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MATERIAL SELECTION REPORT FOR THE EX-VESSEL STORAGE TANK OF THE CRBRP

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Rockwell International

Atomics International Division
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MATERIAL SELECTION REPORT FOR THE EX-VESSEL STORAGE TANK OF THE CRBRP

By

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ABSTRACT

Material selection recommendations for the major components of the ex-vessel storage tank (EVST) of the Clinch River Breeder Reactor Plant are presented. Factors considered are intended service conditions, environment, and ASME Code requirements. Various stainless steels, carbon steels, alloy steels, elastomers, and lubricants are recommended.

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1.0 INTRODUCTION

This report consists of (1) a general description of the ex-vessel storage tank (EVST) and its environments and (2) based on intended service conditions, an evaluation of material requirements together with recommendations for materials, specifications, and grades. This document presents those design details of the EVST needed to provide pertinent information on configurations, environments, and other features necessary for the material evaluations and selections for specific components or applications. This report is based on work completed in 1976 during the design phase of the EVST for the Clinch River Breeder Reactor Plant (CRBRP) project.

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2.0 GENERAL DESCRIPTION

A schematic of the EVST and its major components and assemblies is given in Figure 1. The purpose of the EVST is to provide storage for core assemblies in a temperature-controlled environment of liquid sodium with an argon cover gas. Core assemblies are stored in the turntable, which is suspended in the vertically oriented storage vessel. The turntable has storage tubes long enough to accept two core component pots (CCPs). The closure head has fuel transfer ports for inserting and removing core assemblies. The guard tank is provided to contain the sodium in the event of a leak in the storage vessel. The EVST will be housed in a concrete vault within the reactor service building (RSB). Nitrogen gas will be circulated through the vault to maintain an inert atmosphere.

During maximal normal service, sodium enters the EVST at 400 ± 25°F and exits at temperatures to 515°F at a flow rate of 335 gpm and a pressure of 10 ± 2 in. of water. Sodium temperature will be increased to 600 ± 25°F, the maximum expected temperature, during sodium cleaning operations; this could occur 60 times during the lifetime of the EVST.

The major components of the EVST (storage vessel, guard tank, turntable drive gear, main bearing, support structure, top shield, thermal shield, heaters, and piping) are designed for 30 years. The motor, gears, and drive system are designed for 10 years. The design goal for elastomer seals will be 5 years. The instrumentation and control components' useful life is 30 years. The turntable must be capable of being positioned for loading and unloading of core assemblies 325 times during each reactor refueling period, which will occur a maximum of once per year.

ASME B&PV Code requirements for the major components of the EVST are summarized in Table 1.

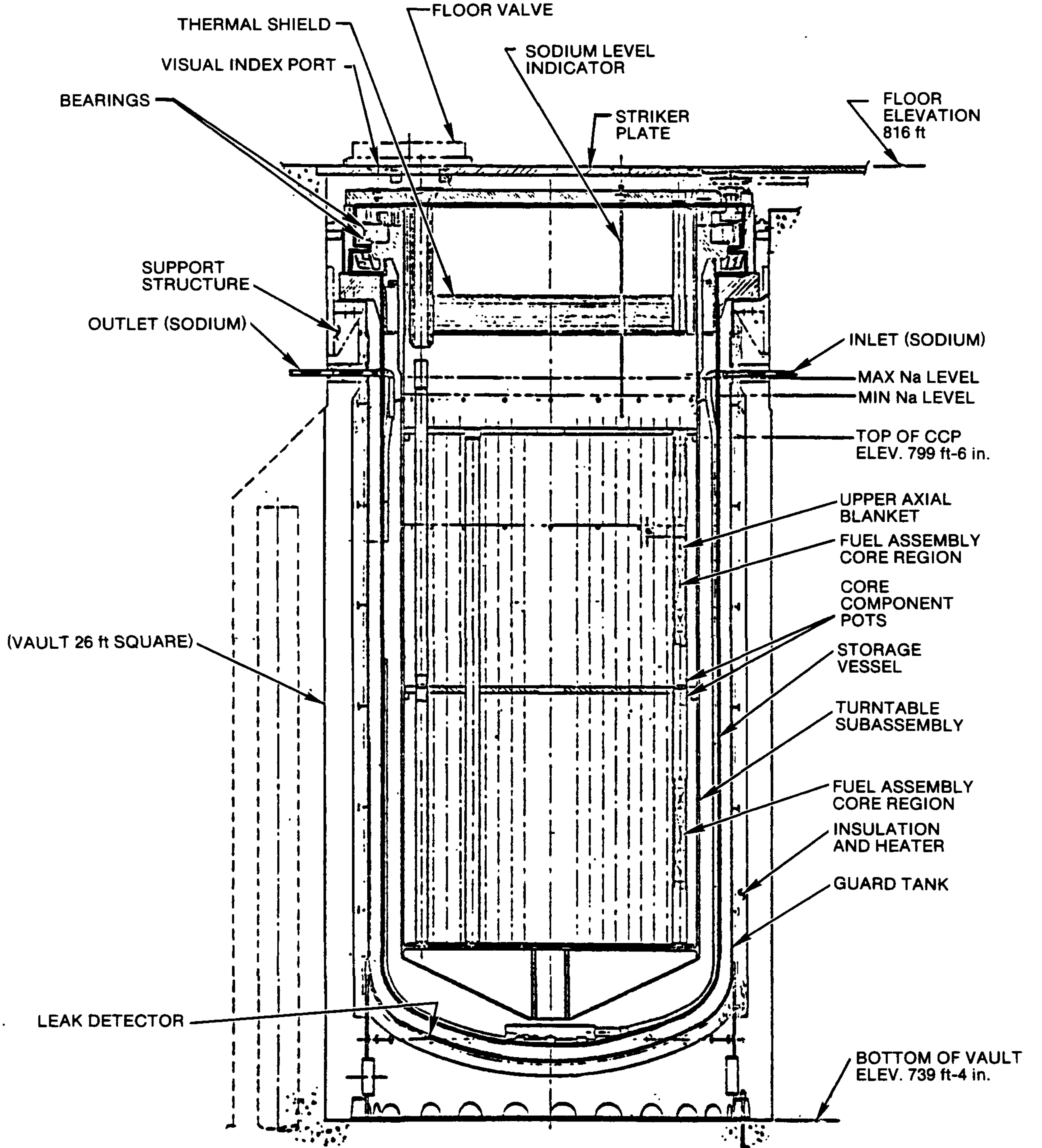

Figure 1. EVST Components

TABLE 1

EVST CONSTRUCTION CODE REQUIREMENTS

Storage vessel	Section III, Class 2
Storage vessel support	Section III, NF, Class 2
Turntable	Section III, NF, Class 2
Closure head	Section III, Class 2
Guard tank	Section III, Class 3
Guard tank skirt	Section III, NF, Class 3
Striker plate	AISC
Floor valve adapter	
Pressure boundary	Section VIII, Division 1
Nonpressure boundary	AISC

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3.0 ENVIRONMENTS

The EVST components will be subjected to the environmental conditions summarized in Table 2.

TABLE 2

EVST ENVIRONMENTS

Sodium	
Inlet temperature	400 ± 25°F
Outlet temperature	375 to 515°F
Cleanup temperature	600 ± 25°F
Drainage temperature	400 ± 25°F
Argon cover gas	
Operating temperature	375 to 625°F
Operating pressure	0.36 ± 0.07 psig
Drainage pressure	5 psig
Nitrogen gas (vault)	
Operating temperature	45 to 135°F
Normal pressure	-3-1/2 to -2-1/2 in. water
Crud removal pressure	2 psig
Radiation	
RSB floor level	0.2 mR/h
Maintenance	10 mR/h
Transfer	200 mR/h

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4.0 MATERIAL SELECTION

4.1 STORAGE VESSEL

The EVST is a vertically oriented vessel with a diameter of 230 in. and an overall height of 555 in. It has a flange at the top and an elliptical dished head at the bottom. The vessel is fitted with 11 nozzles, a sodium flow distributor at the bottom, and a seismic key around the flange. The internal environments of the vessel are liquid sodium and argon cover gas; sodium vapor and sodium frost will also be present in the cover gas or on component surfaces. The exterior environment will be vault nitrogen. The vessel design temperature is 650°F; the maximum expected service temperature is 600 $\pm$ 25°F.

The material selection for the vessel proper (i.e., shell plates, bottom head, and piping/nozzles) is Type 304 stainless steel. Stainless steel is highly resistant to both sodium and atmospheric corrosion, fabricable by conventional manufacturing processes, and an alloy that is widely used and proven in nuclear service. Carbon steel was considered, but the economy in basic material cost was somewhat offset by increased fabrication costs. More importantly, a major objection to the use of carbon steel is the possible formation of the black powdery residue in the sodium, which could find its way into the reactor during transfer of fuel assemblies. The generation of such residues has been observed by several sites in the cleaning of carbon or low-alloy sodium systems. In all cases, the residues have been attributed to the reduction by sodium of oxide films generated on the components during fabrication; rust and postweld heat-treat scale are sources of this residue. In the case of storage vessels, such oxide films can be removed rather easily just before sealing and filling with inert gas. On the other hand, vessels filled with complicated internal structures cannot be cleaned after assembly and would provide rust films to generate the powdery residue. The EVST falls into this latter category.

The material selection for the top support flange assembly is a low-alloy carbon steel. The flange is a massive component about 296-in. OD, 230-in. ID, and 30-in. thick, and the use of a carbon steel will result in a substantial cost reduction relative to the selection of a stainless steel. This part of the vessel will be exposed only to the argon cover gas with some sodium vapor, and the internal surfaces could be cleaned prior to final closure. An advantage to using such a steel is the match in thermal expansion with that of the large-diameter ferritic bearing and its support structure. A disadvantage is that a transition must be made from the ferritic steel of the flange to the austenitic material of the rest of the vessel. This transition will use Inconel 600 between the lower edge of the flange skirt and the austenitic stainless steel vessel. Postweld heat treatment is required of any welds made in the carbon or low-alloy steel flange. Special weld qualifications and procedures will be required for joining the dissimilar metals. The flange could be either a forging or rolled plate. However, fabricators have reported laminations in heavy plate sections, and on this basis, a forging per SA508 is recommended.

4.2 CLOSURE HEAD

The closure head assembly consists of a center plate, thermal shield, cooling sleeves, fuel transfer port plugs, outer ring, and dip seal. The assembly is 285 in. in diameter (outer ring), and the overall height is about 165 in. The entire assembly is positioned within the storage vessel and will be exposed to the argon cover gas. The top surfaces of the center plate/outer ring assembly will be exposed to RSB air. The closure head, with its thermal shield, will maintain the striker plate temperature at less than 115°F when the EVST sodium is at 625°F.

A low-alloy carbon steel is recommended for the center plate and outer ring components. These are massive 12-in.-thick plates weighing about 57 and 45 tons, respectively. The use of a carbon steel instead of stainless steel will result in a significant cost reduction. Also, these parts can be readily cleaned before final assembly and are not exposed to liquid sodium. The recommended steel is plate per ASME SA533.

The thermal shield assembly consists of a stack of 25 reflector plates plus a bottom support plate, hanger rods, spacers, and a top flange. Type 304 stainless steel is recommended for all parts because they will be extremely difficult to clean after being assembled. Any ferritic steel could oxidize during fabrication and assembly operations, and the corrosion products (rust) could contribute to a contamination problem (as discussed above).

The cooling sleeves are supported by the striker plate and extend through the thermal shield. The assemblies consist of a 29.5-in.-diameter top flange, a cooling tube, and a shielding base. The overall length is 10 ft 9 in. The environment is argon gas. Using the same rationale as for the thermal shield, stainless steel is selected because of its inherent resistance to atmospheric oxidation.

The fuel transfer port plugs are housed in the cooling sleeves in an argon atmosphere. The preferred material is stainless steel; however, if cost effective, a nickel-plated or stainless weld-clad carbon steel could be an acceptable alternate material.

4.3 TURNTABLE

The turntable assembly is a cylindrically shaped "lazy susan" with 334 storage tubes and 24 preheat tubes held in position by grid plates. The tubes and plates will be immersed in the EVST sodium. The upper part of the turntable, including the flange assembly and dip seal trough, will be exposed to the argon cover gas.

Type 304 stainless steel is selected for those parts that are exposed to sodium (i.e., storage and preheat tubes, grid plates and supporting shell plates, and gussets). The use of a lower cost ferritic steel was not considered to be acceptable because of the potential contamination problem discussed above.

A low-alloy carbon steel is recommended for the top flange since it is not exposed to sodium and can be cleaned prior to vessel closure. An Inconel 600 transition should be used in joining the ferritic steel flange to the stainless steel shell to minimize differential expansion mismatch and heat-treating problems.

The dip seal trough can also be made of a carbon steel. The dip seal material is DC-550 Silicone, a Dow Chemical product that is compatible with carbon steel.

4.4 TURNTABLE DRIVE

The turntable, supported by an antifriction roller bearing, is rotated by two 8-hp dc motors using a bull gear/pinion gear assembly. The turntable drive is designed by the Franklin Institute Research Laboratory. The materials used for this design, 4340 and 52100 alloy steels, are conventional in similar drive systems.

4.5 GUARD TANK

The guard tank is a cylindrical structure that encloses the storage vessel and is intended to contain the EVST sodium in the event of a leak. The assembly consists of the guard tank proper, supporting skirt, flange and gussets, leak detector guide tubes, drain line, electrical heaters, and insulation. The normal environment will be vault nitrogen with a design temperature of 675°F.

Carbon steel is selected for all guard tank components. It is low cost and structurally acceptable for this application. The surfaces will probably oxidize during assembly, but this does not impose any operational problem.

4.6 SUPPORT STRUCTURE

The support structure includes a striker plate, guard tank embedment, storage vessel support, and SISI tubes and plug. The environment will be vault nitrogen except for the surfaces of the striker plate, which will be exposed to RSB air.

Carbon steel is recommended for these supporting structures inasmuch as they are structurally acceptable and most economical. The striker plate surfaces should be painted or otherwise protected from corrosion or mechanical damage.

4.7 MISCELLANEOUS

Materials selection for elastomeric seals in EVST are given in Ref. 1. EPDM (Parker E692-75) is recommended for most applications. The closure head seals will be metallic.

Recommendations for greases and lubricants for EVST applications are given in Ref. 2. A diester-base lubricant conforming to MIL-G-21164 (Aero Shell Grease 17 or Everlube 211G) is recommended for internal bearings and gears. For external applications such as chains and gearboxes, lubricants such as Gulf Harmony Grade 53 or Gulf Harmony Grade 59EP are recommended. A leaded-bronze self-lubricating bearing plate, such as Lubrite B-237 or Lubron J-236, is recommended for the vessel flange mounting.

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5.0 CONCLUSIONS AND RECOMMENDATIONS

Material selection recommendations for the major components of the EVST are summarized in Table 3.

TABLE 3

EVST MATERIAL SELECTIONS

	Material	Form	Specification
Storage vessel			
Flange	CS[a]	Forging	ASME SA508, Cl 2
Flange taper section	CS	Plate	ASME SA508, Cl 2
Shell	SS[b]	Plate	ASME SA240, Gr 304
Head	SS	Plate	ASME SA240, Gr 304
Piping	SS	Pipe	ASME SA312, Type 304
Nozzles	SS	Forging	ASME SA182, F304
		Fittings	ASME SA403, Gr 304
Distributor box	SS	Plate	ASME SA240, Gr 304
Closure head			
Center plate	CS	Plate	ASME SA533, Gr B, Cl 1
Outer ring	CS	Plate	ASME SA533, Gr B, Cl 1
Thermal shield			
Reflectors	SS	Plate	ASME SA240, Gr 304
Wall	SS	Plate	ASME SA240, Gr 304
Bottom support	SS	Plate	ASME SA240, Gr 304
Flange	SS	Plate	ASME SA240, Gr 304
Hanger rods	SS	Bar	ASME SA479, Gr 304
Spacers	SS	Tube	ASME SA213, Type 304
Cooling sleeves			
Top flange	SS	Plate	ASME SA240, Gr 304
		Forging	ASME 182, F304

TABLE 3

EVST MATERIAL SELECTIONS
(Continued)

	Material	Form	Specification
Cooling tube	SS	Pipe	ASME SA312, Type 304
		Tube	ASME SA213, Type 304
		Bar	ASME SA479, Gr 304
		Forging	ASME SA182, F304
		Plate	ASME SA240, Gr 304
Shielding base	SS	Plate	ASME SA240, Gr 304
		Forging	ASME SA182, F304
Thermal shield	SS	Plate	ASME SA240, Gr 304
Shielding ring	CS	Plate	ASME SA36
Fuel transfer port plugs			
Plug body	SS	Bar	ASME SA479, Gr 304
Plug base	SS	Plate	ASME SA240, Gr 304
Plug pipe	SS	Pipe	ASME SA312, Type 304
Floor valve adaptors		Tube	ASME SA249, Type 304
	SS	Plate	ASME SA240, Gr 304
	SS	Forging	ASME SA182, F304
	CS	Plate	ASTM A36
	CS	Forging	ASTM A181
<u>Turntable</u>			
Top flange	CS	Forging	ASME SA508, Cl 2
Shell	SS	Plate	ASME SA240, Gr 304
Grid plates	SS	Plate	ASME SA240, Gr 304
Support plates	SS	Plate	ASME SA240, Gr 304
Storage tubes	SS	Tube	ASME SA213, Type 304
Preheat tubes	SS	Tube	ASME SA213, Type 304
Dip seal blade	CS	Plate	ASME SA516

TABLE 3

EVST MATERIAL SELECTIONS
(Continued)

	Material	Form	Specification
Guard tank			
Shell	CS	Plate	ASME SA516, Gr 65
Head	CS	Plate	ASME SA516, Gr 65
Support skirt	CS	Plate	ASME SA516, Gr 65
Leak detector guide tubes	CS	Pipe	ASME SA106, Gr B
Bottom flange	CS	Plate	ASME SA516, Gr 65
Support structure			
Striker plates and support	CS	Plate	ASME SA516, Gr 65
Storage vessel support	CS	Plate	ASME SA516, Gr 65
SISI tubes and plugs	CS	Plate	ASME SA516
High-strength bolts	AS[c]	Bolts	ASME SA540, Gr B-23
Turntable drive			
Drive gears	AS		ASTM A290, Cl G (modified hardness)
Bearing rollers	AS		Modification 52100
Bearing collars	AS		Modification 52100
Thrust races	AS		Modification 52100
Bearing support block	CS	Forging	ASME SA508, Cl 2
Miscellaneous			
Elastomer seals			
To 120°F maximum	BUNA-N		Parker E741-75 (or equivalent)
To 210°F maximum	EPDM		Parker E692 (or equivalent)
Metal seals	Inconel 718, copper plated		
Dip seal	Silicone oil		Dow Corning DC550 (or equivalent)
Lubricants			
O-ring seals	Silicone grease		Dow Corning DC55M

TABLE 3

EVST MATERIAL SELECTIONS
(Continued)

	Material	Form	Specification
Gears and bearings (internal)	Diester-base grease		MIL-G-21164 (Aero Shell Grease 17 or Everlube 211G)
Chains and gear (external)			Gulf Harmony B53 or 59EP (or equivalent)
Bolting materials	AS	Cr-Mo-V	ASME SA540, Gr B23, Cl 1
	AS	AISI 4140	ASME SA193, Gr B7
	CS		ASME SA325
	SS	Gr A286	ASTM A453, Gr 660, Condition B
	AS		ASTM A490
	SS	Gr A286	ND112-0015-0208-A-286
	SS	Gr A286	ND112-0025-0526-A-286
	SS		MS35307, Type 300 SS

[a]Carbon steel
[b]Stainless steel
[c]Alloy steel

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REFERENCES

1. "Material Selections for Elastomeric Seals in System 41," ESG-DOE-13438 (1984)

2. "Selection of Lubrication Materials for the EVST," ESG-DOE-13445 (1984)

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