3E.1.1 Reactor Containment Building Liner Plate and Anchorage System

This critical section presents the analysis and structural design methodology and design results of the Reactor Containment Building (RCB) Liner Plate and Anchorage System. The RCB Liner Plate and Anchorage System is described in Section 3.8.1.1.3 and Section 3.8.1.4.10. The dimensions of the RCB are shown on Figure 3B-12—Reactor Building Dimensional Section A-A to Figure 3B-14—Reactor Building Dimensional Section C-C.

The RCB liner plate is a concrete-backed, carbon steel leak-tight liner plate that covers the entire inner surface of the RCB, including the basemat. The RCB is a safety-related, Seismic Category I structure as described in Section 3.8.1.1. The design details for the RCB Liner Plate and Anchorage System are described in this critical section.

3E.1.1.1 Model

The finite element ANSYS static model of the Nuclear Island (NI) Common Basemat Structures (ANSYS NI static model) described in Sections 3.8.1.4.1 and 3E.1 is used for the design of the RCB Liner Plate and Anchorage System. The RCB Liner Plate portion of the ANSYS NI static model is constructed from SHELL181 elements. In the ANSYS NI static model, shell elements are created over the solid concrete element to represent the weight of the liner plate. The material properties of the shell elements do not contribute to the structural stiffness. The nodal strain values from the nodes that are attached to the shell elements and solid elements are extracted for the relevant load cases.

The nomenclature for the forces and moments results of the ANSYS NI static model is shown on Figure 3E.1-1.

3E.1.1.2 Load Combinations and Loads

The load combinations applied to the RCB Liner Plate and Anchorage System are described in Section 3.8.1.3.2. The design of the RCB Liner Plate and Anchorage System is achieved using the results obtained from the model pertaining to the A-Series load combination shown in Table 3E.1-4. The load factors for liner plate and its anchorage system is 1.0 per section CC-3700 of ASME Section III Division 2. This critical section is designed for the soil cases shown in Table 3.7.1-6.

Independent loads considered for the RCB Liner Plate and Anchorage System are shown in Table 3E.1-2 and described in Sections 3.8.1.3.1 and 3E.1. Independent loads not considered in the ANSYS NI static model are shown in Table 3E.1-3. Missing loads added to the design include the additional strains from polar crane loads, differential settlement/construction sequence, accidental torsion, creep and shrinkage.

The strains caused by polar crane are determined by applying the loads at the location of the polar crane brackets and calculating the forces/moments transformed to the center of the reactor containment walls. The polar crane additional strains for seismic and non-seismic conditions are determined separately and combined with appropriate load combinations for the design.

Separate analyses were performed to determine the effects of accidental torsion and differential settlements/construction sequence. The additional hoop and meridional strain values for the missing loads are extracted from the results of the analyses and the maximum/minimum strains are included in the applicable load combinations for the design.

Creep and shrinkage strains are determined using the same methodology used to calculate the prestress losses, (i.e., methodology specified in ACI 209R-92). A concrete through thickness temperature of 76°F is used for determining the temperature correction factor for the creep and shrinkage strain used for the design. The effect on strains resulting from the slight increase of prestress loss because of the use of the calculated creep and shrinkage strains is also accounted for in the design.

The strain values induced by missing loads are shown in Table 3E.1.1-1—Additional Strains.

3E.1.1.3 Analysis and Design Methods

The design of the RCB Liner Plate and Anchorage System is performed using the applicable codes, standards, and specifications in Sections 3.8.1.1.3 and 3.8.1.2.1.

Load combination A01, A02, A03, A06, A08 and A15 are the applicable load combination cases for the design of the liner plate and liner plate anchorage system. Load combinations A02, A06 and A15 were determined to be the governing load combinations by extracting the strains from the ANSYS NI static model and combining the missing load strains. These three load combinations give the highest hoop and membrane stresses for the operating and accident conditions.

The design of the RCB Liner Plate and Anchorage System is performed to satisfy ASME Section III Division 2. The design is performed using the energy methodology described in Bechtel Topical Report 1 “Containment Building Liner Plate Design Report” (BC-TOP-1).

The thermal independent loads extracted from the ANSYS NI static model and have been increased by 10% to provide the design margin.

3E.1.1.4 Critical Section Design

The RCB Liner Plate and Anchorage System critical section is capable of carrying the applied design loadings provided they are constructed in accordance with the material properties in Section 3E.1 and the section geometry in this critical section.

The governing design data for the RCB Liner Plate and Anchorage System is shown in Table 3E.1.1-2—Governing Design Data for the RCB Liner Plate and Anchorage System.

An Elevation View of the RCB Liner Plate and Anchorage System is shown on Figure 3E.1.1-1—Elevation View RCB Liner Plate and Anchorage System. The liner plate strain check criteria for membrane strains are in accordance with CC-3720 of the ASME code and shown in Table 3E.1.1-3—Strain Check Result for the Liner Plate. The energy method design results for the anchorage system are shown in Table 3E.1.1-4—Energy Method Design Results for the RCB Liner Plate Anchorage System.

Design details for the RCB Liner Plate and Anchorage System are shown on Figure 3E.1.1-2—RCB Liner Plate and Anchorage System (Section 1-1) through Figure 3E.1.1-4—Liner Plate and Anchorage System (Section 3-3).

Table 3E.1.1-1—Additional Strains

Load Case (2)	Hoop @ T=0 year	Hoop @ T=60 year	Meridional @ T=0 year	Meridional @ T=60 year
Creep Strain	-0.42×10^{-3}	-0.46×10^{-3}	-0.25×10^{-3}	-0.28×10^{-3}
Shrinkage Strain	-0.14×10^{-3}	-0.14×10^{-3}	-0.14×10^{-3}	-0.14×10^{-3}
Strain due to Increase in Prestress	-0.0253×10^{-3}	-0.0275×10^{-3}	-0.0088×10^{-3}	-0.0092×10^{-3}
Load Case	**Hoop**		**Meridional**	
Accidental Torsion (cracked)	-0.005×10^{-3}		-0.0023×10^{-3}	
Polar Crane (Case a)(1)	0		-0.0927×10^{-3}	
Polar Crane (Case b)(1)	-0.0094×10^{-3}		-0.0827×10^{-3}	
Polar Crane (Case c)(1)	-0.1492×10^{-3}		-0.2641×10^{-3}	
Polar Crane (Case d)(1)	0		-0.0453×10^{-3}	
Polar Crane (Case e)(1)	-0.1492×10^{-3}		-0.2327×10^{-3}	
Differential Settlement	-0.0211×10^{-3}		-0.0085×10^{-3}	

Notes:

1. There are five cases for the polar crane load as follows:
   - Polar Crane (Case a): Dead + Live + Vertical or Longitudinal impact under non-SSE cases (applicable to Load Combinations A02 and A03).
   - Polar Crane (Case b): Dead + Live + Transverse impact under non-SSE cases (applicable to Load Combinations A02 and A03).
   - Polar Crane (Case c): Dead + Live + SSE (applicable to Load Combination A06).
   - Polar Crane (Case d): Dead (applicable to Load Combinations A01 and A08).
   - Polar Crane (Case e): Dead + SSE (applicable to Load Combination A15).
2. T_0 is the point when the plant first begins operating while T_{60} is the point when the plant ceases operation. T_0 and T_{60} means the cylindrical wall concrete has an age of 5 years and 65 years, respectively.

Table 3E.1.1-2—Governing Design Data for the RCB Liner Plate and Anchorage System

	Load Combination	Static Model Strain ε		Creep ε[1]		Shrinkage ε[1]		Correction to Prestress ε[1]		Accidental Torsion ε[2]		Polar Crane ε		Differential Settlement ε		Total Strain ε_{tot}	
		Hoop	Meridional	Hoop	Meridional	Hoop	Meridional	Hoop	Meridional	Hoop	Meridional	Hoop	Meridional	Hoop	Meridional	Hoop	Meridional
		$x10^{-3}$	$x10^{-3}$	$x10^{-3}$	$x10^{-3}$	$x10^{-3}$	$x10^{-3}$	$x10^{-3}$	$x10^{-3}$	$x10^{-3}$	$x10^{-3}$	$x10^{-3}$	$x10^{-3}$	$x10^{-3}$	$x10^{-3}$	$x10^{-3}$	$x10^{-3}$
Normal/Extreme Env Condition	A02	-0.551	-0.275	-0.42	-0.25	-0.14	-0.14	-0.0253	-0.0088	0	0	-0.0094	-0.0827	-0.0211	-0.0085	-1.167	-0.765
Normal/Extreme Env Condition	A06	-0.583	-0.342	-0.46	-0.28	-0.14	-0.14	-0.0275	-0.0092	-0.0049	-0.0023	-0.1492	-0.2641	-0.0211	-0.0085	-1.386	-1.046
Accident Condition	A15	-1.539	-1.447	-0.46	-0.28	-0.14	-0.14	-0.0275	-0.0092	-0.0049	-0.0023	-0.1492	-0.2327	-0.0211	-0.0085	-2.342	-2.120

Notes

1. For A02, creep and shrinkage taken at T0 (5 years). For others, creep and shrinkage taken at T60 (65 years).
2. Only applicable to seismic load combination A06 and A15.

Table 3E.1.1-3—Strain Check Result for the Liner Plate

Category	Combination	Compression[1] Strain ε_{tot} Hoop	Compression[1] Strain ε_{tot} Meridional[2]	Allowable Compression Strain[1]	Demand to Capacity Ratio
		$x10^{-3}$	$x10^{-3}$	$x10^{-3}$	
Service	A03	-1.213	-0.810	-2.00	0.61
Factored	A15	-2.342	-2.120	-5.00	0.47
Category	**Combination**	**Tension[3] Strain ε_{tot} Hoop**	**Tension[3] Strain ε_{tot} Meridional[2]**	**Allowable Tension Strain**	**Demand to Capacity Ratio**
		$x10^{-3}$	**$x10^{-3}$**	**$x10^{-3}$**	
	A01	-0.368	-0.295	2.00	NA
	A06	-0.338	-0.142	3.00	NA

Notes:

1. Compression is negative.
2. This strain is the meridional strain that is corresponding to the hoop strain.
3. If no tension values were identified, the least compressive value is shown.

Table 3E.1.1-4—Energy Method Design Results for the RCB Liner Plate Anchorage System

Conditions	A02		A06		A15	
	(a)	(b)	(a)	(b)	(a)	(b)
Anchor Displacement (inch)	0.0236	0.032	0.0305	0.0402	0.0463	0.0626
Allowable Anchor Displacement (inch)	δu/4=0.25 in/4=0.625 in		δu/4=0.25 in/4=0.625 in		δu/2=0.25 in/2=0.125 in	
Total Energy Required in Anchor (kip*in)	0.062	0.099	0.092	0.137	0.166	0.248
Total Energy Capacity in Anchor (kip*in)	1.326					
Energy Safety Factor on Anchor	21.4	13.4	14.4	9.7	8.0	5.4
Anchor Displacement Safety Factor	2.65	1.95	2.05	1.55	2.70	2.00
Component in Plastic	Plate and Anchor	Anchor	Plate and Anchor	Anchor	Plate and Anchor	Anchor

Notes:

1. Conditions:
   - (a) With bent plate capacity included and E_c=4.769 x10^6 psi.
   - (b) Without bent plate capacity and E_c=4.769 x10^6 psi.

Figure 3E.1.1-1—Elevation View RCB Liner Plate and Anchorage System

Figure 3E.1.1-2—RCB Liner Plate and Anchorage System (Section 1-1)

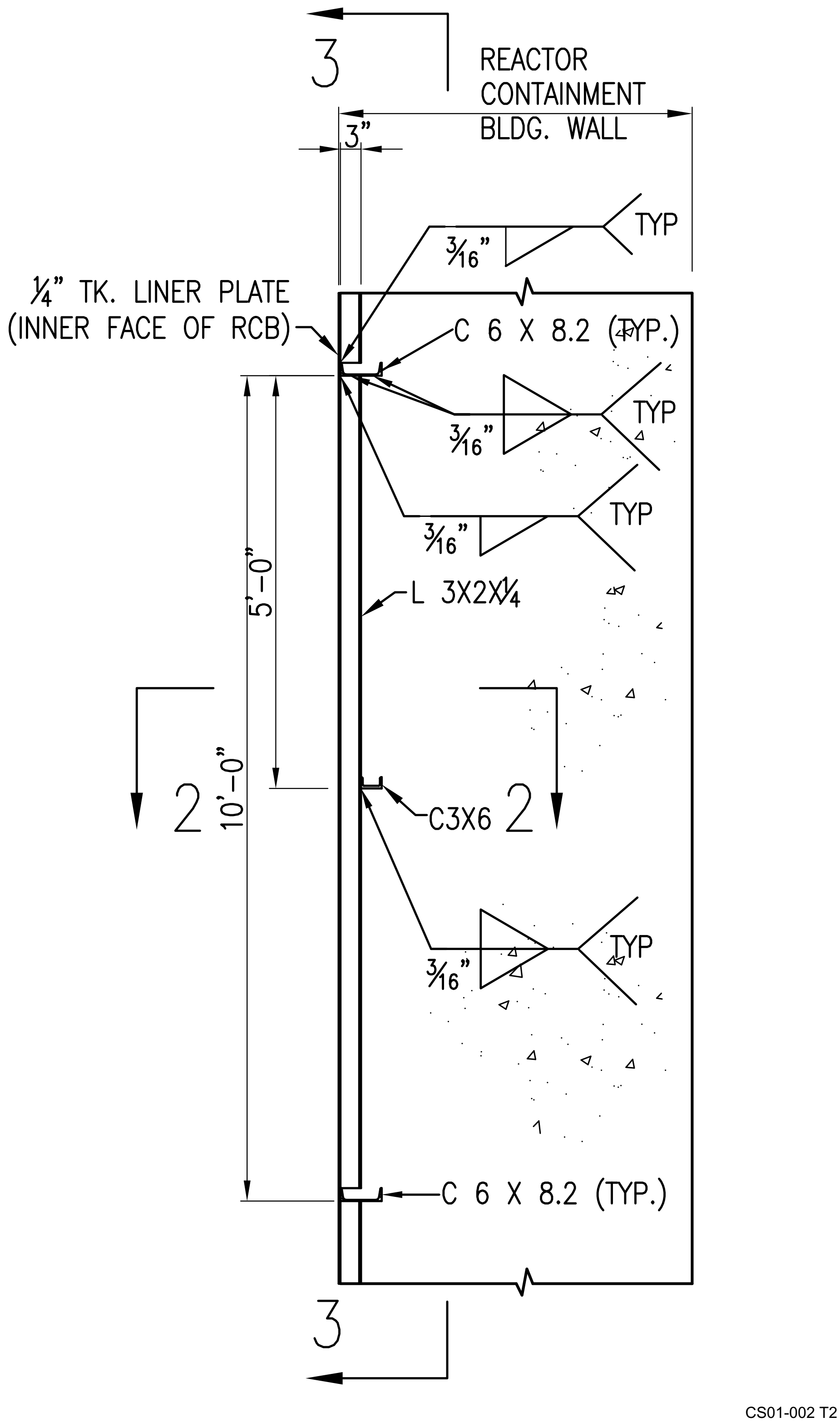


Figure 3E.1.1-3—RCB Liner Plate and Anchorage System (Section 2-2)

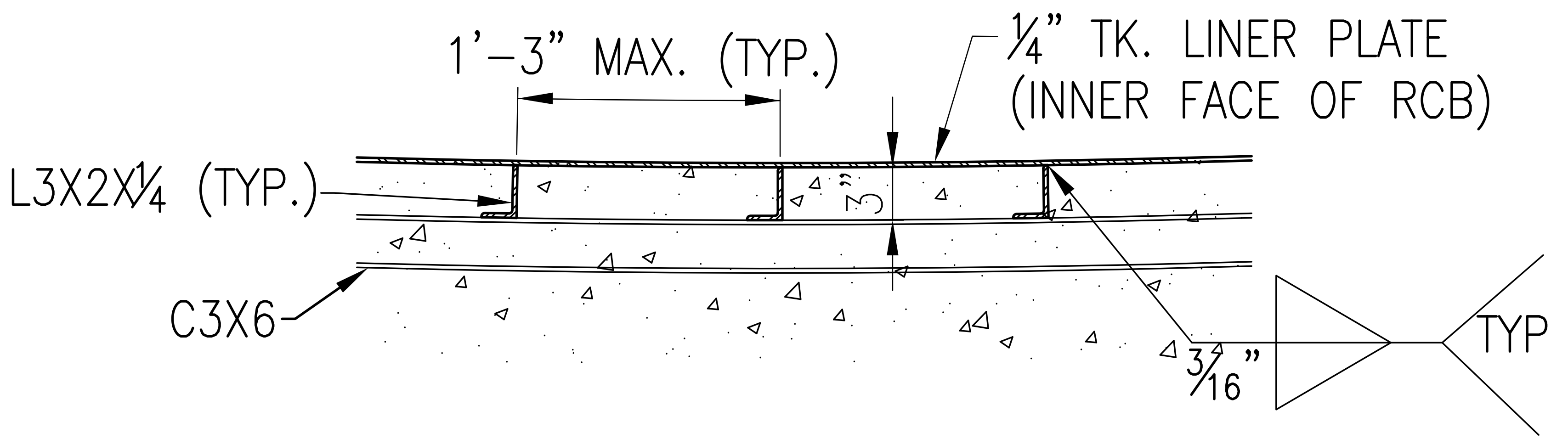
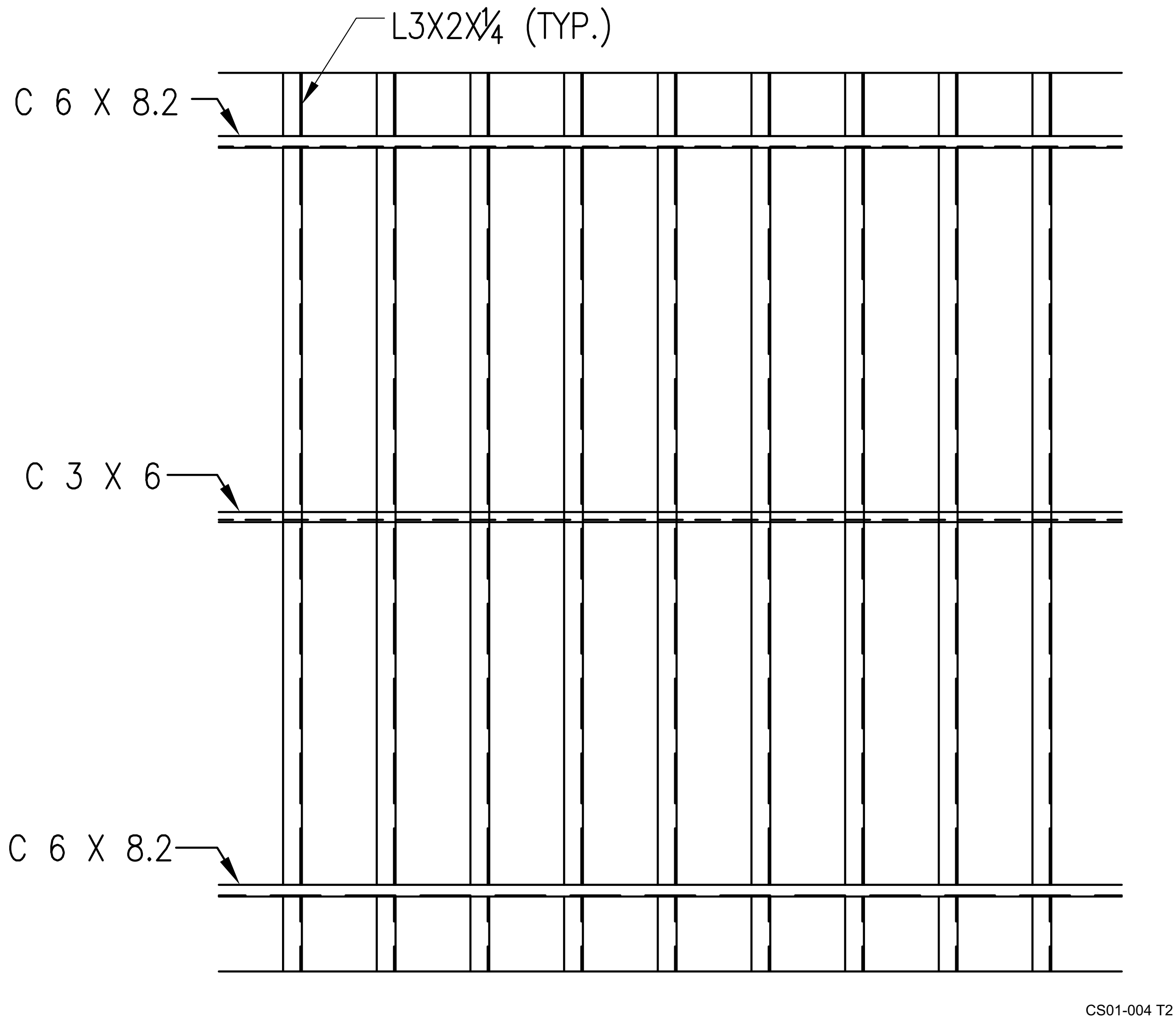


Figure 3E.1.1-4—Liner Plate and Anchorage System (Section 3-3)



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