General Proposal Requirements
PIP-II Buncher Fabrication

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Document Approval

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Revision History

Revision	Date of Release	Description of Change
-	25 OCT 2013	Initial release
A	8 JULY 2015	Modified from prototype to production
B	June 2022	Modified from PXIE to PIP-II procurement; updated format

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1. Purpose

The General Proposal Requirements document establishes basic rules and expectations for vendors answering the PIP-II Bunching Cavity Procurement's Request For Proposal (RFP).

2. Scope

This document describes general requirements for Sellers interested in replying to Fermilab's RFP for the fabrication of component F10004875 (BUNCHER CAVITY ASSEMBLY). This is a normal-conducting quarter-wave bunching cavity (later identified as cavity) operating at an RF of 162.5 MHz. This cavity is used in the Medium Energy Beam Transport (MEBT) section of the PIP-II Linac, within the Warm Front End (WFE). The cavity is approximately 300 mm in diameter and 800 mm in height. It is almost entirely constructed out of OFE Copper. Also included in the procurement is the mounting plate (F10040077) to be used for handling and shipping.

3. Acronyms

L2M	WBS Level 2 Manager
L3	WBS Level 3 System
L3M	WBS Level 3 Manager
MEBT	Medium Energy Beam Transport
OFE	Oxygen-Free Electronic
PIP-II	Proton Improvement Plan II Project
RF	Radio-Frequency
RFP	Request For Proposal
TRS	Technical Requirements Specification
WFE	Warm Front End

4. Reference Documents

#	**Reference**	**Document #**
1	BUNCHER CAVITY ASSEMBLY drawing	F10004875
2	Fermilab Engineering Specification ES-107240	
3	RF STRUCTURE ASSEMBLY drawing	F10002141
4	STEM drawing	F10001700
5	BEAM LINE ELEMENT drawing	F10005030
6	CENTRAL BLOCK ASSEMBLY drawing	F10001708

7	CENTRAL BLOCK drawing	F10005029
8	STEM ASSEMBLY drawing	F10001698
9	PLATE, BUNCHING CAVITY drawing	F10040077

5. Preliminary Terms and Conditions

5.1. Quantities and Schedule

There are 2 Bunching Cavities needed. The 2 cavities will be ordered at the same time and are expected to be manufactured in 9 months, including hold-points and inspections by Fermilab delegates as described ahead.

High-precision machining and furnace-brazing will comprise the bulk of the fabrication. Accurate tooling and fixturing methods will be of critical importance for the success of this effort.

5.2. Post-award Submittal

Once the contract is awarded, the chosen supplier shall submit the following documents:

1. Manufacturing inspection plan, including brazing and welding procedures
2. Vacuum leak procedures, including fixturing plans and inspector qualification
3. Handling and Transportation plan, including fixturing and packaging
4. Quality Control plan, including control of nonconformances, training/qualification requirements, and reference to all inspection results to be shared

5.3. Risks

Based on the experience gained at Fermilab on similar projects, it is believed that, if parts are machined according to prints and handled carefully, and if the brazing strategy is developed by (or in collaboration with) an experienced furnace-brazing company, the outcome will be acceptable for this project.

Risks of manufacturing (dimensions and finishes) will be mitigated by developing appropriate handling and machining fixtures and by careful inspection of critical components prior to brazing.

Major risks of furnace-brazing are typically limited to failures of the brazing equipment (e.g. temperature regulation). Brazing risks, related to the correct positioning of parts, or quality of braze joints, are addressed at the component level (joint design) and by adopting a robust assembly scheme based on the experience of the company performing the furnace-brazing. Finally, deviations due to thermal cycling or uncertainty in brazing-gaps are typically acceptable, and if necessary, in some cases can be adjusted after brazing. Development of representative braze-joint samples is strongly recommended.

5.4. Involvement of Fermilab Personnel

Fermilab experts involved in similar projects in the past will be available throughout the manufacturing process and will help to address any issue that may arise. It is anticipated that the Fermilab liaison engineer and other Fermilab key representatives will visit the Seller and sub-contractors repeatedly throughout the fabrication. After the contract is officially awarded, a kick-off meeting will be organized to

discuss the overall plan in detail to make sure that the two parties are in complete agreement on the scope of work.
Several hold-points are defined (see below) and will require the approval of Fermilab personnel to proceed. One hold-point in particular will involve RF measurements performed by Fermilab personnel and machining operations to fine-tune the RF resonant frequency and will take place at the location of manufacturing.

5.5. Design Changes

With the ultimate goal of obtaining a high-quality cavity which satisfies the requirements, reducing costs and reducing overall risk, design changes suggested by the Seller will always be welcomed and implemented, if possible, in the drawing package.
All changes will need approval of the Fermilab liaison engineer and procurement prior to proceeding.

6. Manufacturing

6.1. Machining

For the final product, all copper components must be manufactured using only Oxygen-Free Electronic Copper (UNS C10100). Blistering and severe expansion will result if lower grades of copper are furnace-brazed. If blistering is observed at any stage of manufacturing, the affected components must not be machined any further and the liaison engineer must be contacted immediately.
Performance-driving components are machined with stringent (but achievable) tolerances to maximize chances of successful brazing of the main assembly.
Critical surfaces of inner components shall be machined with a maximum Ra = N7 (1.6 μm, 63 μin). Extreme care shall be exercised to avoid damage to such surfaces (scratches, nicks, dents). Stress-relieving prior to final machining (and brazing) is strongly recommended. Freshly annealed copper parts shall be left to rest several days in appropriate holding fixtures to allow hardening prior to handling or machining.
Sharp edges must be treated with copper-dedicated scraping tools. Mechanical polishing of defects by means of abrasives shall be limited to extreme cases, shall be strictly regulated, and must be approved by the Fermilab liaison Engineer on a case-by-case basis.

6.2. Brazing

Manufacturing drawings provided by Fermilab define a possible way of brazing. Modifications to the design of brazed joints may be suggested by the Seller. Design of all brazed joints shall be mutually agreed upon between the Fermilab liaison Engineer and the Seller (and sub-contractor(s) if applicable).
Any volume with trapped air that could find its way to the interior of the cavity, identified as “virtual leak”, should be avoided when brazing cavity elements together. Vent holes should be used to relieve these volumes.
Risk of overflowing of brazing alloy into the inside volume of the cavity shall be avoided, although performance may still be acceptable in some cases. Elaborate re-work may be necessary in cases of extensive overflow.

Every part must be cleaned thoroughly before furnace-brazing since any trace of grease, dirt or fingerprints would be baked and mated to the cavity surfaces indefinitely. Brazing procedure shall be provided as part of the post-award submittal.

6.3. Welding of Flanges

Vacuum flanges must not be baked at high temperatures (typically < 450°C, see supplier specification) as this may cause warping or softening of the sealing surface critical to vacuum performance. For this reason, flanges may only be welded on cavity ports after all brazing steps are completed.

Knife-edges of all vacuum flanges should be meticulously protected at all times. Plastic protection caps shall always be in place unless access through flange is necessary. Extreme care should be taken when installing and removing copper gaskets to avoid damaging the knife-edges with metal tools. Welding procedures shall be submitted as part of the post-award submittal.

6.4. Leak Tests

All joints specified as leak tight on the drawings must be tested by the Seller with a Helium detector following Fermilab Engineering Specification ES-107240. Prior to leak-testing subassemblies, their structural integrity shall be protected if necessary. Certain subassemblies may not be able to survive a leak test without proper fixturing. A calibrated leak shall be used as part of the leak check verification process. The inspector's training qualification/certification for performing vacuum leak check using a helium spectrometer shall be included in the post-award submittal.

6.5. Forging

Any forgings must undergo additional quality checks before and after machining. Experience has demonstrated supposedly oxygen-free copper forgings to contain gas pockets and to potentially leak after subsequent processing. Any part fabricated using forging must have a material verification plan that includes machining and vacuum brazing samples approved by Fermilab engineering. If applicable, this shall be considered part of the post-award submittal.

7. Hold Points and Deliverables

7.1. Manufacturing Plan and Schedule

After the first kick-off meeting, the Seller shall submit a manufacturing inspection plan to the liaison Engineer for acceptance. The plan shall identify the overall manufacturing strategy describing the sequence of operations and highlighting which operations are outsourced. This shall include brazing and welding procedures and inspection steps. A detailed project schedule shall accompany the plan identifying intermediate milestones necessary to control that the project stays on schedule for the final delivery. Acquisition of material and manufacturing of components can only begin after a formal approval from Fermilab is received.

7.2. Material Certifications

Material certifications for all purchased material shall be provided to Fermilab. For commercial components, information on supplier and part number shall be provided. If any doubt arises regarding the quality of the material received, Fermilab personnel can be involved in helping to make a decision. All documents should be sent to Fermilab shortly after acquisition or as soon as they become available. Approval by Fermilab is required before proceeding with fabrication. Independent verification of materials may be required at Fermilab's discretion.

7.3. Intermediate Leak Checks

All copper components expected to withstand vacuum shall be leak checked prior to final brazing.
Copper forgings that are used to make up the cavity shall be leak checked before any machining and again after any rough-machining and annealing cycle. This approach is aimed at identifying flaws in the material early in the fabrication.

7.4. Final Leak Check

The Bunching Cavity final assembly shall be certified leak-free at the lowest sensitivity achievable on a helium mass spectrometer leak detector, or better than 2×10^{-9} std.cc/s of Helium. A leak-check procedure shall be submitted to Fermilab for approval before pulling vacuum on the final assembly. Fermilab may opt to witness this process in person.

7.5. Inspection of Components

The following components, once finished, shall be approved for use by the liaison engineer. Inspection reports produced by the Seller (mechanical measurement reports and visual inspection reports at a minimum) shall be provided to Fermilab. Additional inspections may be performed by Fermilab representatives at the Seller's location.

1. F10001697 – DRIFT TUBE
2. F10001700 – STEM
3. F10005030 – BEAM LINE ELEMENT
4. F10001708 – CENTRAL BLOCK ASSEMBLY
5. F10005029 – CENTRAL BLOCK
6. F10001698 – STEM ASSEMBLY

7.6. RF Measurements on partially-assembled cavity

As a precautionary step, prior to final brazing of cavity, the dry-fitted assembly (F10002141 – RF STRUCTURE ASSEMBLY) shall be at the disposition of Fermilab representatives to perform RF measurements. These measurements will be performed at the Seller's location to avoid shipment of delicate components. At this stage, the RF resonant frequency of the cavity can still be adjusted, if necessary, by machining the vacuum-side of the STEM FLANGE. It is estimated that this machining will consist in the removal of maximum 1 mm of material in 2-3 steps of 100-500 μm each.

7.7. Discrepancy Reports

Any substantial discrepancy encountered in the manufacturing of the cavity shall be promptly communicated to the liaison engineer and a solution shall be mutually determined. Each discrepancy and solution shall be attached to the manufacturing report (see below).

7.8. Handling and Transportation

It is required that a Handling and Transportation Plan be submitted prior to beginning fabrication. It should include any fixtures needed for handling or transportation. All critical surfaces should be protected. This applies to shipments to and from sub-contractor locations and to and from Fermilab. Accelerometers can be provided by the Buyer to verify certain shipments if desired. It is highly recommended that all critical components and assemblies are shipped using high-quality wooden containers encasing custom-cut high-density foam. The cavity should be mounted to plate (F10040077) for stability.

Before proceeding with shipment, open box high-resolution photos of the bunching cavities' packaging shall be provided to the liaison engineer and procurement specialist for review.

7.9. Manufacturing Report or Traveler

Prior to final shipment, the Seller shall furnish copies of inspections and tests performed by the Seller (or designated sub-contractor) to determine conformance of the products to the requirements.

Documents of greatest interest are:

1. Material Certificates
2. Leak-check documentation
3. Visual inspections of critical components
4. Mechanical measurements of critical components
5. Discrepancy reports (if any)