Science & Technology Facilities Council
Rutherford Appleton Laboratory

ESS Freia Neutron Chopper Proposal

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Summary

This document presents a basic specification for the choppers of the Freia neutron reflectometer currently being designed for the European Spallation Source ERIC. The purpose of the document is to obtain cost estimates and to identify technical issues with Suppliers.

Revision History

Revision	Revision Date	Summary of changes
1	31/07/17	First Issue

Approvals

This document has the following approvals:

Name	Title
Jim Nightingale	Lead Engineer

Contents

Definitions

STFC – Science and Technology Facilities Council
ISIS - the name of a neutron facility in Oxfordshire, UK
Freia – the name of a reflectometer instrument currently in design
ESS – European Spallation Source
ERIC - European Research Infrastructure Consortium
European Spallation Source ERIC – official title of the neutron source currently being constructed in Lund, Sweden

1 Introduction

The European Spallation Source ERIC is a neutron facility currently under construction in Sweden. STFC ISIS are collaborators providing engineering resource for the concept phase of the Freia instrument.

Freia is a neutron reflectometer with a sample position approximately 23m from the moderator. More details can be found on the European Spallation Source ERIC website:

https://europeanspallationsource.se/article/revealing-change-over-time-freia-brings-fast-kinetic-studies-reflectometry

A project toll-gate review will occur in summer 2017, where the instrument concept, scope and budget will be fixed. This concept specification is in order to approach Suppliers and gather realistic technical solution, budget and project timescales.

2 Requirements Overview

The requirement is for suppliers to provide:

1) Advice on technical feasibility of delivering to this specification – including any concerns
2) Cost to deliver to specification – individual cost estimates to be given for:
    a. Complete chopper assembly: including drive, discs and vacuum housing
    b. Costs to procure discs only,
    c. Commissioning.
3) Realistic delivery timescales and any known commitments that may affect delivery
4) Recommendations that may improve the design and/or reduce cost and improve delivery timescales
5) List of all excluded items

3 Technical Specification

3.1 Basic Description of Freia

Freia consists of an inclined elliptical focussing multi-channel supermirror guide focussed on a sample at ~23m from the neutron moderator. Freia contains 8 chopper axes, the details of which can be seen in table 1. Figure 1 shows a schematic layout of Freia with key components annotated. Figure 2 shows a concept design of the choppers and housings.

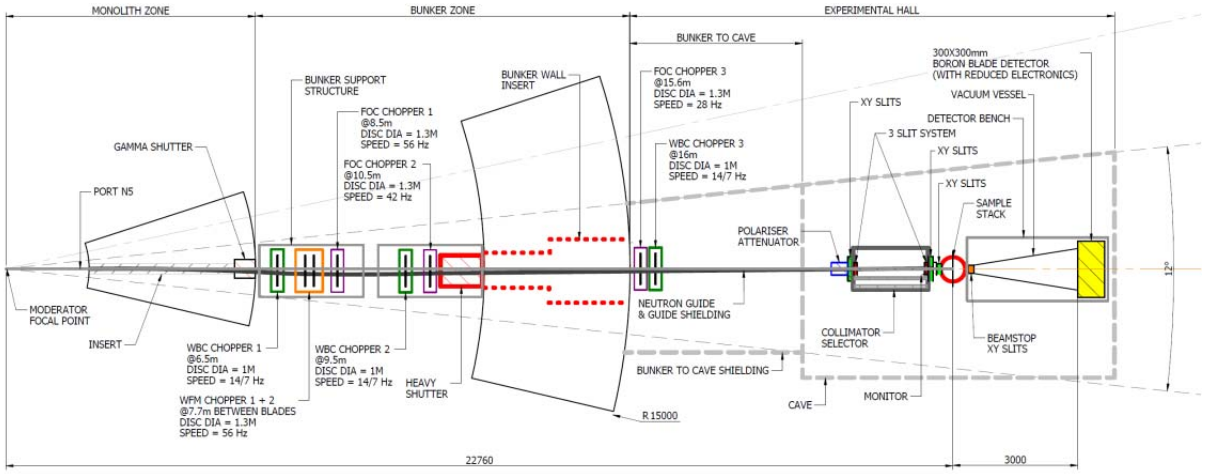

Figure 1- schematic layout of the Freia instrument

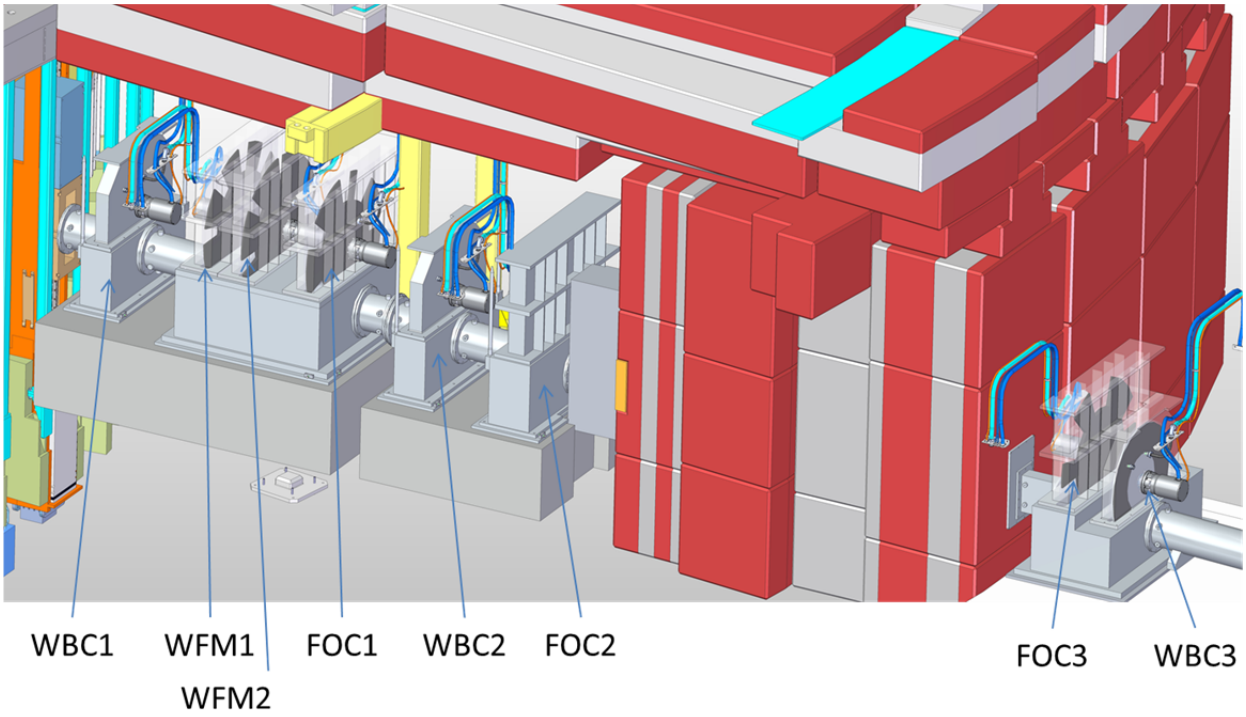

Figure 2- 3D concept layout of ESS Freia chopper assemblies

Type	Single disc	Single disc	Single disc	Single disc	Single disc	Single disc	Single disc	Single disc
Function	Wavelength Bandwidth Chopper 1 (WBC1)	Wavelength Frame Multiplication 1 (WFM1)	Wavelength Frame Multiplication 2 (WFM2)	Frame Overlap Chopper 1 (FOC1)	Wavelength Bandwidth Chopper 2 (WBC2)	Frame Overlap Chopper 2 (FOC2)	Frame Overlap Chopper 3 (FOC3)	Wavelength Bandwidth Chopper 3 (WBC3)
Position (m) from moderator	6.5	7.5195	7.8805	8.5	9.5	10.5	15.6	16
Environment	10^{-3} mbar Vacuum	10^{-3} mbar Vacuum	10^{-3} mbar Vacuum	10^{-3} mbar Vacuum	10^{-3} mbar Vacuum	10^{-3} mbar Vacuum	10^{-3} mbar Vacuum	10^{-3} mbar Vacuum
Installation Variant	Horizontally split housing	Horizontally split housing	Horizontally split housing	Horizontally split housing	Horizontally split housing	Horizontally split housing	Horizontally split housing	Horizontally split housing
Bearing/Drive Type	SKF G5 MB magnetic	SKF G5 MB magnetic	SKF G5 MB magnetic	SKF G5 MB magnetic	SKF G5 MB magnetic	SKF G5 MB magnetic	SKF G5 MB magnetic	SKF G5 MB magnetic
Outer Diameter (mm)	1000	1300	1300	1300	1000	1300	1300	1000
Operating Speed (Hz)	14 (7)	56	56	56	14 (7)	42	28	14 (7)
Disc Windows	1*	7*	7*	7*	1*	7*	7*	1*
Beam Height (mm)	226*	235*	238*	241*	247*	249*	232*	229*
Absorber†	B4C Resin	B10 (B4C)	B10 (B4C)	B10 (B4C)	B4C Resin	B10 (B4C)	B10 (B4C)	B4C Resin
Absorber Thickness †	~10mm	>0.4mm (>3mm)	>0.4mm (>3mm)	>0.4mm (>3mm)	~10mm	>0.4mm (>3mm)	>0.4mm (>3mm)	~10mm
Notes	*refer to drawing JBN-003992	*refer to drawing JBN-003228	*refer to drawing JBN-003236	*refer to drawing JBN-003229	*refer to drawing JBN-003993	*refer to drawing JBN-003230	*refer to drawing JBN-003231	*refer to drawing JBN-003994

† minimum thickness estimated – please refer to section 3.2.5 for full requirements

Table 1 – ESS Freia chopper specification

3.2 General Requirements

3.2.1 Compliance

The chopper system must comply with all ESS standards. Control must be delivered using the ESS Chopper Integrated Control (CHIC) detailed in ESS-0042906 and associated documents. These documents will be made available during formal tender but are not covered in this proposal. However, they are available upon request.

3.2.2 Radiation Environment

The radiation environment is anticipated to be significantly higher than current neutron facilities. Choppers positioned within the first 11m from the target are expected to fully operate in radiation environments of up to 2Gy/h. Material activation is a concern and therefore the chopper housing should be constructed from aluminium and steels avoided where possible.

3.2.3 Vacuum

The choppers should be designed to operate under process vacuum (10^{-3} mbar). Housings must have replaceable vacuum seals and seals near the neutron beam should be metallic (e.g. the guide vessel/chopper housing interfaces).

3.2.4 Drive

All choppers should be directly connected to a standard SKF G5 magnetic bearing drive system. Supplier must provide details of recommended alternative if they are not willing to supply to this specification.

3.2.5 Neutron Attenuation

All chopper blades need to use boron to achieve a minimum neutron transmission of 10^{-9} at 2Å. Equivalent minimum boron thicknesses have been estimated in Table 1 but this heavily depends on mixture and application. Therefore it is the Suppliers responsibility to ensure that the transmission specification above is achieved.

3.2.6 Remote Handling

Choppers located within 11m from the target cannot be easily accessed and will need remote handling solutions in order to remove and replace from a safe distance. Common lifting features will need to be integrated to ensure compatibility with ESS designed lifting mechanisms. These designs are not available at this stage and therefore do not form part of this specification but will be required during formal tender.

3.2.7 Connections

Radiation levels will also affect the ability to access electrical and mechanical connections. Choppers will need to be designed with an ESS designed remotely operable connection panel. A concept of this can be seen in figure 3. Further details can be found in ESS document ESS- 0041170. This is not yet fully specified and does not form part of this specification but will be required during formal tender.

3.3 Chopper Housings

Owing to the number of gaps in the Freia guide all choppers should be of a horizontally split vacuum vessel design. This comprises of an upper housing (containing the disc and drive) sealed to a lower housing that contains sections of neutron guide. This minimises the number of vacuum windows required. A concept design of the WBC1 chopper housing is shown in figure 3, below and a schematic concept design can be seen in drawing JBN-04800.

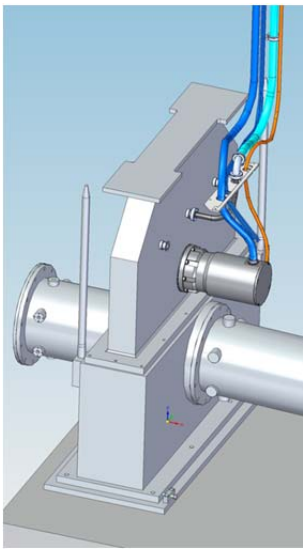

Figure 3- 3D concept of 'horizontally split' WBC chopper housing, including guide vessels

Freia has several choppers in close proximity and therefore benefits from shared vacuum vessels. Figure 4 shows WFM1, WFM2 and FOC1 sharing a combined lower housing. Likewise, figure 5 shows FOC3 and WBC3 in a shared housing.

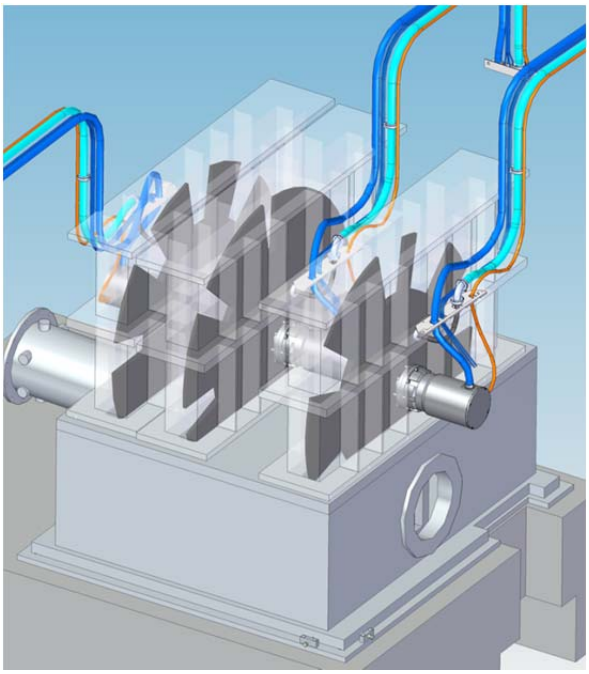

Figure 4- 3D concept of combined 'horizontally split' chopper housing (WFM1+WFM2+FOC1)

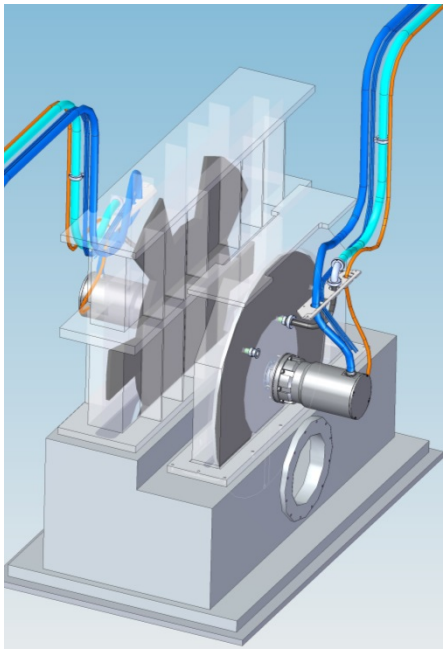

Figure 5- concept design of combined housing (FOC3+WBC3)

The upper housing design of each WBC, FOC and WFM (containing the discs and drives) should be standardised where possible in order to improve remote handling and extraction and replacement.

The following drawings offer concepts of Freia choppers for consideration:

WBC 1 Chopper assembly concept	JBN-04800
WFM1, WFM2, FOC1 combined assembly concept	JBN-04811
WBC2 and FOC 2 assembly concept	JBN-04857
FOC3 and WBC3 combined housing assembly concept	JBN-04864

It is important to note that these drawings are concept designs for horizontally split choppers. It is expected that the design will evolve following discussion with Suppliers and during detail design.

3.4 Discs

The disc geometries are referenced in table 1 along with drawing numbers.

SKF G5 has an approximate maximum operating load of 40kg. Aluminium discs with ~10mm B4C blades may be feasible for the 1m WBC choppers. However, initial investigation shows that similar designed discs of 1.3m diameter are likely to exceed the load capacity of the drive and not tolerate the operational speeds. Optimised designs or carbon fibre may offer feasible alternatives. The Supplier is requested to propose their recommended disc design and verify its suitability based on previous experience or where possible, feasibility studies.

4 Delivery

Freia is still in concept phase and does not have accurate milestone dates. However, the current estimated timescales are:

Tollgate 2 review (progress to detail design)	September 2017
Insert installation	2020
Bunker zone installation	Early 2022
Outside of bunker installation	Late 2022
Instrument Commissioning	2023

5 Supplier Pro-forma

STFC appreciate that the concept and specification is not well enough developed to request accurate costs. However, cost estimations and delivery plans with error margins will help set a budget and timescale for the project. STFC request that the Supplier provides the following information:

1	Complete chopper assembly
1.1	Estimated cost for upper assembly, comprising of disc, vacuum housing drive and all fixings fasteners for each chopper listed in table 1
1.2	Estimated cost for lower vacuum housing assemblies as shown in section 3.3
1.3	Estimated Time Plan for delivery of components – including key milestones (e.g. feasibility study, design, manufacture, assembly , commissioning)
1.4	Margin of error on estimation and brief explanation of margin
2	Discs
2.1	Evidence of technical experience or feasibility study of proposed disc design
2.2	Cost estimate of each disc
2.3	Estimated Time Plan for delivery of components – including key milestones (e.g. feasibility study, design, manufacture, assembly , commissioning)
2.4	Margin of error on estimation and brief explanation of margin
3	Commissioning
3.1	Estimated cost to commission choppers

STFC would be happy to discuss the concept and design in more detail with Suppliers before producing a formal specification.