PIP-II 40 kW 650 MHz RF Dist. for PIP2IT PDR Report

Document number: ED0012163

Document Approval

Name: Jim Steimel Org: Accelerator Division - FNAL Contact: steimel@fnal.gov Role: Review Coordinator – PIP-II HPRF L3 Manager	Date:
Name: Elvin Harms Org: Accelerator Division - FNAL Contact: harms@fnal.gov Role: PIP-II Accelerator Systems L2 Manager	
Name: Curt Hovater Org: Accelerator Division - RF Group- JLab Contact: hovater@jlab.org Role: Committee Chair	
Name: John Reid Org: Accelerator Division – RF Group - FNAL Contact: jsreid@fnal.gov Role: Committee Member	
Name: Doug Horan Org: Advanced Photon Source – RF Group - ANL Contact: horan@anl.gov Role: Committee Member	

Revision History

Revision	Date Release	Originator: Role:	Description of Change

Revision control is managed via Fermilab Teamcenter Workflows.

Table of Contents

1. Introduction

The review committee is requested to perform an independent evaluation of the Preliminary Design of the RF power distribution system for testing low and high beta (650 MHz) cryomodules at PIP2IT. This scope of this review is limited to RF Distribution (Circulators, Directional couplers, RF transmission media) and does not include the amplifiers nor the fundamental power couplers/cryomodules.

2. Review Agenda

This section shows the details of a typical review agenda which can be tailored to suit the review being held. Changes should be indicated if different from the Review Charge.

40 kW 650 MHz RF Dist. for PIP2IT PDR Agenda

Location: Online

Date: 28-May-2020

Time: 0800-1400 (CDT)

Indico Site: https://indico.fnal.gov/event/23444/

Participants:

Jim Steimel	FNAL	Role: Coordinator
Curt Hovater hovater@jlab.org	Thomas Jefferson National Accelerator Facility (JLab)	Role: Review Chair
Doug Horan horan@anl.org	APS/Argonne National Laboratory (ANL)	Role: Reviewer
John Reid jsreid@fnal.gov	AD/RF dept./FNAL	Role: Reviewer
Ding Sun	FNAL	Role: Presenter

Agenda details:

I. Welcome: Elvin Harms

II. Introduction: Jim Steimel

III. Technical Design: Ding Sun

IV. Schedule, Budget, Safety, QC, etc.: Jim Steimel

V. Closeout – Review Chair
   a. [Summary Statement]
   b. [Preliminary Findings]
   c. [Preliminary Comments]
   d. [Preliminary Recommendations]

3. Review Charge Statement

The review committee is requested to perform an independent evaluation of the Preliminary Design of the RF power distribution system for testing low and high beta (650 MHz) cryomodules at PIP2IT. This

scope of this review is limited to RF Distribution (Circulators, directional couplers, RF transmission media) and does not include the amplifiers nor the fundamental power couplers/cryomodules.

The committee is asked to respond to the following questions:

1. Is the 650 MHz RF distribution design at the preliminary design level (30-50%)?
2. Is the design consistent with system and project requirements?
3. Are the available technical drawings and documentation consistent with this level of design maturity?
4. Are the budget, schedule, identified interfaces and risks, and procurement and quality control plans consistent with this level of design maturity?
5. Are there any impediments to initiating final design work?

4. Attendance List

List review attendees here, including committee, speakers, and prominent audience members. Remote attendees should be included and noted as remotely attending.

Name	Organization
Ahmed Syed	FNAL
Akhilesh Jain	RRCAT
Brian Chase	FNAL
Curt Hovater	JLab
Dave Peterson	FNAL
Ding Sun	FNAL
Doug Horan	ANL
Elvin Harms Jr	FNAL
Genfa Wu	FNAL
Jim Steimel	FNAL
Jeremiah Holzbauer	FNAL
Jerry Leibfritz	FNAL
John Reid	FNAL
Mahendra Lad	RRCAT
Steven Wessein	FNAL
Tom Digrazia	FNAL

5. Reference Documents

The documents listed below establish the framework for all technical reviews held during the PIP-II Project Lifecycle.

1	PIP-II Technical Review Plan – TC ED0008163
2	PIP-II Quality Assurance Plan DocDB # 142
3	PIP-II Systems Engineering Management Plan – TC ED0008164
4	PIP-II IESH Management Plan DocDB # 141
5	121.02 SRF and Cryo Systems Design Plan DocDB # 2605
6	121.03 Accelerator Systems Design Plan DocDB # 2599
7	121.04 Linac Installation and Commissioning Design Plan DocDB # 2581
8	121.05 Accelerator Complex Upgrades Design Plan DocDB # 2593
9	121.06 Conventional Facilities Design Plan DocDB # 2587
10	PIP-II Value Engineering Plan DocDB # 2830

The review coordinator should populate this following table with the document list for this review from their SDP.

Table 1 - Document Deliverables for this review from the System Design Plan

	Document Title	Status (preliminary, final, released)	Comments/Location
1	Linac RF System PRD	preliminary	ED0010220-A
2	HPRF L3 Functional Requirements Specification	final	ED0008023-A
3	PIP2IT 650MHz RF Distribution Functional Requirements Specification	Preliminary	ED0012138--
4	PIP2IT 650MHz RF Distribution Technical Requirements Specification	Preliminary	ED0012142--
5	Master ICD	Released	ED0010433-E
6	Interface Specification Document LB650		Not Found
7	Interface Specification Document HB650		Not Found
8	Interface Specification Document 650MHz RF Distribution - LB650 RF Power Amplifier	Final	ED0006360--
9	Interface Specification Document 650MHz RF Distribution - 650MHz LLRF/RFPI System	Preliminary	ED0012144--
10	650MHz RF Distribution Updated Prevention Through Design Assessment Table	Preliminary	ED0012145--
11	Failure Mode and Effect Analysis		Not Started
12	Updated HPRF RLS (relevant to the PIP2IT 650 systems)	Preliminary	PIP-II docdb #1845-v15
13	650 MHz RF System schematic	Preliminary	In TRS

14	3D Model of RF Distribution Connecting Amplifier and 650MHz Coupler		In Presentation
15	P&ID Drawings for PIP2IT 650 MHz Distribution Cooling (Circulator)		Not Started
16	RF Loss and Thermal Calculations		Not Started
17	Preliminary standing wave calculations		Not Started
18	Component list and specifications	Preliminary	In TRS
19	Preliminary Procurement Plan (stock parts, directional coupler, circulator)	Preliminary	RAPTR Acquisition Plan #027
20	Component Inspection and Validation Plan	Preliminary	In TRS
21	Preliminary Commissioning Plan		Not Started
22	HPRF QC Plan	Preliminary	PIP-II docdb #4292

6. Reviewed Document List

This section indicates which documents the committee reviewed as part of this review. The document list provided should match the documents identified in the relevant WBS L2 System Design Plan referenced above.

Table 2 - Documents presented at this Review

	Document Title	Status (preliminary, final, released)	Comments
1			No documents were explicitly presented during the review.
2			
3			
4			
5			
6			

Committee comments should note any of the following:

- Documents that were expected but not presented.
- Documents that were in a state not commensurate with the review in question (e.g. conceptual design documents at a final design review).
- Standard documentation that, in the committee's expert opinion, should have been in the SDP and presented but was not included.
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7. Findings

General, factual observations about material presented which require no response.

- There is one amplifier for each cavity.
- Distribution begins at the amplifier combiner output and goes to the cavity input coupler, consisting of the circulator, coax transmission line, directional coupler, and transitions (coax to wave guide and vice versa).
- The PIP-2IT test will become the test stand for the PIPII SSR and 650 MHz cryomodules (CM).
- RF test systems are the same for both the 650 MHz LB and HB CMs
- Initially there will be only one amplifier for testing the first HB 650 CM.
- The CMs tested up to 10% over specified gradient, which includes 20 Hz peak microphonics adjustment.
- Coupling into the CM can varies by +/- 25%.
- The circulator must be able to handle up to 70 kW.
- 6 1/8” coax is used from the SSA combiner to the waveguide transition in the vault.
- The circulator will use a water load.
- WR1150 Waveguide is used and this includes the directional coupler.
- The 6 1/8” coax has a 80 kW maximum power rating. The WR1150 waveguide is rated to 62 MW!
- There is a similar distribution system line in Meson building for a 30kW IOT system.
- The circulator probably will have active temperature compensation.
- Circulator arc interlock will have two ports. Presently FNAL will own the interlock but some vendors may require their own arc protection for warranty.
- Dual Directional Coupler: WR1150, 50 dB with 40 dB directivity.
- The 20 kW SSAs will monitor their output power and reverser power and are self-protected.
- Circulators are supported by Al extrusion from the floor and do not attach to SSA cabinets.
- SSA have cooling fans blowing out the top.
- 40 kW SSA is provided by DAE/RRCAT due 10/2020.
- There are two vendors being evaluated for the circulator.
- The circulator will be tested both at low power and high power tests.
- The high power tests will be done at FNAL by FNAL engineers.
- The circulator will be approximately 350 lbs.
- The cooling water temperature for the circulator is specified at 30C.
- The SSA’s will turn off if the VSWR exceeds 1.4:1.
- The structure design will conform to FESHM 5100 standards and get reviewed by qualified mechanical safety engineer.
- Lifting plans will be developed in compliance with FESHM 10200. Critical lifts will be identified before FDR.

- There are trim sections and bellows in appropriate locations to solve fitting issues.

8. Comments

Observations with value judgments, or “soft” recommendations that require action by the design/engineering team, but where a formal written response is not requirement.

1. SSA output Combiner: Is it a hybrid? If so add a water load for additional isolation.
2. Consider incorporating the SSA combiner into the distribution for personal safety reasons.
    a. When one SSA shuts down does the other also?
3. Circulator:
    a. Isolation specifications may be difficult to achieve over the full power band.
    b. The circulator and load water path (impedance) needs to be considered to meet cooling specifications.
    c. Cooling water temperature and how it varies needs to be understood and conveyed to the vendor.
    d. The TCU needs to be able to operate for both pulsed and CW RF across the full power and bandwidth.
    e. The circulator load needs to be removable for maintenance.
    f. Arc detector is not presently in the RFPI scope.
    g. A detailed circulator specification needs to be written for the vendors. This must include the full test expectations, what the vendor tests and what FNAL tests.
    h. Suggest having a first article test for the circulator before releasing production units.
4. Directional Coupler
    a. Specifications are tough but achievable.
    b. Specify the flange with gaskets.
    c. Specify that it is pressure capable.
    d. Coupling material should be Rad-hard.
5. Coax/Waveguide Distribution
    a. Torturous path is not easy to lay out.
    b. The support structure should support microphonic mitigation.
    c. The standing waves and the distribution scattering parameters need to be well understood (especially in the area between the 6 1/8” transition and the cavity coupler).
    d. Keep distribution heating in mind and make sure that all components can handle full SSA power and full reflected power.
    e. System should incorporate the ability to have a low pressure interlock to provide RF (non-ionizing) radiation protection.
    f. Waveguide flanges should be CPRF with gasket. With gasket
6. EH&S
    a. Non-ionizing radiation: Need better guidance from FNAL ES&H division.
        i. LOTO on distribution is good for maintenance activities.
        ii. Antennas how do you verify them? How often? Who owns them?
        iii. Pressurize distribution system at low pressure.
    b. Installation Plan

        i. Hazard analysis, especially concerning the heavier items (circulator).
7. Cost and Schedule
    a. Need breakdown of cost concerning component test plans and installation with labor defined. Testing labor appears to be under-scoped.
    b. Acquisition Plan
        i. Circulator Vendor tests needs to be well defined, especially concerning high power tests made at FNAL. Is this in the contract and Vendor on site for tests?
8. Quality Assurance
    a. Okay for PDR but will need to have much more documentation for the FDR.
9. General Comments
    a. The PIP-2IT distribution system gives you an opportunity to test concepts, overbuild, so that you can economize the design for PIP-II.

9. Recommendations

Items that require formal action and closure in writing prior to receiving approval to move into the next phase of the project, or items that require formal action and closure in writing prior the next review.

1. Antennas are problematic in a personnel safety system for non-ionizing radiation. The distribution system needs to consider a parallel method for protecting against non-ionizing radiation, such as a low pressure interlock in the distribution system.
2. For the FDR the circulator needs to have a detailed specification that includes test plans and vendor expectations.
    a. water temperature/variance
    b. water path circulator to load
    c. isolation over power band
    d. load design
3. For the PIP-2IT test stand consider installing a coaxial dual directional coupler after the SSA combiner.
4. Consider a bottoms up review of the labor plan after you have developed thorough installation and test plans for the system and components.

10. Response to Charge Questions

If the charge is written in the form of questions, duplicate them and directly respond to them here. These responses should reference the relevant recommendations/comments/findings as appropriate.

The committee is asked to respond to the following questions:

1. Is the 650 MHz RF distribution design at the preliminary design level (30-50%)?
   Yes. We would say that it was closer to 30% complete.
2. Is the design consistent with system and project requirements?
   Yes.

3. Are the available technical drawings and documentation consistent with this level of design maturity?
   Yes.
4. Are the budget, schedule, identified interfaces and risks, and procurement and quality control plans consistent with this level of design maturity?
   No. See recommendations.
5. Are there any impediments to initiating final design work?
   No. See recommendations.

11. Value Engineering Opportunities

Value Engineering (VE) opportunities are often discovered during conceptual and preliminary design reviews. The Review Committee will consider Value Engineering in their assessment of the reviewed materials proposed design and provide a list of suggested opportunities below. The PIP-II Project established a *PIP-II Value Engineering Plan* to support this effort [10]. VE opportunities are not intended to be recommendations. Recommendations are captured in Section 9 above. If no VE opportunities are identified, please indicate.

No VE opportunities were identified by the review committee.