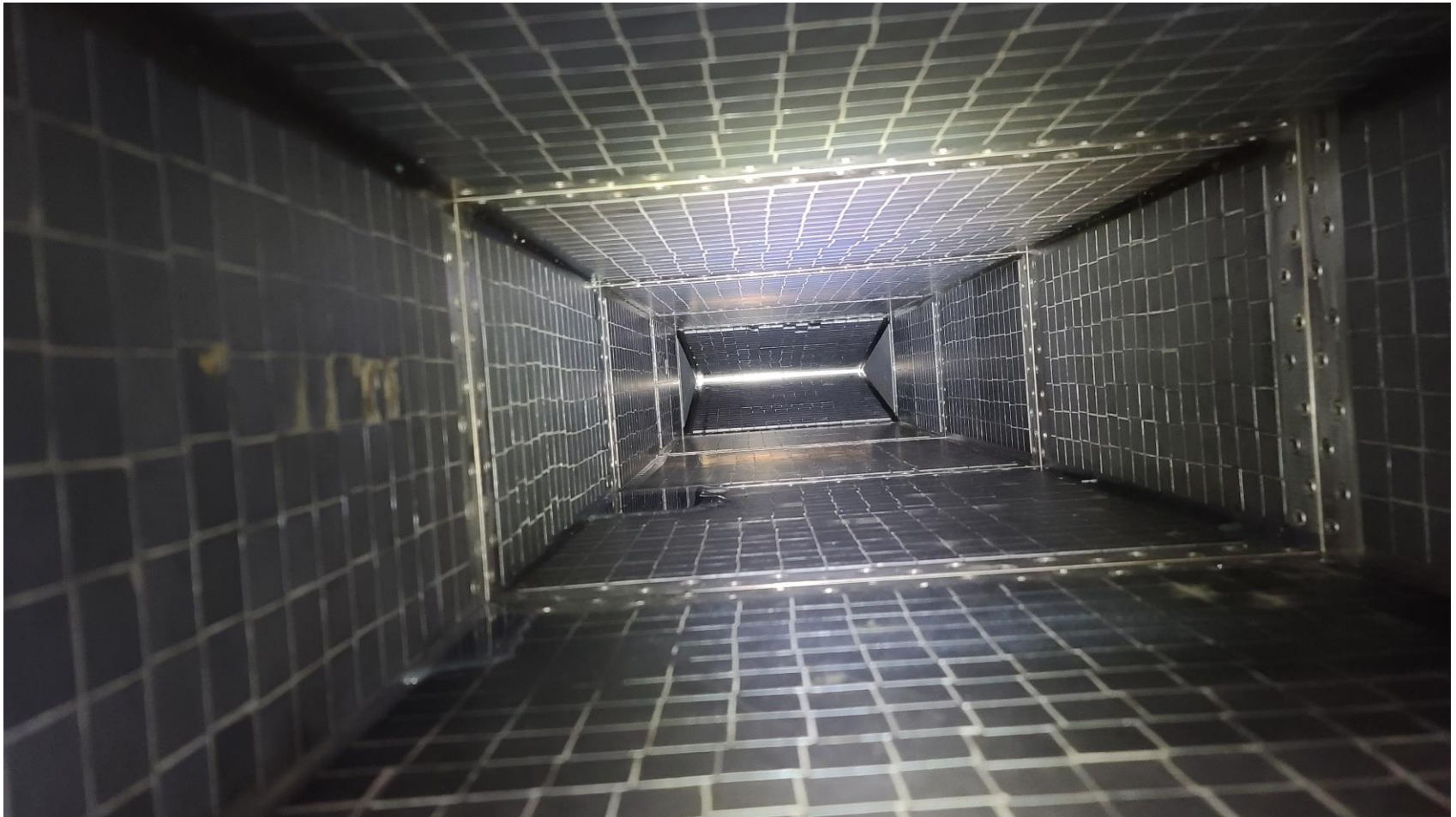


AFT RF load water leakage

- Test Load: circulator port 2 condensation noted after maintenance outage with system connected to load.
- Reject Load: sudden "flaring" of reflected power to klystron above 225 kW during circulator short circuit testing. Steam?
- Both loads found to be leaking at joints at e-plane/H-plane interior corners along length of load. Test load failure ~ 1 year before reject load.
- Spare load from BR RF installed to keep system running



AFT RF load water leakage



Intermittent control system issues

- Result in fast crashes through states without known cause.
- Non-intuitive indicated first fault for amplifier trip-to end state.
- Possibility that we currently read remote V_k adjustment parameter is intermittently set low through the remote interface.
- Troubleshooting still in progress.



Thank you

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Information related to topics not covered in the presentation.

- Klystron Focus Coil panel terminal strip connection faults, melted terminal strip and heated connector lugs. Eventual short circuit across coil with near limits and out of limits Focus V conditions. Better terminal strip and soldering crimped lugs, routine checking required.
- Sorenson focus PS failures- Internal replacement fans were found to alter the internal voltage sense when connected and cause PS to trip on low voltage. Recalibration was required with new fans to allow system compensation.
- FuG IOP and Modulating Anode power supply AC Mains switches- high contact resistance causing intermittent operation after switch use Switches replaced.
- HV switching module contactor failure. Blown fuses. Contactors replaced
- HV switching module electrolytic capacitor replacements as routine maintenance.
- HV switching module discharge resistor replacements- insulators crumbling. Substituted replacements deteriorated quickly, had to reorder original types.
- Klystron Gun and Window blower cabinet issues: Always ran hot inside causing need for precooling of cabinet air input. This to prevent window air input overtemperature trips in hot weather. Window arcs- numerous causes from cabinet interior: crumbling hoses on blower air output from cabinet heat, deteriorating cabinet seals,. New cabinet with post filtration designed. Mechanical analysis of existing cabinet shows window blower selection was too large causing motor heating issue. This temperature aberration was also observed on early visit to NSLS2 during their amplifier commissioning.
- HVPS fast over-voltage trips after restarts traced to fast loss of klystron 161003 current with resulting cathode V power supply overshoot. OK on hot restarts. Occurring at gradually decreasing intervals (10-30 minutes) after cold restarts of tube. Temporarily installed fast HV PS current monitor infers arcs between modulating anode and cathode. This tube always had high mod anode current and did not like filament/ heater power as low as expected from heating curve tests. Only 10.5 K hours on tube. Spotknocking system as used at APS built by FuG for CLS. To be tried to reclaim this tube though lead contamination on external ceramics may also be to blame. If so, cleaning of ceramic may not be easy or possible even with recommended sandblasting due to contamination characteristics.
- Main contactor “engaged” auxiliary switches intermittently indicating contactor not pulled in though contactor working correctly. Mechanical tolerances poor on this setup.
- “Emergency Button” interlock relay in step-start cabinet can transiently “open” when main contactor armature engages (mechanical vibration coupling). Drops system to “Off”.



External reference links

- Links for 161004 mod anode/RF output noise possibilities:
- https://accelconf.web.cern.ch/e92/PDF/EPAC1992_1215.PDF
- <https://arxiv.org/ftp/physics/papers/0008/0008069.pdf>
- Link for spotknocking presentation from APS
- https://www.aps.anl.gov/files/APS-Uploads/RF/Presentations-Lectures-Training/Cross-Training/CrossTraining_Spotknocking.pdf

