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Government of India
Bhabha Atomic Research Centre
Radiological Physics & Advisory Division

Ref: BARC/RPAD/MPS/ 1698

Sept 08, 2017

Invitation to Tender

Brief Description & quantity:

Fabrication of Graphite calorimeter (01 No.) as per our drawing and specifications.

Place of Delivery: 103, CT&CRS Building, RP&AD, BARC, Anushaktinagar, Mumbai – 400 094.

Due Date: 12.10.2017

Please send your quotations for the above fabrication & supply in a sealed envelope super scribed "Fabrication of Graphite Calorimeter for radiotherapy", Attention: Dr. S. D. Sharma, so as to reach the undersigned on or before 12.10.2017. Rate(s) shall be type written only.

DDatta 8.9.2017
(D. Datta)

Quotations should be addressed to:

Dr. S. D. Sharma,
RP&AD, BARC
CT&CRS Building
Anushaktinagar, Mumbai - 400 094

Fabrication of the Graphite Calorimeter for Radiotherapy

The treatment of the cancer by radiotherapy requires the accurate delivery of the prescribed dose (within ±5%), this in turn depends on the highly accurate characterization of the beam produced by the radiation sources (telecobalt or linac). The output measurement of the treatment machine is done by using small volume ion chamber. The ionization chambers used in the hospitals for the radiotherapy beam calibration are calibrated in the terms of D_w (absorbed dose to water) in Co-60 gamma radiation beam in the reference conditions against the available reference standards or primary standards.

The primary standard for the measurement of the absorbed dose to water has the measurement uncertainty better than 1% and measures the physical quantity from its basic definition. Calorimetry is the most direct method of measuring the unit of the absorbed dose to water, the primary standards based on the calorimetry for the measurement of the absorbed dose to water are (a) water calorimeter and (b) graphite calorimeter, both these standards work on the principle of the measurement of the heat energy deposited in the medium per unit time, this in turn is correlated with the absorbed dose rate.

In the radiotherapy dosimetry the quantity of the interest is the absorbed dose at a point in the water medium, the biological tissue is made up mainly of the water, so water as a medium of the dosimetry represents the nearest realization to the dosimetry in the biological tissue, but, water calorimetry is relatively insensitive technique and involves the problem of heat defect, this requires lots of correction factors and adds to the uncertainty of the measurement. On the otherhand, graphite being a form of carbon (Z=6) presents an environment which is close to the biological tissue, has no heat defect and more sensitive as compared to water (the radiation induced rise in temperature of the graphite is 1.4 mK/Gy whereas, for the water it is 0.24 mK/Gy). These properties of the graphite make it a suitable material for the radiotherapy dosimetry.

Primary standard laboratories providing the radiotherapy dosimeter calibration services using calorimeter across the world, like, National Physical Laboratory (United Kingdom), BIPM (France), ARPANSA (Australia), INMRI-ENEA (Italy), National Metrology Institute (Japan) use Graphite calorimeter whereas, the PTB (Germany) employs water calorimeter as a primary standard for the measurement of absorbed dose to water in Co-60 gamma rays or high energy X-rays produced by the medical linear accelerators.

Presently, there are 416 radiotherapy centres in the country delivering the treatments to the cancer patients. Some of them use state of art treatment delivery systems. These hospital use sets of ionisation chamber for the output measurement of the machine, these dosimeters are calibrated against secondary standard, which itself is calibrated against BIPM’s primary standard. As a result of this calibration against the secondary standard, the dosimeters used in the hospitals are traceable to the Primary standard dosimeters, but at the same time the uncertainty in the measurement increases.

Therefore, the development of the graphite calorimeter will improve the accuracy of the radiation dose delivery to the cancer patients by reducing the intermediate step in the chain of the traceability by providing the direct calibration of the dosimeters against the highest meteorological standard.

Specifications:

Construction and working of Graphite Calorimeter:

The graphite calorimeter will consist of three main parts namely (a) Core; 20 mm diameter, 2 mm thickness (b) Jacket; 26 mm diameter, 8mm length and (c) Shield; 32 mm diameter, 14 mm length. The thickness of the wall of the jacket and shield will be 2mm. The drawings of these parts of the calorimeter are enclosed. Four holes need to be drilled in the curved walls of the core at equal gaps, two holes for the sensor thermistors and two for the heater thermistors. Similarly, two holes each on the walls of the jacket and shield for heater and sensor thermistors. The core will be placed inside the jacket, with a separation of 1 mm maintained with the help of the styrene spacers from the walls of the jacket. Similarly, the jacket itself will be enclosed inside the shield by a separation of 1 mm from the shield walls and will be maintained in the position by the styrene spacers.

This assembly will be placed inside a cylindrical cavity of 36 mm diameter and 14 mm length at the centre of the solid phantom of polymethyl methacrylate (PMMA) of size 15x15x15 cm^3. A hollow enclosure as shown in Figure 2 is carved in the solid PMMA phantom to isoloate the components of the calorimeter from external temperature fluctuations. The pressure inside the hollow enclosure is required to be maintained at < 0.01 Pa using oil free pump. Pressure gauze needs to be fitted to display the pressure inside the enclosure. The depth of the centre of the core will be maintained at 5 gm/cm^2 by placing the graphite plates of adequate thickness as the top surface of the calorimeter at the beam entrance as per the drawings.

The wires of the thermistors from core, jacket and shield will be taken out for electrical connections. The tensions of the wires will be in such way that it will keep the components (i.e. core, jacket and shield) suspended inside each other. Individualised Wheatstone bridge and current source will be connected to each of the core, jacket and shield to measure the rise in the temperature and to deliver power to these components respectively. The sensor thermistor leads from the core, jacket and shield form one of the arms of the Wheatstone bridge, and the leads from the heater thermistors requires connections to the current sources to deliver the power to the components.

The core, jacket and shield will be maintained at constant but different temperatures (~ 296.5K, ~296.2K, ~295.9K respectively), higher than the room temperature. In order to maintain these components at the above temperatures, power needs to be delivered at constant rate from the heater thermistors to the components. The bridge will be maintained in the balanced state and the voltage across the bridge will be measured by the nano-voltmeter. In the absence of the radiation the bridges connected to all the components will be in the balanced state and voltages read by all the nano-voltmeters in this situation will be zero.

When the radiation is incident on the calorimeter, it deposits the energy in the components of the calorimeter, this deposition of the energy raises the temperature of the components and the resistance of the thermistor, which forms one of the arms of the balanced Wheatstone bridge changes, this change in the resistance of the thermistors disturbs the balanced state of the Wheatstone bridges and voltage develops across the bridge which will be shown by the nano-voltmeters.

The fabricator should demonstrate the detection and measurement of the signal (i.e. voltage) developed due to the incidence of the radiation beam from the expected extremely noisy environment.

(A) Requirements for the calorimeter parts

(i) The components of the calorimeter should be machined smoothly, as the rough surfaces can introduce the uncertainty in the measurements.

(ii) The graphite material to be used for machining the components should strictly have the properties given in the specification table or better than this.

(iii) Holes in the body of core, jacket and shield should be drilled exactly as per the drawings, as the inaccurate drilling will lead to the misalignment of the holes while taking out the leads of the thermistor for electrical connections.

(iv) Heat exchanges between the components are to be minimized by 1 mm vacuum gaps, jacket and shield should be coated with very thin aluminized Mylar to avoid the heat losses.

(v) These three bodies are encompassed by the phantom by 2 mm vacuum gap.

(B) Requirements for Vacuum chamber and PMMA phantom

(i) The cavity encompassing the three bodies in the PMMA phantom is also aluminized to minimize the loss of the heat.

(ii) The vacuum inside the chamber should be maintained strictly at <0.01 Pa and the machining of the PMMA phantom should ensure that the walls of the chamber should withstand the inward pressure of the suction of air without bending/breaking.

(iii) The lids, connectors and valves should ensure that the pressure inside the chamber be maintained at the specified value.

(iv) For electrical shielding the entire chamber should be enclosed within the Al housing except the front window.

(C) Requirements for electronic components

(i) The rise in the temperature of the graphite material is 1.4 mK/Gy of the dose delivered. Therefore, the sensor thermistor measuring the temperature should be sensitive enough to detect the temperature change of this order.

(ii) The specifications of the thermistors, resistors and other components are given in the technical specifications table.

(D) Trolley

(i) A trolley needs to be provided for smooth transfer/movement of the system. The design of the trolley should be such that, it facilitates the safe placement, movement and adjustment of the Graphite calorimeter in the irradiation room.

Terms and conditions:

User: User refers to the scientific staff of Radiological Physics & Advisory Division, Bhabha Atomic Research Centre, Mumbai.

Vendor: Vendor refers to Fabricator of Graphite Calorimeter.

Development Sequence:

(1) User will explain in details about each items mentioned in the specification to the vendor.

(2) Vendor will propose and obtain approval for the structured lay out of the system.

(3) Each module of the system will be checked and approved by the user before linking in to the system.

(4) Once all the modules are linked, the system will be provided to the user for independent evaluations. Detailed report will be provided to the vendor and necessary modifications will be done by the vendor.

(5) After satisfactory performance of the system, vendor will supply the system to the user.

Documentation

It is the sole responsibility of the vendor to provide detailed user guide of system. The user guide should contain an extensive description of the overall functioning of each component of the system.

User Training:

The vendor must provide extensive training to the users for operating the system.

Work Progress Inspection: Progress of the work will be monitored by the team of BARC officers.

Warranty

The vendor must provide the warranty of atleast one year of the components used and functioning of the fabricated graphite calorimeter.

Pre-dispatch inspection

The pre-dispatch inspection and training shall be done at the manufacturer`s site.

Declaration by the Vendor

Vendor shall submit a **Declaration** stating that **Terms & Conditions** as described above are agreeable. Vendor shall also mention in the **Declaration** that the specifications put forth by the User can be met to the fullest satisfaction of the User.

Confidentiality Undertakings

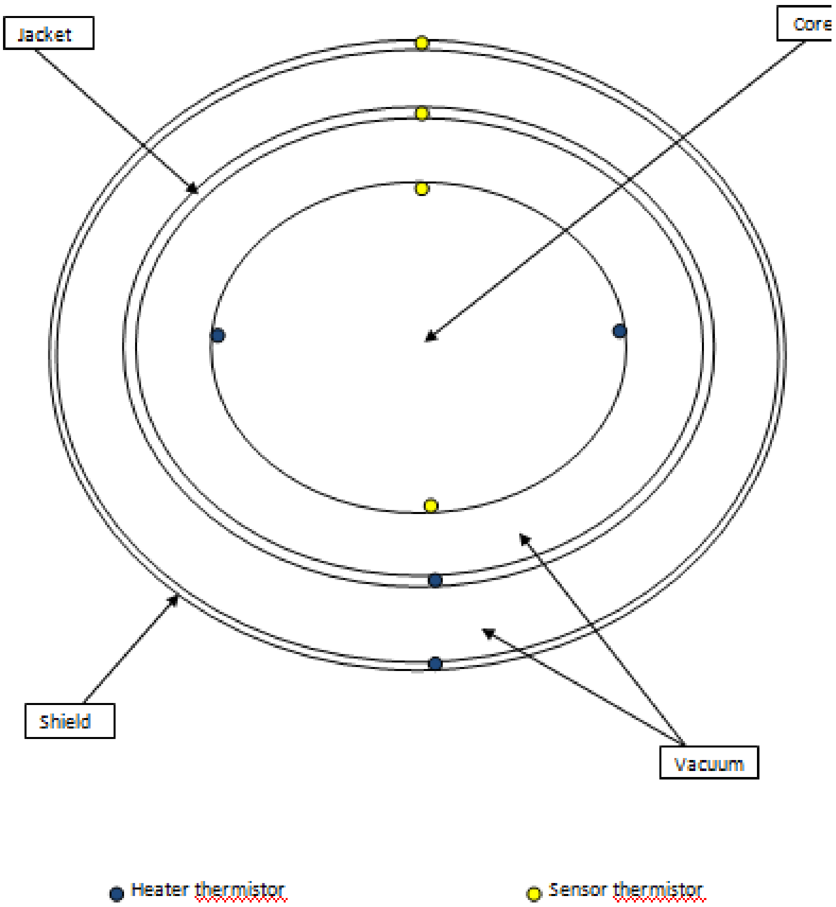
The Vendor shall submit an Undertaking stating that Graphite Calorimeter evolved through this contract is the sole property of Government of India, Bhabha Atomic Research Centre (BARC), Mumbai. No party shall disclose any information to any third party concerning the matters under this contract generally. In particular, any information identified as "Proprietary" in nature by the disclosing party shall be kept strictly confidential by the receiving party and shall not be disclosed to any third party without the prior written consent of the original disclosing party. This clause shall apply to the sub-contractors, consultants, advisors or the employees engaged by the thirds party with equal force.

The contractors, consultants, advisors or the employees engaged by the contractor shall not use the BARC's name for any publicity purpose through any public media like press, radio, and internet without prior written approval of the BARC.

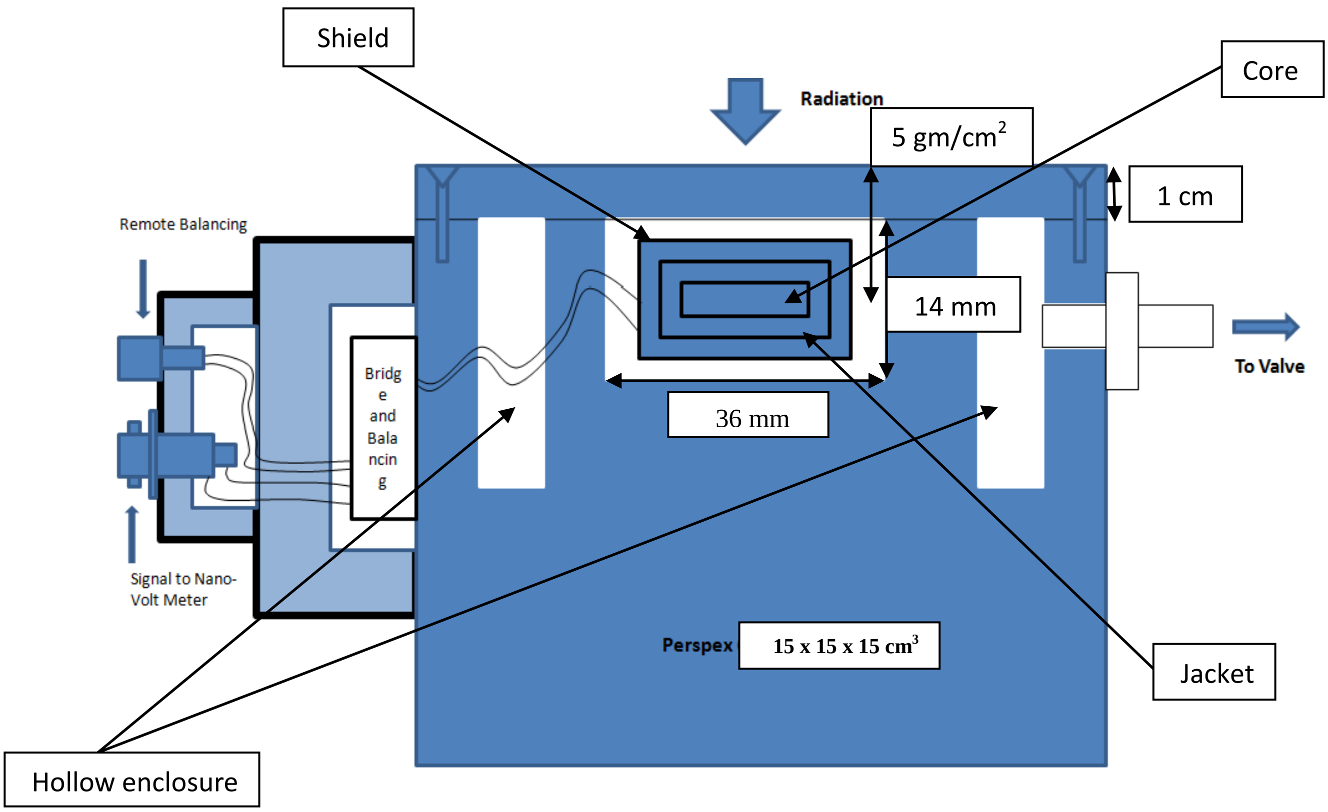
Summary of Technical Specifications

Component	Specification
Graphite block	Density ≥ 1.9gm/cm^3, Purity ≥ 99.5%, Particle size ≤ 2.5μm, Thermal Conductivity ≥ 90 W/m-K (It will be made available by RP&AD, BARC)
Sensor thermistors	NTC Type, Glass bead or any other material, Dia< 0.4 mm, Length< 1mm, Resistance~8-10 KΩ at 25°C, Relative sensitivity> 0.038K^{-1}, Beta value >3500.
Heater thermistors	NTC Type, Nominal Resistance ~10KΩ at 25°C, Tolerance better than 5%, 0/100 Beta value >3500 ± 2%, Dia < 0.4 mm, Length< 1mm
Connecting wires	Platinum/copper wires for connection
Standard Resistors	Precision resistors, Temperature coefficient of resistance <5 ppm/°C, Resistance 10 KΩ ± 1%
Glue for embedding the thermistors in holes	Epoxy glue of high thermal conductivity
Variable resistors	Should be able to vary the resistance in steps of 0.1 Ω
Nano-voltmeter	Keithley nano-voltmeter (It will be made available by RP&AD, BARC)
Vacuum Pump	Should be able to create a vacuum < 0.01Pa in the volume of 5 Litres
Pressure Gauze	Range: 0-0.5 mbar with accuracy better than 0.1%
Polymethyl Methacrylate	15x15x15 cm^3
Stable power supply	Low noise DC power supply of low drift(< 2 parts in 10^4 in 2 years), Operational voltage 1-3V
Current sources	DC voltage range 10 nV to ± 1200 V DC current range 1 nA to ± 120 mA Resolution 10μV/1nA Stability of voltage generation 30 ppm **Or** Fulfilling the requirements of the application
Digital Lock-in-amplifier	Stanford Research Systems (LI5640) **Or** Fulfilling the requirements of the application (It will be made available by RP&AD, BARC)

Cross Section of the Calorimeter at the centre of core



Calorimeter & Phantom housed with Vacuum Chamber



Vacuum pump arrangement with vacuum chamber