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MATERIAL SELECTION REPORT FOR THE IN-VESSEL TRANSFER MACHINE OF THE CRBRP

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Rockwell International

Atomics International Division
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LIQUID METAL FAST BREEDER REACTOR
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ABSTRACT

Material selection recommendations for the parts of the in-vessel transfer machine of the Clinch River Breeder Reactor Plant are presented. Factors considered are intended service conditions, environments, and ASME Code requirements. Various material such as stainless steels, carbon steels, Inconel 718, aluminum bronze, and elastomers are recommended for appropriate parts of the machine.

CONTENTS

FIGURES

1.0 COMPONENT DESCRIPTION

The in-vessel transfer machine (IVTM) will operate in conjunction with the reactor head, triple rotating plug system in performing refueling operations. Its function is to lower, lift, or rotate core components within the reactor vessel. The IVTM will be installed and used during reactor core shutdown periods and removed from the reactor before reactor startup.

The IVTM consists of an in-vessel section and a drive section. The in-vessel section will be installed in the small rotating plug (SRP) and will form part of the boundary for the containment cover gas during refueling operations. Below the seals, the in-vessel section will be exposed to sodium or sodium vapor. The drive section, located above the reactor, will operate in air and be accessible to operating personnel.

The major components of the IVTM are shown in Figure 1.

This report is based on work completed in 1975 during the design phase of the IVTM for the Clinch River Breeder Reactor Plant (CRBRP) project.

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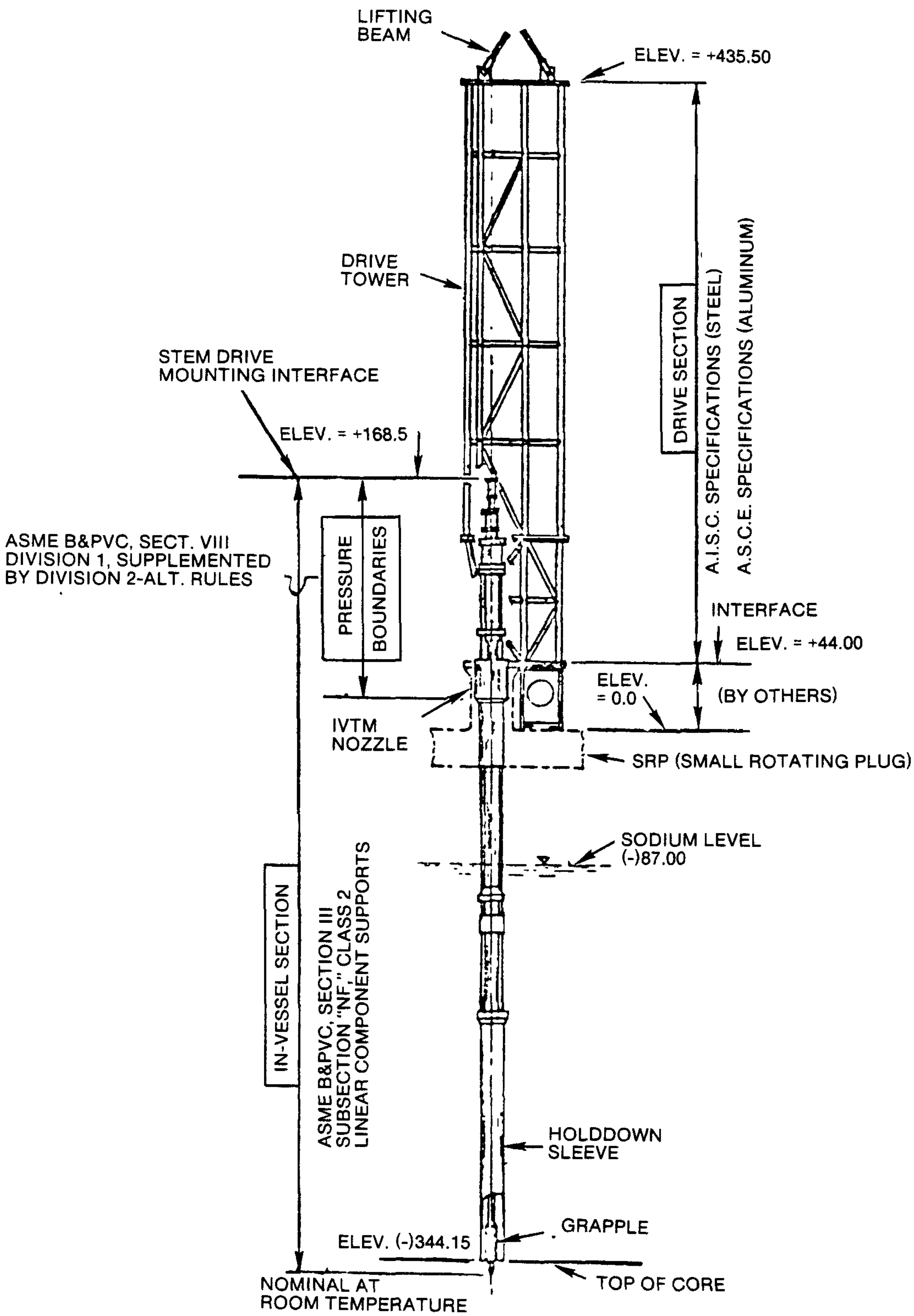

Figure 1. IVTM Boundary Definition

2.0 DESIGN ENVIRONMENTS

2.1 IN-VESSEL SECTION

2.1.1 Sodium

Temperature	600°F maximum
Oxygen	5.0 ppm maximum
Hydrogen	0.4 ppm maximum

2.1.2 Cover Gas (Argon Plus Sodium Vapor)

Temperature	475 ± 25°F
Oxygen	10 vol ppm maximum
Hydrogen	8 vol ppm maximum
Carbon	25 vol ppm maximum
Nitrogen	(TBD)
Fission and activation products	

2.1.3 Storage Gas (Argon)

Temperature	50 to 120°F
Pressure	10-in. H_2O above RCB pressure
Oxygen	(TBD)

2.2 DRIVE SECTION

2.2.1 Air (Ambient)

Temperature	40 to 90°F
Pressure	28 to 32 in. Hg
Relative humidity	40 to 60%

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3.0 MATERIAL SELECTION CONSIDERATIONS

3.1 AUSTENITIC STAINLESS STEEL

Austenitic stainless steel shall be used for all components in the in-vessel section except for (1) those applications where higher allowable design stresses are required or (2) assemblies where loaded moving surfaces are allowed. The austenitic stainless steels (Types 304 and 316) are the reference materials of construction for CRBRP Primary Coolant System. Type 304 has been selected for IVTM components.

3.2 HIGH-STRENGTH MATERIALS

Inconel 718 is recommended for those components of the in-vessel section that require higher strength than that of the austenitic stainless steels (Types 304 or 316). At the 600°F design temperature, Inconel 718 has a tensile strength of 169.6 ksi (minimum) compared to 58.1 ksi (minimum) for Type 304 SS or 65.7 ksi (minimum) for Type 316 SS.[1]

3.3 WEAR-RESISTANT MATERIALS

Inconel 718 and a cobalt-base alloy (Stellite 3 or equivalent composition) are recommended for components subject to wear or self-welding. These selections are based on technology developed under the in-vessel handling machine (IVHM) program for the Fast Flux Test Facility (FFTF). Feature tests conducted at LMEC demonstrated that Inco 718-to-Inco 718 and Inco 718-to-Stellite 3 couples resisted wear in sodium at FFTF refueling temperatures. Before the tests, the test materials were soaked at 1100°F to simulate exposures at FFTF primary sodium temperatures. The resultant test data justified the selection of these materials for IVHM, and this in turn provides a technical basis for their selection in the IVTM.

Inconel 718 shall be used for those in-vessel section components that are subjected to low contact pressures with either austenitic stainless steel or other Inconel 718 components.

For high contact pressures, the material couple shall be Inconel 718 in contact with a cobalt-base alloy. The recommended alloy should be of the composition specified in MIL-C-24248, Composition IV, which is the equivalent composition of Stellite 3.

3.4 GUIDE MATERIALS

The recommended material for in-vessel guides or guide bushings is aluminum bronze. There is considerable experience with aluminum bronze in sodium systems. Acceptable alloys are AMPCO-18-13 or AMPCO-18-22. The mating bearing surface may be Type 304 (Cr plated) or Inconel 718.

3.5 DRIVE SECTION STRUCTURE

The recommended structural material is carbon steel. Acceptable specifications are ASTM A36, which covers all common mill shapes for steel structures, and ASTM A53 for welded or seamless pipe.

A structural grade of aluminum, such as 6061, is acceptable for application where the use of a lighter material would be advantageous. The -T6 temper is commonly used for structures; however, the strength is lowered to that of the annealed condition if welded.

3.6 NONMETALLIC MATERIAL

Nonmetallic material applications include seals and bushings. The selection of seal materials should be considered to be tentative and subject to change in view of current LMFBR seal and development programs. At this time, ethylene propylene rubber (EPR) is recommended for the IVTM seals. EPR is somewhat marginal with respect to the 300°F (maximum) service temperature; however, its superior resistance to permeation by gases makes it a better choice than silicone rubber.[2] For example, at 300°F, the permeation rate of hydrogen through silicone rubber is about 10^{-6} ($cm^3 \cdot cm/s \cdot cm^2 \cdot cm$ Hg ΔP)

compared to only 7 x 10^{-8} for EPR. Buna-N rubber is less permeable than either EPR or silicone rubber, but it is temperature limited to about 200°F.

For nonmetallic bushing applications, the recommended material is a low water absorption grade of nylon such as Type 6.[3]

3.7 MATERIAL PROPERTIES

Design allowables and other properties for structural materials should be as published in the applicable codes shown in Figure 1. Material properties not covered by the Code shall be taken from the Nuclear Systems Materials Handbook, TID 26666.[1] For elastomer seals, refer to the Design Guide for Reactor Cover Gas Elastomer Seals.[2]

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4.0 IVTM MATERIAL SELECTION

INCONEL 718	
Bar and forgings	ASTM A637, Gr 718 AMS 5662
Plate	AMS 5596
Tubes	AMS 5589
COBALT ALLOY (STELLITE 3 EQUIVALENT)	
Casting	MIL-C-24248, Composition IV
STAINLESS STEEL	
Pipe	ASME SA312, Type 304 ASME SA376, Type 304
Tubing, seamless Welded	ASME SA213, Type 304 ASME SA249, Type 304
Plate	ASME SA240, Type 304
Bars and shapes	ASME SA479, Type 304
Forgings	ASME SA182, F304
Forged and bored pipe	ASME SA430, FP304
Fittings	ASME SA403, WP304
Castings	ASME SA351, CF8
STEEL BALLS	QQS-773, Class 440C Heat treat to 56 R_c minimum
GUIDE MATERIAL	
Aluminum bronze	AMPCO-18-13 or AMPCO-18-22
SPRING WIRE (SS)	ASTM A313 or AMS 5688 or QQ - W - 423 FS302, Condition B

SEALS

EPR or silicone, if above 300°F

NONMETALLIC (BUSHINGS, ETC.)

Nylon general purpose Type 6

STRUCTURAL STEEL

Plate and shapes	ASTM A36

A286 SS

Bar, forgings, and tube	AMS 5735
Boiling	ASME SA453, Gr 660, Condition B

CARBON STEEL PIPE

Welded or seamless	ASTM A53

ALLOY STEEL (4130)

Bars and forgings	AMS 6370 or MIL-S-6758
Tubing	ASTM A519, Gr 4130, or AMS 6371

ALUMINUM ALLOY

Pipe	ASTM B241, Alloy 6061-T6
Plate	ASTM B209, Alloy 6061-T6
Shapes	ASTM B308, Alloy 6061-T6

BOLTING (STEEL)	ASTM A325, or ASTM A490, or ASTM A193

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REFERENCES

1. TID 26666, "Nuclear Systems Materials Handbook"

2. W. J. Kurzeka and F. R. Welch, "Design Guide for Reactor Cover Gas Elastomer Seals," AI-AEC-13145 (March 7, 1975)

3. "Materials Selector, 76," Materials Engineering, p 144-145 (September 1975)

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