PXIE RFQ / RFQ Cooling System
Interface Control Document

Prepared by: C. Baffes, PXIE Warm Front End Integration	Fermilab	cbaffes@fnal.gov
Approved by: J. Steimel, FNAL RFQ Liaison	Fermilab	steimel@fnal.gov
Approved by: A. Shemyakin, PXIE Injector manager	Fermilab PXIE	shemyakin@fnal.gov
Approved by: M. Ball, PXIE Fluids Lead	Fermilab AD Fluids group	reese@fnal.gov
Approved by: J. Czajkowski, RFQ Cooling System Responsible Engineer	Fermilab	jerzy@fnal.gov
Approved by: A. Lambert, RFQ Engineer Responsible for Cooling	LBL	arlambert@lbl.gov
Approved by: D. Li, LBL RFQ Liaison	LBL	DLi@lbl.gov

Revision History

Revision	Date	Section No.	Revision Description
"-"	2014-Apr-24	All	Initial Release.

List of Open Issues to be resolved in a subsequent revision:

- Need to finalize coolant supply temperature at interface (see Table 1). This must be resolved well before tuning of the RFQ at LBL.
- Need to determine and document location of interface points on the RFQ body (see [5])

TABLE OF CONTENTS

1. Introduction:

The PXIE Radio Frequency Quadrupole (RFQ) accepts the beam at 30 keV as it exits the LEBT and accelerates it to 2.1MeV where it is transferred to the MEBT section. The RFQ requires active water cooling to maintain acceptable temperatures. Two separate cooling circuits exist: once cools only the RFQ vanes; the other cools the RFQ walls and pi-mode rods. Differential temperature between these circuits is used to keep the RFQ on resonance, so temperature adjustability and stability are required.

The LBL-provided RFQ is made up of four longitudinal modules. The modules are plumbed in parallel, with the FNAL-provided Cooling System interfacing to each module separately.

For the purposes of this section, the "RFQ" refers to the LBL-provided RFQ itself, up to interfaces points for individual channels or circuits.

The "Cooling System" refers to the FNAL-provided system that provides temperature-controlled water at specified flow rates to each of the RFQ modules/circuits. The Cooling System responds to temperature setpoint commands issued by the LLRF System.

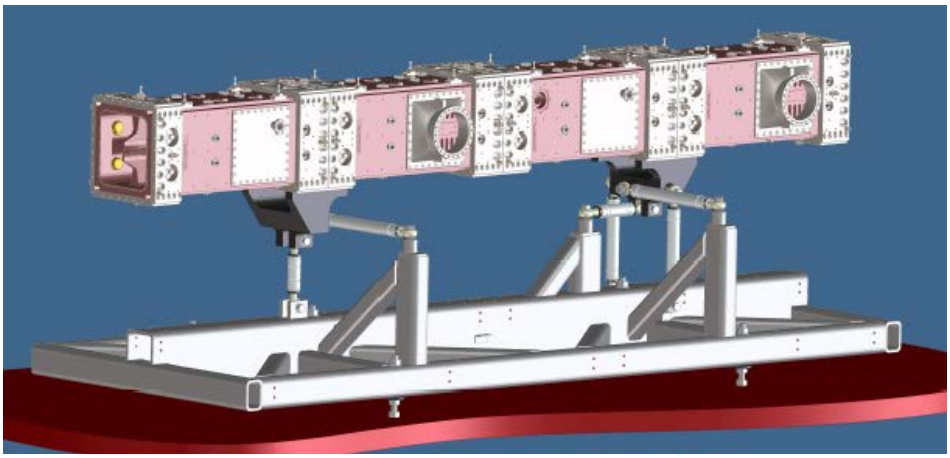

Figure 1: PXIE RFQ

2. Scope:

This document captures interface definition and requirements between the RFQ itself and the RFQ Cooling System. The intention is to capture the requirements between systems that will allow for mechanical interface, cooling and tuning of the RFQ.

Other documents relevant to the RFQ/ RFQ Cooling System interface include:

- The overall requirements and specifications for the RFQ are documented in [1]
- The overall interface agreement between LBL and FNAL is documented in [2]
- The Technical Requirements Specification for the RFQ Cooling System is [3]
- LBL design of cooling of the RFQ is documented in [4]

3. RFQ power and total flow rates

The Cooling System shall provide for the adjustment of flow and temperature within the limits established in Table 1.

The Cooling System shall provide valving that allows flow in either circuit to be balanced and adjusted between RFQ modules as described in Table 2.

Table 1: Total Power and Flow Requirements on Cooling System

Parameter	Vane Circuit	Wall/Pi-rod Circuit	Comments
Heat Load			
Nominal Load	29kW	50kW	[4]
Maximum load	38kW	65kW	30% Contingency [4]
Flow Rate			
Minimum Flow	44 GPM	88 GPM	
Nominal Flow	65 GPM	128 GPM	Design Condition [4]
Maximum Flow	87 GPM	172 GPM	
Supply Temperature at Interface			
Nominal Supply Temperature	35°C (TBR)	35°C (TBR)	Proposed to allow mixing architecture for cooling system Currently in conflict with [1]

Table 2: Module Power and Flow Requirements on Cooling System

Parameter	Vane Circuit	Wall/Pi-rod Circuit	Comments
Module 1			
Heat Load			
Nominal Load	7.19kW	12.2kW	Analysis Prediction [4]
Maximum load	9.5kW	16.3kW	~30% Contingency added
Module 2			
Heat Load			
Nominal Load	7.17kW	12.8kW	Analysis Prediction [4]
Maximum load	9.5kW	16.3kW	~30% Contingency added
Module 3			
Heat Load			
Nominal Load	7.17kW	12.8kW	Analysis Prediction [4]
Maximum load	9.5kW	16.3kW	~30% Contingency added
Module 4			
Heat Load			
Nominal Load	7.34kW	12.3kW	Analysis Prediction [4]
Maximum load	9.5kW	16.3kW	~30% Contingency added
Requirements Common to All Modules			
Flow Rate			
Minimum Flow	11.0 GPM	22 GPM	
Nominal Flow	16.3 GPM	32 GPM	Design Condition [4]
Maximum Flow	21.7 GPM	43 GPM	

The temperature rise of the cooling water is a function of the power and the flow rate, both specified above. As such, there are no requirements levied on temperature rise. However, nominal temperature rises are given in Table 3, for Reference Only. These relatively small temperature rises inform the accuracy and resolution of the thermometry required (see [3]).

Table 3: Water Temperature Rise (Reference Only)

Parameter	Vane Circuit	Wall/Pi-rod Circuit	Comments
Temperature rise through the RFQ	~1.4°C	~1.0°C	7.5 ft/s coolant velocity

4. Cooling System Interface Requirements on the RFQ

The RFQ shall provide flow characteristics as shown in Table 4

Table 4: Cooling System Requirements on RFQ

	Vane Circuit	Wall/Pi-rod Circuit	Comments
Pressure Drop At Maximum Flow Rate	<60psig	<60psig	Pressure drop at the interface location
MAWP	100psig	100psig	
Hydrostatic Test Pressure	1.5X MAWP	1.5X MAWP	B31.3

5. Physical Interface

The Cooling System shall use 100% Water.

The Cooling System shall provide filtration and a method to prevent biological growth, e.g. bacteria

There is no explicit requirement for Low Conductivity Water (LCW). The Cooling System may use low or normal conductivity water. However, conductivity shall be maintained at a high enough level to prevent aggressive attack of the copper.

The Cooling System shall keep O_2<20ppb (required), and preferably <10ppb (goal) at the skid location to limit CuO particulate.

The Physical Interface between the RFQ and the Cooling System shall be at the locations shown in Figure 1, Figure 2 and Figure 3 below. The physical placement of the RFQ interfaces is shown in [5].

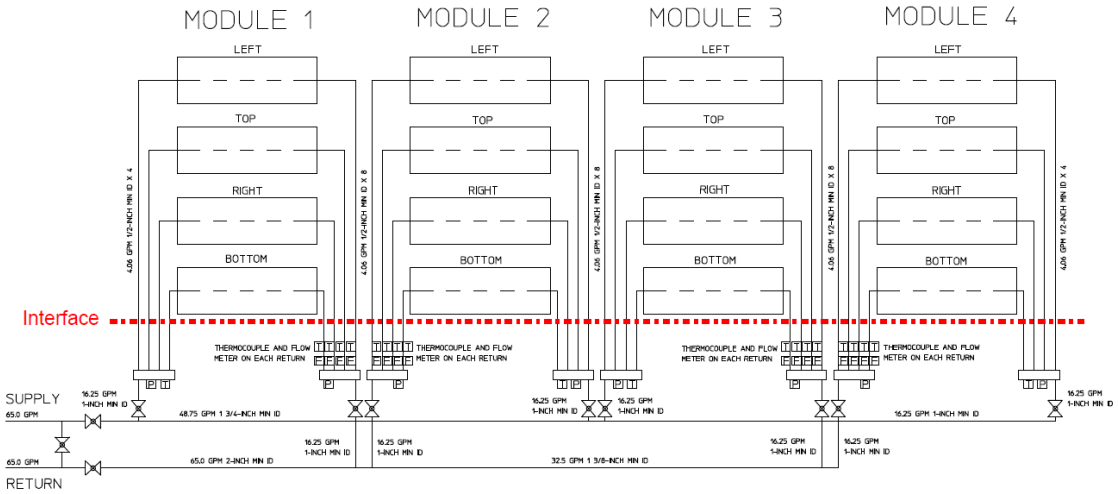

Figure 2: Vane Circuit Interface Location
Above Red Line: LBL. Below Red Line: FNAL.

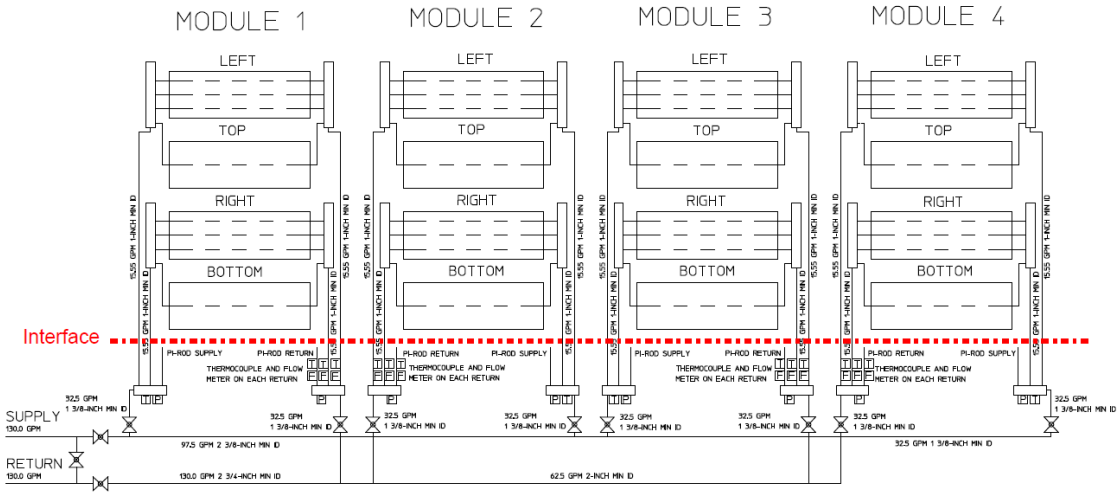

Figure 3: Wall/Pi-rod Circuit - Wall Interface Location
Above Red Line: LBL. Below Red Line: FNAL.

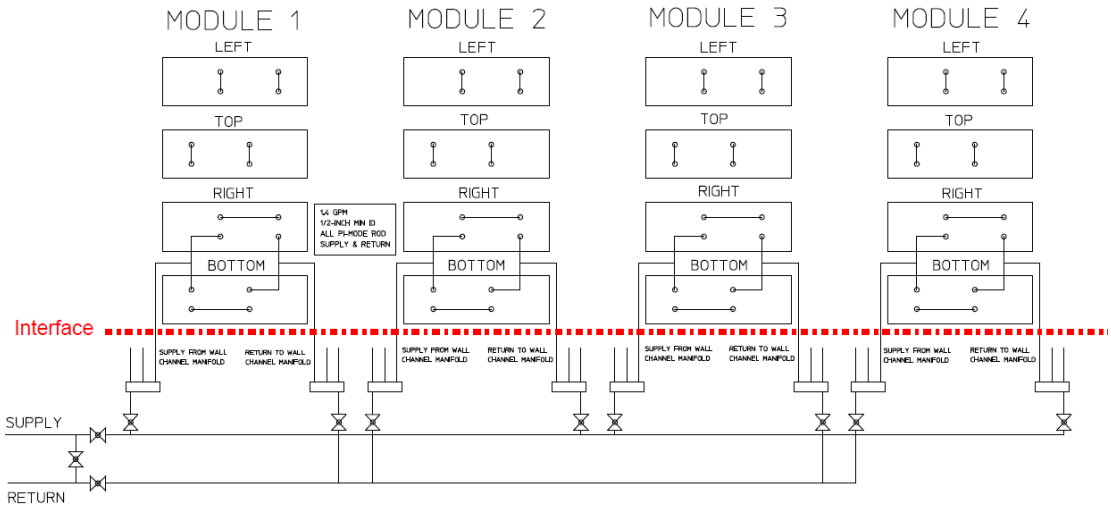

Figure 4: Wall/Pi-rod Circuit – Pi-Rod Interface Location
Above Red Line: LBL. Below Red Line: FNAL.

For each circuit, Cooling System shall provide manifolds, flexible hoses, and fittings to interface points hard-connected to the RFQ

The RFQ shall provide interfaces, rigidly connected to the RFQ, as follows:

Table 5: Interface Fittings

Sensor	Qty (Per Module)	Qty (Total)	Fitting on RFQ	Comments
Vane Channel Supply	4	16	½" NPT – Male SCH 40	On RFQ Body Single-channel interface
Vane Channel Return	4	16	½" NPT – Male SCH 40	On RFQ Body Single-channel interface
Wall Circuit Supply	2	8	1.25" NPT – Male SCH 40	On an LBL manifold
Wall Circuit Return	2	8	1.25" NPT – Male SCH 40	On an LBL manifold
Pi-rod Supply	1	4	½" NPT – Male SCH 40	On an LBL manifold
Pi-rod Return	1	4	½" NPT – Male SCH 40	On an LBL manifold

The RFQ shall provide torque reaction features on each interface fitting. A hex or wrenching flats is preferred.

FNAL shall specify, provide and install all temperature and pressure sensors (below the red interface line) on FNAL-provided piping or manifolds.

6. Valving, Instrumentation and Trip Requirements

The Cooling System shall provide a means to control the flow (in either circuit) to each module individually, within the limits given in Table 2. For example, it shall be possible to supply Module 1 with the Table 2 "Minimum Flow" and Module 2 with the "Maximum Flow" simultaneously. This may be a manual "set and forget" valve adjustment.

The Cooling System shall provide valving within the Wall/pi-rod circuit that allows flow to be adjusted or balanced between the wall channels and the pi-rod channels. This valving may be manual (i.e. "set and forget").

The FNAL-provided cooling instrumentation of the RFQ shall be as follows. Trip limits shown are as required by LBL. FNAL may choose to implement additional trip limits on these or other cooling parameters.

Table 6: Instrumentation Requirements and Trip Definition

Sensor	Qty	Trip Limits: High/Low
Module Supply Temp	4	
Module Supply Pressure	4	
Module Return Pressure	4	
Vane Channel Return Temp	16	
Vane Channel Return Flow	16	Nominal Flow (4.06gpm) +/- 25%
Module Supply Temp	4	
Module Supply Pressure	4	
Module Return Pressure	4	
Wall Channel Return Temp	8	
Wall Channel Return Flow	8	Nominal Flow (15.5gpm) +/- 25%
Pi-rod Channel Return Temp	4	
Pi-rod Channel Return Flow	4	Nominal Flow (0.9gpm) +/- 25%

7. Testing Requirements

LBL shall perform a hydrostatic pressure test of each circuit prior to delivery. Final vacuum leak check shall occur after pressure test. Test pressure shall be as shown in Table 4. Documentation of test shall be provided to FNAL.

LBL shall perform a flow/pressure drop measurement for each module and circuit, from the supply interface point to the return interface point. Pressure drop at nominal flow rate shall be measured and documented. Documentation of test shall be provided to FNAL.

FNAL shall perform a hydrostatic pressure test of each circuit after integration with the Cooling System.

Pressure testing of the Vane and Wall/Pi-rod circuits shall be performed simultaneously, both at the RFQ level and at higher-level testing of the integrated system.
Note: Vane circuit and Wall/Pi-rod circuit are separated only by a diverter sleeve, not a pressure and leak-tight connection. A small amount of pressure crosstalk would be expected.

8. References:

Documents with reference numbers listed are in the Project X DocDB:
http://projectx-docdb.fnal.gov

[1] Project X RFQ: Functional Physics Requirements
Document #: Project-X-doc-894

[2] LBL/FNAL RFQ Interface Agreement
https://sharepoint.fnal.gov/experiment/pxie/Shared%20Documents/PXIE%20RFQ/PXIE%20RFQ%20Interface%20Control%20Document%20062713.docx

[3] RFQ Cooling System Technical Requirements Specification
Document #: Project-X-Doc-1272

[4] LBL Engineering Note 10825 rev A:
PXIE RFQ Cooling Specification and Configuration

[5] We need a drawing from LBL showing manifold and interface point locations on the RFQ. To be incorporated in a future revision.