Science & Technology Facilities Council

UK Research and Innovation

Specification for the Supply of RF Windows for the CLARA Windows at Daresbury Laboratory

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Approvals:

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1. Introduction

1.1 STFC

Contracts will be awarded by the Science and Technology Facilities Council (STFC). All contractual issues will be managed by the relevant authority (UK Shared Business Services Limited; UKSBS or STFC) with technical issues being the responsibility of the Accelerator Science and Technology Centre (ASTeC) and the Technology Department at Daresbury Laboratory.

1.2 Compact Linear Accelerator for Research and Applications

A next-generation light source test facility is to be constructed at the Daresbury Laboratory which will be known as CLARA (Compact Linear Accelerator for Research and Applications), shown in Figure 1. The aim of the CLARA project is to develop a normal conducting test accelerator capable of generating longitudinally and transversely bright electron bunches and to use these bunches in the experimental production of stable, synchronised, ultra-short photon pulses of coherent light from a single pass FEL (Free Electron Laser) with techniques directly applicable to the future generation of light source facilities.

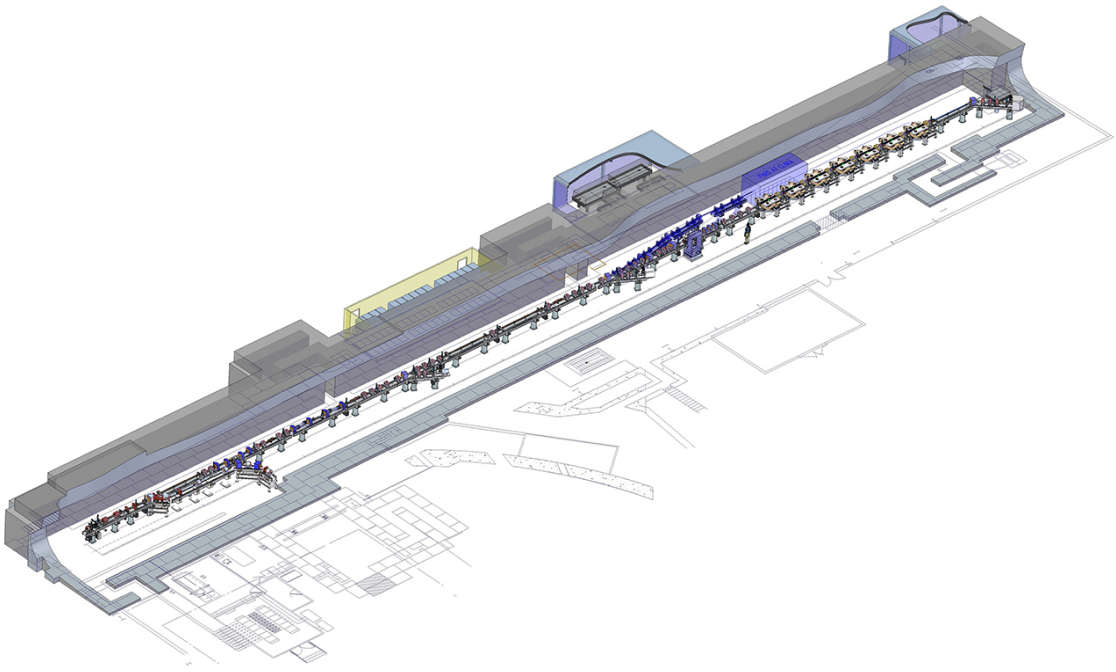

Figure 1: CLARA layout.

Presently at Daresbury Laboratory the Versatile Electron Linear Accelerator (VELA), a 6 MeV machine, is being operated. As part of a complimentary programme of work the CLARA facility is being developed to provide 250 MeV electron beam. The CLARA facility is to be situated in

the 'Electron Hall' located at Daresbury Laboratory and a schematic for CLARA is shown in Figure 2.

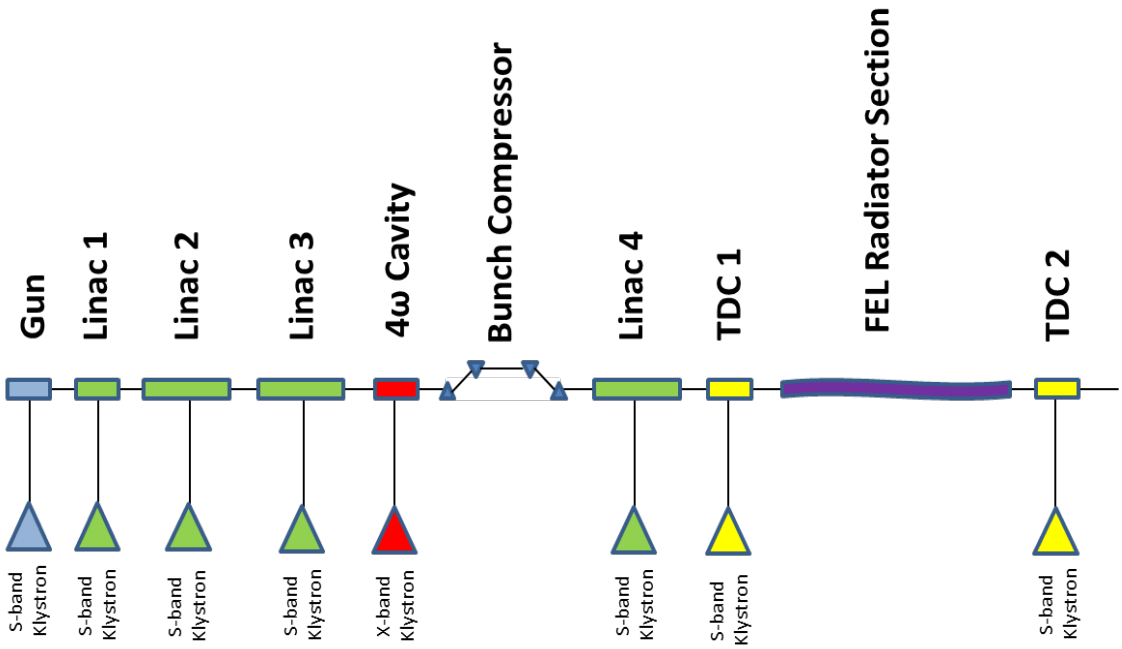

Figure 2: CLARA schematic.

1.3 Operation

The CLARA facility will be operated daily and run for long periods of time. It is planned to operate the electron test accelerator for approximately 4000 hours per year. During operational running of CLARA the linac klystron modulators will often be run at full peak power for long periods, but will also be required to operate at various peak RF power levels with different pulse duration and repetition rates, so as to provide the various operating schemes for the accelerator science to be performed.

1.4 RF Window Requirements

STFC requires RF windows for the CLARA linacs 2, 3 and 4 which require two windows each, as well as two spares, a total of 8 windows. Each window must be capable of handling RF peak powers of up to 45 MW. All of these RF systems will be operated at a frequency of 2998.5 MHz with a pulse width of up to 3 µs and a repetition rate up to 400 Hz. However, it should be noted that these conditions may not all be required at the same time. Detailed waveguide requirements for the RF windows are defined in this document.

1.5 Specification Abstract

This specification concerns design finalisation, manufacture, and delivery, to Daresbury Laboratory, of eight high power RF windows for the CLARA Linacs 2, 3 and 4 along with supporting documentation. The requirement comprises of:-

1. High power RF vacuum windows
2. Docuementation
3. Suitable gaskets
4. Delivery to Daresbury Laboratory

2. General Conditions

This document describes the technical specifications and procedures to be followed for the procurement of the high power S-band RF windows for CLARA.

2.1 Scope of Contract

2.1.1. The contract will cover the design (as required), manufacture, and delivery of the CLARA RF windows at STFC Daresbury Laboratory (hereinafter referred to as STFC), Warrington.

2.1.2. The Contractor will be required to co-operate closely with STFC and its authorised representative at all stages of the contract. Final design schemes and technical issues will be resolved after adequate discussion.

2.1.3. Regular progess reporting including: monthly written reports of progress against schedule and technical status and progress to date.

2.1.4. The provision of RF power to the RF cavities has been determined by STFC and is described within this document.

2.1.5. A manufacturing warranty for the RF window, covering all aspects of the mechanical fabrication under the Contractor's responsibility, for not less than 12 months duration after delivery of each part of the waveguide to STFC.

2.1.6. The manufacturer will be responsible for any departure from anticipated performance due to the failure to adhere to any part of this specification.

2.1.7. No change to the specified requirements is permitted without the written permission of STFC. However, if at any stage of the contract it is clear that advantage could be gained by such modification then the manufacturer is encouraged to bring it to the attention of STFC.

2.2 Sub-Contracts

2.2.1 Full details of all sub-contracts must be available to STFC.

2.3 Price and Payment Schedule

2.3.1 The price for major items is to be clearly defined within the bid at AW5.2 Price Schedule PR18145.

2.4 Timescales and Delivery

2.4.1. Timescales for the project are very important. It is envisaged that the contract will be placed 5 February 2019 and the bidder should provide the best indication of delivery based on this date. It should be noted that a latest acceptable delivery date would be 20 weeks from date of order (anticipated to be 12 February 2019), earlier delivery would be of benefit.

2.4.2. A draft manufacturing programme is required with the tender bid and a detailed programme including all necessary acceptance tests shall be issued by the Contractor within one week of contract placement and must be approved by STFC. This programme must contain sufficient detail to enable progress of the contract to be monitored accurately.

2.4.3. Written progress reports must be submitted to STFC at intervals of one month during the contract by e-mail addressed to Alan Wheelhouse.

2.4.4. No change may be made to the agreed programme without the written approval of UK Research and Innovation – STFC, who must be contacted immediately of any circumstances which might prevent the contract delivery date from being met.

3. RF System

3.1 Description of System

3.1.1. Each Linac RF systems for CLARA will consist of a klystron modulator, a klystron, a RF waveguide section, a normal conducting RF cavity, and a low level RF (LLRF) system.

3.1.2. The maximum peak RF output power is 80 MW at a frequency of 2998.5 MHz.

3.1.3. The RF will be pulsed with a pulse length of up to 3.0 μs, with a repetition rate between 1 Hz and 400 Hz.

3.1.4. Tight amplitude and phase control of the RF power into the cavities is required to ensure that accelerating voltage is maintained at a constant level and is synchronised with the electron beam. The amplitude and phase stability provided by the klystron modulator will be a key component in providing this required control.

3.1.5. During operation the output power to the cavities may be varied. This variation may be done hourly.

3.1.6. During operation the RF pulse width may be varied from 0.25 µs up to at least 3.0 µs. This variation may be done hourly.

3.1.7. During operation the repetition rate may be varied. This variation may be done hourly.

3.1.8. The RF parameters for the Linac cavities are shown below:-

Table 1:- Specification for the Linac cavities

Parameter	***Value***
Frequency	2998.5 MHz
Bandwidth	~ 5 MHz
Accelerating Voltage	100 MeV
Accelerating Gradient	25 MV/m
Peak RF input power	up to 80 MW
Pulse Repetition Rate Range	1 – 400 Hz
RF Pulse Width	0.25 - 3.0 µs
Amplitude stability	0.0001
Phase Stability	0.1°
Operational Temperature range	30 - 45°C
Input	WR284 (DESY flange)

4. RF Windows

4.1 Waveguide Layout

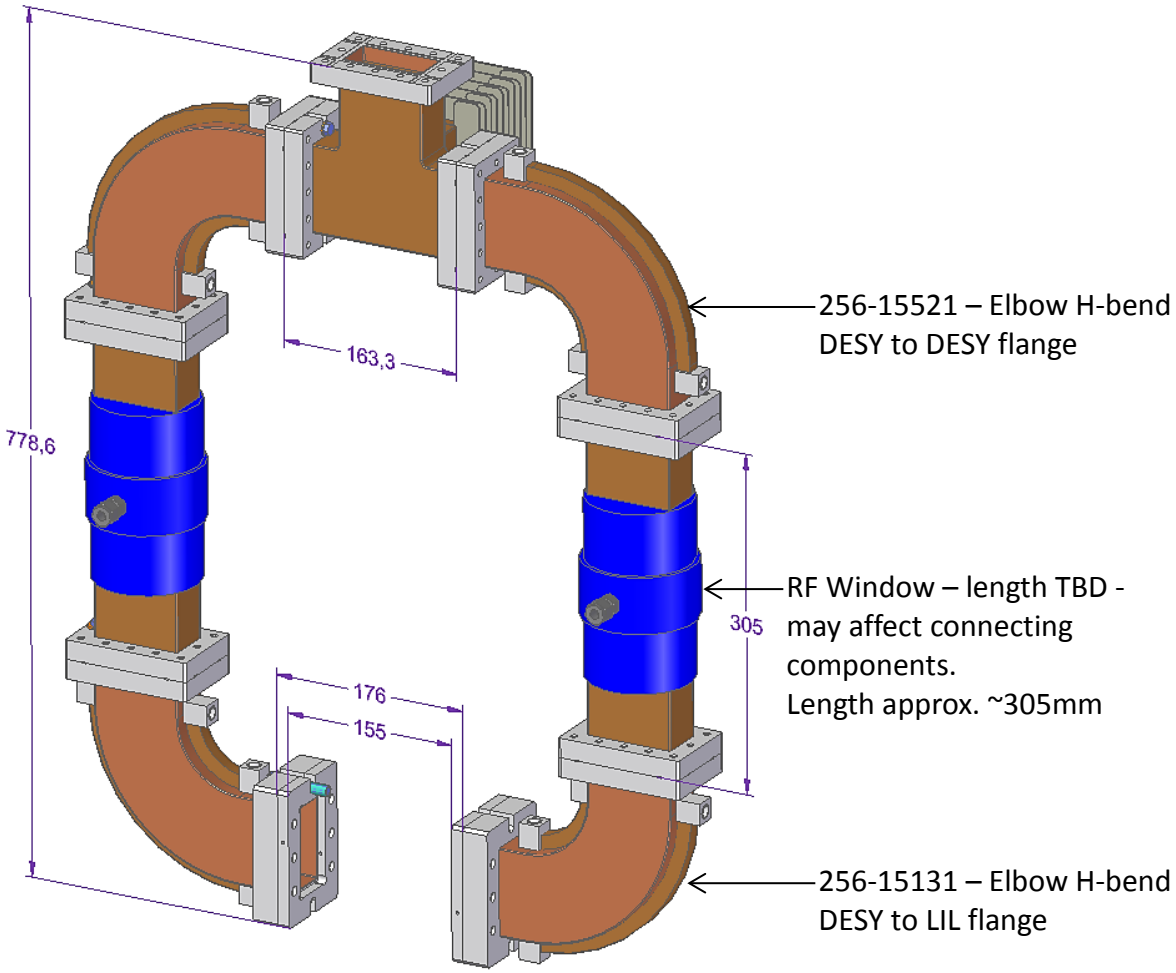

Figure 3: Layout of the waveguide section feeding into the Linac coupler ports. (Note: The elbows and splitter are not part of the contract).

4.2 45 MW RF Window Requirement

Defined below are the requirements for the 45 MW high power RF ceramic window.

Table 2:- 45 MW RF Window Specification

Item	**Parameter**
Waveguide type	WR284
Peak RF Power (MW)	45
RF Pulse Width (µs)	3.0
Maximum Repetition Rate (Hz)	400
Average RF Power (kW)	25
Operating Frequency (MHz)	2998.5 ± 5.0
VSWR for Operating Bandwidth	1.2:1
Insertion Loss (dB)	0.1 dB at 2998.5 MHz
Cooling	Supplier to determine and implement adequate cooling of the window for safe operation at the rated peak and average rated power levels. All relevant details, including connector details are to be provided as part of the bid documentation.
Multipactor	It should be ensured that the window is free from multipactor during operation.
Flanges	DESY-type (top and bottom)
Operating Pressures	$< 1 \times 10^{-8}$ mbar at cavity side.
Vacuum Tightness	$\leq 10^{-9}$ mbar L/s (with Copper gasket)
Cleanliness Requirements	See:- spc-003-Cleaning of Vacuum Items.pdf (Attached)
Baking Requirements	150 ^{o}C for 24 hours
Warranty	>12 months

4.2.1 Tolerances

Baseline tolerances are defined in the drawings provided and also within generic summary in listed below. In some instances the Contractor may be able to demonstrate to the satisfaction

of STFC that certain tolerances are unnecessarily high to achieve the RF specification (and/or difficult to achieve) . Within a framework of reasoned argument and evidence provided an agreement may be reached that certain tolerances may be relaxed. However, it is important to note that such agreement must be specified at the time of tender and formalised as written agreement between Contractor and STFC. Note that if default tolerances are not accepted at time of tender submission without offering alternative then this could reduce scoring or even disqualify.

The final approved drawings should show all the agreed tolerances

General Tolerances:

- Inside waveguide dimensions: ± 0.1 mm
- Flange Flatness: ± 0.02 mm
- Flange parallelism (between either end) : 0.2 mm
- Flange perpendicularity to main waveguide axis: ± 0.2 mm
- Waveguide straightness 1 mm
- Twist of waveguide tubing: 5 minutes (maximum)
- Twist of flanges with respect to each other: 5 minutes (max) for length of 4 m
- Length tolerance: greater of ± 0.5mm or 0.05% x specified length
- Bow of the waveguide < 0.1% of the length
- Inside step between flange and waveguide body ~ ± 0.1 mm

4.2.2 Braze Joint

The joint between stainless steel flange and copper body shall be brazed in vacuum furnace to ensure that vacuum cleanliness and low outgassing performance on the internal vacuum walls can be maintained . Alternatives to brazing involved more exotic techniques such as diffusion bonding may be proposed but will be accepted only if vacuum and RF performance characteristics can be guaranteed and only after written agreement with STFC.

Details of the brazing/bonding method and filler metal should be specified in the tender return.

4.2.3 Flange Design and Gaskets

DESY flange - Our flange drawing – ref 256-15129-A - for WR284 DESY type vacuum flange follows all design features and tolerances as defined in original standard DESY Zeuthen design (Ref drawing PI-DIA-26.2.024 TDS Adapterflansch-17.5). However STFC and supplier must agree on all design details on flange before committing to manufacture and this shall be done during first design review. This also applies for suitable gasket.(Note that no gasket drawing is supplied with tender - this will be agreed design review)

4.2.4 Joint Step

The braze joint between flange and body tube has been set as high tolerance in terms of dimensions and step alignment at +/-0.1mm. An example illustration of the control is shown below. This step / flatness at the joint applies to the bulk materials and any braze filler material that potentially has migrated through this joint via capillary action during the braze process . i.e. this should not stand proud of the joint.

If suppliers believe that this particular tolerance is excessive or difficult to achieve they must be able to state what tolerances they will achieve and also demonstrate with sufficient evidence that high power RF breakdown will not occur using their proposed more relaxed tolerances (i.e. whilst operating with the RF power parameters and vacuum conditions we have specified for the system). This should be stated and specified at tender return stage.

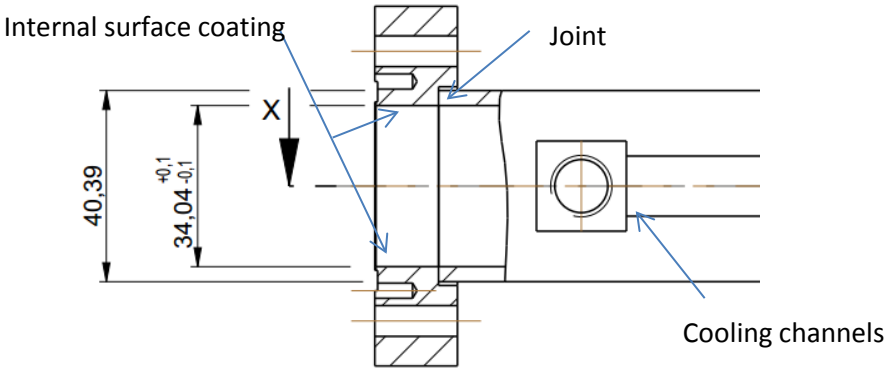

Figure 4.5.1b: Flange to waveguide body joint and finish

4.2.5 Cooling Channels

Cooling channels are envisaged as either copper alloy (brass) soldered or stainless steel brazed onto main body.

Cooling channel diameter is not envisaged to be critical and with average power and expected losses being low - the cooling channels are more of thermal stabilisers as opposed to large heat sinks.

Note that water fitting connection must be made into the channels. To be compatible with our existing system these should be ¼" NPT. Details of design should be fixed and agreed at the first design review.

4.2.6 External Paint / Coating

To protect against long term tarnish/corrosion on the outside of the copper body of the waveguide the component should be painted or otherwise coated in some protective adherent layer. The paint shall be high quality and adherent (e.g. epoxy powder coat) applied only on the outside surfaces. The end flange surfaces or internal vacuum surfaces shall at no point be coated by any paint and care should be taken so that the paint shall not enter any fastener holes on the flanges. A distance of 2-5mm around any hole - to clear any bolt, nut or washer used to fasten the flanges - shall be unpainted. Details of the paint and of colour shall be agreed at design review. By default waveguide colour is black at STFC.

4.2.7 Tolerances

Baseline tolerances are defined in the drawings provided and also within generic summary in listed below. In some instances the Contractor may be able to demonstrate to the satisfaction of STFC that certain tolerances are unnecessarily high to achieve the RF specification (and/or difficult to achieve) . Within a framework of reasoned argument and evidence provided an agreement may be reached that certain tolerances may be relaxed. However it is important to note that

such agreement must be specified at the time of tender and formalised as written agreement between supplier and TSFC. Note that if default tolerances are not accepted at time of tender submission without offering alternative then this could reduce scoring or even disqualify.

The final approved drawings should show all the agreed tolerances

General Tolerances:

- Inside dimensions: ± 0.1 mm
- Flange Flatness: ± 0.02 mm
- Flange parallelism (between either end) : 0.2 mm
- Flange perpendicularity to main waveguide axis: ± 0.2 mm
- Waveguide straightness 1 mm
- Twist of waveguide tubing: 5 minutes (maximum)
- Twist of flanges with respect to each other: 5 minutes (max) for length of 4 m
- Length tolerance: greater of ± 0.5mm or 0.05% x specified length
- Bow of the waveguide < 0.1% of the length
- Inside step between flange and waveguide body ~ ± 0.1 mm

4.3 Warranty

4.3.1 The terms of the warranty, which the manufacturer proposes to apply should be stated in the tender. The manufacturer must guarantee the equipment against failure due to either faulty components or manufacture. The minimum expected warranty will be twelve months from the delivery of the equipment. Please confirm in your bid, but note that a longer warranty would be advantageous.

4.3.2 Any other warranty statements that apply as part of the tender should be clearly defined within the tender documentation.

4.3.3 The Supplier shall maintain and apply a quality assurance program compliant with ISO-9001 or equivalent for the design, manufacture and testing of all systems and equipment provided by them. CE or equivalent marking of equipment should be applied wherever required.

4.4 Transport

4.4.1 Following the final vacuum test at the Contractor's premises, all blanking flanges must remain on the window. The vessel is to be let up from vacuum with dry nitrogen on both sides (dew point < -70°C) and the port used for connection to the leak detector and/or pumps is to be blanked off with a flange and gasket.

4.4.2 All shipments should arrive with a full inventory list of contained parts within the shipment (i.e. all drawing numbers listed). The Contractor shall retain a master list of items pertaining to the contract which can be called on at any time by STFC Daresbury to indicate items already shipped or in transit (along with shipment number and scheduled delivery date) and equally show outstanding items that have not yet shipped

4.4.3 Each individual component must carry a clear and unambiguous label outside the protective wrap or packaging enabling quick identification upon delivery and allow for intermediate storage without fully unpacking the item. This label is in addition to the permanent identification marks or labels that each component carries as defined under mechanical design section.

4.4.4 Components and assemblies must be protected during storage and carriage in such a way as to prevent movement due to any vibration, shock or knocks during transit. If any evidence of component damage due to vibration shock in transit is apparent upon delivery then STFC Daresbury reserve the right to review the packaging and delivery methods and also ask for tiltwatch and/or shockwatch indicators to be fitted to all subsequent shipments.

4.4.5 All components and assemblies to be transported in such a way as to allow adequate access of handling equipment. Details of packing and required handling equipment to be approved by STFC before delivery. All packaging will be retained by STFC unless agreed otherwise.

4.4.6 Prior to final sealing up of containment for transport (pallet/ crate…etc) a photograph of the contained parts and/or assemblies in a sealed and 'ready to ship' state should be captured and sent to STFC prior to dispatch.

4.4.7 **Important:** None of the contract deliverables shall not be despatched for delivery to Daresbury laboratory until both the following conditions have been met;

(a) Final drawing of deliverables have previously been received and accepted in writing by STFC

(b) The RGA report & vacuum test data have been submitted and approved in writing by STFC.

4.5 General Terms

4.5.1 The Contractor will be required to co-operate closely with STFC and its authorised representative at all stages of the Contract. Technical issues will be resolved after adequate discussion.

4.5.2 No change to the specified requirements is permitted without the written permission of STFC. However, if at any stage of the Contract it is clear that advantage could be gained by such modification then the Contractor is encouraged to bring it to the attention of STFC.

4.5.3 The Contractor must supply a suitable warranty covering all manufacturing work for each RF window, valid for not less than 12 months from delivery and acceptance of each finished RF window to STFC.

4.5.4 As well as technical performance and adherence to the fabrication processes and quality metrics defined, the schedule of production and delivery is critical. Contractors must therefore take a systematic approach to schedule planning, estimating, tracking progress and applying all reasonable corrective action to eliminate or minimise delays. This includes the use of appropriate methods, processes and tools for schedule management, as well as regular formal reporting of status, progress, issues etc.

4.5.5 The Contractor shall also take a systematic approach and use formal tools where required to manage technical and delivery risks, and shall incorporate project Risk Management into their day-to-day work under this Contract.

4.5.6 Unless otherwise agreed in writing, STFC must approve the final design before the Contractor proceeds to ordering of any materials, components or equipment required to fulfil this contract and equipment manufacture shall not start without STFC's written prior agreement on the design.

4.6 STFC Access to the Contractors Premises

STFC is to be granted access to the manufacturing facilities of the Contractor and its subcontractors at any time.

4.7 Data to be supplied with the RF windows

Measurements of the RF window properties will be provided.

- Reflection (S11, S22) and Transmission (S21) parameters for frequencies between 2.9985 +/- 50 MHz. Measurement of the VSWR (must be less than < 1:1.2).

4.8 Inputs and Supplies from STFC

For the provision of the Contract STFC will ensure that the Contractor has:-

- The latest specification for the drawings of the mating flanges.

4.9 Subcontractors

Full details of all subcontracts must be made available to STFC within the bid documentation provided during Contract tender. This shall include:

- Scope of work for each subcontract or subcontractor
- Approximate value of each subcontract
- Commercial relationship subcontractor to supplier (e.g. subsidiary, shared parent company, separate entity, etc)
- History of work undertaken by subcontractor for Contractor (number of recent similar subcontracts, frequency, value, success?)

STFC may request the Contractor to access or inspect its subcontractor premises.

The Contractor is solely and fully responsible to STFC for any works undertaken by any of its subcontractors.

4.10 Contractor's Qualification

The Contractor and all its subcontractors are required to maintain a quality-management system according to EN ISO 9001 or equivalent. The quality control system of sub-Contractors has to be independent from the Contractor's quality system. The Contractor's valid certificate according to EN ISO 9001 or equivalent is to be submitted with the bid.