

ANHVPS-11: Arc Protection and Fast Recovery in X-Ray High Voltage Power Supplies

A practical ATI guide to specifying arc detection, event-energy limiting, arc recovery, retry logic, reporting, and acceptance testing for real high-voltage loads.

How to use this note: Read the first table to write the RFQ, then use Section 6 to prove the requested detection, event-energy limit, arc recovery, retry policy, and reporting behavior.

Arcs are not exotic surprises in high-voltage systems. They are normal stress events that occur in real X-ray tubes, cables, analytical sources, piezo stacks, ultrasonic loads, and pulsed loads. Ordinary current regulation and over-current protection keep a supply well behaved during expected load changes; microsecond arc detection is the faster emergency channel for a sudden low-impedance discharge. The buying question is therefore not whether a box claims “arc protection,” but whether its complete arc behavior is specified and verified.

Arc behavior to specify	What it means	Useful RFQ wording
Detection latency	How quickly the supply recognizes a microsecond low-impedance event; this is different from ordinary current-loop response or slow over-current protection.	State required arc detection time, sensed signals, measurement condition, and whether voltage collapse, current spike, and dv/dt are combined.
Energy per event	Maximum event energy delivered into a hard arc before the supply limits or blanks the output.	Specify mJ or J at full operating voltage with representative cable capacitance; ask for the verification method in Section 6.
Arc recovery profile	Voltage return behavior after the arc: ramp rate, recovery overshoot, ringing, settling time, and re-strike response.	State maximum overshoot, settling band, re-strike policy, and recovery time target.
Retry and reporting	How the supply retries, backs off, latches, and communicates arc information to the host.	State retry count, cool-down time, digital fault line, arc-count pulse, serial message, timestamp, or trend log.

Arc emergency team

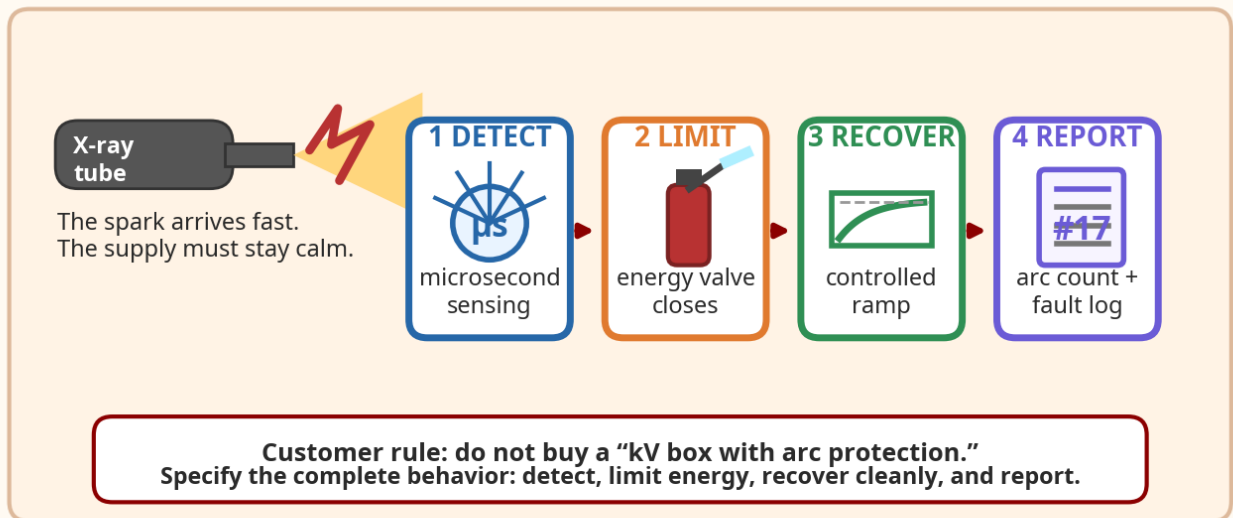


Figure 1. Detect, limit, recover, and report—the arc emergency team.

1. What actually happens during an arc

During an arc, load impedance can collapse from megaohms to a few ohms or less in microseconds. For the supply, the event often begins as a capacitive discharge: energy stored in the output multiplier, cable, and load finds a sudden low-impedance path. Public HVPS application guidance emphasizes that arc currents can be much larger than the normal DC output current and that ordinary current feedback is not the same mechanism as microsecond arc detection.[1]

The small equation $E \approx 1/2 C V^2$ explains why arc behavior must be specified with cable length, output capacitance, and operating voltage. Doubling voltage increases stored energy by four. A long cable that looks harmless in a schematic can become a significant part of the arc-energy budget.

Worked example: If the effective output-plus-cable capacitance is 100 pF at 60 kV, the stored energy is about 0.18 J. If a longer cable or load raises the capacitance to 500 pF at the same voltage, the stored energy becomes about 0.90 J. These numbers are illustrative, but the lesson is real: a complete specification states the representative capacitance, voltage, allowed event energy, and test condition.

Energy bucket

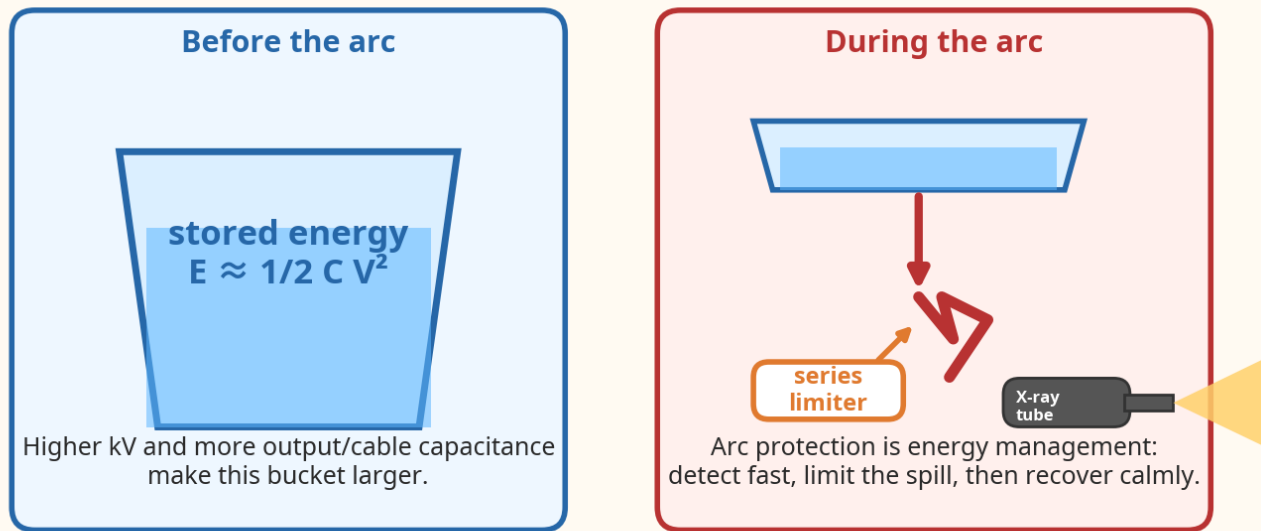


Figure 2. Stored energy is the arc fuel; protection controls the spill.

The business cost of poor arc protection is practical and expensive. Each uncontrolled event can shorten tube life, trigger image retakes, create false rejects, shift calibration, interrupt production, or start a field-service investigation with too little fault data. A few milliseconds of better behavior can prevent hours of downtime later.

2. The four-step arc-handling sequence

Every professional X-ray generator or high-voltage supply follows the same logical fire drill. Weak designs skip a station; strong designs make each station measurable. The sequence is simple enough to remember but demanding enough that it must be specified and verified.

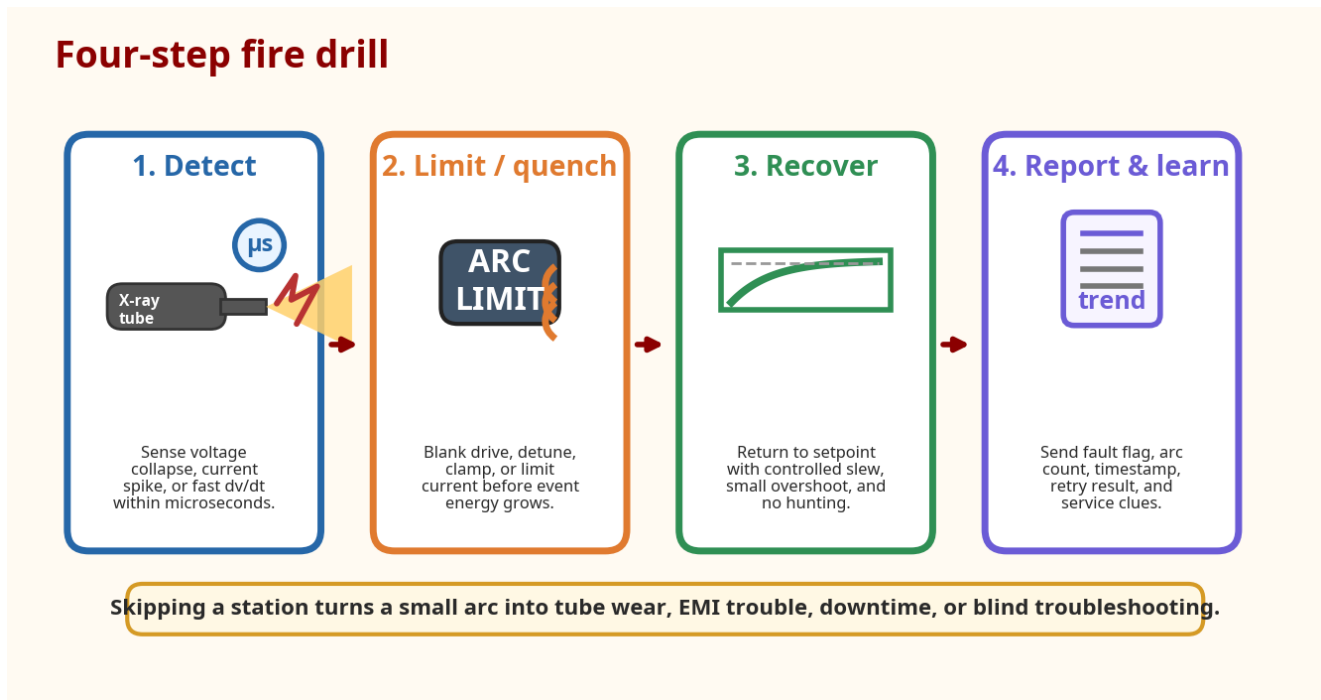


Figure 3. Four stations: detect, limit, recover, and report.

Step	Good behavior	Why customers care
Detect	Fast current/voltage/dv/dt sensing reacts in microseconds rather than waiting for ordinary current-loop dynamics.	Early recognition limits electrode pitting, EMI shock, and control-loop confusion.
Limit / quench	Drive blanking, active limiting, resonant detuning, series resistance, or clamps reduce delivered energy.	The arc becomes a controlled event instead of a destructive plasma pulse.
Arc recovery	The output returns with defined slew, low recovery overshoot, and stable settling.	Prevents one spark from becoming a chain of re-strikes or image artifacts.
Report & learn	The host receives a fault, count, timestamp, retry result, or severity clue.	Arc-rate trends support tube conditioning, maintenance, and field-service diagnosis.

The customer-facing lesson is direct: “arc protected” is not a complete requirement. A useful requirement says how fast the supply detects, how much energy it may deliver, how it returns to setpoint, and what information reaches the host.

3. Design techniques that actually work

A good arc-protection design combines fast sensing, controlled energy flow, and thoughtful retry logic. Spellman’s public explanation separates fast arc sensing from the slower current feedback loop used for normal DC regulation.[1] XP Power similarly frames arcing as stored-energy discharge through limiting elements and describes arc counting with inhibit behavior when the arc rate becomes unsafe.[2] Basic short-circuit and overcurrent protection are valuable safeguards, but public protection discussions also show why they should not be mistaken for a full arc-behavior specification.[3]

The best implementation depends on voltage, current, cable capacitance, duty cycle, tube type, grounding, and interface. For example, a compact analytical source may prioritize very clean recovery and software-visible arc count, while a production inspection cabinet may prioritize configurable retry policy and uptime without hiding repeated tube stress.

Technique	Strength	Watch item	Best use
Fast current sensing	Responds to large arc discharge current that normal DC feedback may not represent.	Sensor bandwidth, isolation, noise immunity, and threshold selection.	X-ray supplies, analytical sources, and real loads with cable capacitance.
Voltage-collapse / dv/dt sensing	Captures the sudden output event even when average current is low.	Divider bandwidth, safe layout, and false-trigger rejection.	Sensitive tubes and systems where rapid voltage collapse is the clearest symptom.
Series limiting and active blanking	Controls peak current and removes drive before stored energy grows.	Thermal stress in limiters and switch SOA during repetitive arcs.	OEM systems where tube life and fast return matter.
Short-circuit / overcurrent protection	Protects hardware during sustained faults and abnormal loads.	Useful but not equivalent to fast arc detection, event-energy limiting, or defined arc recovery.	Baseline protection that must be paired with application-specific arc behavior.
Retry / adaptive back-off	Avoids nuisance lockout while preventing rapid repeated arcs.	Must be matched to tube conditioning and safety policy.	Production tools that need uptime but cannot hide repeated tube stress.
Arc counting and host reporting	Turns a fault into data for maintenance and troubleshooting.	Define interface, timestamp, count reset, and severity estimate.	Systems requiring field diagnostics, service logs, or predictive maintenance.

Mini-glossary for RFQs: these four terms often decide whether arc protection is truly engineered or only named on a datasheet.

Term	Plain meaning for specification work
dv/dt	The rate of voltage change. A very fast voltage collapse is often a cleaner arc clue than average current alone.
SOA	Safe operating area: the voltage, current, energy, and time region where switches or limiters can survive repetitive stress.
Crowbar	A protective clamp path that intentionally diverts or dumps energy so the tube or load does not receive the full event.
Re-strike	A second arc triggered during recovery, often caused by overshoot, ringing, humidity, contamination, or an aggressive retry profile.

Smart arc bouncer analogy: A good supply lets normal regulated current through the door, stops the disruptive arc, then writes down what happened. Regulation, arc blocking, arc recovery, and fault reporting are separate jobs; buying only one of them is like hiring a bouncer who checks tickets but ignores the fight.

Smart arc bouncer

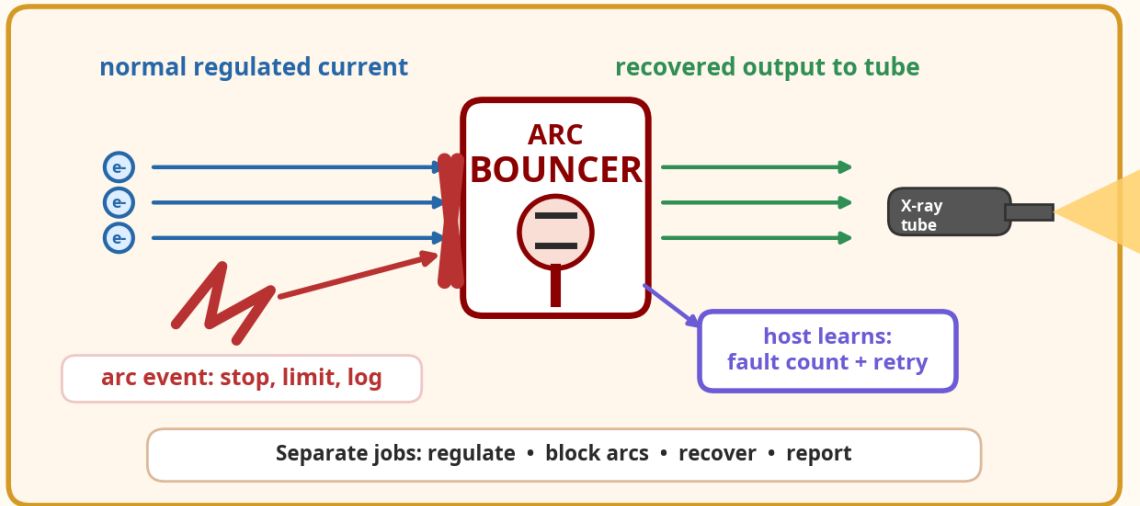


Figure 4. The smart bouncer separates normal current from arc events.

Important warning: Simple current-limit foldback may protect a bench supply on a resistive load, yet still oscillate, overshoot, or silently stress a real tube with cable capacitance. Verification must use representative cable and load conditions.

4. Recovery is where good designs prove themselves

The event is not finished when the spark disappears. Arc recovery determines whether the tube returns to useful operation or receives a second insult. A controlled ramp, bounded recovery overshoot, defined settling time, and sensible retry policy prevent one arc from becoming a burst of re-strikes.

Arc recovery waveform

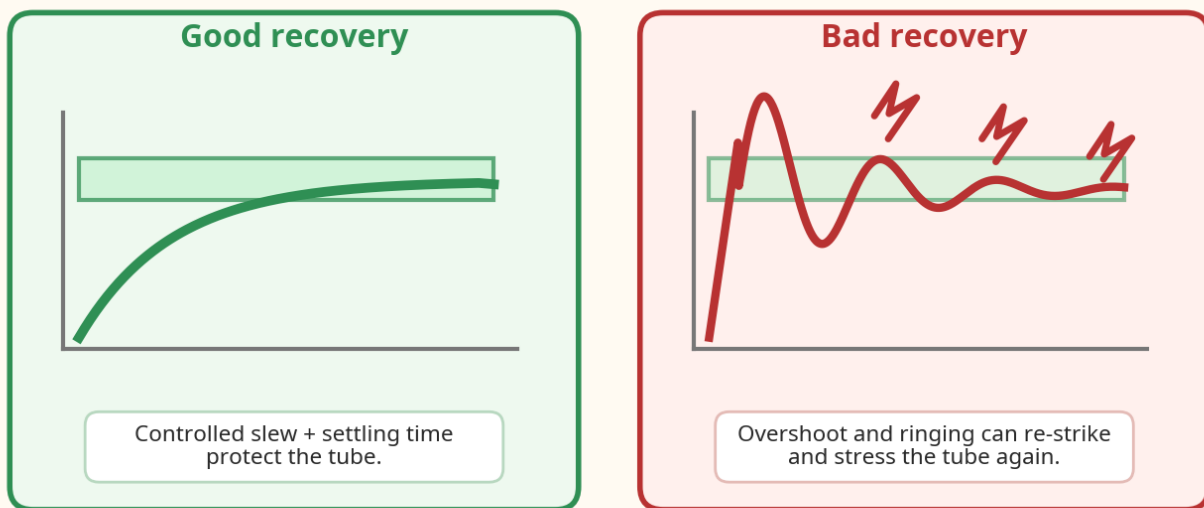


Figure 5. Calm arc recovery avoids overshoot and re-strike.

Arc reporting should also support learning. A single arc during tube conditioning may be acceptable. A rising arc rate, repeated arcs immediately after recovery, or event clusters after humidity or cable changes are diagnostic clues. The best host interface turns sparks into maintenance data rather than mysteries.

Observed pattern	Likely interpretation	Recommended customer response
One isolated arc after long idle time	Often normal tube conditioning, humidity, or a transient surface event.	Recover with controlled ramp and log the event.
Rising arc rate over days or weeks	Possible tube aging, cable stress, contamination, or insulation tracking.	Review arc log, cable routing, environmental conditions, and tube condition.
Several arcs immediately after recovery	Overshoot, excessive ramp rate, or retry policy may be re-triggering the fault.	Specify recovery waveform and back-off behavior, not just trip threshold.
Arc counter increments but no host alarm	Fault reporting may be incomplete for the OEM control system.	Require visible arc-count, fault line, serial report, or timestamped event record.

5. Application lanes: different loads punish poor arc handling differently

The same arc specification rarely fits every high-voltage load. Dental imaging, XRF, cabinet inspection, NDT/security, capacitor charging, and piezo or ultrasonic systems all translate an arc into a different business problem. The right ATI conversation begins with the application lane, not only the maximum kV.

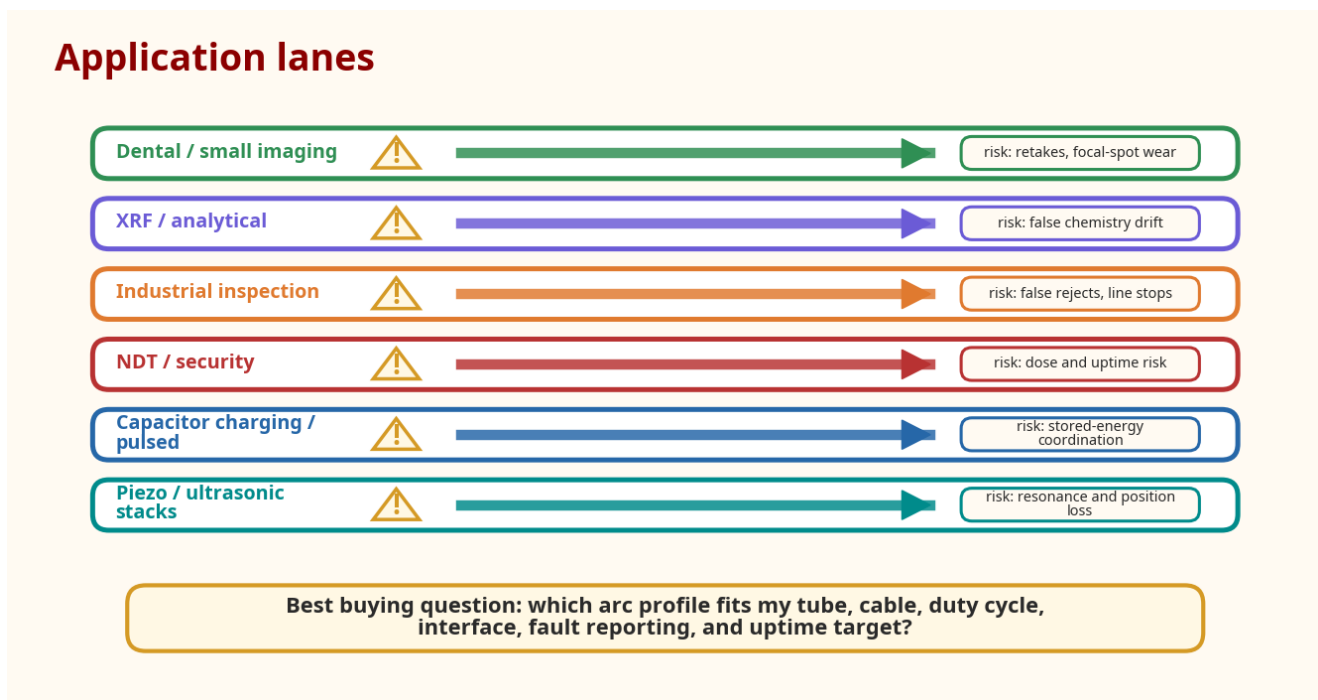


Figure 6. The same spark creates different consequences by application lane.

Application lane	What poor arc handling looks like	Preferred arc behavior	Information to give ATI
Dental / small imaging X-ray	Retakes, focal-spot wear, unstable image tone, and early tube replacement.	Very low event energy, clean recovery, visible fault indication.	Tube model, kV/mA, exposure timing, cable, interlock, and allowed recovery time.
XRF / analytical source	False chemistry shifts, calibration drift, and frequent re-standardization.	Minimal overshoot, stable post-arc settling, arc-count reporting to software.	Target spectrum repeatability, tube/current range, software interface, and grounding.
Industrial inspection / cabinet X-ray	False rejects, missed defects, line stoppages, and mysterious dose variation.	Configurable retry/back-off, clear host fault, and production arc-rate trend.	Duty cycle, uptime target, host interface, cable length, and inspection sequence.
NDT / security / higher-energy systems	Long downtime, tube stress, field-service calls, and difficult root-cause analysis.	Conservative energy limit, robust reporting, interlock coordination, safe latch policy.	Voltage/current range, enclosure, safety chain, cable, load simulator, and service policy.
Capacitor charging / pulsed HV	Bank over-discharge, switch stress, pulse inconsistency, and timing errors.	Fast isolation, coordinated crowbar or clamp, and predictable recharge after event.	Stored energy, pulse rate, charge voltage, peak current, and end-of-charge tolerance.
Piezo / ultrasonic stacks	Mechanical shock, depolarization stress, acoustic ringing, and lost positioning confidence.	Fast arc isolation, conservative retry, and recovery that avoids exciting stack resonance.	Stack capacitance, drive waveform, mechanical load, repetition rate, cable length, and allowed recovery profile.

6. Verification, RFQ checklist, and ATI call to action

A datasheet phrase is not a test result. Customers should ask how the supply behaves when the output is shorted at representative voltage, when repetitive arcs occur at realistic duty, when cable capacitance is included, and when the host must receive fault information. A practical acceptance ladder is: bench hard-short test, representative cable/load test, tube simulator test, controlled tube-conditioning test, and production arc-log review.

Copy this into your RFQ email: “Please specify arc detection latency, maximum event energy at our representative cable capacitance, peak current behavior, arc recovery overshoot/settling time, retry/back-off policy, latch conditions, and host fault-reporting format.”

If your main risk is...	Choose this profile emphasis	Prove it with...
Tube life or insulation stress	Lowest event energy, fast detection, conservative retry/back-off.	Hard-short and cable/load tests at representative voltage.
Image, spectrum, or position repeatability	Low recovery overshoot, quiet settling, visible arc count.	Post-arc waveform capture and production arc-log review.
Factory uptime	Configurable retry, clear host fault reporting, trend log.	Repeated-event testing at realistic duty cycle.
Pulsed or capacitive loads	Peak-current coordination, clamp/crowbar strategy, predictable recharge.	Stored-energy and pulse-sequence test with real cable capacitance.

Question before selection	Good answer	Risk if ignored	Risk level
How fast must arcs be detected?	Detection latency is stated with method and measurement condition.	Tube pitting, EMI reset, repeated arcs.	High
How much energy is allowed per event?	Maximum mJ/J is defined at full voltage and representative capacitance.	Reduced tube life and overheated limiters.	High
What does recovery look like?	Overshoot, settling time, ramp rate, and re-strike behavior are specified.	One arc becomes a burst of arcs.	High
What retry/back-off policy is acceptable?	Retry count, delay, adaptive behavior, and latch-off conditions are defined.	Nuisance trips or hidden tube stress.	Medium-High
What does the host learn?	Fault flag, arc count, timestamp, severity clue, or serial packet is available.	Blind troubleshooting and service confusion.	Medium-High
How is performance verified?	Test uses representative cable, load or tube simulator, and pass/fail criteria.	Bench-only performance fails in the real system.	High

Verification should use representative high-voltage probes, current monitors, adequate bandwidth, short ground paths or ground springs where appropriate, interlock-aware fixtures, and the same cable/load capacitance expected in the machine. The same test plan should document whether short-circuit protection is merely surviving a fault or whether the complete arc behavior also meets the detection, energy, and arc recovery targets. ATI’s public high-voltage supply pages describe high-voltage supplies for precision applications with features such as galvanic isolation, arc protection, customizable outputs, low ripple, and high efficiency.[4] ATI’s X-ray HVPS page lists relevant features including high precision, voltage/current programming, overcurrent protection, arc and short-circuit protection, safety interlock, integrated filament capability, and OEM customization.[5] The online store positions ATI X-ray HVPS products for medical imaging, nondestructive testing, security inspection, and laboratory X-ray applications with stable adjustable high-voltage output and comprehensive protections.[6]

Final customer rule: Email ATI the tube or load model, kV/mA range, cable length, duty cycle, exposure or pulse sequence, effective capacitance if known, acceptable arc rate, arc recovery target, interlock strategy, control interface, and fault reporting needs. Then the quote conversation becomes about engineered behavior rather than a risky checkbox.

References

[1] Spellman High Voltage Electronics, “Current Loop/Arc Detection Circuitry,” accessed 2026-06-03. <https://www.spellmanhv.com/en/Technical-Resources/Application-Notes-HVPS/AN-18>

[2] XP Power, “High voltage AC-DC power supplies,” accessed 2026-06-03. <https://www.xppower.com/high-voltage-ac-dc-power-supplies>

[3] Anshan Leadsun Electronics, “How To Protect The Arc And Short Circuit Of High Voltage Power Supply,” 2021. <https://www.hvsemi.com/news/how-to-protect-the-arc-and-short-circuit-of-hi-48387321.html>

[4] Analog Technologies, Inc., “High Voltage Power Supplies,” accessed 2026-06-03. https://www.analogtechnologies.com/High_Voltage_Power_Supply.html

[5] Analog Technologies, Inc., “X-RAY High Voltage Power Supply,” accessed 2026-06-03. https://www.analogtechnologies.com/x-ray_high_voltage_power_supply.html

[6] Analog Technologies online store, “X-Ray High Voltage Power Supply,” accessed 2026-06-03. <https://shop.analogtechnologies.com/X-RAY-High-Voltage-Power-Supply.html>