Assembly Concerns for Flash X-Ray Accelerators *

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Abstract

Proper accelerator assembly is critical in maximizing the return on investment of project funds. This critical task is most often accomplished by trained technicians. Pulsed Power-driven X-ray source assembly includes project planning, system design, drawing creation, and review as vital steps toward project success. The actual assembly procedures also are critical in ensuring the accelerator performs properly and will continue to perform efficiently and safely for years. This paper presents information on assembly concerns, including hardware selection, material selection, material treatments, documentation concerns and general assembly guidelines. This paper will mainly focus on oil and water containing sections including Pulse Forming Lines and Induction Voltage Adders.

I. CONFIGURATION CONTROL

Project planning must include configuration control to maintain proper documentation and tracking of changes. In multi-organization projects a lead laboratory/company is typically designated at the beginning of the project to track all drawings and set up a review process as each laboratory/company has different review procedures. Newly built systems often require a test phase where unforeseen problems are discovered and solved [1]. The technicians that will assemble the accelerator should play a significant role in the entire project review process and be encouraged to formally offer their insights.

All vendor procedures and additional documentation should be saved and cataloged as future reference material (i.e. technical manuals for roughing pumps, water de-ionization systems, etc.). Inserting this vendor data in labeled notebooks, as shown in figure 1, is one way to organize. These can also include technician developed notes, checklists, or procedures, which will lead to greater control over assembly and refurbishments as required.

Figure 1. Sample documentation archiving.

Another organizational tool is the responsibility matrix. This pairs individuals with sub-systems and therefore identifies each technician's responsibility for assembly and/or refurbishments. It can be posted at the work site, and limits the number of folks authorized to work on and report about sub-systems lending naturally to increased configuration control. Inviting peer review from team members working the project can also help to focus on established process and will encourage the documentation and inclusion of lessons learned into such process.

Finally, identifying the on-site accelerator SME and requiring that all hardware, software, procedure, checklists, and modifications that divert from the established accelerator configuration be reviewed and approved before implementation will result in removing unwanted variables which is vital to configuration control.

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14. ABSTRACT
Proper accelerator assembly is critical in maximizing the return on investment of project funds. This critical task is most often accomplished by trained technicians. Pulsed Power-driven X-ray source assembly includes project planning, system design, drawing creation, and review as vital steps toward project success. The actual assembly procedures also are critical in ensuring the accelerator performs properly and will continue to perform efficiently and safely for years. This paper presents information on assembly concerns, including hardware selection, material selection, material treatments, documentation concerns and general assembly guidelines. This paper will mainly focus on oil and water containing sections including Pulse Forming Lines and Induction Voltage Adders.

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II. MATERIAL SELECTION

Design engineers will normally select materials optimized for mechanical strength and electrical characteristics. Corrosion resistance is also considered if the hardware will be in contact with water or corrosive chemicals. Stainless Steel is normally used on all hardware in contact with de-ionized water used in Pulse Forming Lines (PFLs) and Water Cable/Water Coax assemblies. External hardware on these assemblies may be carbon steel to help prevent galling, but all internal hardware is typically passivated Stainless Steel to resist corrosion.

D. Weidenheimer's paper "Design of a Driver for the Cygnus X-ray Source' [2] describes a water-filled coax with the capability to reliably transport the energy at the required voltage for the 3-cell IVA while transforming impedance in several steps along its length. Both aluminum and stainless steel were evaluated for construction of the coax. The length of the coax needed to be at least 20 meters for facility siting. Stainless steel was chosen for its ability to support > 15 M•-cm water easily and thereby minimize shunt losses along the coax length. Series losses are greater than that for aluminum, but scale as $(\rho_2/\rho_1)^{1/2}$, as opposed to shunt losses that scale linearly with water resistivity. Stainless is also superior from a structural standpoint.

Aluminum is another commonly used metal in accelerators. It may be the standard 6061, or the harder 7075-T6 used on diode hardware subject to damage. Aluminum is routinely treated by Alodining or Anodizing as covered in the treatments section. Thorough review of material selection is required to ensure the best material has been specified before procurement is initiated.

Even the current contact (finger stock) used should be selected for the application. Beryllium-Copper is the standard used in most applications. Stainless Steel can be ordered for internal use in de-ionized water systems such as PFLs and water coax lines. Whenever possible, use of dissimilar metals should be avoided.

The following four steps may be taken to prevent, or at least minimize, corrosion potential in the event that it is necessary to use dissimilar metals in intimate contact with one another:

1. Limit contact between metals with widely different electrochemical potentials.

2. Insert a third metal between the two dissimilar metals which reduces the potential difference of the galvanic coupling. For example, nickel or tin plated copper is suitable for use with aluminum and silver combinations.

3. Design the flange interface so that the surface area of the anodic metal is significantly larger than the cathodic metal. The electromotive force (EMF) difference remains the same. However, the current density is decreased, so the corrosive attack on the cathodic metal is reduced.

4. Eliminate moisture, salts and other electrolytes from entering the joint interface by improved flange design or, if not possible, use an environmental seal outboard of the conductive element in a dual EMI shield/environmental seal.

Briefly returning to the initial statement of this section, torlon is another commonly used material. It is an excellent electrical insulator and also provides high strength mechanical properties. However, it is not impervious to sheer tension and even if carefully assembled into a structure can un-expectantly fail or develop hairline fractures that stray current will repeatedly follow. We believe that research into a torlon replacement material, non-tensioned mounting scheme, or shape reinforcement technique could benefit assembly and maintenance of accelerators across the pulsed power industry.

Finally, the material selection process might also provide that some further consideration be given to the accomplishment of assembly and any expected refurbishments or scheduled change outs. The technicians are the obvious source of opinion on how specific material selections might impact assembly and refurbishments effecting ongoing accelerator operations.

III. MATERIAL TREATMENTS

Common metal treatments include Passivation, Alodining and Anodizing. According to ASTM A380, passivation is "the removal of exogenous iron or iron compounds from the surface of stainless steel by means of a chemical dissolution, most typically by a treatment with an acid solution that will remove the surface contamination, but will not significantly affect the stainless steel itself." In addition, it also describes passivation as "the chemical treatment of stainless steel with a mild oxidant, such as a nitric acid solution, for the purpose of enhancing the spontaneous formation of the protective passive film." In lay terms, the passivation process removes "free iron" contamination left behind on the surface of the stainless steel from machining and fabricating. These contaminants are potential corrosion sites that result in premature corrosion and ultimately result in deterioration of the component if not removed as shown in figure 2.

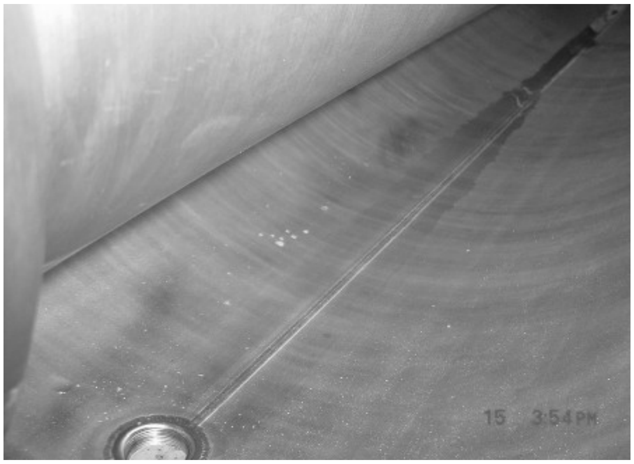

Figure 2. Non-passivated Stainless Steel corrosion.

In addition, the passivation process facilitates the formation of a thin, transparent oxide film that protects the stainless steel from selective oxidation (corrosion).

Alodining (chemical conversion) is a coating method intended to provide corrosion prevention to bare aluminum products, as well as to improve adhesion of painting processes. It provides good corrosion protection, even protecting when scratched: Alodined 2024 aluminum withstands salt spray 150-600 hours before forming white corrosion. Untreated 2024 aluminum will corrode in less than 24 hours. Alodining provides an excellent electrically conductive surface. Alodining adds no measurable weight and does not alter the dimensions of parts (does not make holes smaller). However, the alodined surface is not as durable as anodizing or a good paint, and assembled parts cannot be alodined. (Neither can they be anodized.)

Anodizing is used mainly on Aluminum for its electrical properties, hardness, thermal properties as well as other properties. One major reason anodizing is used in pulsed power accelerators is its exceptional electrical characteristics. Aluminum oxide and its alloys can be used as electrical insulators. The high temperature stability of the coating permits operation up to 500C. Anodic coatings typically exhibit a voltage breakdown of 2,000-3,000 v/mil, a dielectric constant of 7.4-7.6 and resistivity in the same order of magnitude as glass and porcelain.

Technicians with a clear understanding of the purpose of each surface treatment necessary to a particular accelerator function will focus on providing the care required to protect such surfaces and treatments. They will also be the first to point out defects and request surface treatment rework partly due to the fact that the maintenance of these accelerators will fall to them.

IV. DESIGN CONSIDERATIONS

Early identification of lifting points will help in placement of hoist rings, lifting eyes and other assembly and maintenance lift points. A qualified mechanical engineer should review all recommendations to ensure the material will withstand the lifting stresses and to ensure the appropriate safety factor is considered.

Figure 3 displays a mobility modification to the CYGNUS accelerators after they were relocated to the U1a facility 1000 feet underground at the Nevada Test Site (NTS). The casters were designed to be mounted using the same bolt holes as the hydraulic rams on the ends of the Marx tanks. By welding plates to the sides of the tanks the rams were installed before the Marx tank was set in place. The hydraulic cart and gas bottles were also mounted to the Marx tank (Figure 4) to facilitate easy movement. All modifications were reviewed by the Marx tank designer prior to installation. This step was critical in maintaining structural integrity of the tank.

Figure 3. Caster relocation on CYGNUS machines.

Figure 4. Hydraulic cart and Zero Air bottle relocation on CYGNUS machines.

V. GENERAL ASSEMBLY CONCERNS

As stated in the Material Selection section, Stainless Steel is commonly used on hardware in contact with de-ionized water. To resist galling of threads on stainless bolts to stainless threads an anti-seize compound must be used. As standard anti-seize would contaminate de-ionized water systems a compound such as High-Purity Goop™[1] (a Fluorocarbon-based thread lubricant used to resist galling at temperatures up to 400° F) can be used on stainless steel, titanium and nickel alloys.

In vacuum applications common thread lubricants and sealants outgas and possibly contaminate the vacuum system. Vacuum-compatible versions resist galling, have extremely low vapor pressures, and are chemically nonreactive with a wide range of materials.

A common misunderstanding is that vacuum grease will help keep a system tight (leak proof). In fact, vacuum grease should be applied sparingly, and all excess grease removed before hardware is placed in the system. The grease is crucial when parts require the ability to rotate or move, such as an O-ring used in a slip joint, or butterfly valve. A clean O-ring is normally sufficient when movement is not required. High quality vacuum grease, such as Dow Corning® High Vacuum Grease #976V, has much greater stability at the higher end of the temperature range(-40° C to 260° C), than hydrocarbon greases such as Apiezon® M, but its initial room temperature pump down characteristics are not as quite as good taking noticeably longer to out-gas. This grease is very popular as a general laboratory lubricant, due in large part to its low cost.

Apiezon® greases are known for their high quality and consistency and also, their excellent compatibility for high vacuum applications. Use vendor data, such as this chart from Apiezon's website, to help in the selection of the proper lubricant.

Typical Property		L Grease	M Grease	N Grease
Main areas of application		High Vacuum	General Vacuum	Cryogenic
Typical working temperature range,	°C °F	10 to 30 50 to 86	10 to 30 50 to 86	-269 to 30 -452 to 86
Melting point - ASTM.D 566-02 (IP 132/96),	°C °F	42 to 52 108 to 126	40 to 48 104 to 118	42 to 52 108 to 126
Vapor pressure @ 20°C / 68°F, Torr		7.0×10^{-11}	1.7×10^{-9}	6.0×10^{-10}
Relative density @ 20°C / 68°F		0.896	0.894	0.911
Resistant to radiation		Yes	Yes	*N/R
Lubricity 4 Ball Test - ASTM.D 2596 (IP 239/97), kg		150	140	150
Coefficient of expansion per °C over 20-30°C		0.00076	0.00075	0.00072
Thermal conductivity @ 20°C, w/m °C		0.194	0.194	0.194
Electrical strength, V/mil (0."001)		730	850	820

[1] The Swagelok website, www.swagelok.com, is an excellent reference which can be used to look up the appropriate thread lubricant for your specific applications.

As a final - general assembly concern, we believe that safety must be included in any professional presentation that touches on personnel activities. A proper appreciation of the several hazards associated with accelerator assembly, refurbishment, as well as operation, is necessary education for any truly qualified technician, designer, or other similar contributors.

VI. SUMMARY

Performance of pulsed power driven X-ray accelerators is dependent on many elements, such as configuration control, material selection, material treatments, design considerations and general assembly practices. The Cygnus accelerator, from which this paper is largely based, is proof that a dedicated team of scientists, engineers and technicians can work together to ensure project success by sharing information on these elements while constantly striving to improve processes and operations.

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