

RF MACHINES AT APS



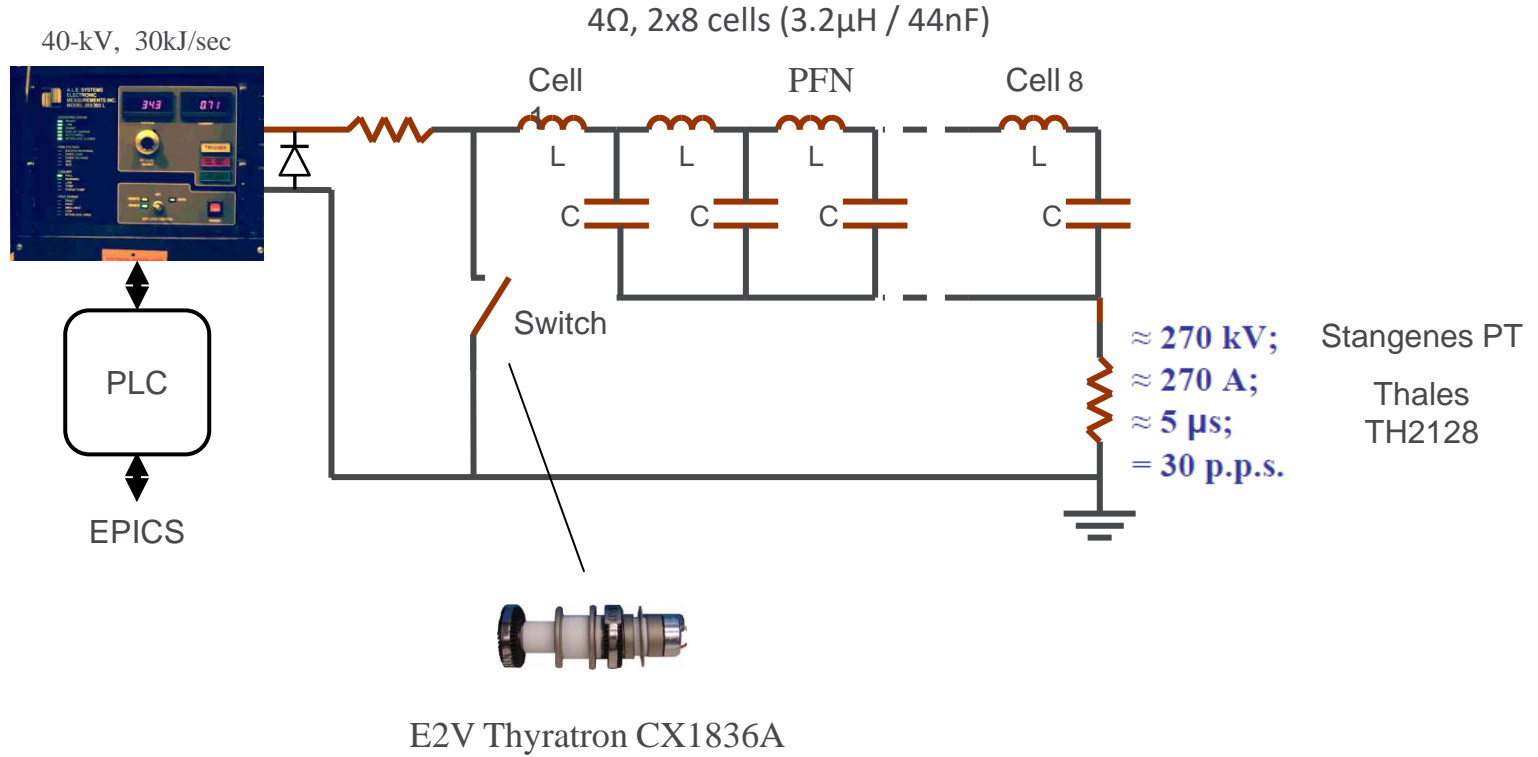
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PRESENT DAY LINAC MODULATORS K1-8

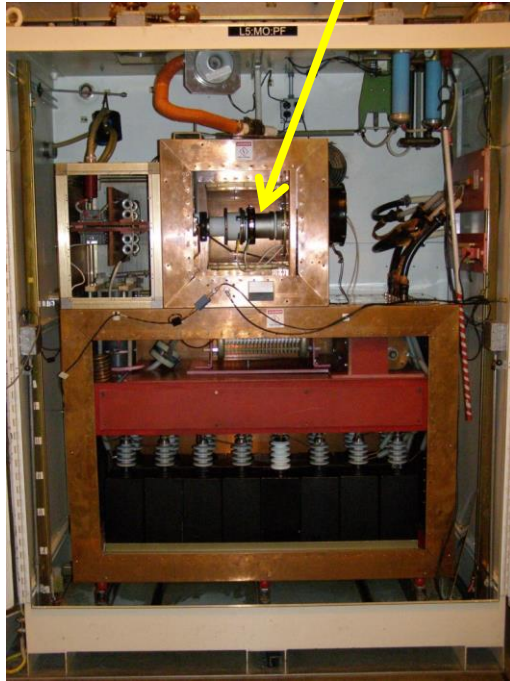
- Modulators K1,3,4,5,6 &7 use conventional pulse forming network.
- 4.5 μ s pulse width, 30Hz rep rate, 30MW.
- TED TH2128D klystron.
- K6 used for spares and testing.
- K7 within building 413 test stand.
- ScandiNova solid-state modulator, recently installed at K2 & K8.
- 4.5 μ s pulse width, 30Hz rep rate, 50MW.
- Canon E3712 klystron.
- K8 within building 413 test stand.
- Digital LLRF



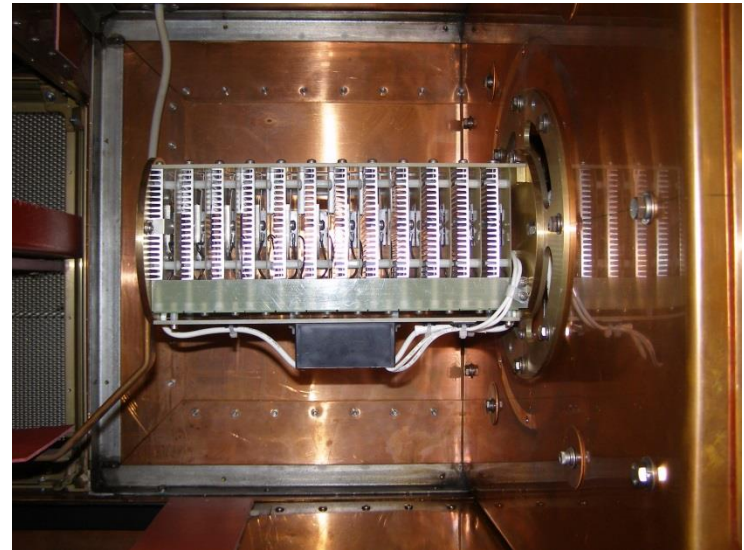
LINAC MODULATOR



CX1863A Thyatron



S56-12 Thyristor



Thyratron vs. Solid-State Switch

	Thyratron	Solid-State Switch
Peak Forward Voltage, kV	70	48 (60)*
Peak Anode Current, kA	10	7 (10)*
Rate of Rise (di/dt), kA/ μ s	10	30
Triggering Pulses	Up to 1,500 V	Fiber-optic & 24V
Filament Power, Watts	610	0

* Numbers in the parentheses are for non-repetitive voltage (current)

PFN CAPACITOR - ORIGINAL EXCEEDED 100X LIFETIME SPECIFICATION



Old: Allen-Bradley Controller

- Limited amount of information transmitted PLC↔EPICS, quantity 128 - 16 bit words.
- Table transfer - discrete and integers (16 bit).
- Open Frame.

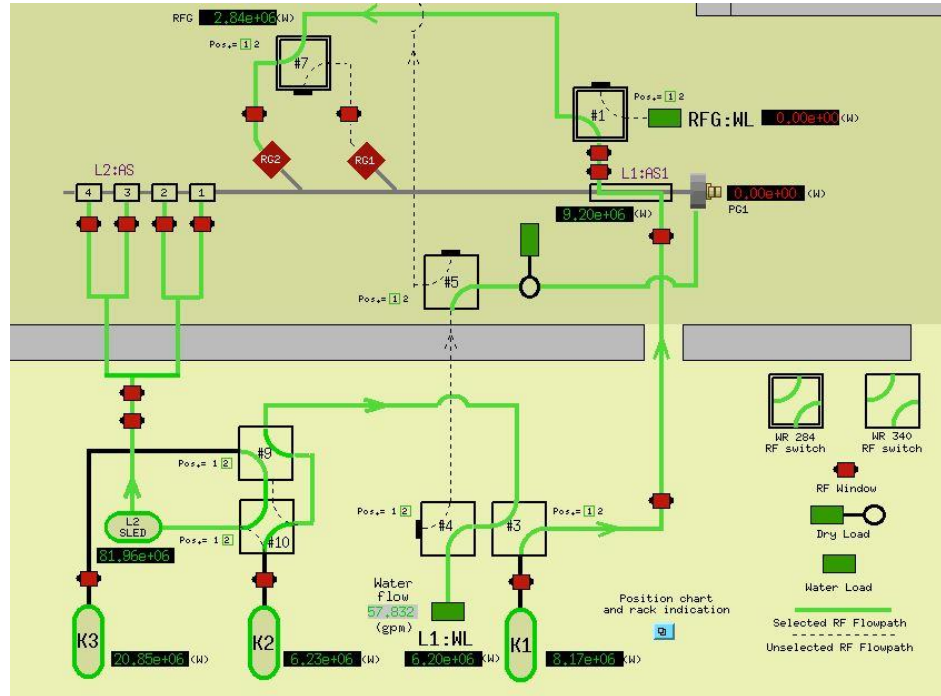


New: Automation Direct Controller

- Large amount of information transmitted via floating point (32 bit) and discrete.
- Microprocessor monitored by EPICS.
- RF Group standardized PLC.
- Chassis construction with filtered connectors.
- Last unit installed May 2014.



LINAC RF SWITCHING SYSTEM



PAR FUNDAMENTAL 1&2



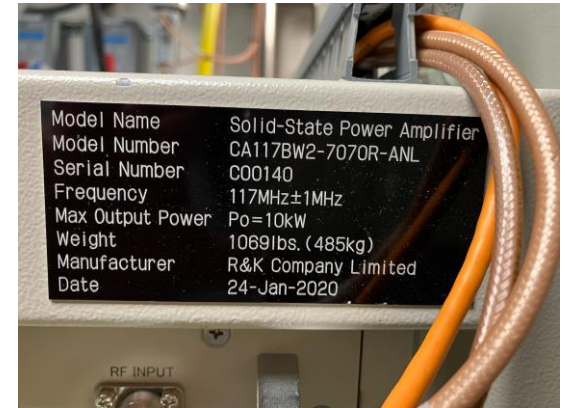
- Two amplifiers, 1 operation & 1 backup.
- APS constructed
- 9.77MHz
- CW operation.
- 5kW.
- Eimac Triode YU-106 in grounded grid configuration.
- Recently upgraded LDMOS driver amp.

PAR HARMONIC 1&2

117MHZ, 2HZ PULSED

CIRCULATOR USED BETWEEN AMP AND CAVITY TO PROTECT THE AMP

- 3kW.
- Eimac Triode 3CX3000A7.
- Back-up.
- New 10kW solid-state system.
- Main.



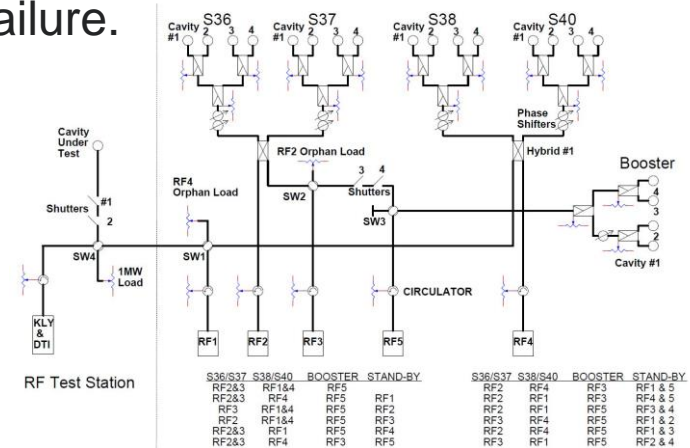
STORAGE RING RF1,2,3 & 4 - BOOSTER RF5

- 2MW dc power supply.
- Ignitron crowbar.
- SCR phase angle control for output voltage.
- TH5188 tetrodes used for mod-anode voltage regulation.
- 352MHz, 1MW rf CW klystron.
- Thales 2089A or EEV K3513.

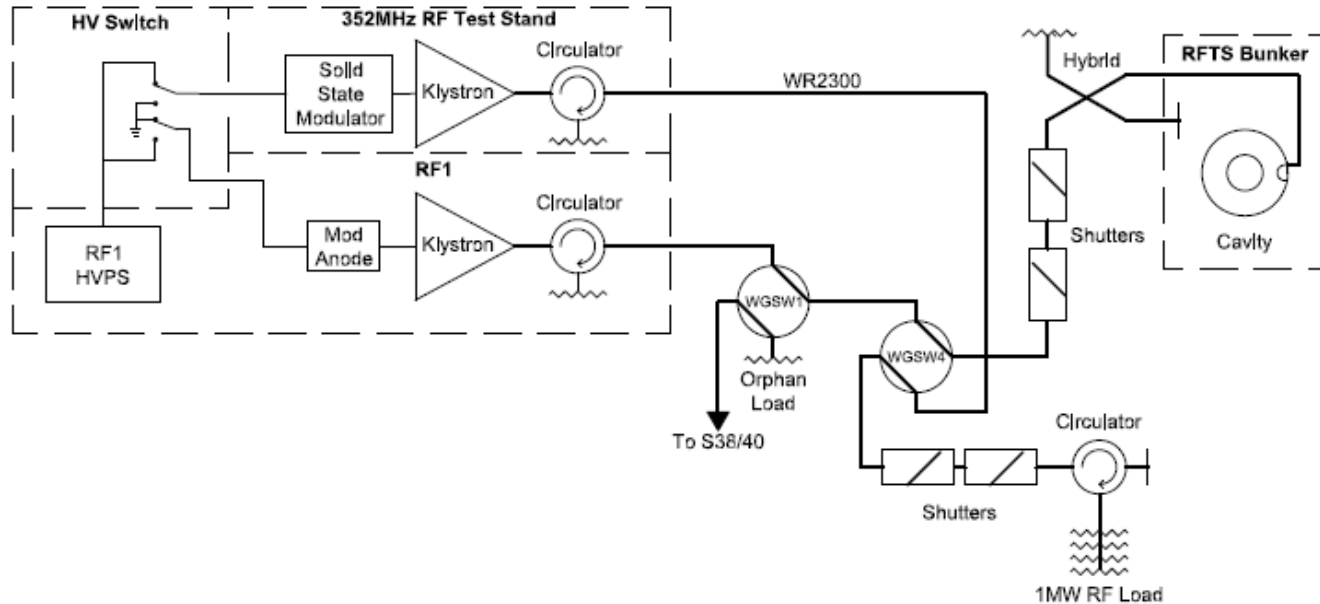


RF SYSTEM OPERATION

- Storage Ring can operate using two RF stations.
- RF3 backs up RF5 for Booster operation.
- Waveguide switching (WGSW) allows 12 operating modes.
- Maintenance performed 3 times / year.
- Repairs performed when system is offline, LOTO with ZVV.
- Typically, 2-3 WGSW per year due to system failure.



352MHz RFTS Line Diagram



2MW DC KPS Control Interface

Old: Manufacture Design

- Obsolete boards and ICs
- 486 PC running Windows95 GUI
- Proprietary E²PROM program
- GPIB communication error
- No longer supported by manufacture



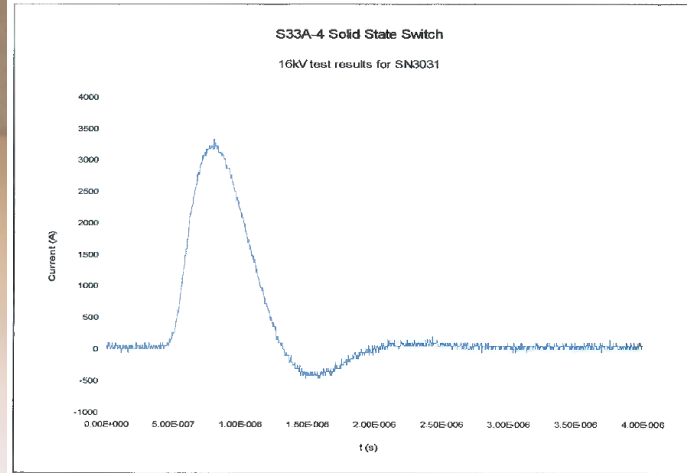
New: Automation Direct Controller

- Same details as LINAC Modulator Controller
- Final unit installed 2013.



Crowbar Ignitron Trigger

5C22 → JAN8613 → S33A-4

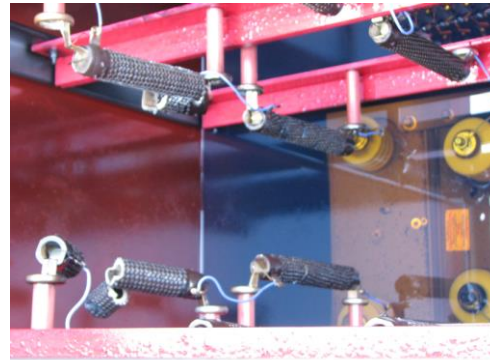
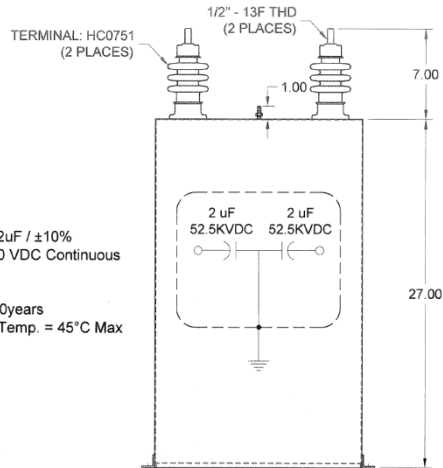


Vendor's test data 16-kV @3.2-kA_{pk}

RF5 Example



- 1 Failed capacitor.
- 4 Damaged 16Ω , 300W resistors.
- Loose transformer ground connection.
- Carbon deposits on components and walls.
- Loose transformer core block hardware.
- ~1% of diodes damaged.



SYSTEM OBSOLESCENCE AND UPGRADE

- 352MHz 1MW klystrons are no longer available, we have 5 spares.
- APS has decided to replace klystron systems RF1-RF4 with solid-state (SS) as soon as possible.
- Single amplifier system per cavity.
- Considering SS replacement for Booster RF5.

DESIGN CONSIDERATION

- ScandiNova modulator: Recommended and used at other national laboratories, many hospitals and industries purchasing smaller units, good presence in industry, good vendor communication, modular IGBT circuitry, turn-key system, provided a list of modules and components for spares.
- For SR, up to 10% of SSA system module failure and full output power is still possible.
- Allow ~20% power overhead.
- SS implementation will be qty. 12, 160kW CW systems, each driving one single-cell accelerating cavity.
- 200kW circulator between SSA and accelerating cavity to isolate / protect SSA.
- Plan to stock spare power amplifier assemblies and drain power supplies to allow for module-level repair of failed units.

THANK YOU FOR YOUR ATTENTION



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