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MATERIALS SELECTION FOR THE EX-VESSEL TRANSFER MACHINE OF THE CRBRP

DOE Research and Development Report

Prepared for the United States
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Rockwell International

Atomics International Division
Energy Systems Group

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MATERIALS SELECTION FOR THE EX-VESSEL TRANSFER MACHINE OF THE CRBRP

By

W. T. Lee

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ABSTRACT

This document describes the major components of the Clinch River Breeder Reactor Plant ex-vessel transfer machine (EVTM) and their recommended materials of construction. For parts that will be exposed to reactor atmosphere, Type 304 stainless steel is preferred unless (1) the design load requires higher strength material and/or (2) the moving parts come in direct contact in sodium.

Parts operating outside the reactor atmosphere will be fabricated of carbon or low-alloy steel. Because of the low total fluence (7.5×10^4 n/m^2), radiation embrittlement of the carbon or low-alloy steels will be insignificant. However, materials for the grapple chain and inflatable seals will be specified on the completion of the development testing at AI.

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1.0 SUMMARY

Materials are selected for ex-vessel transfer machine (EVTM) applications primarily based on (1) compatibility with the design operating environments (sodium, fission products, and reactor containment building air) and (2) satisfactory strength at maximum temperature to sustain the stresses imposed on the components under steady-state and upset conditions.

For parts that will be exposed to the reactor atmosphere, the material will be fabricated of Type 304 austenitic stainless steel unless one or both of the following conditions prevail:

- The strength is inadequate to carry the design stresses
- The moving parts come in direct contact in sodium.

Austenitic stainless steels are preferred for reactor atmosphere service because they enhance sodium decontamination and minimize the formation of corrosion products that might contaminate the reactor. In addition, these alloys are preferred for surfaces in contact with elastomer seals to avoid any corrosion, which might degrade the ability to seal. However, because these steels tend to self-weld and gall in high-temperature sodium, alternate materials must be used for bearings and other rubbing surfaces. Consequently, grapple fingers will be made of Inconel 718, and the cams that will actuate these fingers will be fabricated of Stellite. Pivot pins for the grapple fingers will also be Inconel 718 and will turn in a Stellite bushing. A sleeve is provided in the grapple to guide the finger actuation rod. The sleeve will be fabricated of aluminum bronze (AMPCO-18-13), which will provide a satisfactory bearing against the Type 304 stainless steel actuation rod. An Inconel X-750 spring will hold the actuation rod in the "down" position (fingers extended).

Parts operating outside the reactor atmosphere will be fabricated of carbon or low-alloy steel. Gears and drive shafts for the several valves and for the grapple hoist will be made of alloy steel (AISI 4140 or 4340). Bearings will be of conventional commercial material. Other structural components

or parts will be made of carbon steel. Radiation embrittlement of carbon steel used for the EVTM components will be insignificant because of the low total fluence (approximately 7.5×10^4 n/m^2). Precautions will be taken to protect all the carbon steel from rusting during all phases of fabrication, storage, shipping, and assembly.

Elastomer seals will be required in several places in the EVTM. Both static and inflatable seals will be required, depending on the particular application. Based on previous studies, the basic recommendations for elastomeric seals are to:

- Use Buna N for seal applications when service temperatures are below 140°F
- Use EPDM in sealing applications where operational temperatures are too high for Buna N but are below 190°F
- Use metallic O-ring seals only where higher service temperature and/or longer service life is required than can be obtained with elastomeric materials.

The final selection of seal materials will be determined by the data generated in AI under the seal testing program and by the computed final operating temperatures.

Lead and polyethylene B foam will be used for gamma and neutron shielding where adequate shielding cannot be provided by the materials of construction of the EVTM components. From previous studies, the recommended lubricant for O-ring seals is Dow Corning DC-55, and the recommended lubricant for threaded fasteners is "Nickel-Never-Seez."

This report is based on work performed in 1976 during the design phase of the EVTM under the CRBRP project.

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2.0 INTRODUCTION

The EVTM is a single-barrel machine (Figure 1) that transfers single-irradiated and nonirradiated core assemblies contained in core component pots (CCPs) between the reactor, ex-vessel storage tank (EVST), and the fuel handling cell (FHC). It also transfers bare, nonirradiated core assemblies from the new fuel unloading station (NFUS) to the EVST. The EVTM is mounted on the trolley, which in turn is positioned on rails on top of the gantry. The gantry moves on crane rails between the reactor containment building (RCB) and the reactor service building (RSB).

The EVTM handles four types of core assemblies: fuel, blanket, control, and radial shield. During transfer to and from the reactor, the core assemblies are contained in sodium-filled CCPs. Heat generated by the irradiated core assemblies is radiated to the cold wall and is removed by forced or natural air convection from the cold wall. Cold wall heaters maintain the preheat of nonirradiated core assemblies when transferring into sodium or transferring the assemblies to the reactor.

For reactor refueling, the EVTM removes new nonirradiated core assemblies from the FHC and places them in the EVST conditioning thimble, transfers new core assemblies from the EVST conditioning thimble into CCPs in the EVST sodium pool, removes new core assemblies in CCPs from the EVST and places them in the reactor, and removes irradiated core assemblies in CCPs from the reactor and returns them to the EVST.

The EVTM is sealed to prevent the spread of radioactive gases and is pressurized with argon gas to exclude oxygen from the sodium-filled CCPs. The radiation limits are 200 mrem/h during transient conditions, and 200 mrem/h during steady-state conditions when the core assembly is stationary in the cask.

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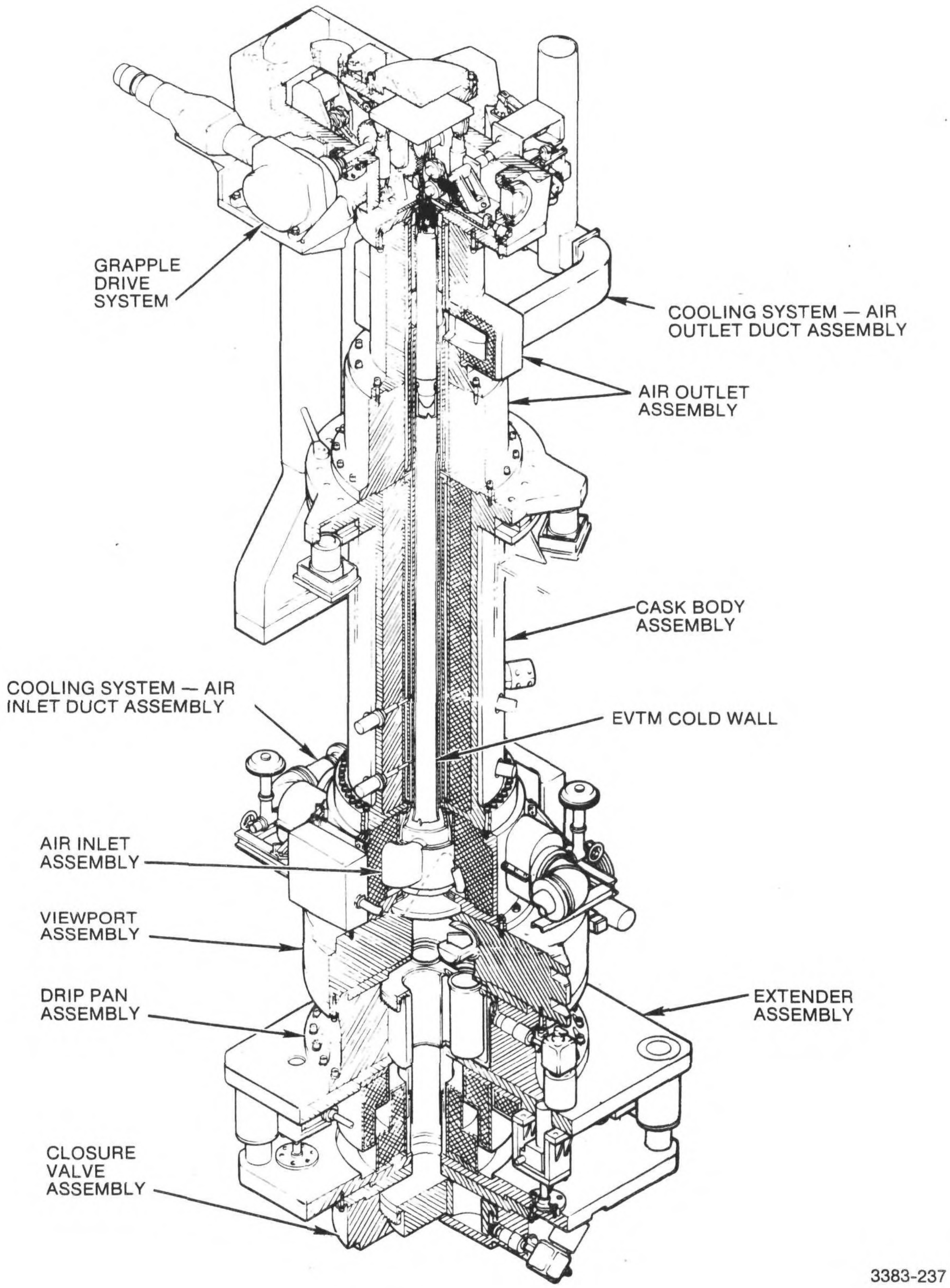

Figure 1. EVTM

3.0 MATERIALS SELECTION FOR MAJOR ASSEMBLIES

Selection of materials is primarily based on: (1) compatibility with the operating environments (sodium, fission products, and RCB air) and (2) satisfactory strength at design temperatures to sustain the stresses imposed on the components under the steady-state and upset conditions. Specifically, the requirements are as follows:

- Containment boundary materials are selected to satisfy the applicable section of the ASME Boiler and Pressure Vessel Code Section III Class 3. Material selection is also based on compatibility with and resistance to sodium, argon cover gas, fission products, and adjacent materials, as well as on ease of sodium removal. The direction of grain flow for pressure boundary material in contact with liquid sodium is generally parallel to liquid metal containment boundary surfaces.

- Materials inside the reactor containment boundary are selected based on strength and wear requirements, compatibility with and resistance to sodium, argon cover gas, fission products, radiation, and adjacent materials. These materials are selected using appropriate ASTM Materials Standards, where available. In addition, adequate clearance and sodium drainage must be provided for the moving parts in the design to avoid the possibility of frozen sodium preventing the movement of moving parts.

- Materials outside the reactor containment will be exposed only to ambient RCB or RSB air. Components will be fabricated of materials conforming to ASTM, AISI, or appropriate federal specifications.

The reference nil ductility temperature, RT_{NDT}, should not exceed 40°F for all ferritic steels in compliance with EVTM specification requirements.

For the envelope that contains the reactor cover gas and sodium vapor and grapple, the design of the EVTM is based on the ASME Boiler and Pressure Vessel Code Section III Class 3. Its structural components are designed for a 30-year lifetime with scheduled replacement of the seals every 5 years,*

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*Hold items, the life to be determined by test data to be developed at AI.

replacement of dynamic external components every 10 years, and replacement of chain every 2 years (hold).* Those structures and components for which the preceding life expectancies cannot be assured should be designed to permit easy maintenance or replacement, but they will have the maximum life required to achieve a complete refueling cycle.

The EVTM is made of 11 major assemblies:† (1) the grapple drive system, (2) core assembly grapple, (3) CCP grapple, (4) grapple adapter, (5) cold wall, (6) cooling system (air inlet and outlet module), (7) cask body, (8) view port, (9) drip pan, (10) extender, and (11) closure valve assemblies. Other assemblies include a maintenance platform, which provides access to the grapple drive system and the exhaust blower. Each assembly involves several components, the materials for which have been selected based on the specific requirements for the components.

In compliance with the EVTM design specification, the EVTM will operate in the following operating environments:

- Internal environment--sodium vapor, fission gases, and argon (grapple in liquid sodium up to 1200°F)
- External environment--RCB or RSB air
- Storage environment--air with temperatures of 10 to 140°F and humidity of 10 to 90% rh.

3.1 GRAPPLE DRIVE SYSTEM

The grapple drive system provides the mechanical means to:

- Raise and lower the grapple at selected rates that may be varied from zero to 24 ft/min
- Activate and release the grapple fingers
- Provide a maximum lift force of 3500 lb.

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*Hold items, the life to be determined by test data to be developed at AI.
†Excluding instrumentation and control and platforms and ladders.

The internal environment in the grapple drive enclosure will be argon, solid sodium, sodium vapor, and fission products with a maximum temperature of 250°F. The recommended materials are as follows:

• Parts that will contact the internal environments	304 SS
• Shafts	4140 alloy steel, minimum yield strength of 125,000 psi
• External parts (e.g., supports, platforms)	Carbon steel
• Chain assembly for lifting the grapple assembly	Under development

Details of the materials selected for this assembly are shown in Table 1.

3.2 CCP GRAPPLE ASSEMBLY

The CCP grapple is used to transfer CCPs that contain core assemblies between the EVST, FHC, and the reactor.

The grapple (approximately 826 lb) is 7.625 in. in diameter and is 64.26 in. long. The major components of the grapple are the grapple body, head, actuating rod, grapple fingers, springs, and nose.

The recommended material for the grapple body is Type 304 stainless steel.

The grapple contains three fingers which are loaded uniformly. Each finger pivots on a pinned joint to permit the necessary rotation for engaging and disengaging the fingers. The fingers are actuated by two cams mounted on the actuating rod. The fingers are actuated from the engaged to disengaged position by a 3.50-in. stroke of the actuating rod. The grapple fingers are made of Inconel 718. The bushings (which are inserted into the fingers) are made of Stellite material. The pin on which the finger pivots is also made of Inconel 718. These materials are selected for strength and wear resistance in sodium.

TABLE 1

MATERIALS LIST FOR GRAPPLE DRIVE SYSTEM
(Sheet 1 of 2)

Part Description	Material	
	Designation	Specification
Chain storage compartment[a]	304 SS	ASME SA240
Actuator lever arm[a]	304 SS	ASME SA240
Chain actuator moveable idler arm[a]	304 SS	ASME SA240
Bolts	Alloy steel	ASME SA193, Gr B7
Liquid spring drive chain idler housing	304 SS	ASME SA240
Lower cover housing body	304 SS	ASME SA240
Readout guard	Carbon steel	Commercial
Brake shaft	4140 alloy steel	AMS-6378A
Brake platform	Carbon steel	ASTM A36
Housing body[a]	304 SS	ASME SA240
Housing cover[a]	Cast SS	
Brake safety cover	Carbon steel	Commercial
Brake shaft housing adapter	304 SS	ASME SA479
Chain actuator counterweight arm	Carbon steel	Commercial
Actuator shaft housing adapter	304 SS	ASME SA240
Actuator shaft housing adapter frame	Carbon steel	ASTM A36
Bolts	Alloy steel	ASME SA193, Gr B7
Drive support housing	Carbon steel	ASTM A36
Brake shaft housing adapter	304 SS	ASME SA240
Chain actuator coupling arm	Carbon steel	ASTM A36
Actuator arm support cover	Carbon steel	ASTM A36
Idler shaft	4140 steel	AMS-6378A
Bolts	Alloy steel	ASME SA193, Gr B7
Shaft adapter	Carbon steel bar	AISI 1018
Load cell idler housing	304 SS	ASME SA240
Load cell platform	304 SS	ASME SA240
Drive support housing cap	304 SS	ASME SA240
Drive support housing base	304 SS	ASME SA240

TABLE 1

MATERIALS LIST FOR GRAPPLE DRIVE SYSTEM
(Sheet 2 of 2)

Part Description	Material	
	Designation	Specification
Eight-pocket wheel seal adapter	304 SS	ASME SA240
Spring pin	420 SS	All-metals screw back
Chain actuator moveable idler drive shaft	4140 steel	AMS-6378A
Chain actuator shaft	4140 steel	AMS-6378A
Drive shaft	4140 steel	AMS-6378A
O-rings	Nitrile or Buna N	
Chain compartment seal	Parker Gask-O-Seal	Buna N
Pivot cap--chain lead-in	304 SS	ASME SA240
Rod end housing	4130 steel	Minimum yield 100,000 psi
Moveable carriage holddown bolt	304 SS	ASME A240
Chain lock	304 SS	Commercial
Actuator arm for linear transducer	Micarta	Commercial
Up travel stop switch support	304 SS	Commercial
Fan mounting plate	Carbon steel	Commercial
Air deflector	Carbon steel	Commercial
Plunger up travel switch	304 SS	Commercial
Compression springs ground ends	304 SS	Commercial
Plunger retainer	304 SS	Commercial
Light source mount	Carbon steel	Commercial
Outer glass retainer	304 SS	Commercial
Rubber gasket	Nitrile 34-40 shore hardness	Commercial
Glass (sight)	Inner Corning Glass--Code 1723	Commercial
Inner glass retainer	Carbon steel	Commercial
Radiation shield	Carbon steel	Commercial
Actuator arm up travel switch	304 SS	Commercial

[a]Major part.

The actuating rod actuates the fingers by means of 3.50 in. of stroke, which is instigated by the single actuating chain. To actuate (disengage) the fingers, there must be a pull force exerted on the actuating rod by the actuating chain. This pull force must first overcome an initial 217-lb preload caused by a compression spring bearing against the actual rod and the weight of the actuator rod (61 lb). Over the 3.50-in. actuating stroke of the actuator rod, the spring force increases to 516 lb. The recommended spring material is Inconel X-750.

The head (or upper end of the grapple) is where the lifting fixtures of the grapple are located. It is recommended to be made of Type 304 stainless steel.

The nose of the grapple, recommended to be made of A-286, is the guidance for the grapple when it is being lowered into the CCP. The nose is tapered, threaded, and locked into the lower body of the grapple. The nose also provides for drainage of the sodium from the internal parts of the grapple when immersed in the reactor pool.

Details of the recommended materials for the CCP grapple are shown in Table 2. The bolts in sodium vapor are lubricated with Nickel-Never-Seez against galling and seizure.

3.3 CORE ASSEMBLY GRAPPLE

The core assembly grapple is used to transport new bare core assemblies between the FHC and the EVST. It weighs 863 lb, is 7.625 in. in diameter, and is 75.75 in. long.

The fingers of the core assembly grapple do not have the extra lip to prevent accidental release of the core assembly. To minimize the chance of accidental release of the core assembly, the lower cam requires more pretravel before it will disengage from the lifting finger and allow the finger to disengage and drop the core assembly.

TABLE 2

MATERIALS LIST FOR CCP AND CORE ASSEMBLY GRAPPLE

Body (8 by 16 in.)	304 SS bar (ASME SA479)
Rod, actuating	304 SS bar (ASME SA479)
Body weldment	
Head	304 SS bar (ASME SA479)
Pin, disconnect (with chrome plate)	A-286 SS bar (ASME SA453, Gr 660, Condition B)
Bushing CCP grapple	Stellite 3--Mil-C-24248A (ships) Comp. IV cobalt alloy
Bushing	304 SS bar (ASME SA479)
Bushing insert	Ampco-22 aluminum bronze casting
Spring (inner)	Inconel X-750 wire (AMS 5699)
Spring (outer)	(Heat treated to 250,000 psi min.)
Shim	304 SS plate (ASME SA240)
Retainer spring	304 SS bar (ASME SA479)
Ring	304 SS plate (ASME SA240)
Finger	Inconel 718 bar (ASTM A637)
	Precipitation harden per ASTM A637, Gr 718
Spacer	304 SS tubing
Nose	A-286 SS bar (ASME SA453, Gr 660, Condition B)
Washer	Inconel 718 (ASTM A637, Gr 718)
Cam (upper and lower)	Cobalt alloy Mil-C-24248A, Comp. IV
Lock--pivot pin	Chrome-plated 304 SS
Cover	304 SS plate (ASME SA240)
Retainer	304 SS bar (ASME SA479)
Ring	Unalloyed depleted uranium (ASTM B419-64)
(For weight)	Nickel plate per ST0118NA0001
Key, closure	Chrome plate, 304 SS bar (ASME SA479)
Pivot pin	Inconel 718 bar (ASTM A637, Gr 718)
Nose pin (chrome plated)	304 SS (ASME SA479)

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Since the functions of the core assembly grapple and the CCP grapple are similar, the same materials are recommended for both. Table 2 lists the recommended materials for each part.

3.4 GRAPPLE ADAPTERS

The grapple adapters will enable the EVTM grapples to lift and remove the shielding plug to allow access to the reactor. The adapters are designed to match the lifting finger configuration of both EVTM grapples. The grapple adapters are made of forged Type 304 stainless steel, machined to match the internal dimensions of the CCP for one adapter and to match the internal dimensions of the core assembly on the other adapter.

3.5 COLD WALL

The primary functions and requirements of the cold wall are to: (1) contain radioactive gases and contamination, (2) absorb and dissipate the radiant decay of an irradiated core assembly, and (3) maintain the preheat temperature of a new core assembly being transferred from the EVST to the reactor. The cold wall is designed to be capable of dissipating 20 kW of decay heat while maintaining the fuel pin cladding temperature below 1250°F.

The cold wall is located between the view port on the bottom and the grapple drive system on top. It is positioned inside the cask body assembly. The cold wall, by means of dual-groove O-rings, seals in contamination. These seals are located on the flange between the cold wall and view port and the upper flange to the grapple drive system.

The cold wall absorbs heat from the CCP and rejects it to the annular air region between the cold wall and the cask body. To increase the volume efficiency of the cooling air, the cold wall has longitudinal fins spaced around the periphery of the main tube. To increase the emissivity, the cold wall internal pipe surfaces will be coated with a layer of black chrome.

The cold wall contains electrical resistance heater elements. The electrical heaters are mounted between the fins, which are mounted on the periphery of the main cold wall tube. The heater elements will keep the cold wall temperature at 400 $\pm$ 25°F in order to maintain the temperature of the new fuel assembly being transferred from the EVST to the reactor.

The cold wall assembly will also incorporate metal bellows to compensate for the axial differences caused by thermal expansion. The bellows is mounted with one bellows acting as the primary containment boundary and a second bellows being used as a backup in the event the primary boundary develops leakage.

The following materials are recommended for the major parts:

• Cold wall piping and flange	304 SS
• The internal surfaces of the pipe for better heat exchanger efficiency	Black chrome-plated 304 SS
• Pins or bolts	A-286 (chrome plated)
• Bellows	Austenitic SS
• Elastomer seals (O-rings) for $T < 140°F$*	Nitrile (Buna N high-temperature grade)
$140 > T < 190°F$*	Ethylene-propylene rubber

Materials for other parts are listed in Table 3.

*Subject to final verification of proper temperature in the seal areas.

TABLE 3

MATERIALS LIST FOR EVTM COLD WALL
(Sheet 1 of 2)

Part Description	Material	
	Designation	Specification
Hex head screw	A-286 (chrome plated)	ASME SA453, Gr 660, Condition B
Heater lock wire	300 Series SS	Commercial
Heater extension wire	304 SS	Commercial
Heater cage clamp angle	304 SS	ASME SA240
Heater cage frame angle	304 SS	ASME SA240
Heater band/clip	304 SS	ASME SA240
Lower flange[a]	304 SS forging	ASME SA182
Reducer[a]	304 SS cold rolled	ASME SA240
Lower pipe[a]	304 SS cold rolled	ASME SA240
Pin	A-286 bar (chrome plated)	ASME SA413, Gr 660, Condition B
Lower flange bolt	A-286 (chrome plated)	ASME SA453, Gr 660, Condition B
Center pipe[a] (cold wall)	304 SS	ASME SA312
Black chrome-plated ID 304 SS pipe[a]	Black chrome plate	ST0109NA-0034
Inner shroud[a]	304 SS	ASME SA312
Bellows stop	304 SS	ASME SA240
Split ring for bellows	304 SS	ASME SA240
Shroud guide for bellows	304 SS	ASME SA240

TABLE 3

MATERIALS LIST FOR EVTM COLD WALL
(Sheet 2 of 2)

Part Description	Material	
	Designation	Specification
Outer shroud for bellows	304 SS	ASME SA240
Bellows[a]	304 SS or 321 SS	ASME SA240
Upper flange	304 SS	ASME SA182
Inner flange	304 SS	ASME SA240
Clamping ring	304 SS	ASME SA240
Bellows end ring	304 SS	ASME SA240
O-ring for bellows	Nitrile (Buna N)	Commercial
Retainer bolts	A-286 (chrome plated)	ASME SA453, Gr 660, Condition B
Long locating pin	A-286 (chrome plated)	ASME SA453, Gr 660, Condition B
Fins/channels	304 SS	ASME SA240
Heaters sleeve	Fiberglass	Mil-1-003190C
Sealant for heaters	Zirconium-based cement	Sauereisen Cement Co., Pittsburgh, Pennsylvania
Brazing alloy for heater wire	B Au-4 (HT)	ASME
Base connector plate for heater	Diallyl phthalate	Mil-U-14, Type GDI-39
Brazing alloy for heater	BNi-5 (HT)	ASME
Heater sheath	321 SS	Commercial

[a]Major parts.

3.6 COOLING ASSEMBLIES

3.6.1 Air Inlet Assembly

The air inlet provides the cooling air for the cold wall and also supplies the electrical connections for the air inlet duct assembly. The air inlet consists of four main sections: body, ducting, electrical connectors, inner shell, and support structure. The materials of the air inlet assembly will be exposed to the RCB air environment at 250°F maximum. The recommended materials are carbon steel and structural steel. Details are shown in Table 4.

3.6.2 Air Outlet Assembly

The air outlet assembly is located directly below the grapple drive system and is located directed above the cask body assembly. The air outlet assembly is held to the cask body assembly and grapple drive system by 1-1/4-in. socket head cap screws. It has the following six basic assemblies with the recommended materials of construction:

• The support assembly (46 in. diameter by 33 in. thick)	Carbon steel forging, ASME SA266, Class 1
• The upper support assembly (32 in. diameter by 55 in.)	Carbon steel forging, ASME SA266, Class 1
• Liner assembly (14 in. diameter by 88 in. long)	Carbon steel wrapped with Min-K insulation
• Duct shield assembly (17 in. by 14.5 in. by 18 in.)	Carbon steel plate
• Bolts	Alloy steel bolting material, ASME SA540, Grade B23, Class 5

3.7 CASK BODY

The cask body will provide the main support for equipment and personnel shielding around the irradiated components. The materials will not contact

TABLE 4

MATERIALS LIST FOR EVTM AIR INLET
(Sheet 1 of 2)

Part Description	Material	
	Designation	Specification
I-beam	Steel	A-36
Blower mounting plate	Carbon steel	ASTM A516, Gr 55
U-bolt washer and nut	Alloy steel	ASTM SA546, Gr B23, Class 5
C-channel	Steel	A-36
Plate	Steel	A-36
90° SR elbow	Steel	ASTM A135, Gr A
Connector	Steel	ASTM A135, Gr A
Tee connector	Steel	ASTM A135, Gr A
Transition coupling blower to air	Steel	ASTM A135, Gr A
Stud	Alloy steel	ASTM SA540, Gr B23, Class 5
Bottom transition coupling studs shield	Lead	ASTM B29
Shield--right elbow	Lead	ASTM B29
Shield--left elbow	Lead	ASTM B29
Shield--large elbow	Lead	ASTM B29
Shield--valve	Lead	ASTM B29
Shield--top transition	Lead	ASTM B29

TABLE 4

MATERIALS LIST FOR EVTM AIR INLET
(Sheet 2 of 2)

Part Description	Material	
	Designation	Specification
Cap screws	18-8 SS	
Cap screw	A-286	ASTM A4136, Gr 660, Condition B
Inner shell of air inlet	Carbon steel plate	ASTM A516, Gr 55
Inner lead containment housing	Carbon steel	ASTM A516, Gr 55
Thermal insulation on inner shell	Min-K, 1 in. thick, Type B01	Johns-Manville
Insulation retaining wrap	304 SS sheet	ASTM A240
Insulation retainer	Carbon steel	ASTM A414
Pig lead	Pig lead	ASTM B29
Upper flange	Carbon steel	ASTM A266, Class 1
Lower flange	Carbon steel	ASTM A516, Gr 55
Outer shell	Carbon steel	ASTM A516, Gr 70
Air duct side wall	Carbon steel	ASTM A516, Gr 55
Electrical housing	Carbon steel	ASTM A106, Gr A

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any sodium. For components made of carbon steel, the cask body will be exposed to the worst radiation damage with a maximum neutron radiation of 2.5 x 10^9 n/cm^2/year. For the 30-year design life, the total fluence will be 7.5 x 10^{10} n/cm^2, or 7.5 x 10^4 n/m^2, which is too low for producing any significant embrittlement of the steel due to radiation.[1] The following materials are recommended for the major parts:

• Outer shell	Structural steel, ASME SA36
• Inner shell	Carbon steel, ASME SA106, Grade A
• Flanges	Structural steel, ASME SA36
• Bolts	Alloy steels, ASME SA543, Grade B23, Class 5

Details of the materials selected for various parts are summarized in Table 5.

3.8 VIEW PORT

The view port assembly, mounted between the drip pan assembly and the air inlet assembly on the EVTM, is used to inspect the level of sodium within the drip pans. It can also be used to inspect the operation of the grapples.

The assembly consists of an outer housing and a rotatable camera assembly, mounted within a removable plug. The view port is supported from the air inlet assembly by bolts. The recommended materials for the major parts are:

• Outer housing	304 SS, ASME SA182
• Removable plug (outer bearing sleeve)	304 SS
• Camera body	304 SS

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[1] J. A. Williams and C. W. Hunter, "Irradiation Strengthening and Fracture Embrittlement of A533-B Pressure Vessel Steel Plate and Submerged-Arc Weld," ASTM TP-529, Symposium on Effects of Radiation on Substructure and Mechanical Properties of Metals and Alloys (June 25-30, 1972)

TABLE 5

MATERIALS LIST FOR CASK BODY

Part Description	Material	
	Designation	Specification
Bottom flange	Carbon steel casting	ASME SA216, WCA
Outer shell	Carbon steel	ASME SA36
Inner shell	Carbon steel pipe	ASME SA106, Gr A
Sheet for strapping band	304 SS	ASME SA240
Top flange	Carbon steel	ASME SA216, WCA
Cap screw	Alloy steel	ASME SA540, B23, Class 5
Flange	Carbon steel	ASME SA36
Lead for shielding	Lead	ASTM B29
Detector tube-T/C tube/sleeve	1018 carbon steel	AISI 1018
Detector tube	1018 carbon steel	AISI 1018
Flange for detector tube	Carbon steel	ASME SA36

The mirror is a quartz glass, aluminum surface mirror. To prevent formation of frost, a heater is cemented to the rear of the quartz glass. A thermocouple mounted in contact with the front surface of the mirror is used to sense the temperature. The heater and mirror are insulated from their mount by a 0.62-in.-thick Min-K insulation sheet.

3.9 DRIP PAN ASSEMBLY

Located above the extender and below the view port, the drip pan assembly is a shielded component with an external motor-driven rotor. The drip pan assembly basically consists of two plates to act as top and bottom flanges, a rotor to hold these drip pans and contain a through port, a body, and a drive shaft assembly. The top flange of the drip pan assembly has two guide pins for proper positioning of the drip pan assembly. The following materials are recommended for the major parts:

- Top and bottom flanges — 304 SS, ASME SA240
- Rotor assembly — 304 SS, ASME SA240
- Drip pan outer housing (body) — 304 SS forging, ASME SA182
- Drive shaft assembly — 4140 alloy steel, AMS-6378A
- Guide pins — Alloy steel, ASME SA193, Grade B7

Materials selection for other parts is shown in Table 6.

3.10 EXTENDER ASSEMBLY

The extender, mounted between the drip pan assembly and the closure valve assembly, raises and lowers the closure valve. The extender is raised to allow the closure valve to clear obstacles on the floor and to allow for access during decontamination. The extender is lowered to allow the closure valves to mate with the floor valve during the fuel transfer process. The extender consists of four main parts: the body, the bellows, the actuating components, the guides, and the seals.

The body consists of upper and lower sections. Both sections consist of the flange, circular shielding ring, and the segmented shielding section. The flanges are made from Type 304 stainless steel plates machined to the proper configuration. The shieldings consist of two main parts made of carbon steel and filled with lead for radiation shielding.

The bellows assembly is the pressure containment boundary of the extender. The bellows assembly consists of an upper flange, lower flange, and two separate bellows that are fabricated of austenitic stainless steel. Other auxiliary supporting structures are fabricated of carbon steels.

The seals of the extender prevent the internal atmosphere from escaping to the outside atmosphere. The main sealing areas are the body flanges and the bellows flanges. The seals on the body flanges seal the extender to the adjacent modules. The seals for the body flanges consists of two 1/4-in.-diameter O-rings located in adjacent grooves. The selection of seal materials is discussed in Section 3.12.

TABLE 6

MATERIALS LIST FOR EVTM DRIP PAN

Part Description	Material	
	Designation	Specification
Drip pan outer housing	304 forging	ASME SA182
Rotor stop	Alloy steel, Gr B7	ASME SA193
Pipe plug	Carbon steel	AISI 1018
Rotor assembly	304 SS	ASME SA240
Bearing outer retainer	304 SS	ASME SA240
Shim	Stainless steel, laminated	MS22499
Top plate drip pan	304 SS	ASME SA240
Pinion gear	Alloy steel	ASTM A290, Class C
Square key--long	Carbon steel	AISI 1018
Hexagonal screw cap	Alloy steel	ASME SA540, Gr B23, Class 5
Quad ring	Buna N	
O-ring	Buna N	
Press fit pin	Alloy steel	ASME SA193, Gr B7
Junction box bracket	304 SS	ASTM A240, Gr 304
Fiber filler	Diallyl phthalate	MIL-M-14G, GD 1-30
Upper flange casting drip pot	300 series casting	ASME SA351, Gr CF8
Spacer collar	304 SS tube	ASME SA213
Reflector plate	304 SS plate	ASME SA240
Swaged pin	304 SS bar	ASME SA479
Heater plate	304 SS plate	ASME SA240

The upper flange will have the grooves machined into the flange, while the lower flange will provide a sealing surface for the O-ring with the grooves machined into the closure valve upper flange. The flanges of the bellows are sealed to the body flanges by the bellows seals. These seals are 3/16 in. in diameter. O-rings with the twin grooves are machined into the body flanges, with the bellows flanges providing the mating sealing surfaces. The selection of seal materials is discussed in Section 3.12.

3.11 CLOSURE VALVE ASSEMBLY

The closure valve assembly, a fully shielded rotary valve, is designed to provide a leak-tight seal of the EVTM. It allows base core assemblies, sodium-filled CCPs containing core assemblies, and sodium drip pans to enter and leave the EVTM while preventing the entrance of air of the release of radioactive gases. It basically consists of the cover, valve body assembly, rotor bearing, gear, valve rotor, pinion, drive shaft, and seals. The following materials are recommended for the major parts:

• Cover	Type 304 SS, ASME SA240
• Gear and pinion	ASTM A290, Class G forging
• Top and bottom flange	304 SS forging, ASME SA182
• Rotor or valve disk	304 SS forging, ASME SA182
• Valve body	304 SS casting, ASME SA351, CF8
• Drive shaft	4140 alloy steel, AMS-6378A
• Inflatable seals	Materials to be determined by development test at AI

Materials for other parts of the closure valve assembly are listed in Table 7.

3.12 ELASTOMERIC MATERIALS AND LUBRICANTS

3.12.1 Elastomeric Materials

Guidelines for evaluation and selection of elastomeric materials for reactor refueling system applications have been established in another document. O-ring material is primarily Buna N. It is recommended for temperature applications to 140°F but can withstand higher temperatures (to 240°F) for short times. The maximum computed gamma radiation dosage on the EVTM seal material will be approximately 3×10^6 rad/year. For a 5-year design life, the seal materials will accumulate a total dosage of 1.5×10^7 rad due to gamma heating, which can moderately damage the seal materials. Recent test data show that the EPR and Buna N will still perform satisfactorily under this radiation

TABLE 7

MATERIALS LIST FOR CLOSURE VALVE

Part Description	Material	
	Designation	Specification
Inflatable seal	Under testing	
Limit torque bracket	304 SS	ASME SA240
Bolts	Alloy steel	ASME SA540, Gr B23, Class 5
Body valve	304 SS casting	ASME SA351, CF8
Lower flange	304 SS forging	ASME SA182
Valve disk	304 SS forging	ASME SA182
Upper cover	304 SS plate	ASME SA240
Cap screw	Alloy steel	ASME SA540, Gr B23, Class 5
Pinion gear	High-strength alloy steel	ASTM A290G, 105,000-psi yield
Nut		MS19068-143
Washer		MS19070-143
Inner bearing	New Departure Sandusky, Ohio	
Shims		MS224994, No. 3, Type 2, Class 1
Snap ring		MS16624-4275
Outer bearing	New Departure Sandusky, Ohio	
Quad ring	Minnesota Rubber Co.	
Plug seal	304 SS bar	ASME SA479
Drive shaft	4140	AMS-6378A
Bearing outer retainer	304 SS casting	ASME SA240
Wiper seal	Buna N	Parker Co.
Bevel gear	High-strength steel	ASTM A290, Class E, 80,000-psi yield
Spacer	304 SS plate/sheet	ASME SA240
Bushing	Bronze	ASTM B255, Type II
Bracket	304 SS	ASME SA182
Clamping ring	304 SS forging	ASME SA182
Locking wedge	4130 steel	ASTM A322

condition. The materials for inflatable seals will be selected after completion of the AI seal development testing program. The EVTM upset thermal transient conditions are not yet well characterized for various components, particularly in the sealing areas. The seal materials selection and life will, therefore, be governed by the new upset temperatures in the seal areas.

3.12.2 Lubricants

The recommended lubricant for O-ring seals is Dow Corning DC-55.

The recommended lubricant for threaded fasteners is Nickel-Never-Seez. This lubricant has been extensively tested by HEDL and GE and found to be superior to the Neolube-type lubricants.

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4.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the design conditions of EVTM and experience with materials in sodium service, the following conclusions and recommendations are made:

- For parts that will be exposed to reactor sodium atmosphere, Type 304 stainless steel is recommended as the principal material of construction unless one or both of the following conditions prevail:
  - Design load requires higher strength material
  - The mating parts are in direct contact in sodium.
- The principal recommended higher strength materials encompass Inconel 718, Inconel X-750, and A-286.
- The principal materials recommended for critical parts in direct contact in sodium environments are Stellite, Inconel 718, and/or chromium-plated stainless steel (304 SS or A-286).
- For parts that will be exposed to environment outside the reactor, carbon steel and alloy steels are recommended as the principal materials of construction.
- Buna N (high-temperature grade) and EPDM are recommended for O-ring seal materials for the 5-year design life at temperatures below 140 and 190°F, respectively. For higher design temperatures, it is recommended that the design criteria be changed by reducing the seal design life (e.g., 2 to 3 years) or by considering the use of metallic seals. Inflatable seal material(s) will be selected on the completion of the seal testing program at AI.
- The grapple chain drive materials will be selected on the completion of the grapple chain testing at AI.

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