REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**199-8223**
SRP Section:	**03.08.01 – Concrete Containment**
Application Section:	**03.08.01**
Date of RAI Issue:	**09/08/2015**

Question No. 03.08.01-13

Appendix A to 10 CFR Part 50, General Design Criteria (GDC) 1, 2, 4, 16 and 50, provide the regulatory requirements for the design of the concrete containment. Standard Review Plan (SRP) 3.8.1, Section II specifies the materials for construction of concrete containments with emphasis on the extent of compliance with Article CC-2000 of Section III, Division 2, of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, with additional guidance provided in Regulatory Guide 1.136.

DCD Section 3.8.1.5.1.2, “Prestressing System,” identifies the material for the prestressing elements and in the case of the anchorage components, refers to the tendon manufacturer’s respective material specifications. However, the staff was unable to find the manufacture’s specifications for the bearing plates, anchor head assemblies, and the wedges which are part of the anchorage system Per Appendix A to 10 CFR Part 50, GDC 1, 2, 4, 16 and 50; and SRP 3.8.1, the applicant is requested to identify what manufacture tendon system is used for the design of APR1400, and if the information is not publicly available, provide the manufacturer’s technical literature on this type of tendon system, including their anchorage system.

Response – (Rev. 1)

The post-tensioning system of the containment is VSL E6-42 multi-strand system using a wedge block with wedge type anchors. VSL E6-42 multi-strand system uses the same anchorage system as VSL E6-43 which is identified in the VSL International Brochure (Attachment 1) available to the public. Although the VSL E6-42 system is not listed in the VSL International Brochure, it is introduced in the VSL Korea Brochure (Attachment 2). A translation of the VSL Korea Brochure is provided in Attachment 2 as well.

The VSL International Brochure is summarized in the VSL Korea Brochure which provides only one option of material properties without any other options. In this process, different material properties were used to consider the local conditions. The dimensions in certain anchorage types indicated in the brochures may vary with material properties, including concrete

compressive strength, yield strength of reinforcing steel and tendon stressing force. The dimensions which do not match between the VSL International and Korea brochures come from the difference of material properties applied in both brochures.

In general, dimensions of anchorage assemblies in the VSL brochures are standard detailing recommended by VSL. However, the dimensions of anchorage assemblies used in the APR1400 are calculated by the supplier to consider the material properties applied in the APR1400. The material properties are described in DCD 3.8A.1.2.

The multi-strand system employs 0.6 inch diameter, seven wire, low relaxation strand manufactured in accordance with ASTM A416, Grade 270, as described in DCD Tier 2, Appendix 3.8A, Subsection 3.8A.1.2.4. The type of prestressing system, including the manufacturer and product designation, and description for duct material will be added to DCD Tier 2, Subsection 3.8.1.6.3 as shown in the Attachment 3 to this response.

Impact on DCD

DCD Tier 2, Subsection 3.8.1.6.3 will be revised as shown in Attachment 3 to this response.

Impact on PRA

There is no impact on the PRA.

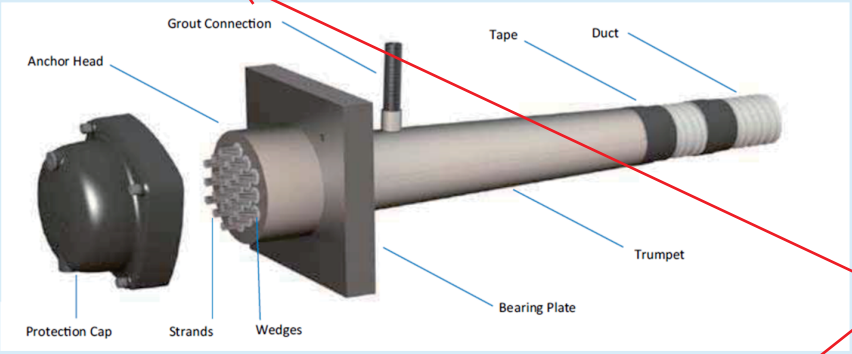
Impact on Technical Specifications

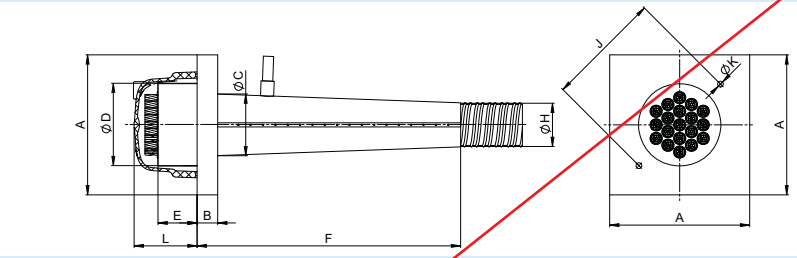
There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

Multistrand Post-Tensioning System
Internal Bonded Post-Tensioning
ANCHORAGE TYPE E 0.6





Unit	ØC	ØD	E	ØH [2]	L	øK	Concrete 23/28 & 28/35 MPa □A	B	F	J [1]	Concrete 32/40 & 36/45 MPa □A	B	F	J [1]	Concrete 43/53 MPa □A	B	F	J [1]
6-1	18	53	50	25	-	-	75	10	150	86	70	10	150	79	65	10	150	78
6-2	50	90	50	50	-	-	110	10	200	136	100	10	200	122	95	10	200	115
6-3	56	95	50	55	105	M12	135	15	205	135	125	15	205	135	120	15	205	135
6-4	65	110	55	60	110	M12	160	20	210	150	145	20	210	150	130	20	210	150
6-7	84	135	60	72	120	M12	205	30	320	210	175	25	315	210	160	25	315	190
6-12	118	170	75	92	135	M16	270	40	500	265	230	35	495	265	210	35	495	240
6-15	143	190	85	97	145	M16	305	45	585	275	265	40	580	275	240	40	580	275
6-19	150	200	95	107	155	M16	340	50	640	280	290	45	635	280	270	45	635	280
6-22	172	220	100	122	160	M16	370	55	745	310	320	50	740	310	290	50	740	310
6-27	185	240	110	132	170	M16	410	60	690	330	350	55	685	330	320	55	685	330
6-31	192	260	120	142	180	M16	435	65	755	360	370	60	750	360	340	60	750	360
6-37	215	280	135	155	200	M16	480	75	905	370	410	70	900	370	375	65	895	370
6-43	248	320	145	165	215	M20	520	80	1030	420	450	75	1025	420	410	70	1020	420
6-55	255	340	160	185	230	M20	580	95	1045	452	500	90	1040	452	450	80	1030	452

Notes

All dimensions in [mm]

System applicable to strands with Ap = 140 mm² or Ap = 150 mm²

Concrete strength is defined as minimum required $f_{c,cyl}$ / $f_{c,cube}$ in MPa at time of stressing

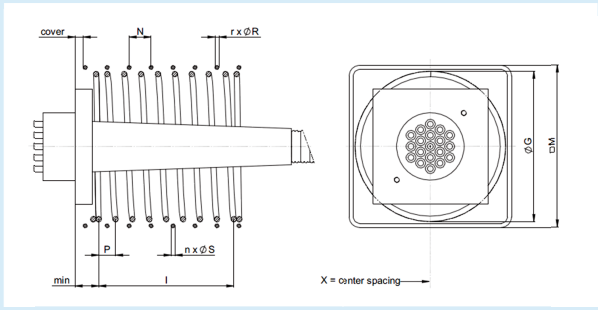
(1) J- spacing of bolts for fixation to formwork

(2) ØH-Inner dia of the trumpet

System can be used with corrugated steel duct or with PT-Plus® duct

E6-43
Post-tensioning
System

Multistrand Post-Tensioning System
Internal Bonded Post-Tensioning
ANCHORAGE TYPE E (Strand F_{pk}= 279 kN)
LOCAL ZONE REINFORCEMENT f_y= 500 N/mm²



Reinforcement consists of a combination of spiral and stirrups

CONCRETE 23/28 MPa

Unit	Spiral Reinforcement ØS	n [1]	P	ØG	l	Orthogonal Reinf. ØR	r [2]	N	M	X
6-1	10	5	60	100	180	-	-	-	-	120
6-2	12	5	60	150	180	-	-	-	-	170
6-3	12	5	55	185	165	-	-	-	-	205
6-4	12	6	50	220	200	-	-	-	-	240
6-7	12	6	60	260	240	12	4,0	75	295	315
6-12	16	7	65	345	325	12	7,0	70	390	410
6-15	16	7	75	390	375	16	6,0	75	435	455
6-19	16	9	60	450	420	16	6,0	90	495	515
6-22	16	10	60	490	480	16	7,0	75	535	555
6-27	16	11	55	545	495	16	8,0	70	595	615
6-31	16	12	55	585	550	16	10,0	60	635	655
6-37	20	11	65	645	585	16	9,0	75	695	715
6-43	20	13	60	705	660	16	10,0	70	750	770
6-55	20	14	60	805	720	16	15,0	55	855	875

CONCRETE 28/35 MPa

Unit	Spiral Reinforcement ØS	n [1]	P	ØG	l	Orthogonal Reinf. ØR	r [2]	N	M	X
6-1	10	5	65	90	195	-	-	-	-	110
6-2	12	5	60	135	180	-	-	-	-	155
6-3	12	5	55	165	165	-	-	-	-	185
6-4	12	6	50	195	200	-	-	-	-	215
6-7	12	6	50	225	200	12	5,0	75	260	280
6-12	16	7	65	315	325	12	6,0	75	350	370
6-15	16	7	65	345	325	16	6,0	75	390	410
6-19	16	8	60	395	360	16	7,0	75	440	460
6-22	16	10	50	430	400	16	7,0	75	475	495
6-27	16	11	50	485	450	16	9,0	65	530	550
6-31	16	11	50	525	450	16	10,0	60	570	590
6-37	20	11	60	580	540	16	9,0	75	625	645
6-43	20	12	55	630	550	16	11,0	65	675	695
6-55	20	14	55	720	660	16	14,0	55	765	785

CONCRETE 32/40 MPa

Unit	Spiral Reinforcement ØS	n [1]	P	ØG	l	Orthogonal Reinf. ØR	r [2]	N	M	X
6-1	10	5	65	85	195	-	-	-	-	105
6-2	12	5	60	125	180	-	-	-	-	145
6-3	12	6	50	155	200	-	-	-	-	175
6-4	12	6	45	180	180	-	-	-	-	200
6-7	12	7	45	210	225	12	5,0	65	245	265
6-12	16	7	55	290	275	12	6,0	60	325	345
6-15	16	8	55	320	330	16	7,0	60	365	385
6-19	16	8	55	370	330	16	8,0	60	415	435
6-22	16	10	45	400	360	16	8,0	60	445	465
6-27	16	11	45	450	405	16	10,0	50	495	515
6-31	16	12	45	490	450	16	12,0	45	535	555
6-37	20	11	55	540	495	16	11,0	55	585	605
6-43	20	13	50	585	550	16	14,0	45	630	650
6-55	20	14	50	670	600	16	18,0	40	715	735

CONCRETE 36/45 MPa

Unit	Spiral Reinforcement ØS	n [1]	P	ØG	l	Orthogonal Reinf. ØR	r [2]	N	M	X
6-1	10	5	65	75	195	-	-	-	-	95
6-2	12	5	55	115	165	-	-	-	-	135
6-3	12	5	50	145	150	-	-	-	-	165
6-4	12	6	45	170	180	-	-	-	-	190
6-7	16	6	65	195	260	12	4,0	80	230	250
6-12	16	7	50	270	250	12	5,0	70	305	325
6-15	16	8	50	300	300	16	6,0	70	345	365
6-19	16	8	50	345	300	16	7,0	60	390	410
6-22	16	10	45	375	360	16	8,0	55	420	440
6-27	16	11	45	425	405	16	10,0	50	470	490
6-31	16	11	45	460	405	16	12,0	45	505	525
6-37	20	11	50	505	450	16	10,0	60	550	570
6-43	20	12	50	545	500	20	10,0	65	595	615
6-55	20	13	50	625	550	20	12,0	60	675	695

Notes

All dimension in [mm]

Min. yield strength for local zone reinforcement fy = 500N/mm²

Min. required concrete strength $f_{c,\ cylinder}$ / $f_{c,\ cube}$ in MPa at stressing

Strand A_p = 150mm², f_{pk} = 1860N/mm² (GUTS), F_{pk} = 279kN

For max. tendon force and temporary over stressing refer to 4.1 and 4.2.8 resp.

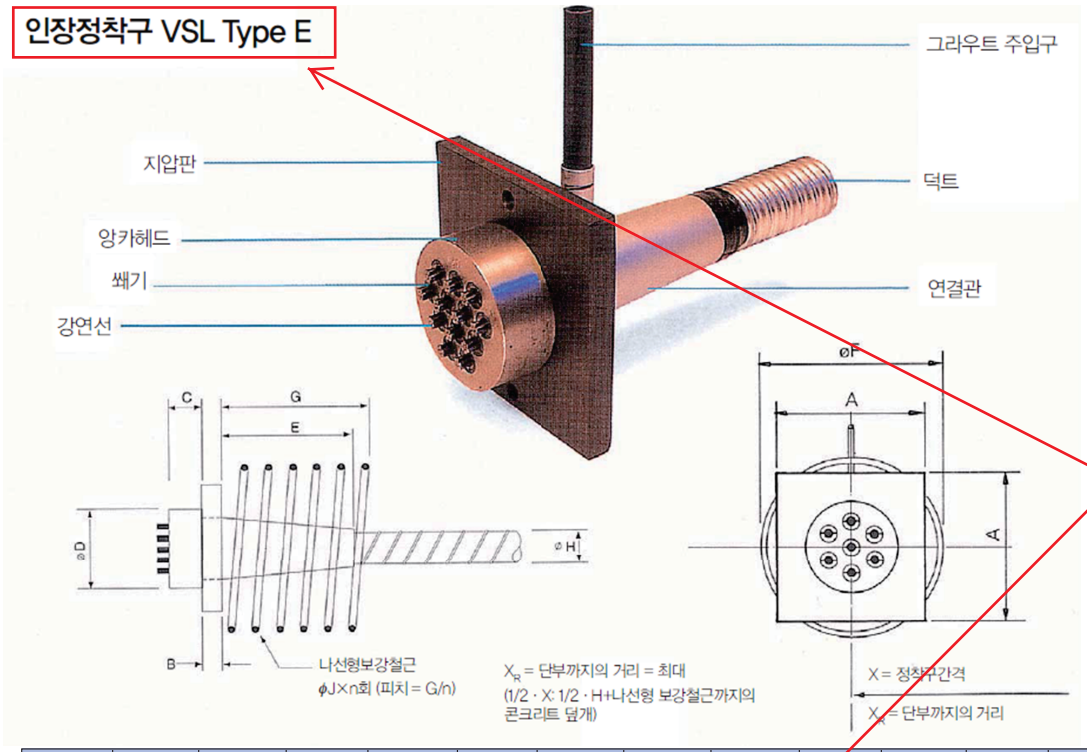
X = minimal center spacing between anchorages

For calculation of minimum edge distance refer to 4.4.1

n = number of spiral turns including first and last required as anchorage length

Reinforcement, edge distance, center spacing may be modified, contact VSL

인장정착구 VSL Type E



E6-42
Post-tensioning system

	텐던단위	A	B	C	øD	E	øF	G	H	øJ	n	X[2]
강연선 12.7mm(0.5")	5-1	70	15	45	42	70	80	90	–	10	2	90
	5-3	115	20	50	90	190	130	150	–	10	3	155
	5-4	130	20	50	95	190	160	150	51/54	10	3	180
	5-7	175	25	55	110	190	205	200	51/54	13	4	235
	5-12	230	35	60	150	370	285	250	63/66	16	5	305
	5-19	290	40	75	180	470	365	300	84/87	16	6	385
	5-22	315	45	85	190	480	395	360	87/90	19	6	415
	5-31	370	55	95	230	550	470	400	100/103	19	8	490
	5-37	405	60	–	–	570	510	420	–	19	7	535
	5-42	440	60	–	–	680	550	480	–	22	8	580
	5-55	500	70	–	–	680	620	540	–	22	9	655
강연선 15.2mm(0.6")	6-1	75	15	50	53	70	80	90	–	10	2	105
	6-2	110	15	–	–	190	130	150	–	10	3	150
	6-3	135	20	50	95	190	160	150	51/54	10	3	185
	6-4	160	25	55	110	190	190	200	51/54	13	4	210
	6-7	205	35	60	150	290	260	250	63/66	16	5	280
	6-12	270	40	75	180	460	345	300	84/87	16	6	365
	6-19	340	50	95	230	590	440	350	100/103	19	7	460
	6-22	370	55	100	230	690	470	400	110/113	19	8	495
	6-31	435	65	120	290	690	560	480	130/133	22	8	590
	6-37	480	70	–	–	830	610	540	–	22	9	640
	6-42	520	75	–	–	950	650	640	–	25	8	690
	6-55	580	90	–	–	950	740	630	–	25	9	780

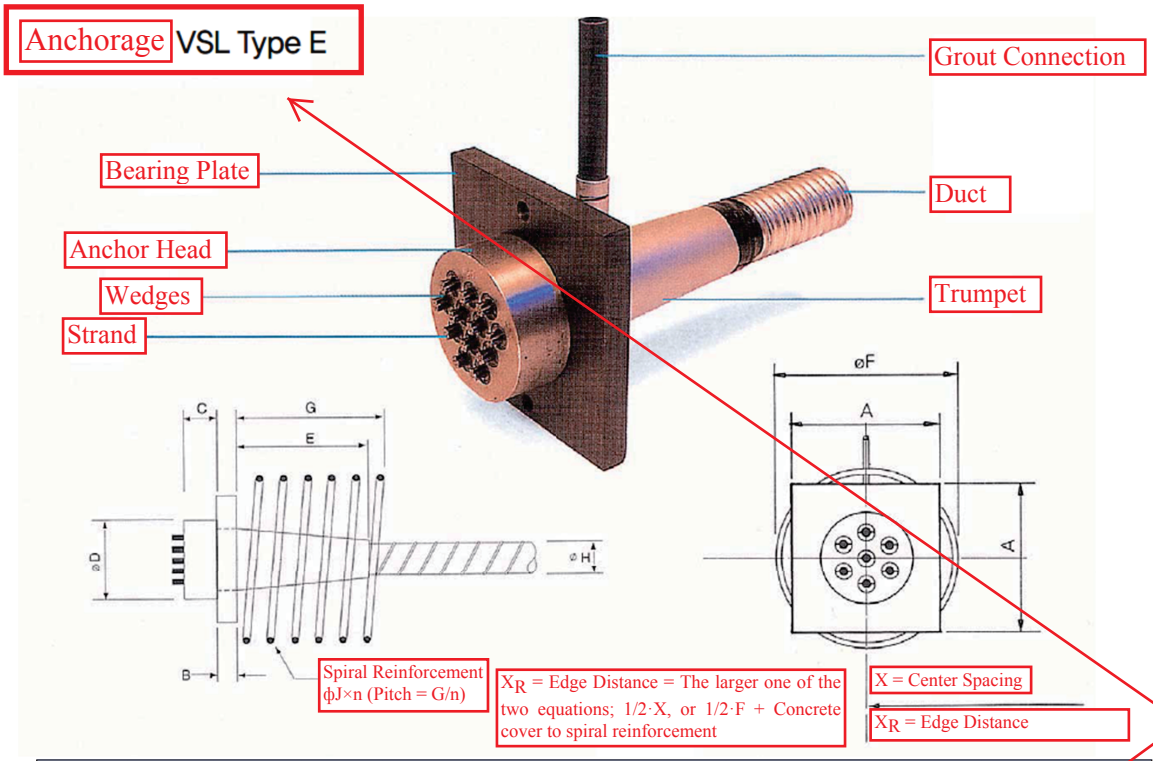
단위 : mm

– 덕트의 치수는 파형강재 덕트의 경우임. 이 치수는 경우에 따라 다소 차이가 있을 수 있음.
  폴리에틸렌덕트(PT-PLUS™)에 대한 치수는 6 페이지 참조.
– 정착구의 치수, 간격과 보강철근은 다음의 조건에 준한 것임.
  • 인장시 콘크리트의 압축강도 : 200kg/cm²

• ø12.7mm(0.5") 강연선 인장하중 : 18,700kg
• ø15.2mm(0.6") 강연선 인장하중 : 26,600kg
• 나선형 보강철근의 항복 강도 : 4,000kg/cm²(SD 40)

MULTISTRAND SYSTEMS

Anchorage VSL Type E



E6-42

	Unit	A	B	C	ϕD	E	ϕF	G	H	ϕJ	n	X[2)]
Strand 12.7mm (0.5")	5-1	70	15	45	42	70	80	90	–	10	2	90
	5-3	115	20	50	90	190	130	150	–	10	3	155
	5-4	130	20	50	95	190	160	150	51/54	10	3	180
	5-7	175	25	55	110	190	205	200	51/54	13	4	235
	5-12	230	35	60	150	370	285	250	63/66	16	5	305
	5-19	290	40	75	180	470	365	300	84/87	16	6	385
	5-22	315	45	85	190	480	395	360	87/90	19	6	415
	5-31	370	55	95	230	550	470	400	100/103	19	8	490
	5-37	405	60	–	–	570	510	420	–	19	7	535
	5-42	440	60	–	–	680	550	480	–	22	8	580
	5-55	500	70	–	–	680	620	540	–	22	9	655
Strand 15.2mm (0.6")	6-1	75	15	50	53	70	80	90	–	10	2	105
	6-2	110	15	–	–	190	130	150	–	10	3	150
	6-3	135	20	50	95	190	160	150	51/54	10	3	185
	6-4	160	25	55	110	190	190	200	51/54	13	4	210
	6-7	205	35	60	150	290	260	250	63/66	16	5	280
	6-12	270	40	75	180	460	345	300	84/87	16	6	365
	6-19	340	50	95	230	590	440	350	100/103	19	7	460
	6-22	370	55	100	230	690	470	400	110/113	19	8	495
	6-31	435	65	120	290	690	560	480	130/133	22	8	590
	6-37	480	70	–	–	830	610	540	–	22	9	640
	6-42	520	75	–	–	950	650	640	–	25	8	690
	6-55	580	90	–	–	950	740	630	–	25	9	780

Unit : mm
- Duct dimension is for corrugated steel duct.
  It could be vary with case by case.
  The dimension for polyethylene duct(PT- PLUS™)is shown in Page 6.

- Dimension, spacing and reinforcement of anchorage are based on the following condition.
  (1) Concrete strength ($f_{c,\ cylinder}$) : 19.6MPa
  (2) 0.5" dia. strand tension load (F_{pk}) : 183.4 kN
  (3) 0.6" dia. strand tension load (F_{pk}) : 260.9 kN
  (4) Yield strength of reinforcement (fy) : 392.3 MPa (SD 40)

Concrete Mix Design

The concrete mix design for the concrete containment conforms with the requirements of Subarticle CC-2230 of the ASME Section III, Division 2.

Concrete Compressive Strength

The specified minimum compressive strength of 41.37 MPa (6,000 psi) at 91 days is used for the containment wall and dome. For the containment common basemat, the specified minimum compressive strength of 34.47 MPa (5,000 psi) at 91 days is used.

3.8.1.6.2 Reinforcing Bars and Splices

The material to be used for reinforcing bars conforms with ASTM A615 (Reference 15) and the requirements described in Subarticle CC-2330 of ASME Section III, Division 2.

The mechanical splices conform with the permitted types described in Subarticle CC-4331.2 of ASME Section III, Division 2. The material to be used for bar-to-bar splice sleeves in reinforcing bars conforms with ASTM A513, A519, or A576 (References 16, 17, and 18, respectively). The material to be used for reinforcing bar splice sleeves attached to liner plates or structural steel shapes is a carbon steel conforming to ASTM A513, A519, or A576 Grades 1008 through 1030.

3.8.1.6.3 Prestressing System

The material to be used for prestressing system is given below.

Prestressing Steel

The material for prestressing elements conforms with ASTM A416 (Reference 19) and the requirements described in Subarticle CC-2420 of ASME Section III, Division 2.

The prestressing system of the concrete containment is VSL E6-42, multi-strand system using wedge block with wedge type anchors.

Anchorage Components

Materials for anchorage components such as bearing plates, anchor head assemblies, and wedges conform with the tendon manufacturer's respective material specifications. In addition, the materials for anchorage components conform with the requirements described in Subarticle CC-2430 of ASME Section III, Division 2 and NRC RG 1.136.

Non-Load-Carrying and Accessory Materials

shall be ferrous in conformance

Non-load-carrying materials such as tendon duct, channel, trumpet, and transition cones ~~conform~~ with the requirements in Subarticle CC-2441 of ASME Section III, Division 2. The temporary and permanent corrosion prevention materials conform with the requirements of Subarticle CC-2442 of ASME Section III, Division 2.

3.8.1.6.4 Liner Plate within Containment Backed by Concrete

The materials, fabrication procedures, and examination requirements conform with the technical provisions of Subarticles CC-2500, CC-4500, and CC-5500 of ASME Section III, Division 2.

The containment liner materials backed by concrete meet the requirements of Subarticles CC-2500 of ASME Section III, Division 2, and conform with the following specifications:

Application	Specification
Liner plate, embedment plate	SA-516 Grade 55, 60, or 70 SA-240
Liner anchor	SA-36

The material to be used for containment wall liner at El. 78 ft through El. 101 ft conforms with ASME SA240 (Reference 20) and the requirements described in Subarticle CC-2500 of the ASME Section III, Division 2.

The fabrication of the containment steel boundaries backed by concrete is in accordance with Subarticle CC-4500 of ASME Section III, Division 2. The qualifications of welders