TECHNICAL SPECIFICATION

GRAPHITE RAW CORE MATERIAL

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1 INTRODUCTION

Note, items highlighted in grey are negotiable with the vendor.

1.1 Context

ThorCon's NPP is designed to be a passively safe fission power plant with fuel in liquid form that circulates in a closed loop through a graphite-moderated core at low pressure (the pressure at the top of the reactor is 3 bars) rather than in solid form as is the case for conventional NPPs, which operate at a pressure of up to 160 bars. The plant is designed to prevent significant radiation releases, and its safe operation relies upon a limited number of safety systems. The plant is designed to shut down, remove decay heat, and confine radioactive material without depending on electricity or operator actions.

1.2 General Notes

ThorCon's graphite needs are like those of a prismatic HTGR. Dimensional change as a function of fluence and temperature is very important. Density is probably a bit more important. Conductivity less so, since MSR's do not depend on the graphite as a decay heat path in a loss of coolant. The main difference is ThorCon needs a graphite that will resist salt intrusion at reactor pressure (5 bara).

Specifications are target values. The vendor shall state the warranted values of the above properties and the properties in Table 2. The density, thermal conductivity, and specific heat shall be characterized over a 300K to 1200K temperature range. The graphite will change shape under neutron irradiation. Changes in length are readily accommodated as long as the graphite maintains its integrity. The load on the graphite is its own weight standing vertically. We expect the graphite life will be set by when the graphite returns to its original size radially. If the vendor has data on the dimensional change as a function of fluence and temperature this would be most helpful. The graphite will be used in a demonstration reactor and the data on graphite lifetime will be gathered. The target lifetime is $3x10^{22}$ n/cm^2 for energies greater than 50keV at 740°C.

Other considerations:

- Holes will be drilled lengthwise through the logs to allow salt to flow and remove heat deposited in the graphite.
- Lower boron equivalent impurity will lower ThorCon's fuel costs so options (and costs) for lower impurity levels are of interest.
- Both extruded and isostatically pressed graphite will be considered as options, although the latter will be challenging for the 4 meter length requirement.
- All blocks shall be marked such as to provide full traceability

1.3 Glossary

AG = against grain and orthogonal to extrusion direction
CMM = coordinate measuring machine
HTGR = high temperature gas reactor
MSR = molten salt reactor
NPP = nuclear power plant
WG = with grain and parallel to extrusion direction

2 MATERIAL SPECIFICATIONS

2.1 Required Properties

Table 1 below outlines the raw material form and properties needed prior to machining activities. In addition to meeting these material requirements, the vendor also must disclose the exact values predicted and later attained per the test method/standard specified. ThorCon understands that many of these requirements are interdependent, hence they should be viewed as an overall "wish list" and somewhat negotiable. A "lot" is a core's worth of graphite consisting of an estimated 150x 4-meter long blocks which are machined into an estimated 550x finished components. A separate specification is used for the detailed finished components. This specification is only for the raw blocks dimensioned at 4m in length as a hard requirement and with a cross section of 0.750m x 0.375m which is negotiable. Vendor to state max achievable cross-section dimensions.

Table 1: Required Specifications

Specification		Units	Value	Tol	Test Method or Standard	Test Frequency	Notes
Density		kg/m3	1800	±5%	ASTM C559-16 (2020)	1x per lot	
Flexural strength		MPa	18	min	ASTM C651-20 (2020)	1x per lot	1
Tensile strength		MPa	14	min	ASTM C565-15 (2021)	1x per lot	1
Compressive strength		MPa	50	min	ASTM C695-21 (2021)	1x per lot	
Grain size		µm	800	max	ASTM E112-13 (2021)	1x per lot	
Pore size		µm	1	max	Mercury intrusion test per ISO 15901 (2016) Salt intrusion test per ASTM D8091–16	10% per lot	2
Boron		ppm wt	4	max	ASTM D8186-18 (2020)	1x per lot	3
Lifetime dose		n/cm2	1.8e22	min			4
Dimensions	Length	m	4	±0.001	Caliper or equivalent	5% per lot	5,6,7
	Width	m	.750	±0.001	Caliper or equivalent	5% per lot	5,6
	Height	m	.375	±0.001	Caliper or equivalent	5% per lot	5,6
Face Flatness		µm	250	max	ASME Y14.5 2018	5% per lot	6
Face Parallelism		µm	250	max	ASME Y14.5 2018	5% per lot	6
Face Orthogonality		µm	250	max	ASME Y14.5 2018	5% per lot	6

2.2 Disclosed Properties

Table 2 below highlights material properties that are not specified but must be measured and disclosed to ThorCon per the test method/standard specified.

Table 2: Properties for vendor to provide

Specification	Units	Expected Range	Test Method or Standard	Test Frequency	Notes
CTE	m/m/K	120-180	ASTM E228-22 (2023)	1x per lot	1
Specific heat	J/kg-K	1700-1900	ASTM E1269-11(2018)	1x per lot	
Thermal conductivity	W/m-K	120-180	ASTM C518-21 (2021)	1x per lot	1,8
Ash	ppm	10-30	ASTM C561-16 (2023)	1x per lot	
Modulus of Elasticity	GPa	7-12	ASTM E111-17 (2017)	1x per lot	
Resistivity	Ohm-m	7-10	ASTM C611-21 (2021)	1x per lot	
Vanadium	ppm wt		ASTM D8186-18 (2020)	1x per lot	
Chlorine	ppm wt		ASTM D8186-18 (2020)	1x per lot	
Sulfur	ppm wt		ASTM D8186-18 (2020)	1x per lot	

Notes:

1. Both AG and WG directions to be reported if anisotropic
2. Salt intrusion test to be carried out by ThorCon with samples provided by vendor
3. Disclose “boron equivalent” as well, including breakdown of constituent elements
4. At >50keV and minimum temperature of 712°C. By design only. No current test available.
5. Instrument to be calibrated annually at a minimum with accuracy of 10% of tolerance or better
6. CMM preferred
7. Length is in the WG/extruded direction
8. Report as a function of temperature from 20°C to 800°C at a minimum of ten evenly spaced increments

3 MACHINING

3.1 External Machining

The blocks will be machined to the general shape and geometrical tolerances stated in Table 1. Detailed drawings will be provided identifying the datum structure for each block type.

3.2 Internal Machining

Patterns of holes will be specified per block or group of blocks. These holes will be in the extruded 4-meter direction, and hence will require gun-drilling assuming extruding the holes is not feasible. Detailed drawings will be provided with the hole dimensions, tolerancing and allowable hole mismatch/overlap (if drilling from both sides) in a separate specification. Gun-drilling length:diameter ratio will be kept within standard industry capabilities with estimated hole size to be no smaller than 15 mm.

It is expected that impregnation is required to achieve the less than one micron pore size requirement. Vendor will state the depth purification and impregnation can reach into the graphite. It is anticipated that the holes will be drilled prior to final impregnation to allow the impregnate to adequately seal the graphite against salt intrusion.

4 PROCUREMENT SCHEDULE

Plans call for building a pre-fission test platform in two years; followed by construction of a demonstration plant two years later; followed by building 3 GWe worth of power plants starting three years later. We anticipate demand to grow to a build rate of 10 GWe/year. Table 3 shows the quantity of graphite required over time. This estimate is based on ThorCon's raw graphite block needs prior to machining and assumes rolling batch shipment of blocks as they are produced.

Table 3: Procurement schedule

Delivery Range	Tonnes	Notes
9/23 - 6/24	<10	Samples for component testing
7/24 - 11/24	300	Non-fission test "reactor" (unpurified acceptable)
8/25 – 2/26	300	Demonstration plant reactor 1
2/26 – 5/26	300	Demonstration plant reactor 2
4/29 – 8/31	7200	Ramp-up of production plants
4/32 – 9/34	28800	Ramp-up to demand of 10 GWe/yr deployment (24000 tonnes/yr)
2035+	See notes	Continuing growth due to production plus existing reactor replacement