POWER COUPLER MANUFACTURING AND QUALITY CONTROL AT CPI EDB

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Abstract

CPI EDB has been designing and manufacturing fundamental power couplers for superconducting accelerators for over a dozen years. We have manufactured approximately 200 power couplers of 16 different designs. Power coupler frequencies have ranged from 175 MHz to 3.9 GHz and power levels have ranged from 5 kW to 500 kW average power. We have developed and qualified several key manufacturing processes including a high-RRR copper plating process and a titanium nitride coating process. In addition, we have established uniform quality control and inspection processes which ensure that the power couplers will meet the requirements for the intended use in superconducting accelerators. These processes have been developed, improved and/or qualified in collaboration with colleagues at superconducting accelerator facilities throughout the world. This paper will provide an overview of these critical manufacturing and quality control processes.

POWER COUPLER BUILT BY CPI EDB

CPI Electron Device Business (CPI EDB) has been fabricating power couplers for superconducting linear accelerators since 2000. Table 1 lists the power couplers built at CPI EDB.
Figures 1 and 2 show representative examples.

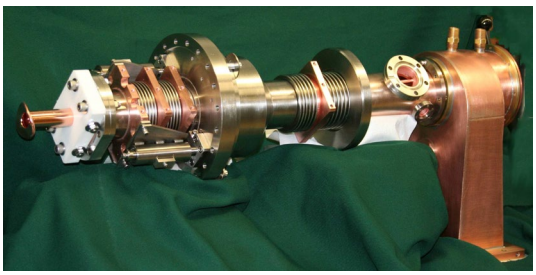

Figure 1: VWP3032 power coupler for Cornell.

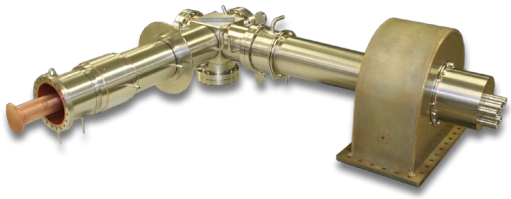

Figure 2: VWP3107 power coupler for AES.

Table 1: Power Couplers Built at CPI EDB

CPI EDB Model Number	Accelerator Application	Freq. (MHz)	Peak, Avg. Power (kW)
VWP 3097	IFMIF Facility (CEA Saclay) [1]	175	200, 200
VWP 3098	Facility for Rare Isotape Beams (MSU) [2]	322	14, 14
VWP 3124	Radio Frequency Quadrapole (ORNL)	402	600, 50
VWP 3107	NSLSII Upgrade (AES,BNL)	500	500, 500
VWP 3070	Energy Recovery Linac Gun (AES) [3]	704	500, 500
VWP 1185/86	Free Electron Laser Injector (AES) [4}	748	350, 350
VWP 1133	Spallation Neutron Source (SNS) [5]	805	1000, 60
VWP 1162	Rare Isotape Accelerator Prototype (MSU) [6]	805	1000, 10
VWP 1137, 3049 (TTF3)	Tesla Test Facility and ILC R&D (CNRS Orsay, DESY, Fermi, SLAC) [7]	1300	1100, 7.2
VWP 1136	Tesla Test Facility (AMAC) [8]	1300	1100, 7.2
VWP 3126	XFEL (EuXFEL)	1300	1100, 7.2
VWP 3032	Energy Recovery Linac (Cornell, Triumf)) [9,10]	1300	75, 75
VWP 3069	Energy Recovery Linac (Daresbury) [11]	1300	75, 75
VWP 3113	SRF Accelerator (Peking University)	1300	60, 60
VWP 3108	Energy Recovery Linac (Cornell) [12]	1300	5, 5
VWP 3088	XFEL Third Harmonic Accelerating Cavity (Fermi, DESY) [13]	3900	45, 12.5

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KEY MANUFACTURING PROCESSES

Several key manufacturing processes were developed at CPI EDB for the fabrication of power couplers. We developed a high-RRR electroplating process for copper on stainless steel as well as a process to deposit an anti-multipactor TiN coating on surfaces [14]. The TiN coating process replicated the process developed at DESY.

Both processes have been in nearly-continuous use for over ten year. The high-RRR plating process was originally qualified at CNRS-Orsay 10 years ago. It has been re-qualified 4 more times since then by DESY for TTF3 (VWP3049) and 3.9 GHz (VWP3088) power coupler production runs. The most recent re-qualification of the high-RRR copper plating process occurred in November 2013. The TiN coating was originally qualified 10 years ago at DESY and has been re-qualified twice since then, once at DESY and once at CEA Saclay. Details of the initial qualification are included in [14].

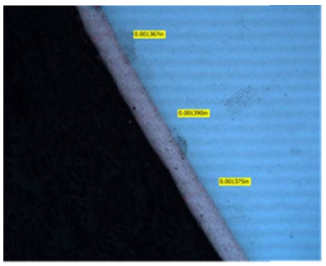
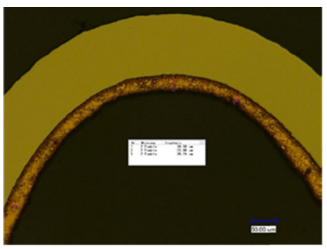
High-RRR copper plating of power coupler components is a particularly challenging process. While specifications vary, there are common requirements for high purity, high cleanliness, good adhesion, and uniform copper plating. Table 2 indicates the typical specifications for high-RRR copper plating. Included in Table 2 are examples of desired copper plating.

QUALITY CONTROL PROCEDURES

CPI EDB makes use of established workmanship acceptance criteria for power couplers. These workmanship standards are a result of our collaborative efforts over the years with experts at DSEY, CNRS-Orsay, Fermi Lab, SLAC, Cornell, CEA-Saclay and elsewhere. In-process inspection is done on production power couplers against quality assurance documents that provide some objectivity against what are arguably subjective standards.

The TTF3 couplers (VWP3049) have workmanship acceptance criteria documents for the key assemblies (warm, cold, and waveguide assemblies). Each of these documents detail areas to be visually inspected, with or without magnification. Inspection with a borescope is also required for many features. For the warm assembly 27 areas are highlighted for visual inspection. For the cold assembly there are 20 inspection points. Four features are included as inspection points on the waveguide assembly. Three conditions are called out for each inspection point. A Target Condition is defined as “a condition close to perfect/preferred, however, it is a desirable condition and not always achievable and may not be necessary to ensure reliability of the assembly in its service environment”. An Acceptable Condition is defined as “a condition that, while not necessarily perfect, will maintain the integrity and reliability of the assembly in its service environment.” A Defect Condition is defined as “a condition that may be insufficient to ensure the form, fit, or function of the assembly in its end use environment.”

Table 2: Copper Plating Specifications and Examples

Require-ments	Typical Specifica-tion	Example of Desired Results
Thickness Uniformity	± 30%	
Surface finish	32 micro-Inch finish	
Micro-thickness uniformity	No concavities	
Cleanliness, Oxide free		
RRR value	30 - 80	

The acceptance documents have been populated with photographs of Target Conditions, Acceptable Conditions, and Defect Conditions as these conditions are identified. Currently these documents are works-in-progress and will be updated for the VWP3126 production program for the EuXFEL.

Figure 2 shows an example of the one critical feature in the VWP3049 cold assembly (e-beam weld) and the photos in the associated workmanship standard. A sample borescope photo of the Target Condition for the e-beam weld is shown at

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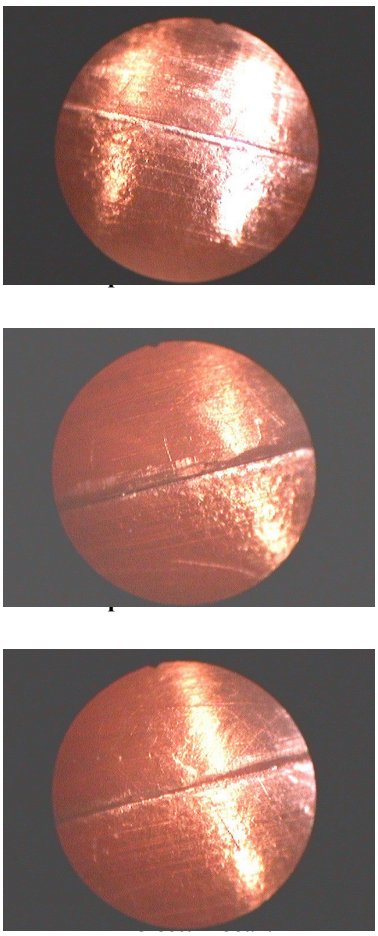
the top of Figure 3. The bottom two borescope photos in Figure 3 show Acceptable Conditions. There is no depression in the Target Condition weld while a slight depression is evident in the Acceptable Condition welds. Some minor scratches are seen in the photos of the Acceptable Conditions. We have no examples of the Defect Conditions for this feature at this time.

ONGOING ACTIVITIES

CPI EDB is currently expanding its power coupler manufacturing capabilities by adding an ISO 4 – ISO – 6 clean room for cleaning and final assembly of power couplers. This clean room is being built to support production at a rate of up to 8 power couplers per week.

Area (16) Weld: internal form, irregularities, penetration

Target: *E-beam Weld*



No weld material visible.

Figure 3: Example from CPI EDB workmanship standard.

CONCLUSION

CPI EDB has successfully manufactured 200 power couplers over the last 12 years of 16 different designs. We have established and qualified several key manufacturing and quality control processes that have been refined during several production programs and are in current use.

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