Tennessee Valley Authority, 1101 Market Street, Chattanooga, Tennessee 37402

JUL 26 1991

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Gentlemen:

In the matter of the Application of	)	Docket Nos. 50-390
Tennessee Valley Authority	)	50-391

WATTS BAR NUCLEAR PLANT (WBN) - UNITS 1 AND 2 - SUPPLEMENT TO TVA CIVIL ENGINEERING BRANCH (CEB) REPORT NUMBER 84-08 - NRC OIE BULLETIN 79-02 - PIPE SUPPORT BASEPLATE DESIGNS USING CONCRETE EXPANSION ANCHORS - FINAL REPORT - REVISION 2 - DECEMBER 10, 1984

1.0 BACKGROUND

Since the issuance of OIE Bulletin 79-02 in 1979, TVA has submitted formal responses to the Bulletin, to unresolved items related to the Bulletin, and to NRC requests for additional information. This supplement:

1. Summarizes the responses to the NRC questions and requests for information submitted subsequent to the issuance of CEB report 84-08 (Reference 1).

2. Provides additional information to demonstrate that the requirements of the Bulletin have been incorporated in the design methods used by TVA and in the recent programs for reevaluation of pipe supports.

3. Discusses sections of CEB Report 84-08 - Revision 2, which are affected and updated by this supplement.

2.0 PREVIOUS RESPONSES TO BULLETIN

CEB Report 84-08, Revision 2 provided WBN's formal response to the Bulletin. This response provided a copy of the TVA anchorage design standard and the results of a sampling program for engineered pipe supports.

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Subsequent to this submittal TVA met with NRC Region II to discuss the 79-02 response and the issue of non-retrievable pipe support calculations. The 79-02 response was accepted on the condition that 100 percent of the pipe support calculations be reviewed for compliance with the factor of safety requirements of the Bulletin and that all nonretrievable pipe support calculations be regenerated (References 2 and 3). This work was to be completed prior to the first refueling outage of WBN Unit 1.

3.0 RESPONSES TO NRC QUESTIONS (REFERENCE 4, 5, AND 6)

Shortly after the meeting with Region II, TVA received a request for additional information from NRR. These questions related primarily to baseplate flexibility and prying. TVA provided a response to these questions in Reference 5. Several changes to design methods were subsequently made since the Reference 5 response; accordingly, the responses were updated in Reference 6.

4.0 RECENT WBN ACTIVITIES

TVA initiated the WBN Hanger Analysis and Update Program (HAAUP) analysis in 1989. This program involved the reanalysis of piping systems and reevaluation of pipe supports. The baseplates and anchorages for the HAAUP program were evaluated in accordance with TVA Civil Design Standard DS-C1.7.1.

A copy of Civil Design Standard DS-C1.7.1 Revision 5 is enclosed. This Civil Design Standard incorporates several changes used in the HAAUP reevaluation effort that increase the conservatism of the methods; specifically, an increase in the anchor stiffnesses and the inclusion of prying forces for thin baseplates which are analyzed by hand methods.

The HAAUP program covers both large and small bore piping. The large bore program is complete and all expansion anchorages have been reevaluated and meet the requirements of the Bulletin. In the small bore program, the revision of the load rating of small bore typical pipe supports has been completed. The expansion anchorage designs for this program are being performed in accordance with the Bulletin requirements. The evaluation of individual small bore pipe support variances and of engineered supports will be completed in accordance with the Bulletin requirements by March 1992.

5.0 UPDATE OF CEB REPORT 84-08 (REVISION 2)

The CEB Report 84-08 Revision 2 addresses four areas where industry problems with expansion anchors have been identified which may impair the operability of piping systems:

1. The effects of plate flexibility.

2. Factors of safety for wedge-type anchors and shell type anchors.

3. Anchorage behavior under cyclic loads.

4. Anchor installation.

As described in Sections 3 and 4 above, the CEB Report 84-08, Revision 2, is being supplemented as follows:

5.1 SECTION 2.0 - TVA Baseplate Analysis Methods - The CEB Report discusses the use of rigid plate analysis of pipe support baseplates at WBN. The HAAUP reanalysis was performed using TVA DS-C1.7.1 which implements Bulletin 79-02 requirements for rigid and flexible baseplates. Thus, the potentially improper use of rigid baseplate analysis where a flexible analysis should have been used is no longer an issue for pipe supports.

5.2 SECTION 3.0 - TVA ALLOWABLE DESIGN LOADS - The HAAUP reanalysis for pipe supports was performed using TVA DS-C1.7.1 which implements Bulletin 79-02 expansion anchor factor of safety requirements. Thus, allowable tensile design loads are based on a factor of safety of 5.0 for self-drilling anchors and 4.0 for wedge bolts.

5.3 SECTION 4.0 - EVALUATION OF BASEPLATE SAMPLE - The adequacy of pipe support calculations is no longer based on sampling. The HAAUP program covers the entire population of both large and small bore piping.

The method of distribution of shear loads to anchors in inverse proportion to their tensile load was removed from Civil Design Standard DS-C1.7.1 Revision 3 by QIR-CEB-85-007 on October 30, 1985.

5.5 APPENDIX B - CIVIL DESIGN STANDARD DS-C1.7.1 - The current revision level is Revision 5, which is enclosed.

5.6 APPENDIX C - TVA GENERAL CONSTRUCTION SPECIFICATION NUMBER G-32 - The current title revision level is: General Engineering Specification G-32 Revision 15.

5.7 APPENDIX E - DISTRIBUTION OF SHEAR IN BEARING CONNECTIONS - Refer to discussion in item 5.3 above.

5.8 APPENDIX H - JUSTIFICATION OF ACCEPTABILITY OF SUPPORTS WITH FACTORS OF SAFETY LESS THAN 5.0 - As a result of the HAAUP Program, pipe supports at WBN with self-drilling anchors meet the required factors of safety.

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6.0 SUMMARY

The baseplate and anchorage designs for pipe supports at WBN were performed using the methods provided in Civil Design Standard DS-C1.7.1 which incorporates the Bulletin 79-02 requirements. Pipe support designs as updated by the HAAUP program are in compliance with the requirements of NRC OIE Bulletin 79-02.

7.0 REFERENCES

1. TVA Civil Engineering Branch (CEB) Report Number 84-08 - NRC OIE Bulletin 79-02 - Pipe Support Baseplate Designs Using Concrete Expansion Anchors - Final Report - Revision 2 - December 10, 1984.

2. Letter from David M. Verrelli to H. G. Parris, February 15, 1985 (L44 850517 803), Technical Meeting Concerning Watts Bar 1 Design Issue.

3. Letter from TVA to Dr. J. Nelson Grace, May 17, 1985, (L44 850517 803) Watts Bar Nuclear Plant Unit 1 - Pipe Support Base Plate Designs Using Concrete Expansion Anchor Bolts.

4. Letter from Elinor G. Adensam to H. G. Parris, June 28, 1985 (L44 850705 763), Flexibility Requirements in Pipe Support Base Plate Design Using Concrete Expansion Anchors at Watts Bar Nuclear Plant, Units 1 and 2.

5. Letter from J. A. Domer to Elinor Adensam, August 22, 1985 (L44 850822 808), TVA response to Request for Additional Information (RAI) on Baseplate Flexibility.

6. Letter to NRC dated January 31, 1991 (L44 910131 803) from TVA with revised response to NRC request for Information of OIE Bulletin 79-02.

If any questions exist relative to the above, please contact P. L. Pace at (615) 365-1824.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

Mark J. Burzynski for

E. G. Wallace, Manager
Nuclear Licensing and
Regulatory Affairs

Enclosure
cc: See page 5

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50-390 TVA WATTS BAR

SUPPL TO TVA CEB REPORT 84-08 REGARDING NRC OIE BULLETIN 79-02

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TVA 64 (05-9-65) (OP-WP-5-85)

UNITED STATES GOVERNMENT

Memorandum

QA Record

b41 '91 0620 003

TENNESSEE VALLEY AUTHORITY

TO : Holders of DS-C1.7.1

FROM : J. K. McCall, Chief Civil Engineer, LP 4G-C

DATE : June 20, 1991

SUBJECT: CIVIL DESIGN DS-C1.7.1 R5 - GENERAL ANCHORAGE TO CONCRETE - DESIGN STANDARD CHANGE NOTICE DSCN-CEB-91-02

INSTRUCTIONS: The attached pages constitute an advance revision to the subject design standard. Insert these pages in that standard in accordance with the instructions and then file the memo in the front of each controlled copy of the standard.

SIGNATURES/APPROVAL AND ROUTING:

(1) Marvin A. Cones — 6-11-91
PREPARER — DATE

(2) J. K. McCall — 6/13/91
SUPERVISED — DATE

(3) Nathaniel Foster, II — 6-12-91
VERIFIED — DATE

(4) J. K. McCall — 6/13/91
APPROVED — DATE

The implementation date of this DSCN is on or before July 19, 1991
The requirements of this DSCN are to supplement and clarify existing requirements and are not retroactive.

MAC:AC
Attachment
cc (Attachment):
RIMS, MR 2F-C
DCRM, LP 4D-C Attached is the SIGNED ORIGINAL; please distribute copies of this memo and its attachment(s) to all holders of controlled copies of this design standard and release the RIMS copy.

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TENNESSEE VALLEY AUTHORITY

NUCLEAR POWER

B41 '91 0506 002

QA Record

CIVIL DESIGN STANDARD

DS-C1.7.1

GENERAL DESIGN INFORMATION
General Anchorage to Concrete

	REVISION RO	R5	R6	R7	R8	R9
PREPARED	MA Cones	ALR				
SUPERVISED						
VERIFIED	RE Bullock	mac				
APPROVED	RO Barnett	JK McCall				
DATE		05/06/91				

DNE1-7849k

REVISION LOG

Revision Number	Effective Date	Pages Affected	Description of Revision
0	05/31/83		Original issue.
1	12/19/83		Revised subsections 1.1, Appendix A and Appendix B.
2	03/27/84		Revised subsections 1.1., 5.1 and added Appendix C.
3	11/16/84		Revised subsections 5.1 and added Appendix D.
4	07/28/87		Revision 4 incorporates QIRs: CEB-85-001, -005, -007; CEB-86-001, -002, -003, -004, -008, -009R1; and CEB-87-041R1. It also adds Figure 2; deletes old Appendixes A and B; adds new Appendixes C through E; and renumbers existing appendixes accordingly.
5	05/06/91		Revision 5 incorporates Design Standard Change Notices (DSCNs): CEB-87-01, CEB-87-02, CEB-88-02, CEB-88-03, CEB-88-05, CEB-89-01, CEB-89-02, CEB-89-03, CEB-89-04, & CEB-90-02. Also incorporated is QIR CEB WBN 89-403, QIR CEB BFN 89043, Appendix H, changes to Appendix D and note in Section 5.3. Section 2A was created for undercut anchors. It also adds new Appendixes F and G and updates organization titles and abbreviations.
DSCN-CEB-91-02	06/20/91	43-48, B-1-B-2, I-1-I-3	Summary: Clarified edge distance requirements in Sections 8.0, 8.1.1, 8.1.2, and 8.2.1. Added Appendix I for evaluation of anchors adjacent to circular penetrations.

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1.0 GENERAL

This design standard covers the design of anchorages that transmit loads from structural members into the supporting concrete. Design methods are given for anchor bolts and other anchorages with anchor heads, expansion anchors, and embedded strip inserts. This standard is for all anchorages designed by TVA Nuclear Power. For anchorages designed by contractors for NP, the anchorage design methods used must provide at least the same level of conservatism given in this standard. If TVA General Engineering Specifications will apply to the installation of the anchorages, the contractor's design must conform to this standard.

The requirements of the standard are based on manufacturers' information, applicable concrete and steel codes, and research performed by TVA and others.

1.1 Applicability

This standard is applicable to the design of new anchorages and the evaluation of existing anchorages. However, evaluation of existing anchorages for the singular purpose of determining compliance with this standard is not required. Deviations from this standard must be documented in design criteria.

Special evaluations for interim operability may be used for evaluation of existing anchorages in accordance with Section 10.0.

1.2 General Design Philosophy

The design methods of this standard are based on the following general design philosophy:

a. The ultimate capacity of an anchorage should generally be controlled by the capacity of its steel components.

b. For anchorages that are not controlled by steel capacity, an adequate factor-of-safety against failure of the concrete must be maintained.

c. Shear loads on an anchorage may be transmitted either by friction between the baseplate and concrete or by the bearing of the plate against the bolts.

1.3 Reference/Specifications

The latest revisions of the following standards and specifications shall apply where referred to in this standard:

a. American Concrete Institute, Detroit, Michigan. ACI 318 - "Building Code Requirements for Reinforced Concrete."

1.0 GENERAL (Continued)

b. American Society for Testing and Materials, Philadelphia, Pennsylvania.

A 36 - "Standard Specification for Structural Steel."

A108 - "Standard Specification for Steel Bars, Carbon, Cold-finished, Standard Quality."

A193 - "Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service."

A307 - "Standard Specification for Carbon Steel Externally and Internally Threaded Standard Fasteners."

A325 - "Standard Specification for High-Strength Bolts for Structural Steel Joints."

c. Tennessee Valley Authority, Nuclear Power

General Engineering Specification G-29 - "Process Specifications for Welding, Heat Treatment, Nondestructive Examination, and Allied Field Fabrication Operations" (hereafter G-29).

General Engineering Specification G-32 - "Bolt Anchors Set in Hardened Concrete" (hereafter G-32).

General Engineering Specification G-51 - "Requirements for the Grouting and Dry-Packing of Baseplates and Joints During Construction, Modification and Maintenance" (hereafter G-51).

General Engineering Specification G-66 - "Requirements for the Use of Undercut Anchors Set in Hardened Concrete During Installation, Modification, and Maintenance" (hereafter G-66).

Civil Design Standard, DS-C1.8.1 - "Standard Calculation for Evaluating Type II Embedded Plates."

1.4 Definitions

Anchorage--A steel device that is embedded in concrete and used to transfer loads from an attachment to the concrete. An anchorage generally consists of bolts, studs, or expansion anchors but may be built up from steel plates and shapes.

Ductile Anchor--An anchorage whose capacity is controlled by its steel and not by the concrete.

Embedded Bolt--An anchorage that consists of a headed bolt or a threaded rod with an end-nut which is cast into the concrete.

Welded Stud--An anchorage that consists of a headed stud which is welded to a steel plate or shape and cast into the concrete.

Grouted Anchor--An anchorage that consists of a headed bolt or threaded rod with an end nut, all of which is grouted into a hole drilled in hardened concrete.

Threaded Insert (Bolt Coupler)--An anchorage consisting of a headed bolt and an attached coupling nut that are cast into the concrete, leaving one end of the coupling nut flush with the concrete surface. Threaded inserts, which are equivalent to the bolt with a coupling nut, are usually manufactured as a single item.

Undercut Anchor--An anchorage consisting of a steel sleeve, a threaded rod, and an expansion device. The wedging device expands the sleeve into a conical-shaped enlargement of the hole at the base of the anchor to develop an end anchorage.

Expansion Anchor--An anchorage that transfers loads to the concrete by expanding laterally against the sides of a hole drilled in hardened concrete.

Self-drilling Anchor--An expansion anchor consisting of an internally threaded, externally slit, tubular shell with a single cone expander that causes the shell to expand laterally against the sides of a drilled hole. The end of the anchor shell is serrated and is used for drilling the hole.

Wedge Bolt Anchor--An expansion anchor consisting of an externally threaded bolt with a split ring or separate wedge pairs that expand laterally against the sides of a predrilled hole when the bolt is torqued, and that will expand further if the bolt is partially extracted from the hole by a tensile load.

Strip Insert (Unistrut or equivalent)--An anchorage consisting of a commercially available continuous steel channel designed for multiple connections. It is cast into the concrete.

Attachment--The structural member or component that transmits loads to the anchorage.

Baseplate--The steel plate that connects an attachment to the anchorage. It may be either part of the attachment or part of the anchorage.

Embedded Plate--An anchorage consisting of a baseplate with welded stud anchors that is cast into the concrete.

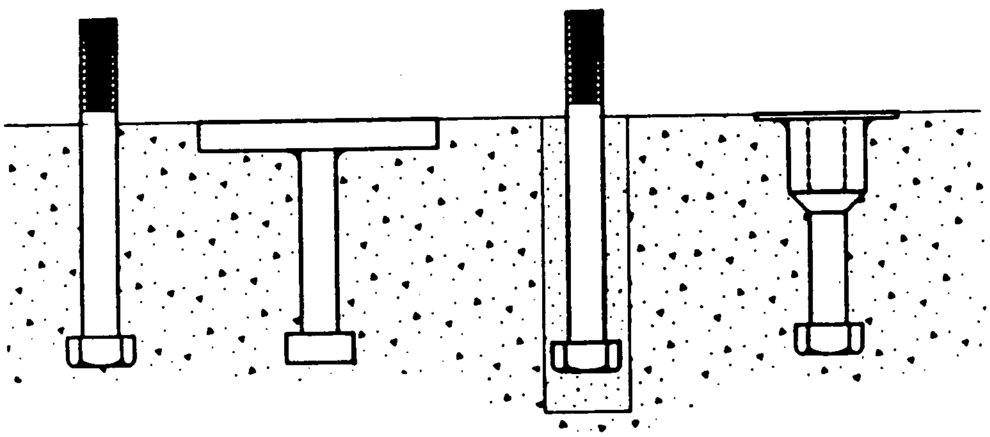
Shear Lugs - Steel bars that are welded to a baseplate and intended to transfer shear to the concrete.

Concrete Edge - Outside corners, expansion joints, contraction joints, unreinforced construction joints, pipe sleeves, conduit penetrations, and similar features shall be considered to be concrete edges. Penetrations for pipe sleeves, conduits, and similar circular features shall not be considered concrete edges if the diameter of the penetration is less than the clear distance between the anchor and the penetration.

2.0 DUCTILE ANCHORS

2.1 Ductile Anchor Types

This section applies to four types of ductile anchors: (1) embedded bolts, (2) welded studs, (3) grouted anchors, and (4) threaded inserts.



Embedded Bolt   Welded Stud   Grouted Anchor   Threaded Insert

All ductile anchors shall be made from steel or alloy steels. Materials with minimum tensile strengths of 150 k/in^2 or greater shall not be used.

2.2 Failure Mechanism

The anchor types listed in subsection 2.1 are described as ductile because they can be embedded deep enough to ensure that the ultimate anchor capacity is controlled by the anchorage steel and not the concrete. A ductile steel failure is desirable since large deformations and energy absorption occur before fracture.

2.0 DUCTILE ANCHORS (Continued)

In general, the anchors listed in subsection 2.1 shall be designed to ensure ductility. This .s accomplished by assuring that the pullout capacity of an assumed concrete spall is at least four times the maximum allowable tensile service load for the anchor. This calculation is affected mainly by the anchor embedment, spacing, and distance to a concrete edge. The details of the method are discussed in Section 7.0.

The anchors listed in subsection 2.1 may be designed as "nonductile" anchors if physical limitations prevent use of embedment, spacing, or edge distance necessary to ensure ductility. For these occurrences the concrete pullout capacity calculated in accordance with Section 7.0 must be at least four times the calculated service design load on the anchor.

2.3 Allowable Tensile Loads

The determination of the size and number of ductile anchors shall be based on the allowable steel stresses given in subsections 2.3.1 and 2.3.2 for service and abnormal loading conditions, respectively.

The allowable shear loads for ductile anchors are a function of the tensile load and the configuration of the baseplate. The allowable shear load shall be determined in accordance with subsection 5.2.

2.3.1 Service Load Conditions

The service load allowable stresses given herein are intended for load conditions with a high probability of occurrence. The loads are termed "service loads" but are also commonly termed "working loads" or "normal loads." For nuclear plant work, the service load allowable stresses shall also be used for "operational basis" events and for "normalized loads" obtained from piping analysis.

The allowable tensile service load stress for embedded bolts, welded studs, grouted anchors, and threaded inserts shall be determined from Table 1. For steels not listed in Table 1, the allowable service load stress shall be determined from equation 1.

$$F_{sa} = 0.55\ F_y \qquad \text{(equation 1)}$$

where:

F_{sa} = Allowable service load stress (ksi)

F_y = Minimum yield stress (ksi)

2.0 DUCTILE ANCHORS (Continued)

Table 1

Ductile and Undercut Anchor Design Data

Type of Anchor	Allowable Service Load Stress F_{sa} (k/in^2)	Minimum Yield Stress F_y (k/in^2)	Minimum Tensile Stress F_{ut}(k/in^2)
A307 and A36 Bolts	20.0	36.0	60.0
A325 Bolts (1/2 through 1 inch)	51.0	92.0	120.0
A325 Bolts (1-1/8 through 1-1/2)	45.0	81.0	105.0
A108 Welded Studs	See subsection 2.3.1	44.0	60.0
A193 Undercut Anchors	52.5	105.0	125.0

For welded studs, the allowable service load stress shall be determined from equation 2 or 3. (Reference: CEB Report 79-18).

$$F_{sa} = 0.55\ F_y - 6.0\sqrt{e/t - 2} \quad \text{for } e/t > 2 \quad \text{(equation 2)}$$

or

$$F_{sa} = 0.55\ F_y \quad \text{for } e/t \leq 2 \quad \text{(equation 3)}$$

where:

e = The minimum clear distance between the attachment welded to the embedded plate and the centerline of the welded stud (inches).

t = The plate thickness (inches).

When welded studs stresses are determined using the Baseplate II computer program, equation 2 does not apply and the allowable welded stud stresses shall be determined using equation 3 for all values of e/t [see calculation CSG-87-120 (B41 870828 004)]. RS

2.0 DUCTILE ANCHORS (Continued)

The maximum allowable tensile service load for embedded bolts, grouted anchors, threaded inserts, and welded studs shall be obtained from equation 4.

$$T_o = A_{st} \times F_{sa} \qquad \text{(equation 4)}$$

where:

T_o = Maximum allowable service load

A_{st} = The net tensile stress area of threaded bolts and bars (see Table 2) or the full cross-sectional area of unthreaded bars and studs. (The 8th edition of the AISC Manual allows the use of the gross cross-sectional area for determining allowable tensile loads for A 307 bolts in structural steel joints. For concrete anchorages, the net tensile stress area as used in the 7th edition shall continue to be used. See CEB 840521 010).

Table 2

Net Stress Areas of Threaded Bolts

(UNC Thread Series)

Bolt Diameter (inches)	Net Stress Area A_{sn} (in^2)	Bolt Diameter (inches)	Net Stress Area A_{sn} (in^2)
1/4	0.032	1-1/2	1.41
5/16	0.052	1-3/4	1.90
3/8	0.078	2	2.50
1/2	0.142	2-1/4	3.25
5/8	0.226	2-1/2	4.00
3/4	0.334	2-3/4	4.93
7/8	0.462	3	5.97
	0.606	3-1/4	7.10
1-1/8	0.763	3-1/2	8.33
1-1/4 (7 thds/in)	0.969	3-3/4	9.66
1-1/4 (8 thds/in)	1.000	4	11.1
1-3/8	1.16	-	-

2.0 DUCTILE ANCHORS (Continued)

2.3.2 Abnormal Loading Condition

For an abnormal loading condition, the allowable tensile load or stress for the anchor may be increased above the value given in subsection 2.3.1. The increase shall be in proportion to the increase in allowable stress permitted for that load condition by the code or criteria used for the design of the attachment or support being anchored.

For example, for nuclear safety-related work, a 60-percent increase in allowable steel stress is generally permitted for "safe shutdown" conditions, so an equal increase is permitted for anchorage steel stresses. For nonsafety-related work, a 33-percent increase in allowable stress is permitted for structural steel members designed using AISC specifications for load conditions including wind or earthquake. An equal increase in anchorage steel stress is permissible.

Increases in allowable stress shall not be permitted for "normalized" loads. The stress increase, if any, allowed for a specific loading condition is compensated for in the normalization procedure.

2.4 Ductile Anchor Detailing Requirements

The drawings that call for ductile anchors shall give sufficient information for the field to determine the type, size, material specification, embedment, spacing, and tightening requirements. The type of anchor shall be designated using the following standard terms:

a. Embedded bolt
b. Welded stud
c. Grouted anchor
d. Threaded insert

Since the installation of embedded bolts, welded studs, and threaded inserts is not covered in a general engineering specification, all information necessary for installation must be given on the drawings. The following sections give the minimum detailing requirements for each type of ductile anchor.

2.4.1 Embedded Bolts

The drawings that call for embedded bolts shall give all the following information:

a. Specification designation for the bolt material
b. Bolt size
c. Total bolt length
d. Embedment (or projection)
e. Tightening requirements

2.0 DUCTILE ANCHORS (Continued)

For example, the drawing may specify a "3/4 dia x 12-inch A 307 embedded bolt." The embedment (or projection) would normally be dimensioned in a detail and the tightening requirements given in a note.

Embedded bolts shall be tightened at least snug tight plus an additional one-half turn unless the joint is intended to allow slip in shear, in which case the nut shall be secured by other means. If a preload (or prestress) is required, a torque must be specified that will reliably result in the required preload, otherwise an alternate tensioning procedure must be given.

If a threaded rod with an end-nut is used, the drawings should give the embedment measured to the far side of the nut and require locking of the embedded nut. If an all-threaded rod is used where a preload is required, the stressed portion of the bolt must be wrapped to prevent bond with the surrounding concrete. The wrapping must also inhibit corrosion.

2.4.2 Welded Studs

The drawings that call for welded studs shall give the following information:

a. Specification designation for the stud material
b. Stud diameter
c. Stud length

For example, the drawing may specify "3/4 dia x 5-3/16-inch welded studs." The stud length called for shall be the length before welding. The drawing shall also specify that the studs shall conform to ASTM A108, Grades 1010 through 1020 with a minimum tensile strength of 55,000 lb/in and a minimum elongation of 20 percent in 2 inches. The drawing shall also call for stud welding to be in accordance with TVA General Engineering Specification G-29.

The drawings that call for welded studs must also limit the angle that the studs may be bent to clear interferences, particularly reinforcing steel. Studs may be bent 15 degrees without a significant decrease in capacity.

2.0 DUCTILE ANCHORS (Continued)

2.4.3 Grouted Anchors

The drawings which call for grouted anchors shall give the following information:

a. Specification designation for the bolt material
b. Bolt size
c. Total bolt length
d. Embedment (or projection)
e. Grout type
f. Preload requirements

For example, the drawings may specify a "1/2 dia x 6-inch A 307 grouted anchor." The grout would generally be identified as either "portland cement grout," "dry pack mortar," or "epoxy grout." The drawing shall also call for the grouted anchor to be installed in accordance with TVA General Engineering Specification G-32. G-32 gives the requirements for hole size, installation, and testing. It also gives the tightening requirements, unless preloading is required. If preloading is required, see subsection 2.4.1. Grouted anchors using portland cement grout or dry pack mortar may be placed in service 7 and 3 days after placement, respectively. Epoxy grouted anchors may be placed in service when final cure is achieved.

Epoxy grout shall be called for only when anchors must be placed in service sooner than 7 days and dry-pack mortar is not suitable for the application. However, epoxy grout shall not be used in:

a. Nuclear plant safety-related structures.
b. Holes greater than 4 inches in diameter.
c. Nonsafety-related structures unless an engineering document specifically states that the maximum temperature at which the anchor must carry the applied loads is less than 120°F and that fire hazard is not significant. (Epoxy may be ignited by welding metal in contact with the epoxy.)

Existing epoxy grouted anchors may be evaluated using CEB report 86-18-C (B41 860709 018). The results in the CEB report for BFN may be applied to SQN since both plants specified Colma-Dur grout (see CDB 820105 031).

2.0 DUCTILE ANCHORS (Continued)

2.4.4 Threaded Inserts

Threaded inserts are generally manufactured as a single unit consisting of an internally threaded coupling device with a nailing flange for attaching to the forms. The coupling device is connected to a headed anchor. The units are purchased to have a capacity equivalent to an ASTM A307 bolt with a standard coupling nut. If a project intends to use threaded inserts, standards sizes and lengths should be developed. Otherwise, the drawing must specify the following:

a. Specification designation for embedded bolt, coupling nut, and attachment bolt.
b. Bolt size and length for embedded bolt and attachment bolt.
c. Thread engagement requirements for both bolts.
d. Preload requirements.

Since the coupling nut or nailing flange for threaded inserts coincides with the concrete surface, torquing of the attachment bolt will not result in a usable preload in the entire anchor. Once the coupler comes in contact with the bottom of the baseplate, additional torque only causes a load in the attachment bolt. If the entire anchor must be preloaded, then a removable washer at least 1/8-inch thick must be placed between the coupler and the formwork prior to concrete placement. When the washer is removed, the resulting gap between the baseplate and the coupler or nailing flange will allow torquing of the attachment bolt to preload the entire anchor.

The drawings must call for the method for preventing fouling of the coupler threads during concrete placement and after form removal.

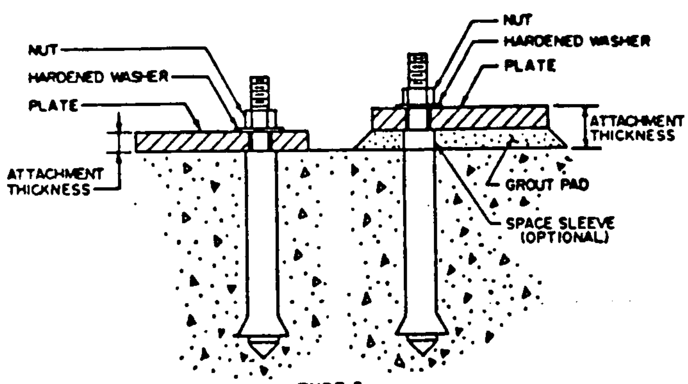
This page added by Rev. 5

2A.0 UNDERCUT (UC) ANCHORS

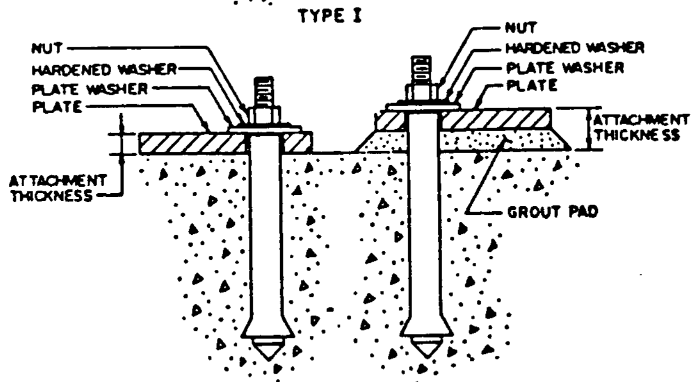
2A.1 UC Undercut Anchor Types

This section applies to two types of undercut anchor installations: Type I and Type II. A Type I installation is a typical UC anchor installation which results in the top of the anchor sleeve being nominally flush with the concrete surface (see figure below). A Type II installation is intended for modification work where existing anchors are drilled out through the baseplate. Therefore, the top of the sleeve for Type II installation is nominally flush with the top of the baseplate (see figure below).

UC anchors are provided in two length groups: regular and shallow. The regular embedment UC anchors are effectively equivalent to ductile anchors designed in accordance with Section 2.0. Shallow embedment UC anchors are primarily intended to replace SSD and WB anchors or to provide capacities which are somewhat larger than those anchors. Their design is effectively equivalent to expansion anchors designed in accordance with Section 3.0.



TYPE I



TYPE II

UC anchors shall be Drillco Maxibolts or an equivalent approved by the Chief Civil Engineer. The bolt (threaded rod) for UC anchors is manufactured with ASTM A 193 steel. The anchors shall conform to the requirements of General Engineering Specification G-66.

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2A.2 Regular Embedment UC Anchors

Design data for regular embedment UC anchors is provided in Table 3. Design of regular embedment UC anchors shall be in accordance with Section 2.0, 5.0, 7.0, and 8.0.

2A.2.1 Failure Mechanism

Regular embedment UC anchors are intended to be designed to ensure ductile anchor failure. However, the anchors may be designed as "nonductile" anchors if physical limitations prevent use of the embedment, spacing, or edge distance necessary to ensure ductility (See Section 2.2).

2A.2.2 Allowable Loads

The allowable tensile service loads for regular embedment UC anchors shall be based on $F_{sa} = 0.5 F_y$ (See Table 1). The allowable service loads for tension and shear for the ASTM C193 rod are provided in Table 3a. The size and number of anchors shall be determined or evaluated in accordance with Section 5.0 (evaluation of the combined effects of tension and shear).

The concrete tensile pullout capacity shall be evaluated in accordance with Sections 7.0 and 8.0 and may control the tensile design load for the anchor.

Stress increases for abnormal loading conditions are permitted for regular UC anchors in accordance with Section 2.3.2.

2A.3 SHALLOW EMBEDMENT UC ANCHORS

Design data for shallow embedment UC anchors is provided in Table 3. Design of shallow embedment UC anchors shall be in accordance with Sections 5.0, 7.0, and 8.0.

2A.3.1 Failure Mechanism

Shallow embedment UC anchors are "nonductile" since the ultimate failure mechanism is fracture of the concrete. Since the anchor embedments are similar to the expansion anchors discussed in Section 3.0, the factor of safety provisions for WB anchors are applied.

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2A.3.2 Allowable Loads

The allowable service loads for shallow UC anchors for tension and shear for the ASTM C193 rod are provided in Table 3a. The minimum size and/or number of anchors shall be determined or evaluated in accordance with Section 5.0 (evaluation of the combined effects of tension and shear.)

The concrete tensile pullout capacity shall be evaluated in accordance with Sections 7.0 and 8.0 and will control the tensile design load for the anchor. The reduced tensile capacity based on concrete pullout capacity is not used in the evaluation in the shear-tension interaction evaluation specified in Section 5.0.

Stress increases for abnormal loading conditions are not permitted for shallow UC anchors.

2A.4 UC ANCHOR DETAILING REQUIREMENTS

The drawing that calls for undercut anchors shall give the anchor size and length. The drawings must also call for the anchors to be installed in accordance with TVA General Engineering Specification G-66 and must specify the installation type. G-66 gives the tightening requirements. The designation abbreviation "UC" may be used for undercut anchors. For example, the drawings may specify a "3/4 diameter x 15-1/2-inch undercut anchor, Type I installation" or a "3/4 diameter x 15-1/2-inch UC, Type II installation."

The anchor centerline for Type II installations shall be detailed on the drawings to provide at least the minimum plate material between the hole edge and plate edge as derived using AISC minimum edge distances from centerline of hole to plate edge. Smaller edge distances may be specified only if documented by calculations.

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TABLE 3[1]

UNDERCUT ANCHOR INSTALLATION DATA

	ANCHOR SIZE	ANCHOR LENGTH[2]	LENGTH CODE	SLEEVE LENGTH[3]	TYPE	MIN SPAC[8]	EDGE DIST[9]	MAX ATTACH THICK[10]	PROJ	
REGULAR EMBEDMENT UC ANCHORS	1/4	4-1/4	None	2-3/4	I	4	3	3/4	1-1/2	
	3/8	6	None	4-1/2	I	6	5	3/4	1-1/2	
	1/2	14-1/4	6	10	I	6	8-1/2	3	4-1/4	
	1/2	14-1/4	6	10	II	6	6-1/2	2	4-1/4	
	1/2	14-1/4	6	10	II	6	5	4	4-1/4	
	1/2	12-1/4	4	8	I	6	6-1/2	3	4-1/4	
	1/2	12-1/4	4	8	II	6	5	2	4-1/4	
	1/2	10-1/4	2	6	I	6	5	3	4-1/4	
	5/8	17	7	12	I	8	10-1/2	3	5	
	5/8	17	7	12	II	8	8-1/2	2	5	
	5/8	17	7	12	II	8	6-1/2	4	5	
	5/8	15	5	10	I	8	8-1/2	3	5	
	5/8	15	5	10	II	8	6-1/2	2	5	
	3/4	17-1/2	4	13	I	12	13	3	4-1/2	
	3/4	17-1/2	4	13	II	12	11	2	4-1/2	
	3/4	17-1/2	4	13	II	12	9	4	4-1/2	
	3/4	15-1/2	2	11	I	12	11	3	4-1/2	
	3/4	15-1/2	2	11	II	12	9	2	4-1/2	
	3/4	13-1/2	INTERNAL HEX	9-1/4	I	12	9	3	4-1/4	
	1	23-1/2	7	18	I	12	17	3	5-1/2	
	1	21-1/2	5	18	I	12	17	1	3-1/2	
	1-1/4	25	5	18	I	24	21	3	7	
	1-1/4	23	3	18	I	24	21	1	5	
SHALLOW EMBEDMENT UC ANCHORS	1/2	8-1/4	INTERNAL HEX	6-1/4	I	6	6	1	2	
	~~1/2~~	~~8-1/4~~	~~INTERNAL HEX~~	~~6-1/4~~	~~II~~	~~6~~	~~6~~	~~3~~	~~2~~	*
	5/8	10	INTERNAL HEX	6-3/4	I	6	6	2	3-1/4	
	~~5/8~~	~~10~~	~~INTERNAL HEX~~	~~6-3/4~~	~~II~~	~~6~~	~~6~~	~~3~~	~~3-1/4~~	*
	3/4	11-1/2	2 SQ HEAD	8-3/4	I	6	8-1/2	1-1/2	2-3/4	
	~~3/4~~	~~11-1/2~~	~~2 SQ HEAD~~	~~8-3/4~~	~~II~~	~~6~~	~~8-1/2~~	~~3~~	~~2-3/4~~	*
	3/4	10-1/2	3 SQ HEAD	8-1/4	I	6	8	3/4	2-1/4	
	~~3/4~~	~~10-1/2~~	~~3 SQ HEAD~~	~~8-1/4~~	~~II~~	~~6~~	~~8~~	~~3~~	~~2-1/4~~	*
	3/4	9-1/2	4 SQ HEAD	6-1/2	I	6	6	1-1/2	3	
	~~3/4~~	~~9-1/2~~	~~4 SQ HEAD~~	~~6-1/2~~	~~II~~	~~6~~	~~6~~	~~3~~	~~3~~	*

* HOLD

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TABLE 3a

UNDERCUT ANCHOR LOAD TABLE

Size	Max Allowable Load (Kips)	
	T_o[4]	V_o[5]
1/4	1.7	1.1
3/8	4.1	2.7
1/2	7.5	5.0
5/8	11.9	7.9
3/4	17.5	11.7
1	31.8	21.2
1-1/4	52.5	35.0

Notes for Table 3 and 3a:

1. All dimensions in inches.

2. Length equals the total length of the anchor. The minimum length anchor which provides the required capacity should be used to reduce drilling

3. Embedment depth equals the sleeve length for Type I installations. For Type II installations, embedment depth equals the sleeve length minus the attachment thickness. If design output documents allow baseplate or attachment thickness to be increased by the installer, the tolerance must be deducted from the embedment for Type II installations. Grout, if any, must be included in the attachment thickness.

4. T_o is calculated in accordance with equation 4 which assumes ductile steel failure. These values are for evaluation of steel capacity using Equation 8. In many cases, anchor failure will be a non-ductile concrete failure due to spacing, embedment, or edge conditions. The ultimate tensile capacity of the concrete must be checked in accordance with Section 7 and 8 in all cases.

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5. V_o is calculated as $\frac{A_{st} \times F_{sa}}{R}$, where R is assumed to be 1.5. These values are for evaluation of steel capacity using Equation 8. For other plate configurations (grouted plates, etc.) the V_o value must be adjusted using the appropriate R-value given in Section 5.3. For UC anchors adjacent to a concrete edge, the shear capacity may be controlled by non-ductile concrete capacity. The ultimate shear (push-off) capacity of the concrete must be checked in accordance with Section 8 in all cases.

6. Minimum concrete thickness is 4/3 of the anchor embedment.

7. Minimum concrete thickness may be decreased by 4/3 times the actual attachment thickness for Type II installations (see G-66).

8. Minimum spacing is the recommended minimum spacing. Smaller or larger spacings may be used as necessary. Concrete pullout capacity must be evaluated for all installations regardless of spacing (see Note 4).

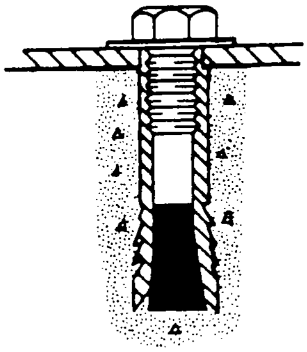
9. Minimum edge distances are the minimum recommended edge distances. Concrete shear (push-off) capacity must be evaluated for all installations adjacent to an edge (see Note 5).

10. Maximum attachment thickness for Type I UC anchors is equal to the (length) - (sleeve length) - (2 bolt diameters). If design output documents provide the field a tolerance for increasing the plate thickness, the tolerance must be subtracted from the tabulated value unless actual plate thickness is known.

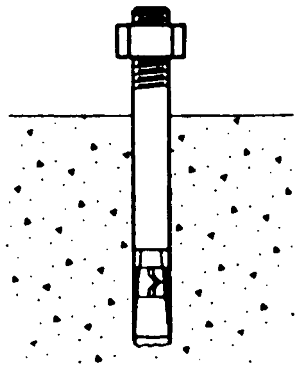
3.0 EXPANSION ANCHORS

3.1 Expansion Anchor Types

Two types of expansion anchors may be used: (1) self-drilling expansion shell anchors, and (2) wedge bolt anchors.



Self-Drilling Expansion Shell Anchor



Wedge Bolt

Each size and brand of self-drilling anchor and wedge bolt anchor must be qualified for use in accordance with TVA General Construction Specification G-32.

Multi-unit lead caulking expansion anchors with brand names such as "Cinch," "Slugin," and "Multi-Calk" were specified and may have been used during the early phase of construction at some nuclear plants. Evaluation of these anchors shall be made in accordance with Appendix G. RS

3.2 Failure Mechanism

Self-drilling expansion shell anchors and wedge bolt expansion anchors are nonductile because their ultimate capacity is not controlled by steel. Self-drilling anchors fail by slipping a limited distance and then by pullout of a cone-shaped concrete spall. Wedge bolt anchors embedded to the depths prescribed in this standard fail by pulling out of the hole without fracture of the concrete. Wedge bolts embedded less than prescribed in this standard may fail the concrete. Since these anchors fail suddenly without large deformations, design loads are determined by applying a factor-of-safety to the ultimate concrete pullout capacity.

3.0 EXPANSION ANCHORS (Continued)

3.3 Allowable Tensile and Shear Loads

3.3.1 Service Load Conditions

The allowable service loads given herein are intended for load conditions with a high probability of occurrence. These loads are termed "service loads" but are also commonly termed "working loads" or "normal loads."

For nuclear plant work, these allowable loads also apply to abnormal loading conditions such as seismic and wind loading. These allowable loads shall not be used for "normalized" loads obtained from piping analyses. (See subsection 3.3.2.)

The allowable service loads for tension and shear for self-drilling anchors are given in Table 4. The tensile loads in the table are equal to 1/5 of the required minimum ultimate concrete pullout capacity given for qualification in G-320(factor-of-safety = 5). The allowable shear loads are 1/4 of the typical ultimate shear capacities for self-drilling anchors (factor-of-safety = 4). The allowable service loads for tension and shear for wedge bolt anchors are given in Table 5. The allowable concrete pullout loads are 1/4 of the required ultimate concrete pullout capacity given for qualification in G-32. The allowable shear loads are 1/4 of the typical ultimate shear capacities for wedge bolt anchors.

The shear loads in Tables 4 and 5 are for single anchors loaded in shear only for baseplates attached to hardened concrete (R = 1.5, see subsection 5.3). For other configurations, the shear capacity is determined in accordance with subsection 5.2.

3.0 EXPANSION ANCHORS (Continued)

Table 4

Self-Drilling Expansion Shell Anchor Design Data

Bolt Size (inches)	Minimum Depth (inches)	Allowable Service Loads[2 4 6] (kips)		Minimum Spacing (inches)
d	L_d	T_o [1 5]	V_o [3]	S
1/4	1.09	0.50	0.30	3.0
3/8	1.53	1.00	0.80	4.0
1/2	2.03	1.55	1.40	5.0
5/8	2.47	2.10	2.25	5.5
3/4	3.25	3.00	3.30	6.5

R5

The following sizes shall not be specified: (See note 7)

5/16	1.31	0.70	0.50	3.5
7/8	3.69	3.55	4.50	7.0

Notes for Table 4:

1. Allowable tension loads are equal to 20 percent of the minimum ultimate tensile capacity required by TVA General Engineering Specification G-32 (factor-of-safety of 5).

2. Allowable loads are based on concrete having a minimum specified compressive strength of 3000 lb/in^2. Increased allowables due to higher specified strengths or strength gain with age are not permitted for new anchor installations.

3. Shear allowables are based on R = 1.5. See subsection 5.3.

4. For self-drilling anchors installed in the Sequoyah Nuclear Plant Unit 2 shield building wall (interior and exterior), the allowable tension and shear loads shall be limited to 50 percent of the values given above. Higher loads may be used only if each anchor is proof loaded in accordance with G-32 to at least 5 times the maximum design load on the anchor. The load reduction is the result of the condition of the concrete at the surface of the slip-formed structure as identified by NCR 72D (CEB 780915 027).

5. For evaluation of existing installations, the allowable tension loads for self-drilling anchors may be increased by the ratio of the square root of the inplace strength to the square root of 3000 lb/in^2. The estimated inplace strength shall be determined in accordance with Appendix D.

6. The full tension and shear allowables may be used for self-drilling expansion anchors installed in high density concrete at Sequoyah Nuclear Plant. (Reference SCR SQNCEB8627)

3.0 EXPANSION ANCHORS (Continued)

7. The 5/16 and 7/8-inch diameter self-drilling anchor sizes shall not be specified for design. These sizes have been discontinued and are not available.

8. For Watts Bar Nuclear Plant only, tension allowables for self drilling expansion anchors shall be reduced by 15 percent when installed in areas of high density concrete. These areas are designated on drawings 41N726-2, 41W27-1, 41W727-2, 41W727-3, and 41N721-1. (Reference CAQR WBP 871047). RS

3.0 EXPANSION ANCHORS (Continued)

Table 5

Wedge Bolt Anchor Design Data

Bolt Size (inches)	Min. Length (inches)		Min. Depth[1] (inches)	Effective Embedment (inches)[9]	Max. Attachment Thickness[2] (inches)		Allowable Service Loads (kips)[3,4,5,6,8]		Min. Spacing (inches)
d	Reg.	Long	L_d	E	Reg.	Long	T_o[7]	V_o	S
1/4	3.0	-	1.75	1.50	1.00	-	0.60	0.50	3.0
3/8	3.5	5.0	2.25	1.90	0.875	2.375	0.90	1.20	4.0
1/2	5.5	7.0	3.75	3.25	1.25	-	2.10	2.00	6.0
5/8	6.0	8.5	4.50	3.90	0.875	3.375	2.75	3.00	7.0
3/4	8.0	10.0	5.50	4.75	1.75	3.25	4.20	4.15	8.5
1	9.0	12.0	7.00	6.00	1.00	4.00	5.20	6.70	9.5

The following size shall not be used

1-1/4	12.0	-	9.00	7.75	1.75	-	8.20	9.75	11.5

Notes for Table 5:

1. Depth to bottom of anchor before tightening.

2. See subsection 3.4 on use of regular and long bolts.

3. Allowable tension loads are equal to 25 percent of the minimum ultimate tensile capacity required by TVA General Construction Specification G-32 (factor-of-safety of 4).

4. Allowable loads are based on concrete having a minimum specified compressive strength of 3000 lb/in^2. Increased allowables due to higher specified strengths or strength gain with age are not permitted for new anchor installations.

5. Shear allowables (V_o) are based on R = 1.5. See subsection 5.3.

3.0 EXPANSION ANCHORS (Continued)

6. For wedge bolts installed in the Sequoyah Nuclear Plant Unit 2 shield building wall (interior and exterior), the allowable tension and shear loads shall be limited to 50 percent of the values given above for wedge bolt anchors less than 1/2 inch in diameter and for "regular" length 1/2-inch wedge bolt anchors. Higher loads may be used only if each anchor is proof loaded (using the procedure for SSD anchors) in accordance with G-32 to at least 4 times the maximum design load on the anchor. The load reduction is the result of the condition of the concrete at the surface of the slip-formed structure as identified by NCR 72D (CEB 780915 027). Reduction in the allowable load and proof loading is not required for 1/2-inch "long" wedge bolt anchors, 1/2-inch "regular" wedge bolts installed with a maximum attachment thickness of 3/4-inch or less, or for 5/8-inch and larger "regular" wedge bolt anchors.

7. For evaluation of existing installations, the allowable tension loads for wedge bolts may be increased by the ratio of the square root of the inplace strength to the square root of 3000 lb/in^2. The inplace strength shall be determined in accordance with Appendix D.

8. Full tension and shear allowables may be used for wedge bolts installed in high density concrete at Sequoyah Nuclear Plant. (Reference SCR SQNCEB8627.)

9. The effective embedment is the minimum depth less one bolt diameter.

10. For Watts Bar Nuclear Plant only, tension allowables for wedge bolts shall be reduced by 15 percent when installed in areas of high density concrete. These areas are designated on drawings 41N726-2, 41W727-1, R541W727-2, 41W727-3, and 41N721-1. (Reference CAQR WBP 871047).

11. For all qualified wedge bolt anchors other than the Hilti Kwik Bolt II (HKB II) the 1/2-inch long anchor shall be 7.0 inches long with a maximum attachment thickness of 2.75 inches. The HKB II 1/2-inch long anchor shall not be used. R5

12. The 1-1/4-inch diameter wedge bolt is no longer available.

13. Revisions to Table 5 based on calculation CSG-90-CA01.

3.0 EXPANSION ANCHORS (Continued)

3.3.2 Abnormal Loading Conditions

The allowable tensile or shear loads for self-drilling anchors and wedge bolt anchors shall not be increased above those given in subsection 3.3.1. The allowable load in the anchor shall not be increased, even though stress increases for abnormal loading conditions are allowed by the code governing the design of the supported member. If the loads to be used for anchor design are "normalized," the loads must be "unnormalized" by multiplying all design loads by the factor used to "normalize" the loads for the controlling load conditions. If the controlling load condition is not known, all "normalized" loads shall be multiplied by 1.6 to obtain the "unnormalized" anchor design loads.

3.4 Expansion Anchor Detailing Requirements

The drawing which calls for the use of expansion anchors shall require that installation be in accordance with G-32. Expansion anchors shall not be called for in concrete with a specified compressive strength less than 3000 lb/in^2, in concrete block or masonry mortar, or in high density concrete. (See exception for SQN in note 6 of Table 4 and note 8 of Table 5.) The drawing shall give only the size and type of anchor. The brand of anchor, length, embedment, and tightening requirements shall not be given since these items are covered in G-32. The length of the bolt for self-drilling anchors shall <u>not</u> be given since G-32 requires use of A 307 or better bolts and requires one nominal bolt diameter of thread engagement. (The designer may be unaware of the depth the anchor is recessed, the width of the gap between the plate and the concrete, or the number of washers used, if any.)

The anchor designations "SSD" and "WB" (defined in G-32) may be used on the drawings in lieu of "self-drilling expansion anchor" and "wedge bolt expansion anchor," respectively. The terms "cinch anchor," "concrete anchor," and like terms shall not be used.

The anchor designation "EA" may be used to call for expansion anchors having a maximum design load that is less than half of the allowable design load for all combinations of tension and shear. When this designation is used, G-32 allows installation of either a qualified self-drilling anchor or a qualified wedge bolt anchor. The "EA" designation also exempts the anchor from testing. (See subsection 3.5.) The "EA" designation shall not be used for anchors supporting piping systems (or tubing) designated as Seismic Category I as defined by NRC Regulatory Guide 1.29.

3.0 EXPANSION ANCHORS (Continued)

Anchors that are to be designated "EA" should be called for on the drawings as either "self-drilling anchors, type EA," "wedge bolt anchors, type EA," or "expansion anchor, type EA."

For wedge bolt anchors, the thickness of the attachment affects the actual embedment. Therefore, the thickness of the attachment for wedge bolt anchors at the location of the anchor must not exceed the value given in Table 5 or the required minimum embed- ment will not be achieved. If the thickness exceeds the thickness for a "regular" length bolt, the drawings must specify a "long" bolt. The requirements for "regular" and "long" wedge bolts are given in G-32. Wedge bolts shall not be used for attachments thicker than the maximum for a "long" bolt.

3.5 Inspection and Testing Requirements

G-32 requires inspection and testing of expansion anchors only in nuclear plant Category I structures. It exempts those anchors designated on drawings as "EA," and anchors for one-hole pipe straps for individual conduits less than 4 inches in diameter, from testing. However, the anchors shall be inspected to determine their compliance with the remaining requirements of G-32.

For nuclear plant non-safety related work, the drawings must state that inspection and testing of expansion anchors are required. Testing shall be specified for all anchors that support structural members necessary for plant operation or personnel safety.

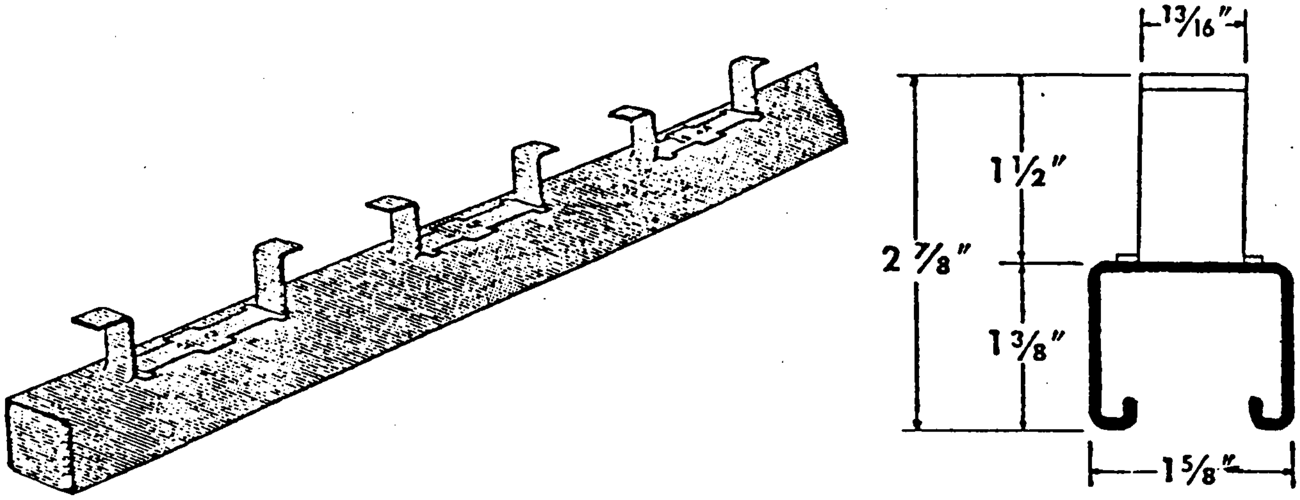
4.0 STRIP INSERTS

4.1 Strip Insert Types

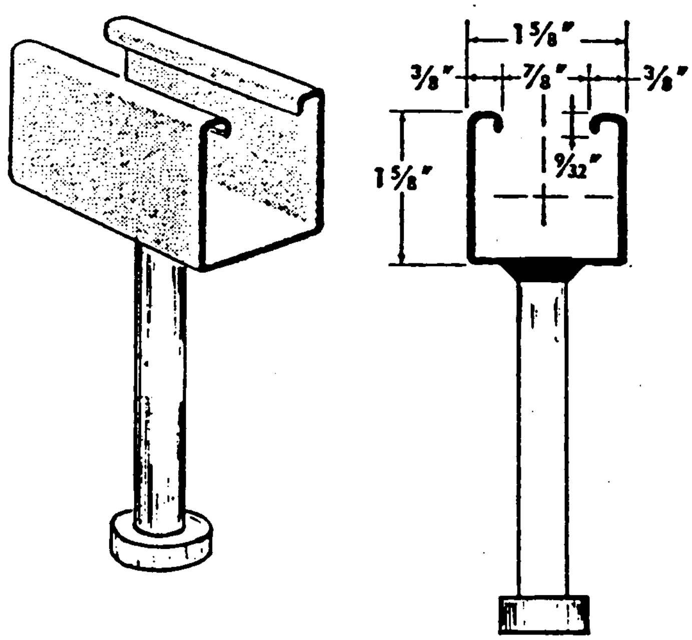
This standard applies to two types of strip inserts: standard and heavy-duty (see Figure 1). Concrete inserts designated as "standard" apply only to continuous Unistrut® series P 3200 channel or its equivalent. Attachments to the channel are made with 1/2-inch connecting bolts supplied by the insert manufacturer.

Concrete inserts designated as "heavy duty" apply only to continuous Unistrut® series P 1000 channel or its equivalent with 3/8- by 4-inch welded studs attached to the channel web at 4 inches on center. (Welded studs should be attached by the insert manufacturer. Field welding of studs should not be permitted unless special welding procedures are issued.) Attachments to the channel are also made with 1/2-inch connecting bolts supplied by the insert manufacturer.

4.0 STRIP INSERTS (Continued)



P3200 Series Continuous Insert
Standard Insert



P 1000 Series
Heavy-duty Insert

Figure 1. Concrete Inserts

4.0 STRIP INSERTS (Continued)

4.2 Failure Mechanism

Except for shear loads acting parallel to the longitudinal axis of the channel, the ultimate capacity is controlled by the steel properties of either the connecting bolts or the channel. The ultimate shear capacity parallel to the axis of the channel is controlled by slip.

4.3 Allowable Tension and Shear Loads

4.3.1 Service Load Conditions

4.3.1.1 Standard Inserts

The allowable tensile service load (T_o) and shear service load (V_o) for standard inserts shall be as follows:

T_o = 2 kips/bolt

$V_o = 1/\cos\theta \leq 2$ kips/bolt

where: θ = the angle from the longitudinal axis of the channel to the direction of the applied shear.

The allowable shear load is for a single anchor loaded in shear only. For other configurations with combined tension and shear that do not meet the requirements for a friction connection, the shear capacity is determined in accordance with subsection 5.3.

The minimum spacing between bolts on standard strip inserts shall be 12 inches.

4.3.1.2 Heavy-Duty Inserts

The allowable tensile service load (T_o) and shear service load (V_o) for heavy-duty inserts shall be as follows:

T_o = 2 kips/bolt $\leq$ 5 kips/foot of channel

$V_o = 1/\cos\theta \leq 2$ kips/bolt

The allowable shear load is for a single bolt loaded in shear only. For other configurations with combined tension and shear which do not meet the requirements for friction connections, the shear capacity shall be determined in accordance with subsection 5.3.

The minimum spacing between bolts on heavy-duty strip inserts shall be 3 inches. (If a minimum spacing of 5 inches is used, the limitation of 5 kips/foot can be ignored.)

4.0 STRIP INSERTS (Continued)

4.3.2 Abnormal Loading Conditions

The allowable loads for abnormal loading conditions may be increased as permitted in subsection 2.3.2.

4.4 Installation Requirements

Since the installation requirements for attachments to strip inserts are not included in a general construction specification, the installation requirements must be given on the drawings or in a project construction specification. The following minimum requirements shall be given:

1. Connecting bolts are to be tightened to a minimum torque of 50 ft/lbs or until a distinct yielding of the lip is detected by decreased resistance to applied torque.

2. The minimum spacing between bolts on standard inserts is to be 12 inches.

3. The minimum spacing between bolts on heavy-duty inserts is to be 5 inches unless a drawing specifically calls for a closer spacing. (The spacing may be reduced to 3 inches if the field is using load tables for field-routed lines and they are assuring the maximum tension load per foot for heavy-duty inserts is less than 5 kips.)

Exceptions to the above requirements or more restrictive requirements should not be given unless they are given in drawings or specifications that will apply to and be available to all crafts or disciplines making attachments to the inserts.

5.0 ANCHOR DESIGN

5.1 Determination of Tensile Loads in Anchors

The tensile load in anchors shall be calculated using a method that accounts for the applied tensile or compressive load parallel to the anchors and the applied bending moments about axes perpendicular to the anchors. Moments about an axis parallel to the anchors and shear loads shall not be considered when determining anchor tensile loads. For Watts Bar (WBN), Sequoyah (SQN), Bellefonte (BLN), and Browns Ferry (BFN); the calculated tensile loads for anchors and the calculated baseplate stresses shall be amplified to account for construction tolerances for location of the attachment and location of the anchors. The method for amplification of loads in expansion and grouted anchors and stresses in plates attached with these types of anchors is given in Appendix B for WBN and SQN, Appendix C for BLN, and Appendix H for BFN. R5

5.0 ANCHOR DESIGN

In general, the method used for determining anchor tensile loads shall include the effect of baseplate and anchor deformations (generally termed "flexible plate analysis"). For ductile anchors, the effects of prying shall be considered.

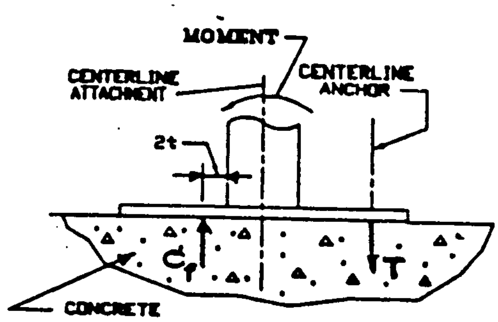
5.1.1 Flexible Baseplate Analysis

The analysis of flexible plates may be performed using refined methods such as the finite element method.

Finite analysis shall use the CDC BASEPLATE II program (reference: CDC Publication 84002770) or other approved program. Modeling of the baseplate shall be in accordance with TVA Civil Design Standard DS-C1.7.3. The stiffness coefficients to be used in the program for the anchors are given in Appendix A.

In lieu of the refined methods, the following approximations may be used for rectangular 1/2-inch and thicker baseplates with a single load applied at the centroid of the anchor group (This method does not account for construction tolerances. Those tolerances must be accounted for in accordance with Appendix B, C, H, or other approved methods.):

a. For baseplates with no more than 4 anchors that are loaded with a moment, the anchor loads may be determined by assuming that the resultant compressive force between the baseplate and concrete is applied two plate thicknesses from the attached member or from stiffners welded to the attached member and the baseplate.



b. For expansion anchored baseplates which are loaded in tension, the maximum anchor load may be determined by multiplying the applied tensile load by the following factors:

R5

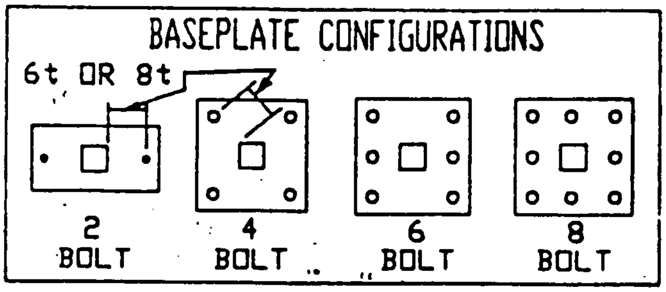
5.0 ANCHOR DESIGN (Continued)

R5

PLATE CONFIGURATION	PLATE THICKNESS 1/2 INCH	3/4 INCH	1 INCH AND GREATER
	For baseplates with all anchors within 6 plate thickness of the attachment		
2-BOLT PLATE	0.60	0.50	0.50
4-BOLT PLATE	0.30	0.25	0.25
6-BOLT PLATE	0.30	0.30	0.30
8-BOLT PLATE	0.20	0.20	0.20
	For baseplates with all anchors within 8 plate thicknesses of the attachment		
2-BOLT PLATE	0.70	0.60	0.50
4-BOLT PLATE	0.35	0.30	0.25
6-BOLT PLATE	0.30	0.30	0.30
8-BOLT PLATE	0.20	0.20	0.20

R5

The general baseplate configurations to which this method is applicable are:



c. For baseplates loaded with combined tension and moment, superposition of the anchor loads determined from a. and b. above may be used.

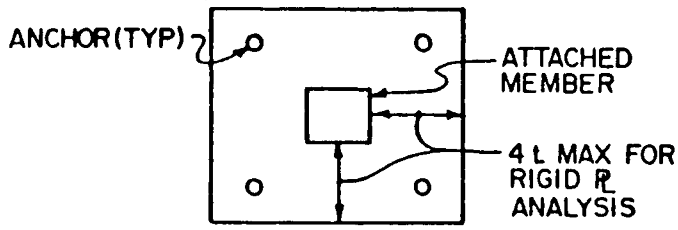
d. Other methods for flexible baseplate analysis may be used if the calculated loads will exceed the anchor loads obtained by a finite element analysis.

5.0 ANCHOR DESIGN (Continued)

5.1.2 Rigid Baseplate Analysis

The method of analysis may be based on the assumption that the surface between the plate and the concrete remains a plane (similar to beam cross-section analysis) for the following two conditions:

1. Rigid plate analysis may be used for expansion anchored baseplates if the plate projects no more than four plate thicknesses from the attached member or from stiffeners welded to the attached member and the baseplate.



2. Rigid plate analysis may be used for baseplates using ductile anchors if studies are performed to:

   a. Ensure the anchor loads calculated by rigid plate analysis are no more than 10 percent less than would be obtained from a flexible plate analysis, or

   b. Ensure the calculated anchor loads are sufficiently less than the allowable loads to ensure that the allowable loads would not be exceeded if a flexible plate analysis were performed. (This provision is included to permit envelopment of common baseplate configurations.)

If stiffeners are used to validate a rigid plate analysis, they must be of sufficient depth, length, thickness, and number to ensure applicability of the rigid plate assumption.

5.0 ANCHOR DESIGN (Continued)

5.2 Design Procedure

Determining the required number, size, and location of anchors is generally a trial and error procedure. The following is an acceptable design procedure. It is based on the assumption that the thickness of the concrete, distances to concrete edges, and anchor spacing are adequate to meet the requirements of Section 7.0.

1. Assume a pattern of anchors which is appropriate for the attached member.

2. Approximate the area of steel using equation 5 for ductile anchors or equation 6 for expansion anchors. For ductile anchors, the shear load may be ignored if the anchorage is expected to meet the requirements of a friction connection. For anchorages with relatively large moments, the total applied tensile load is to be increased to approximate the effect of the applied moment.

$$A_{st} = \frac{R\ V + T}{F_{sa}} \qquad \text{(equation 5)}$$

$$n = \frac{R\ V + T}{T_o} \qquad \text{(equation 6)}$$

where:

A_{st} = The total area of steel required.

R = Coefficient defined in subsection 5.3.

n = Number of anchors.

T = The total applied tensile load.

T_o = Allowable tensile load for expansion anchors (Tables 4 and 5).

V = Total applied shear load.

F_{sa} = Allowable anchor stress for ductile anchors.

5.0 ANCHOR DESIGN (Continued)

3. Determine the tensile loads in the individual anchors in accordance with subsection 5.1. Revise the number, size, and location of the anchors if necessary to optimize the design or reduce anchor stresses or loads.

4. Determine the frictional resistance between the baseplate and the concrete in accordance with subsection 6.1. If the frictional resistance is greater than the applied shear, the connection meets the requirements for a friction connection and no additional computations are required. If the frictional resistance is less than applied shear, the connection is a bearing connection and shear must be distributed to the anchors in accordance with subsection 5.3 or shear lugs must be provided in accordance with subsection 5.4. If the moment about an axis parallel to the anchors (torsion) is significant, the connection should be considered to be a bearing connection.

5.3 Distribution of Shear to Anchor for Bearing Connection

For bearing connections where the applied shear load passes through the centroid of the anchor group, the shear on each anchor shall be determined by dividing the load by the number of anchors. For bearing connections with moments about an axis parallel with the anchors (torsion), the shear on each anchor shall be determined using classical structural steel connection design techniques.

The combined effect of shear and tension shall be evaluated using equation 7 for ductile anchors and equation 8 for expansion anchors, undercut anchors, and strip inserts.

$$\frac{T_i + R\,V_i}{T_o} \leq 1.0 \qquad \text{(equation 7)}$$

$$\left(\frac{T_i}{T_o}\right) + \left(\frac{R\,V_i}{1.5\,V_o}\right) \leq 1.0 \qquad \text{(equation 8)}$$

where:

T_i = the calculated tensile load on the anchor

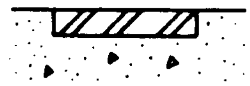
V_i = the calculated shear load on the anchor

T_o = the allowable tensile load on the anchor for tensile loading only

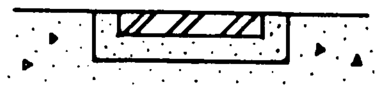
V_o = the allowable shear load on the anchor for shear loading only

5.0 ANCHOR DESIGN (Continued)

R = 1.10 for embedded plates with the exposed surface of the steel coincidental with the concrete surface. (If free concrete edge less than 4 inches from edge of embedded plate, use R = 1.5)

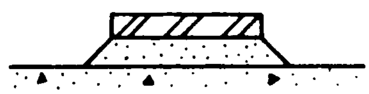


R = 1.25 for plates with recessed grout pads with exposed surface of the plate coincidental with the concrete surface



R = 1.5 for surface mounted plates

R = 1.85 for plates supported on a grout pad with the contact surface exterior to the concrete surface



When shear is directed toward a free edge, the capacity of the concrete shall be evaluated in accordance with Section 8.0.

For evaluation of expansion anchors, UC anchors and strip inserts for existing supports, the combined effects of shear and tension may be evaluated using the following equation:

$$\left(\frac{T_i}{T_o}\right)^{1.7} + \left(\frac{R\ V_i}{1.5V_o}\right)^{1.7} \leq 1.0$$

For evaluation of ductile anchors for existing supports, the combined effects of shear and tension may be evaluated using the following equation:

$$\left(\frac{T_i}{T_o}\right)^{1.7} + \left(\frac{R\ V_i}{T_o}\right)^{1.7} \leq 1$$

Note: The above equation should be utilized to evaluate existing supports however it may be used to reduce the anchor size in a new installation. RS

5.4 Design of Shear Lugs

Shear lugs may be used to transfer shear loads to the underlying concrete only in areas where compression exists between the baseplate and the concrete. Shear lugs shall be designed so that the bearing stress on the concrete or grout is 900 lb/in^2 or less for service load conditions. Only the portion of the shear lug below the face of structural concrete shall be considered effective.

6.0 CONSIDERATIONS FOR FRICTION AND BEARING CONNECTIONS

6.1 Friction Connections

Friction connections may be used only if engineering drawings require the removal of all paint and coatings from the friction surfaces. RS

For friction connections, bolt holes in the baseplate may be oversized as limited in Table 6. Slotted holes may be used.

Table 6

Hole Oversize

Nominal Bolt Size (inches)	Maximum Hole Oversize (inches)
5/8 - 7/8	3/16
1	1/4
1-1/8 - 1-1/2	5/16

Frictional shear resistance shall be the product of the resultant compressive force (C_f) on the baseplate times the coefficient of friction. The coefficient of friction between steel and concrete shall be 0.5. The coefficient of friction for a steel-to-steel connection shall be 0.25.

A friction connection may be achieved by preloading ductile anchors. The long-term reduction in preload of the anchors must be considered.

Members with combined bending and tension may be considered as friction connections if the product of the resultant compressive force times the coefficient of friction exceeds the shear load.

6.0 CONSIDERATIONS FOR FRICTION AND BEARING CONNECTIONS (Continued)

6.2 Bearing Connections

For bearing connections, the bolt holes in the baseplate shall be limited to 1/8-inch oversize.

If the frictional shear resistance is less than the applied shear, the anchorage and baseplate shall be designed as a bearing connection. The frictional shear resistance should not be used to reduce the shear load applied to the anchors.

7.0 EMBEDMENT AND SPACING

Except where the provisions of Appendices E and F are used in the evaluation of existing embedded plates and ductile anchors, the embedment and spacing for all types of anchors (except self-drilling anchors) must result in an ultimate concrete pullout capacity of at least 4 times the tensile service load in each anchor (factor-of-safety = 4.0). For self-drilling anchors, the ultimate capacity shall be at least 5 times the tensile load in the anchor (factor-of-safety = 5.0). The tensile load shall be the load in the anchor calculated in accordance with subsection 5.1. The load must be the "unnormalized" load for expansion anchors. (For ductile anchors and regular embedment UC anchors, increases in stress are permitted for abnormal loading conditions. Since service loads are used for determining the embedment and spacing, the factor-of-safety against concrete failure for abnormal loading conditions is less than 4.0). For evaluation of existing embedded plates, the factor-of-safety given in Appendix E may be applied. R5

In general, the tensile load in the anchor used for determining the embedment and spacing shall be equal to at least the maximum allowable tensile service load for the anchor. However, if the calculated load is less than the allowable service load, the calculated load in the anchor may be used if physical limitations prevent use of the spacing or embedment necessary to obtain a concrete capacity equal to the required multiple of the allowable service load. The allowable tensile load based on the calculated concrete failure mechanism shall not exceed the normal allowable tensile loads given in Sections 2.0, 3.0, and 4.0. The acceptability of the embedment and/or spacing of anchors shall be determined based on providing the required factor-of-safety for the tensile component of the load in the anchor. Shear loads are not considered in the evaluation of anchor spacing or embedment. The shear-tension interaction equations in subsection 5.3 need not be applied even if the embedment or spacing results in a reduced value of T_0. The ultimate capacity for the concrete failure mechanism is not significantly affected by applied shear.

Edge conditions shall be considered in accordance with Section 8.0.

Even though anchors may be loaded entirely in shear, the minimum spacing shall not be less than the absolute minimum spacing in subsection 7.3.2, and the minimum embedment shall not be less than the absolute minimum embedment in subsection 7.2.

7.0 EMBEDMENT AND SPACING (Continued)

7.1 Calculating Ultimate Concrete Capacity

The ultimate pullout capacity of the concrete shall be calculated using the following equations:

$P_c = 3.4\sqrt{f'_c}\ A_c$ for ductile anchors and undercut anchors.

$P_c = 6\sqrt{f'_c}\ A_c$ for expansion anchors

where:

P_c = The ultimate pullout capacity of the concrete (lbs)

f'_c = The specified compressive strength discussed in subsection 7.4 (lb/in^2)

A_c = The effective area of the assumed pullout cone calculated in accordance with subsection 7.1.1 (in^2)

NOTE

The capacities calculated using the above equations are ultimate capacities. A factor-of-safety is to be applied in accordance with Section 7.0.

7.1.1 Calculating Concrete Area

The effective concrete area used for calculating the ultimate concrete capacity shall be the base area of an assumed cone-shaped concrete spall. The base area for a single anchor shall be calculated in accordance with subsection 7.1.1.1. For multiple anchors, the effective area shall be calculated in accordance with subsection 7.1.1.2. The area of the anchor head does not need to be subtracted from the calculated base area of the cone unless it exceeds about 10 percent of the base area. (See Section 9.0 for anchor head requirements).

The computer program CONAN is available for the calculation of concrete areas and of allowable tensile load capacities.

7.1.1.1 Single Anchors

The base area of the assumed concrete spall (A_c) for a single anchor with no adjacent free concrete edges shall be equal to the base area of a cone with the apex on the anchor center-line and the base in the plane of the concrete surface. The height of the cone shall be the effective embedment (E) of the anchor. For ductile anchors, the apex angle for the cone shall be 90 degrees. For expansion anchors, the apex angle shall be $(124 - 6.8E) \geq 90$ degrees, where (E) is the effective embedment in inches.

7.0 EMBEDMENT AND SPACING (Continued)

The effective embedment for embedded bolts and grouted anchors shall be the total depth of the anchors measured from the concrete surface. The effective embedment for welded studs is the after-welding stud length. For embedded bolts made from a threaded rod with an end nut, the effective embedment shall be measured from the concrete surface to the far side of the nut. For undercut anchors, self-drilling anchors, and wedge bolts, the effective embedment is given in Tables 3, 4, and 5, respectively. If the actual attachment thickness is less than the maximum for wedge bolt anchors given in Table 5, the effective embedment may be increased by the difference between the actual and maximum attachment thickness. The designer must consider the installation tolerances on the actual attachment thickness.

For anchors adjacent to a concrete edge, the portion of the base area that extends beyond the edge shall be deducted from the effective concrete area.

7.1.1.2 Multiple Anchors (General Condition)

For multiple anchors, the effective area of the assumed spalls (A_c) for each anchor calculated in accordance with subsection 7.1.1.1 shall be reduced to account for overlap of the bases of the cones for each anchor. The overlap area for two adjacent anchors shall be divided between the two anchors based on a chord connecting the two points of intersection of the circles defining the bases of the cones. The area reduction for an individual anchor shall include the effects of <u>all</u> adjacent tensile anchors whose base overlaps the base of the subject anchor. (Example: If the area for anchor A is being calculated because it is spaced closer to B than the tabulated minimum spacing, the overlap of A with C must be considered, even though A and C are spaced at the tabulated minimum.)

The effect of free concrete edges adjacent to the anchor shall also be considered as discussed in subsection 7.1.1.1. The effect of overlap for two adjacent anchors may be ignored if it is not possible for both anchors to be loaded simultaneously.

7.1.1.3 Multiple Anchors (Special Condition)

The method for reducing the effective area given in subsection 7.1.1.2 applies for most configurations. However, if the chord defined in subsection 7.1.1.2 does not pass between the subject anchors, the area-reduction method may not give valid results. This configuration usually occurs when two anchors are spaced very closely together and their embedments are much different.

7.0 EMBEDMENT AND SPACING (Continued)

The following procedure gives reasonable results for the foregoing configurations.

a. Calculate the effective base area for the two anchors involved (Anchors A and B) neglecting the overlap between anchors A and B themselves. However, overlaps with other anchors adjacent to A or B shall be considered in the calculation of the base areas for both anchors A and B.

b. Calculate the uniform concrete stress for anchor A and for anchor B by multiplying the maximum design load for each anchor by 4 (5 for self-drilling anchors) and dividing the result by the effective area (calculated in paragraph a.)

c. Add the calculated stress for anchor A to the calculated stress for anchor B.

The configuration is acceptable if the combined calculated stress is less than 3.4 $\sqrt{f'_c}$ for ductile anchors and strip inserts or 6 $\sqrt{f'_c}$ for expansion anchors. If one anchor is a ductile anchor and the other is an expansion anchor, compare the calculated stress summation to the allowable stress for a ductile anchor.

7.2 Embedment Limitations

In general, the embedment of anchors shall be limited to 2/3 of the thickness of the concrete member into which the anchor is installed. This limitation provides assurance that failure or slip caused by splitting or spalling of the far face of the concrete member does not occur. The minimum embedments for undercut anchors are given in Table 3, and for expansion anchors in Tables 4 and 5. The minimum embedment for embedded bolts and grouted anchors which are designed on the basis of nonductile concrete failure should be at least 4 bolt diameters.

In addition, special evaluation of anchor embedment is required for anchor groups with 4 or more anchors which are all loaded simultaneously in tension and which are installed in concrete members with thicknesses less than 2 times the anchor embedment. The special evaluation is necessary because the effective concrete area for some multiple anchor groups may be less than the area calculated in accordance with subsections 7.1.1.2 and 7.1.1.3. The reduction occurs because a potential failure surface which extends completely though the slab may have a smaller ultimate capacity than the normally assumed cone-shaped spall.

The potential failure surface for anchor groups in relatively thin members is shown in Figure 2. The cross-hatched area in Figure 2 is the effective stress area. The projected area for the individual anchors calculated in accordance with subsection 7.1.1.2 must be reduced by the A_R factor shown in Figure 2.

7.0 EMBEDMENT AND SPACING (Continued)

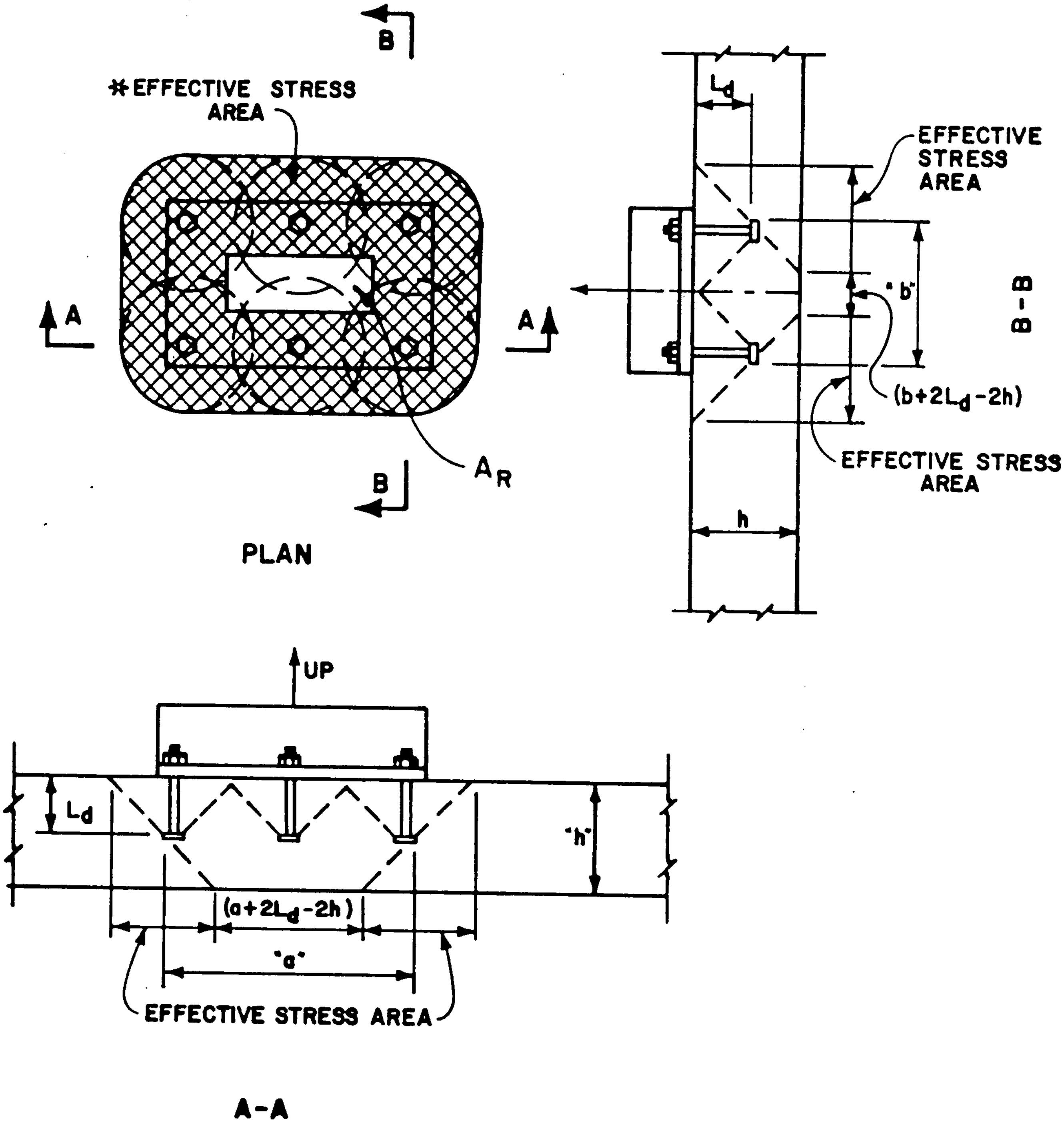
7.3 Spacing Limitations

Generally, the minimum centerline-to-centerline spacing between two anchors with specific embedments is the spacing at which both anchors are assumed to support 100 percent of their normal allowable loads. However, smaller spacings may be used if the allowable loads are reduced. The minimum spacings for fully effective anchors are given in subsection 7.3.1. The minimum spacings for anchors with reduced allowable loads are given in subsection 7.3.2.

7.3.1 Minimum Spacings (Full Allowable Loads)

Except for undercut anchors, when the minimum spacings given in this section are used, the full allowable tensile load on the anchor may be used without calculation of the pullout capacity of the concrete anchors. (See Note 4 of Table 3 for undercut anchors.)

For adjacent ductile anchors the minimum spacing shall be three-fourths of the sum of the individual anchor embedments. The minimum spacing between adjacent expansion anchors and between expansion anchors and strip inserts, embedded plates, grouted anchors, embedded bolts (cast-in-place anchors), or threaded inserts shall be as given in Table 3.6.3 and subsections 3.6.3 and 3.7.3 of G-32.



STRESS AREA REDUCTION FOR LIMITED DEPTH (A_R)

$$A_R = (a + 2L_d - 2h)\ (b + 2L_d - 2h)$$

*Reduced by the total bearing area of the anchor steel. See Section 9.0.

Figure 2

7.0 EMBEDMENT AND SPACING (Continued)

7.3.2 Minimum Spacings (Reduced Allowable Loads)

Spacings less than those given in subsection 7.3.1 may be used provided the ultimate concrete capacity is equal to the required multiple (factor-of-safety) of the calculated anchor service load (see Section 7.0). If reduced minimum spacings are used, the drawings must show both anchors and spacing so that the field installers know that the minimum spacings given in G-32 do not apply (see subsections 3.6 and 3.7 of G-32).

For expansion anchors the minimum spacings shall not be reduced to less than 4 times the nominal bolt diameter of the larger anchor. For spacings between working and abandoned anchors see subsections 3.6 and 3.7 of G-32.

7.4 Concrete Strength

The embedment and spacing for ductile anchors shall be calculated using a concrete compressive strength no larger than the specified compressive strength of the concrete. The spacing for expansion anchors shall be evaluated using a concrete compressive strength of 3000 lb/in^2. For evaluation of existing anchorages, the inplace concrete strength determined in accordance with Appendix D may be used.

8.0 EDGE DISTANCE

A free concrete edge adjacent to an anchor may reduce the capability of an anchor to transfer tension and shear loads to the underlying foundation.

The edge may reduce the ultimate tensile capacity in two ways:

1. By reducing the effective area of the base of the assumed concrete spall, or

2. By reducing the lateral confinement of the concrete which allows failure of concrete by splitting or bursting.

The first condition is included in the determination of the ultimate concrete capacity in subsections 7.1.1.1 and 7.1.1.2. The second condition is covered in subsection 8.1.

8.0 EDGE DISTANCE (Continued)

The edge may reduce the capacity of an attachment or anchor in shear for both bearing and friction connections. The evaluation of edge conditions for bearing connections is covered in subsection 8.2.1. The evaluation for friction connections is covered in subsection 8.2.2.

The ultimate concrete capacity calculated in the following sections shall be at least four times the applied maximum tensile or shear loads on an individual anchor. In general, the calculated ultimate capacity should be at least equal to four times the allowable service, tensile or shear load. (For self-drilling anchors five times the tensile load, four times the shear load.)

For evaluations for edge distance concrete strength increases with age are not permitted because concrete cracking would initiate near the concrete surface. However, the specified strength of the concrete may be used.

8.1 <u>Tension Loads</u>

8.1.1 Ductile Anchors and Regular UC Anchors

Tensile loads in all anchors with an embedded head result in lateral forces at the head that tend to split or burst the concrete. Usually, the surrounding concrete provides adequate lateral restraint to prevent cracking or fracture of the concrete. However, for anchors located near a free edge, the lateral forces may result in a fracture or "blow-out."

The ultimate capacity of the concrete to resist the lateral force shall be calculated by assuming that failure occurs by pushout of a cone-shaped spall. The spall shall be assumed to be a cone with its apex at the anchor head and the base of the cone in the plane of the concrete surface that defines the edge (the plane parallel to the anchor centerline). The apex of the cone shall be on the anchor centerline. The apex angle of the cone shall be 90 degrees. The ultimate blowout capacity of the spall shall be determined by multiplying the base area of the cone by $3.4\sqrt{f'_c}$. If cones for other anchors are adjacent to the edge area of the cone, the effective area shall be reduced as discussed in subsection 7.1.1.1. The calculated ultimate blowout capacity shall then be adjusted by dividing it by 0.2. (This operation is based on the assumption that the lateral force is 20 percent of the tensile load in the anchor.) The edge distance is acceptable if the <u>adjusted</u> ultimate concrete blowout capacity is at least four times the maximum calculated tensile load in the anchors.

8.0 EDGE DISTANCE (Continued)

8.1.2 Expansion Anchors and Shallow UC Anchors

The primary lateral forces developed in the concrete by expansion and shallow UC anchors occur during installation. Therefore, the actual tensile loading on the anchors is not of primary importance in determining the necessary side cover (edge) distance. To prevent splitting or cracking of the concrete during installation, the side cover distance for expansion and shallow UC anchors shall be six nominal bolt diameters.

The edge distance for SSD and WB anchors may be reduced to three bolt diameters provided the drawings require proof load testing of all SSD anchors or torque testing of all WB anchors installed adjacent to the edge. Testing should be in accordance with G-32.

8.2 Shear Loads

8.2.1 Bearing Connections

The ultimate shear capacity of an anchor in a bearing connection located near a free concrete edge shall be determined by calculating the load required to push out a partial cone-shaped concrete spall. The ultimate capacity of the concrete shall be equal to the effective base area of the partial cone multiplied by $3.4\sqrt{f'_c}$.

The assumed cone shall have its apex on the anchor centerline in the plane of the concrete surface. The base of the cone shall be in the plane of the surface which defines the free edge. The apex angle of the cone shall be 90 degrees in the surface containing the baseplate. The base area of the cone for a single anchor is $(\pi m^2)/2$ where m is equal to the edge distance.

The effective area of the base of the cone for an anchor shall be reduced to account for adjacent anchors whose assumed cones overlap the cone for the subject anchor.

The ultimate capacity of the concrete shall be at least four times the shear load applied to the anchor. The applied shear load on the anchor shall be that determined in accordance with subsection 5.3. Reevaluation of tension-shear interaction using a reduced Vo is not required because the interaction check is for evaluation of the steel.

For anchors installed adjacent to circular penetrations, Appendix I provides concrete capacity for evaluation of shear loads.

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8.0 EDGE DISTANCE (Continued)

8.2.2 Friction Connections

For attachments located adjacent to a free concrete edge that meet the requirements for a friction connection, the edge distance shall be evaluated by assuming that the shear loads are distributed as would occur in a bearing connection and the concrete push-off capacity evaluated in accordance with Section 8.2.1.

9.0 ANCHOR HEAD REQUIREMENTS

For embedded bolts, grouted anchors, embedded studs, and threaded inserts, the anchor head shall be equivalent to the standard head on a bolt. Bearing at the anchor head does not require evaluation. Special anchor heads made from steel plates are required only for bolts that go entirely through a concrete member (thru-bolts) or for bolts with sleeves. For thru-bolts a special anchor head shall be used on the backside of the concrete member. The anchor head shall consist of a plate that is sized based on an allowable bearing stress of 0.3f'c. The allowable service load bearing stress may be increased in proportion to the ratio of $\sqrt{A_2/A_1}$ up to a maximum of 0.6f'c (as discussed in Section 10.16 of ACI 318-77).

A sleeved anchor bolt has a steel or plastic sleeve placed concentrically around the bolt for all or part of its length. The sleeve forms a void around the anchor during concrete placement. The void allows the bolt to be moved laterally a small amount during installation for fit-up of the bolt and holes in the attachment. Anchor bolts with sleeves require special anchor heads if the void formed by the sleeve is within 4 nominal bolt diameters of the bolt head. The special anchor head shall be assumed to be circular. Its diameter shall be determined by limiting the bearing stress on the portion of the plate outside the cylinder defining the sleeve. The thickness of the plate shall be equal to at least the difference in radius of the plate and the radius of the sleeve. A square plate with sides equal to the diameter of the assumed circular plate may be substituted.

If special anchor heads are used, the area of the anchor head shall be subtracted from the effective base area of the pullout spall calculated in accordance with subsection 7.1.1.

10.0 SPECIAL EVALUATIONS FOR INTERIM OPERABILITY

The following sections provide acceptance criteria to be used during performance of special evaluations for interim operability. These provisions must be coupled with a program of restoration (including scheduling and tracking) by the implementing project. Anchorages qualified for interim operation must be upgraded as expeditiously as possible. Expansion anchors qualified for interim operation shall be upgraded by the end of the next refueling outage.

10.1.1 Criteria

For special evaluations as defined in Section 10.0, the embedment of Type II embedded plates (see DS-C1.8.1 for definition) shall be considered acceptable if the ultimate capacity of the concrete determined in accordance with Civil Design Standard DS-C1.8.1 is greater than the applied loads for all loading conditions. Refer to Section 7.0 and use unnormalized loads.

A Ø factor of 0.85 may be used in the special evaluation of all Type II plates. (DS-C1.8.1 requires a Ø factor of 0.65 for long-term qualification of Type II plates where the second, or anchor plate, is not embedded beyond the far face reinforcing).

10.1.2 Applicability

The above criteria is applicable to the evaluation of existing Type II embedded plates. If physical modification is required to the embedded plate or supported component to increase the load capacity of the embedded plate or to reduce the load applied to the anchorage, the Type II embedded plate or the supported component must be immediately upgraded to the factor of safety specified in Appendix E.

10.1.3 Basis for Criteria

The design basis for Type II embedded plates was the punching shear provisions for slabs given in ACI 318. The punching shear provisions do not provide the same design margins as the current requirements of industry standards. However, the punching shear method is acceptable because it was the method applied by the industry at the time and it provides an equivalent factor of safety of about 1.2 (by use of a strength reduction factor of 0.85). Upgrading to present day requirements is appropriate when modifications are made.

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10.0 SPECIAL EVALUATIONS FOR INTERIM OPERABILITY (Continued)

10.2 Expansion Anchors

10.2.1 Criteria

For interim operability evaluation of expansion anchors due to as-built, design, material, or documentation problems, the allowable loads for expansion anchors given in Tables 4 and 5 may be adjusted to provide a lower factor of safety. Provisions for application of interim factors of safety to specific features, structures, or programs must be captured and approved in the appropriate specific design input documents (generally the specific design criteria for programs or a Design Criteria Exception Request for case-by-case evaluations).

The lowest factor of safety to be provided in design input documents is 2. TVA has committed to specific interim factors of safety greater than 2 for expansion anchors in:

1. Small bore alternately analyzed pipe supports at Sequoyah.

2. Cable tray supports at Sequoyah.

The interim factors of safety for these two systems is 2.8 for self-drilling anchors and 2.5 for wedge bolt anchors.

10.2.2 Applicability

The above criteria is only applicable to interim operability evaluations for existing expansion anchor installations. These criteria are not applicable to design changes unless an exception is documented in accordance with NEPs.

10.2.3 Basis for Criteria

The factor-of-safety for interim operation are based on NRC OIE Bulletin 79-02. The bulletin allows interim operation of a nuclear plant if the factor-of-safety for expansion anchors is greater than 2 and a program of restoration has been implemented.

10.3 Ductile Anchors at Sequoyah Nuclear Plant Only

10.3.1 Criteria

For special evaluations as defined in Section 10.0, the embedment of welded studs, grouted anchors and cast-in-place anchors shall be considered acceptable if the ultimate capacity of the concrete determined in accordance with this standard is greater than two times the tensile service load (or normalized load) in the anchor. Refer to Section 7.0.

10.0 SPECIAL EVALUATIONS FOR INTERIM OPERABILITY (Continued)

10.3.2 Applicability

The above criteria is applicable to the evaluation of existing anchors. If physical modification to a support or supported component is required to reduce the anchor loads, the resulting anchor capacity must comply with Appendix F.

10.3.3 Basis for Criteria

Prior to the issue of DS-C6.1, the provisions of the ACI 318 code would have been applied to the design of anchorages. Based on the code provisions of ultimate concrete shear strength versus allowable concrete strength the factor of safety is $2 = (4\sqrt{f'c}/2\sqrt{f'c})$ for normal working loads.

APPENDIX A

ANCHOR STIFFNESSES FOR BASEPLATE II PROGRAM

	Self-Drilling Expansion Anchors		Wedge-Bolt Expansion Anchors	
Anchor Size	Tensile Stiffness (k/in)	Shear Stiffness (k/in)	Tensile Stiffness (k/in)	Shear Stiffness (k/in)
1/4	400	1000	400	1000
5/16	400	1000	--	--
3/8	400	1000	400	1000
1/2	400	1000	400	1000
5/8	400	1000	400	1000
3/4	400	1000	400	1000
7/8	400	1000	--	--
1	--	--	400	1000
1-1/4	--	--	400	1000

R5

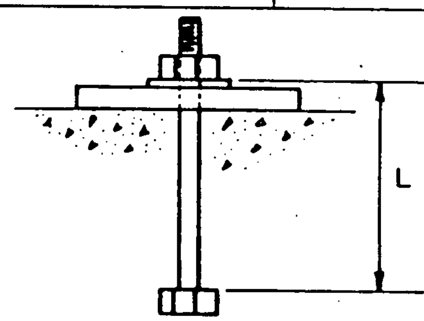

FIGURE A.1

Ductile Anchors

$$k_t = \frac{1}{\frac{0.015}{T_o} + \frac{L}{AE}}$$

$k_s = 1000$

where:

k_t = Tensile stiffness (k/in)

T_o = Allowable service load for anchor (k) - See Equations 3 and 4, subsection 2.3.1 (neglects e/t effects) and Table 3.

L = Stressed length of bolt (in) - See Figure A.1.

A = Net tensile area of anchor (in^2)

E = Modulus of elasticity of anchor (k/in^2)

k_s = Shear stiffness (k/in)

APPENDIX B

PROCEDURE FOR CONSIDERATION OF CONSTRUCTION TOLERANCES (Watts Bar Nuclear Plant and Sequoyah Nuclear Plant)

B.1 SCOPE

This procedure covers the amplification of tensile loads in expansion, undercut, and grouted anchors and the amplification of baseplate bending stresses to account for construction tolerances for location of the attachment and location of the anchors. The use of this procedure allows the designer to account for potential increases in anchor load and baseplate stresses.

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This method accounts for a radial tolerance of 9/16 inch on the location of the attachment and a radial tolerance of 1/4 inch on the location of anchors from their designated locations on the baseplate.

If other tolerances are used, the effects of those tolerances shall be included in the design calculations.

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B.2 APPLICABILITY

The procedure given in this appendix shall be used in all design calculations for anchors and baseplates performed after issue of revision 3 to this standard with the following exceptions:

a. The amplification is not required if the actual installed location of the anchors and attachment to the baseplate are known and are considered in the design.

b. The amplification is not required if the potential effects of more, or less, restrictive tolerances are included in the design calculations and those tolerances are given on the drawing.

B.3 PROCEDURE

Tensile loads in expansion and grouted anchors determined in accordance with Section 5.1 shall be multiplied by an amplification factor to account for construction tolerances. The amplification factor shall be 1.2 for expansion anchors and undercut anchors and 1.6 for grouted anchors. The number, size, and location of anchors, shall then be determined in accordance with Section 5.2. The allowable expansion anchor loads are given in Tables 4 and 5 of this design standard.

To account for construction tolerances, bending stress in expansion, undercut, and grouted anchored baseplates, which are calculated on the basis of the unamplified anchor loads, shall be multiplied by 1.2. (Normalized anchor loads may be used if the amplified bending stress will be compared to the allowable stress for normal or service loading conditions.)

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APPENDIX B (Continued)

B.4 BASIS FOR CRITERIA

Amplification factors were determined for worst-case configurations as dicussed in Reference B.5.1. Actual field usage of expansion anchor installation tolerance allowed use of reduced amplification factors as discussed in Reference B.5.2. The original studies did not include undercut anchors; however, the tolerances applied to those anchors are the same as expansion anchors and their stiffness are enveloped by them.

B.5 REFERENCES

1. Calculations - Watts Bar Nuclear Plant - Baseplate Tolerance Study - 47A050 Notes (CEB 841214 007, -006, CEB 850219 002).

2. Calculations - Expansion Anchor Design - Evaluation of Amplification Factors for Construction Tolerances (B41 850703 001).

APPENDIX C

PROCEDURE FOR CONSIDERATION OF CONSTRUCTION TOLERANCE

(Bellefonte Nuclear Plant Only)

C.1 SCOPE

This procedure covers the amplification of tensile loads in expansion and grouted anchors and amplification of baseplate bending stresses to account for construction tolerances. The amplification accounts for location tolerances for the attachment and for location tolerances for the anchors. Amplification factors are provided for specific concentric baseplate attachments. The use of this procedure allows the designer to account for potential increases in anchor load and baseplate stresses.

This method specifically accounts for the installation tolerances for pipe supports given in drawing 3GA0059-00 series. This drawing gives tolerances for locations of the attachment on the baseplate and for location of anchors from their called-for locations on the baseplate. (1-inch-radial tolerance on attachment location, 3/8-inch radial tolerances on the location of anchors with a limitation of 3/8 inch on the spacing increase of decrease of adjacent anchors.)

If other tolerances are used for expansion or grouted anchors or if tolerances are allowed on other types of anchors (undercut anchors for example), the effects of those tolerances shall be included in the design calculations.

C.2 APPLICABILITY

After June 21, 1985 (issue date of QIR CEB-85-001), the procedure in Section C.3 shall be used for the calculation of anchor loads and baseplate stresses for design of all supports. It shall also be used for evaluation of existing supports and for reanalysis for completed support designs when recalculation of anchor loads or baseplate stress is necessary. Calculation of anchor loads and baseplate stresses for existing supports or for completed support designs is not required for the singular purpose or evaluating the effects of construction tolerances.

Additionally, amplification is not required for the following conditions:

1. If the actual installed location of the anchors and attachment to the baseplate are known and are considered in the design.

2. If the potential effects of the tolerances on drawing 3GA0059-00 series are included in the design calculations.

3. If the potential effects of more, or less, restrictive tolerances are included in the design calculations and those tolerances are given on the drawings.

APPENDIX C (Continued)

C.3 PROCEDURE

Tensile loads in expansion and grouted anchors determined in accordance with subsection 5.1 shall be multiplied by the appropriate amplification factors given below to account for construction tolerances. The factors are applicable to baseplates with a single support attached. The factors for double attachments are for single supports with two attachment points on the baseplate (2 legs).

PLATE CONFIGURATION	ANCHOR AMPLIFICATION FACTOR
2-Anchor, Single Attachment	1.60
4-Anchor, Single Attachment	1.80
4-Anchor, Double Attachment	1.50
6-Anchor, Double Attachment	1.60

The number, size, and location of anchors shall then be determined in accordance with subsection 5.2. The allowable expansion anchor loads are given in Tables 4 and 5 of this standard.

To account for construction tolerances, bending stresses in expansion and grouted anchored baseplates, which are calculated based on the unamplified anchor loads, shall be multiplied by the appropriate amplification factor given below. (Normalized anchor loads may be used if the amplified bending stress will be compared to the allowable stress for normal or service loading conditions.)

PLATE CONFIGURATION	PLATE STRESS AMPLIFICATION FACTOR
2-Anchor, Single Attachment	2.50
4-Anchor, Single Attachment	1.70
4-Anchor, Double Attachment	1.25
6-Anchor, Double Attachment	1.35

APPENDIX D

METHOD FOR DETERMINING INPLACE CONCRETE STRENGTH FOR ANCHORAGE EVALUATION

D.1 SCOPE

This appendix provides instructions for determining the inplace concrete strength which may be used in the evaluation of concrete anchorages.

D.2 APPLICABILITY

These instructions shall be applied only to the evaluation of existing concrete anchorages.

D.3 PROCEDURE

The inplace concrete strength for anchorage evaluations is equal to the specified strength of the concrete plus a strength gain with age. The specified strength of the concrete is determined from the concrete mix designation used on the structural concrete drawings. (Example: 4000 lb/in^2 for mix 400.75 AFW, 5000 lb/in^2 for mix 501.5 BFW.)

For evaluation of self-drilling concrete anchorages at Browns Ferry Nuclear Plant, the estimated inplace concrete strength, for any class of concrete, shall be based on the concrete strength gain for a 90-day "B" mix only. The maximum estimated concrete strength gain shall be limited to 600 lb/in^2. (BFN calculation CD-Q0000-883784 B22 88 0630 109) Concrete strength gains for ductile and undercut anchors shall be evaluated in accordance with Section D.4 of this appendix. (CD-Q0000-883784 B22 880630 102) R5

For Watts Bar Nuclear Plant only, CEB Report 86-19-C shall also be checked to determine if the concrete placement in which the anchors are installed has an equivalent specified strength less than the strength specified on the drawings. For Sequoyah Nuclear Plant, design calculation SCG 3-110 (B25 861216 300) shall be checked to determine if the concrete placement in which the anchors are installed has an equivalent specified strength less than the strength specified on the drawings. If the equivalent strength is lower, it shall be used instead of the specified strength. All WBN and SQN structural concrete has an inplace compressive strength (including strength gain) of at least 3000 lb/in^2 throughout its depth.

The concrete strength gain for anchorage evaluations shall be determined in accordance with Section D.4. The strength gain obtained from Figure D.1 shall be adjusted to account for the embedment depth of the a anchors. The strength gain shall be multiplied by an adjustment factor equal to the ratio of the effective embedment depth of the anchor divided by 8 inches with a maximum value of 1. (See Calculation SCG-CSG-87-203 B25 871207 450.) R5

APPENDIX D (Continued)

D.4 CONCRETE STRENGTH GAIN FOR ANCHORAGE EVALUATIONS

A graph showing the minimum long-term concrete strength gain is shown on Figure D.1. The concrete strength gain varies, depending on the volume-to-surface ratio (V/S) of the concrete member under consideration.

V = Volume of concrete member (cubic feet)
S = Surface area of a concrete member for cooling or drying (square feet)

The long-term concrete strength gain versus (V/S) graph is divided into two sections. The concrete strength gain is generally controlled by drying for (V/S) less than one, and by the maximum average temperature during hydration for (V/S) greater than one.

The following procedure shall be used to estimate the long-term concrete strength gain for anchorage evaluation.

(1) Calculate the volume-to-surface ratio for drying $(V/S)_D$ and use Figure D.1 to find the long-term concrete strength gain.

(2) Calculate the volume-to-surface ratio for maximum average temperature during hydration $(V/S)_H$ and use Figure D.1 to find the long-term concrete strength gain.

(3) Use the smaller of these two long-term concrete strength gains for anchorage evaluation.

For a slab on stay-in-place steel forms, use $(V/S)_H = (1/2)t$ and $(V/S)_D = t$, where t = slab thickness in feet.

For an elevated slab on wood forms, use $(V/S)_H = (2/3)t$ and $(V/S)_D = (1/2)t$

For a wall formed on both sides with wood, use $(V/S)_H = (3/4)t$ and $(V/S)_D = (1/2)t$

For a square column, use $(V/S)_H = (3/8)$ (side dimension) and $(V/S)_D = (1/4)$(side dimension)

For slabs on rock or soil, use $(V/S)_H = (2/3)t$ and $(V/S)_D = t$

For walls cast against rock with wood outer form $(V/S)_H = t$ and $(V/S)_D = t$

For slab with multiple lifts $(V/S)_H$ = (lift thickness) and $(V/S)_D$ = (total depth of concrete on rock or soil)

APPENDIX D (Continued)

For $(V/S)_D$ greater than 1.0, neglect drying and use $(V/S)_H$ for strength gain

For additional information on the volume-to-surface ratio, see Civil Design Standard DS-C1.5.4

LONG-TERM CONCRETE STRENGTH GAIN

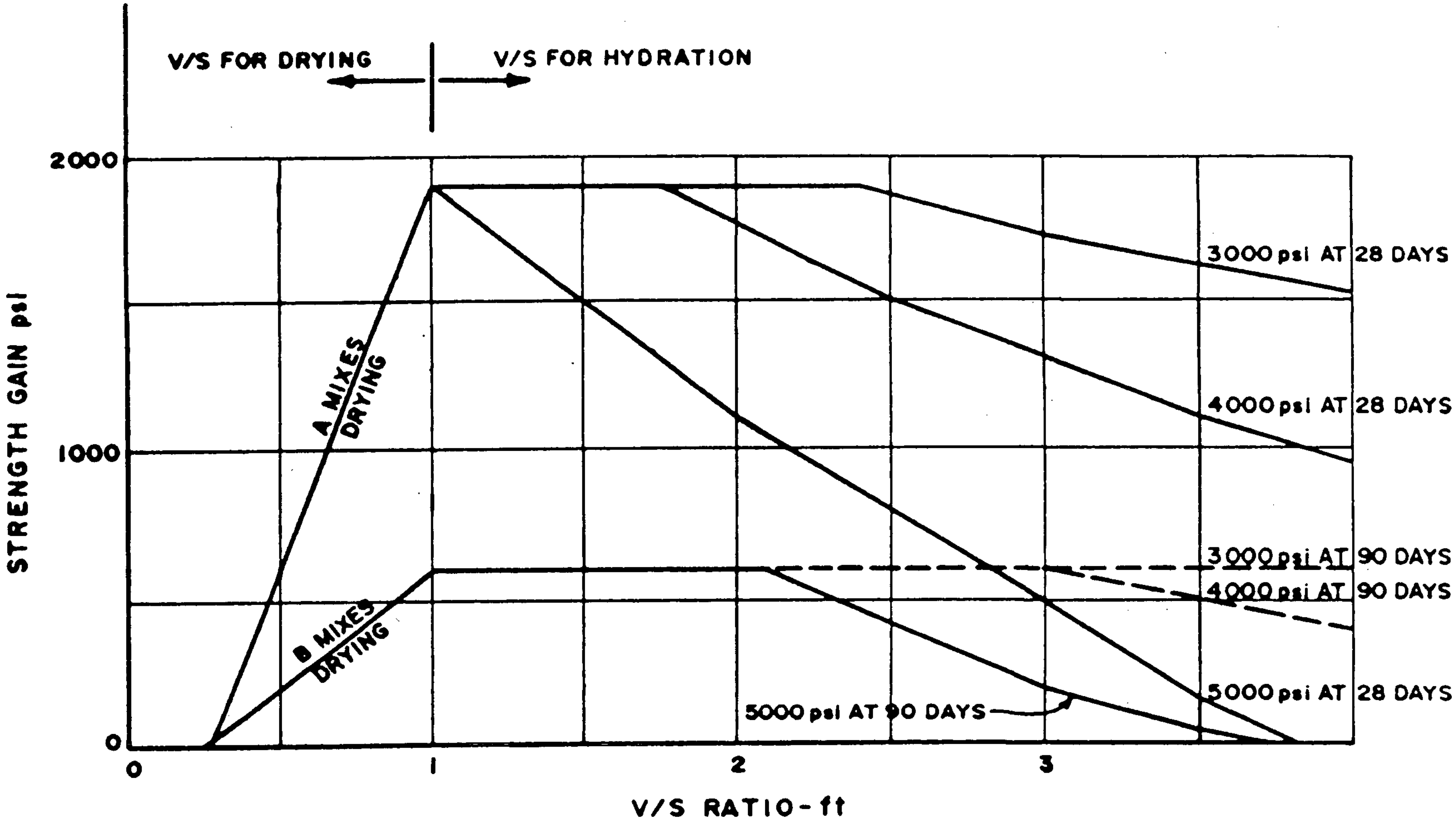

FIGURE D.1

NOTE: For guidelines on determination of V/S, see DS-C1.5.4.

APPENDIX E

EVALUATION OF EXISTING EMBEDDED PLATES

E.1 SCOPE

This appendix provides the methods for evaluation of embedded plates which were designed using the methods provided in Civil Design Standard DS-C6.1 (superseded by this standard in 1983). It also provides methods for evaluation of Type II embedded plates (see DS-C1.8.1) which were designed to the requirements of ACI 318.

E.2 EMBEDDED PLATES WITH WELDED STUD ANCHORS (TYPE I PLATES)

Criteria

For evaluation of existing embedded plates with welded stud anchors (Type I) which were designed in accordance with Civil Design Standard DS-C6.1, the embedment of the anchor shall be considered acceptable if the ultimate tensile capacity of the concrete is greater than 3.1 times the tensile service load in the anchor (see Section 7.0).

Basis for Criteria

DS-C6.1 required the embedment of the ductile anchors to be such that the ultimate concrete capacity was 1.25 times the minimum ultimate tensile capacity of the anchor. For welded stud anchors, the concrete capacity would be 1.25 times 60 k/in^2 times the steel area. Since the working load in the anchor is 0.55 times the yield strength (44 k/in^2 for welded studs), the factor of safety against concrete failure is therefore equal to 3.1 [(1.25 x 60)/(.55 x 44)].

DS-C1.7.1 which superseded DS-C6.1 is based on a factor-of-safety of four for ductile anchors. This change was to make the factor-of-safety against concrete failure independent of the ratio of the ultimate strength of the steel to the yield strength. However, the method given in DS-C6.1 is a valid method that conforms to the methods given in industry standards.

E.3 TYPE II EMBEDDED PLATES

Criteria

For evaluation of Type II embedded plates which were originally designed in accordance with the punching shear provisions of ACI 318, the embedment shall be considered acceptable if the ultimate tensile capacity of the concrete is greater than two times the tensile service load in the anchor (see Section 7.0). The ultimate concrete capacity (see subsection 7.1) shall be based on the following equation:

$$Pc = 4 \times \emptyset \times \sqrt{f'_c} \times Ac$$

APPENDIX E (Continued)

where:

Pc and F'_c are as defined in subsection 7.1

Ac = The effective area of the assumed pullout cone calculated in accordance with subsection 3.1 of DS-C1.8.1.

Ø = 0.85 for Type II embedments with the back plate beyond the far face reinforcement in the wall or slab, or

Ø = 0.65 for all other Type II embedments.

Basis for Criteria

The original design basis for Type II embedments was the ACI 318 requirements for punching shear. This method was the one used at the time these embedments were designed. The above criteria is based on present day industry standards which are somewhat more conservative than original design basis.

Added by R5

APPENDIX F

EVALUATION OF CONCRETE PULLOUT CAPACITY FOR EXISTING DUCTILE ANCHORS AT SEQUOYAH NUCLEAR PLANT

F.1 SCOPE

This appendix provides methods for evaluation of existing welded studs, grouted anchors, and cast-in-place anchors at Sequoyah Nuclear Plant.

F.2 CRITERIA

Existing anchors shall be evaluated in accordance with the methods presented within this standard. The embedment of the anchor will be considered acceptable if the ultimate tensile capacity of the concrete is greater than the required factor of safety times the tensile service load (or normalized load) in the anchor. The required factor of safety is given below. See Section 7.0 for description of tensile service loads.

$$F.S. = \frac{1.25\ F_{ULT}\ As}{.55\ Fy\ As}$$

$$= 2.27\ \frac{F_{ULT}}{Fy}$$

where:

F_{ULT} is the minimum specified tensile strength of the anchor and Fy is the yield strength of the anchor.

The above criteria is only applicable to evaluation of existing ductile anchors. All new anchors require a F.S. in accordance with Section 7.0.

F.3 BASIS FOR CRITERIA

Prior to the issue of DS-C6.1, there was no standard for the design of anchors other than the provisions of the ACI 318 code. Using the shear strength provisions of ACI 318-63 code, a factor of safety of 2 for normal working loads can be derived ($4\sqrt{f'c} \div 2\sqrt{f'c}$). Furthermore, the code would have allowed a factor of safety of 1.5 for earthquake ($4\sqrt{f'c} \div [1.33 \times 2\sqrt{f'c}]$ or $4\sqrt{f'c}$ x load factor $\div [4\phi\sqrt{f'c}]$ where load factor

Added by R5

APPENDIX F (Continued)

EVALUATION OF CONCRETE PULLOUT CAPACITY FOR EXISTING DUCTILE ANCHORS AT SEQUOYAH NUCLEAR PLANT

F.3 BASIS FOR CRITERIA (Continued)

equals 1.25 and Ø = 0.85). Since TVA's original design basis criteria (SQN-DC-V-1.1) allowed a 67 percent increase in allowable concrete stress or a load factor as low as 1.0 for safe shutdown earthquake loadings, the design basis factor of safety for abnormal loads is 1.20 = ($4\sqrt{f'c} \div [1.67 \times 2\sqrt{f'c}]$ or $4\sqrt{f'c}$ x load factor ÷ $[4\phi\sqrt{f'c}]$). These factors of safety are still considered acceptable for operability determinations in accordance with Section 10.3 of this standard.

DS-C6.1 required the calculated ultimate tensile capacity of the concrete to be 25 percent greater than the ultimate tensile capacity of the anchor. The requirement results in the equation for factor of safety in F.2 above. For normal loads, a factor of safety of 3.1 is derived for welded studs and 3.78 for A307 bolts. Since the methods in DS-C6.1 conform to industry standards, the factor of safety in F.2 above is considered acceptable for allowing continued use of an anchorage without modification.

The current requirement of a factor of safety of four times the tensile service load for ductile anchors was made to make the factor of safety against concrete failure independent of the ratio of the ultimate strength to yield strength of the steel.

Added by R5

APPENDIX G

EVALUATION OF EXISTING LEAD CAULKING EXPANSION ANCHORS

G.1 SCOPE

This appendix provides the methods and allowable load to be used in the evaluation of existing lead caulking expansion anchors.

G.2 CRITERIA

Self-drilling expansion anchors (SSDs) may have been substituted for lead caulking expansion anchors called for on some drawings. When possible, the person responsible for evaluating the capacity of lead caulking anchors should initiate an as-built inspection to ascertain the type of anchor installed. If the anchor is confirmed to be a lead caulking anchor or is inaccessible for inspection, the allowable loads in tension and shear in part G.3 shall be used to evaluate its capacity. Otherwise, the appropriate allowables for the type of anchor installed shall be used. With the exception of allowable loads, all provisions of this standard for SSD anchors apply equally to lead caulking anchors.

G.3 ALLOWABLE LOADS

Anchor Diameter (Inches)	Tension[1] (Kips)	Shear[2] (kips)
1/4	.32	.20
3/8	.80	.50
1/2	1.55	.90
5/8	2.10	1.20
3/4	2.68	1.35
7/8	3.55	1.50
1	5.19	1.70

[1] Provides a factor of safety of 5 in f'c = 3000 lb/in^2 concrete.
[2] Provides a factor of safety of 4 in f'c = 3000 lb/in^2 concrete.

Added by R5

APPENDIX G (Continued)

EVALUATION OF EXISTING LEAD CAULKING EXPANSION ANCHORS

G.4 REFERENCES

DNE Calculations, CSG-87-207 (B41 88 0107 004)

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APPENDIX H

PROCEDURE FOR CONSIDERATION OF CONSTRUCTION TOLERANCE (BROWNS FERRY NUCLEAR PLANT ONLY)

H.1 SCOPE

This procedure covers the amplification of bolt forces in expansion and ductile anchors and amplification of baseplate bending stresses to account for construction tolerances. The amplification accounts for location tolerances for the attachment and for location tolerances for the anchors. Amplification factors are provided for specific concentric 4-bolt baseplates with single attachments. The use of this procedure allows the designer to consider the most severe anchor forces and baseplate stresses resulting from the post installation condition.

This method specifically accounts for the installation tolerances for pipe supports given in drawing 47B435 series. This drawing gives tolerances for locations of the attachment on the baseplate and for location of anchors from their called for locations on the baseplate. The design dimension between the bolt hole and center of plate or attachment may be increased one inch. The design dimension between the bolt hole and the attachment may be decreased one-half inch total, including attachment relocation per TVA General Engineering Specification G-43.

H.2 APPLICABILITY

The procedure in Section H.3 shall be applied to new 4-bolt square base plates meeting the following descriptions. For baseplates not meeting these requirements a case by case evaluation must be performed.

1. The single attachment shall be centrally located on the baseplate and all 4-bolts shall have the same stiffness. In addition, the bolts shall be symmetrically located.

2. The bolt spacings shall be no less than 6 inches and no greater than 9 inches.

3. The bolt tensile stiffness shall be no less than 100 k/in and no greater than 1000 k/in.

4. For applicable attachment shapes and baseplate sizes, see Section H.3.

The use of an amplification factor is not required for the following conditions:

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APPENDIX H (Continued)

1. If the actual installed location of the anchors and attachment to the baseplate are known and are considered in the design.

2. If the potential effects of the tolerance on drawing 47B435 series are included in the design calculations.

3. If the potential effects of more, or less, restrictive tolerances are included in the design calculations and those tolerances are given on the drawing.

Issued calculations shall not be reviewed for the sole purpose of determining compliance with this Appendix.

Calculations revised after issue of this Appendix to address increased baseplate loads shall be verified to include one of the following:

(1) The actual installed location of the anchors and attachment to the baseplate have been considered in the design, or

(2) The potential effects of installation tolerances have been considered in accordance with drawing 47B435 series, or

(3) An amplification factor, applied to the loads determined without consideration of installation tolerances, in accordance with Section H.3, or

(4) The potential effects of more, or less restrictive tolerances are included in the design calculations and those tolerances are given in the design drawings.

H.3 PROCEDURE

Tensile and shear loads in expansion and ductile anchors determined in accordance with Section 5.0 shall be multiplied by the appropriate amplification factors given below to account for construction tolerances. In addition, a 1.7 exponent for bolt interaction shall be used.

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APPENDIX H (Continued)

CONFIGURATION ATTACHMENT	PLATE THK.	ANCHOR AMPLIFICATION FACTOR
TS 4 x 6	5/8"	1.45
	3/4"	1.41
	1"	1.35
TS 4 x 4	5/8"	1.47
	3/4"	1.43
	1"	1.39
W 4 x 13 M 4 x 13	5/8" To 3/4"	1.47
3.5" Pipe	5/8" To 3/4"	1.49
Other	5/8" to 1"	1.5

To account for construction tolerances, bending stresses in expansion and ductile anchored baseplates, which are calculated based on the unamplified anchor loads, shall be multiplied by the appropriate amplification factor given below. (Normalized anchor loads may be used if the amplified bending stress will be compared to the allowable stress for normal or service loading conditions).

CONFIGURATION ATTACHMENT	PLATE THK.	BASEPLATE AMPLIFICATION FACTOR
TS 4 x 6	5/8"	1.41
	3/4"	1.39
	1"	1.43
TS 4 x 4	5/8"	1.32
	3/4"	1.32
	1"	1.38
W 4 x 13 M 4 x 13	5/8" To 3/4"	1.32
3.5" Pipe	5/8" To 3/4"	1.29
Other	5/8" to 1"	1.40

H.4 REFERENCES

1. NE Calculation - 4-Bolt Baseplate Design Criteria Addressing Installation Tolerance (CD-Q000-893696, Revision 1).

2. NE Calculation - Construction Tolerance Justification for Calculation CD-Q000-894847, Revision 0).

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APPENDIX I

SHEAR CAPACITY OF ANCHORS LOCATED ADJACENT TO CIRCULAR PENETRATIONS

I.1 SCOPE

This appendix provides allowable shear loads for anchorages located adjacent to circular penetrations such as pipe sleeves.

I.2 CRITERIA

Figures I.1 and I.2 provide allowable loads for shear as a function of edge distance and penetration radius. The loads plotted are the ultimate capacity of a modified concrete push-off cone divided by a factor of safety of 4 using a specified concrete strength of 3000 psi.

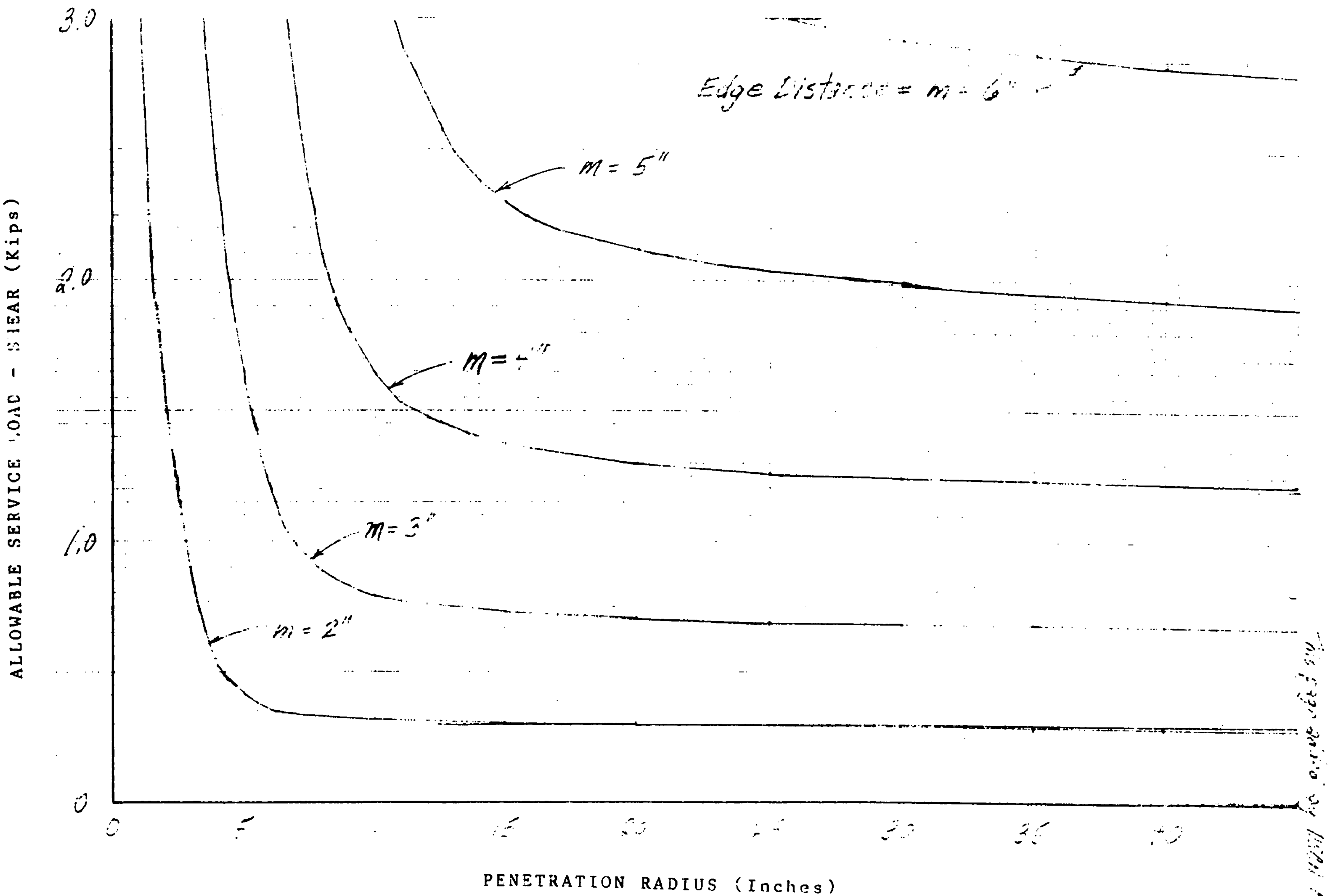
For specified concrete strengths greater than 3000 psi the load from the figures may be increased by $\sqrt{f'c} / \sqrt{3000}$. Concrete strength increases with age shall not be used.

I.3 BASIS FOR CRITERIA

The bases for the values provided in this appendix are included in Reference I.4.1.

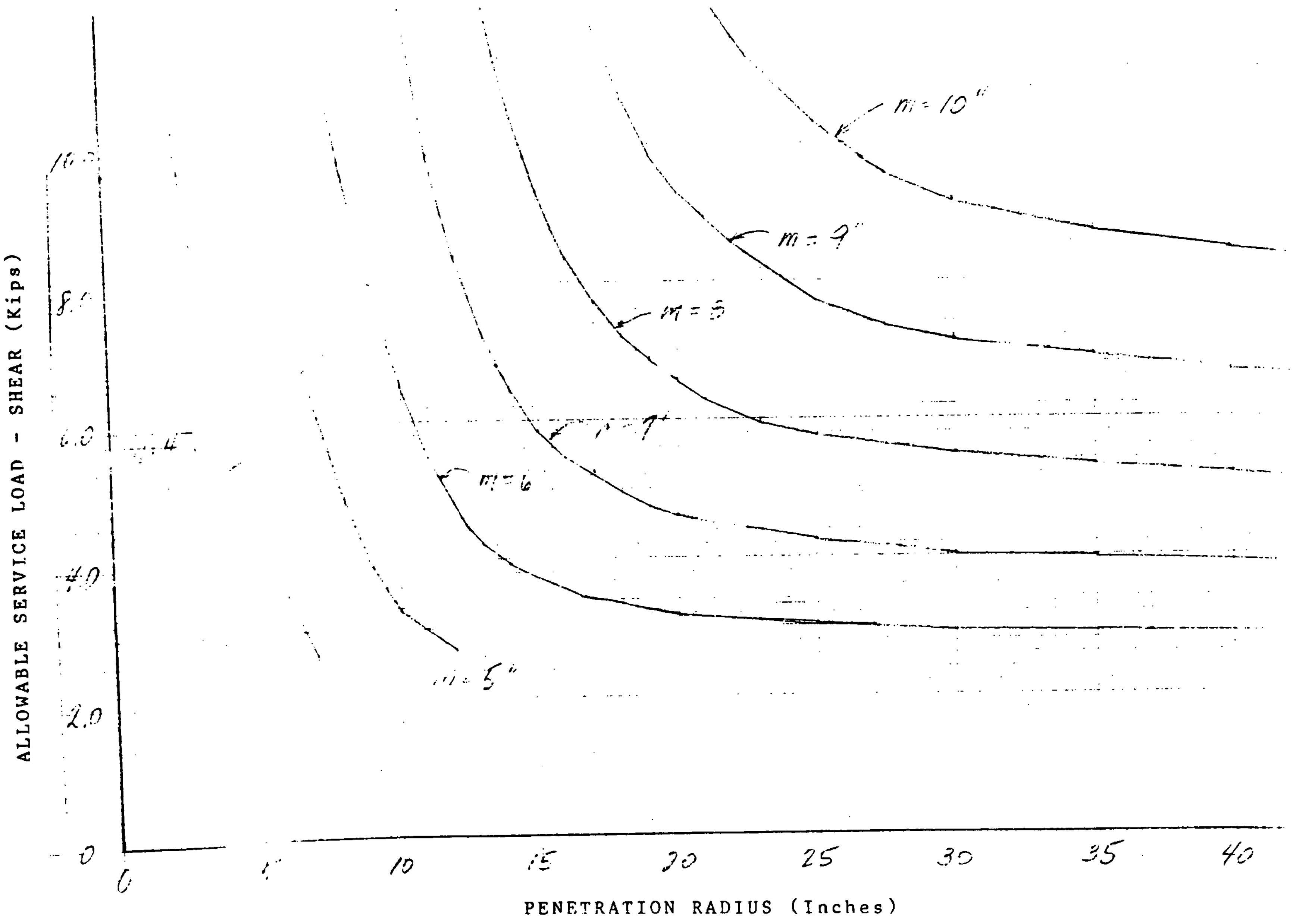
I.4 REFERENCES

I.4.1 Memorandum to the Civil Engineering Support Branch Files from Marvin A. Cones dated January 25, 1983 (CEB830125014).



ALLOWABLE SERVICE LOAD - SHEAR (Kips)
3.0
2.0
1.0
0
Edge Distance = m + 6"
m = 5"
m = 4"
m = 3"
m = 2"
0
5
PENETRATION RADIUS (Inches)

F I G I



ALLOWABLE SERVICE LOAD - SHEAR (Kips)
PENETRATION RADIUS (Inches)
m = 10"
m = 9"
m = 6
m = 5"
2.0
4.0
6.0
8.0
0
10
15
20
25
30
35
40

F I G U R E I.2

ENCLOSURE 1

RESPONSE TO NRC RAI
STRUCTURAL AND GEOSCIENCES ISSUES
SSER OUTSTANDING ISSUE 19(j)

Reference: TVA letter to USNRC Document Control Desk, WBN Evaluation Criteria for Steel Structures with Thermal Restraint, June 6, 1991

NRC Question 1:

Provide examples where the ductility ratio has been applied for an inelastic thermal deflection calculation of beams, frames, and columns which demonstrate their satisfactory use in the following areas:

a) Any industry standard for structural design currently in use (e.g., chemical or transportation industries) and
b) Theoretical discussion with verification by experimental data (include pertinent references).

It is essential to include simultaneous application of a dead load together with a thermal load in the above examples. Discuss also how repeated load (i.e., SSE) is considered in the example.

TVA Response 1:

1. a) The only known industry standard for structural design which could be interpreted to provide guidelines for acceptance of thermally loaded steel structures based on ductility is ANSI/AISC N690, Section Q1.5.8.

For ASME subsection NF design, the stresses induced by thermal expansion or gradient within a support are considered secondary. For level C and D service loads (equivalent to factored load combinations), evaluation is not required for secondary stresses. Also, it has long been nuclear industry practice, as stated in NUREG-0800, that thermal loads can be neglected when it can be shown that they are secondary and self-limiting in nature and where the material is ductile. This approach has been incorporated in the TVA methodology.

b) Enclosure 5 of TVA's referenced June 6 transmittal provides a test correlation study for thermal use of the ductility ratio. This correlation compares results of ANSYS computer models to actual tests where the steel behavior was in the inelastic range.

Loading combinations used in the design and evaluation of steel structures combine the thermal load with the applied dead loads and seismic loads. For further discussion of repeated loads, see the response to Question 2. For further discussion of load sequencing, see the response to Question 5.

NRC Question 2:

Provide a sample calculation of a structure subjected to thermal as well as other loads such as dead, live, and safe shutdown earthquake (SSE). The calculation should utilize the "ductility" concept as proposed in the FSAR Amendment 64. This calculation should deal with a representative structural member with relatively high stresses from the above loadings, including thermal. Provide justifications for any assumptions in generating the calculation results with an explicit demonstration that 1) effect of any assumptions in the final result is negligible or 2) physical data indicates that such assumptions are valid. Also, discuss how the temperature causing thermal stress was arrived at and how the transient nonuniform nature of temperature distribution on structural steel and concrete is considered.

Justification of the ductility factor should be provided. Justification should be based on a discussion where experimental data plays a predominant role rather than theoretical discussion. The above example calculation should include explicitly how energy balance and inelastic evaluations are performed. One should consider the repeated nature of SSE loads and the effect on the structure in inelastic region. (See Question 1).

TVA Response 2:

Calculation WCG-1-771 is provided in Attachment 1. This calculation represents two examples of the application of the thermal methodology in TVA's design guide and design criteria. The design guide and design criteria were provided as Enclosures 3 and 4, respectively, to the referenced June 6 transmittal. The calculation is based on load combinations using dead, live, and seismic loads. (Note: The criteria used for linear analysis has subsequently been revised to restrict the use of the energy balance method for acceptance). Evaluations of actual structures subjected to thermal loads are being prepared under the Thermal portion of the Seismic/Civil Validation Program.

The temperatures used in performing thermal analyses are obtained from Watts Bar environmental data drawing series, 47E235. This data is provided in the format of time-temperature curves and is based on engineering analysis and evaluations.

TVA uses the ductility factor to validate and bound the ductile characteristics of a structure subjected to thermal load. The ductile characteristic of carbon steel is seen from a plot of the variation of stress and corresponding strain. Attachment 2 provides a standard stress-strain curve. This curve shows that a structure is capable of sustaining significant strain-induced load past its elastic capabilities. If the ductility ratio is taken as actual strain divided by strain at yield, the ductility ratio at first yield is 1.0 and the ductility ratio at the onset of strain hardening is 0.014/0.00124, or 11.3. Establishing a limiting value of 3 for the ductility ratio provides an acceptable range to demonstrate ductile behavior while remaining well within the plastic behavior range of the material. Utilizing the structure's plastic characteristic is justified because the thermal loading is strain induced.

The ductility ratio of three based on displacement is also supported by the calculation provided as Enclosure 5 to the referenced June 6 transmittal. The calculation shows that the lateral deformation of the beam and the thermal axial reaction progress in a stable manner. This is demonstrated by the plots in Attachment 3. The points of interest on the plots are:

A. 160 degrees - Initial yield of extreme compression fiber at midspan.
B. 200 degrees - Peak axial reaction reached.
C. 410 degrees - At displacement ratio of 3, the member is responding in a stable manner to each incremental increase in temperature.
NOTE: The structure is stable and not vulnerable to collapse since the section forces are in equilibrium with respect to stress at any specific temperature. After 200 degrees the curvature of the displacement plot indicates that the displacement rate is decreasing with the rising temperature.

Enclosure 1 to our referenced June 6 transmittal provides discussion on use of energy balance. Energy balance is only used in the evaluation for shear and tension, and for compression of very short members.

Since the accident thermal load condition is a relatively short term event, the evaluation of repeated seismic loads is not necessary. Structures subjected to the combination of thermal and dead load may be in the inelastic range, but they do not "ratchet" significantly when repeated seismic loads are applied. This is because seismic cyclic load is below the elastic limit. To demonstrate this, studies have been performed on two thermal worst case structures. Ten cycles of SSE loads are applied after the loading combination of all applicable loads. Results indicate that the changes in displacement and plastic deformations are insignificant due to the cyclic SSE loads.

NRC Question 3:

In your May 8, 1991 response, it was stated that "For regions associated with the formation of a plastic hinge mechanism the maximum acceptable ductility ratio is 3.0 for inelastic analysis." Discuss how the above statement is related to Table 3.8E-2 of the FSAR, i.e., the proposed displacement ratio. Also, provide a specific numerical example where a plastic hinge is included in the beam evaluation.

TVA Response 3:

Table 3.8E-2 of the FSAR will be deleted at the next FSAR update as a result of the proposed revision provided in Enclosure 2 of our referenced June 6 transmittal. Thermal evaluations no longer rely on evaluation of a plastic hinge mechanism.

NRC Question 4:

Provide specific values for ε_μ and ε_γ for Watts Bar structural steel as a function of temperatures. Also, provide a basis for such values.

TVA Response 4:

Strain in the elastic region is equal to the stress divided by the modulus of elasticity. The modulus of elasticity reduces linearly from 29000 ksi at 70 degrees to 25000 ksi at 900 degrees. Therefore, the yield strain at 70 degrees is 0.00124 (Fy/E, or 36/29000) and the yield strain at 900 degrees is 0.00144 (36/25000). The ultimate strain is based on the specified elongation given in the ASTM specification. For A36 steel, the ultimate strain is 0.21 in/in. Table 3.8E-2 of the FSAR which uses the symbols ε_{μ} and ε_{γ} will be deleted at the next FSAR update.

NRC Question 5:

Use one of the load combinations (i.e., item 8 of page 3.8E-6) to demonstrate how different loadings and stresses are combined. When stresses are combined rather than loads, one should address the following:

When the resultant stresses are within elastic limits, the orders of combination, whether it is stress or load, would make no difference. However, the load combination item 8 of page 3.8E-6 allows the stresses to be in an inelastic region. In this case, the order would make a definite difference. Provide justification why stress combination is correct by means of physical data as well as theoretical analysis.

TVA Response 5:

Loads (instead of stresses) are combined in the nonlinear analysis. The load sequence first applies all nonthermal loads, including seismic, on the computer model. Incremental temperature steps are then applied starting at the ambient temperature and increasing to the accident temperature. This is the most critical loading sequence in terms of the ductility ratio results used for member qualification. The ductility ratio will be smaller if the SSE loads are applied after the thermal loads. This is due to the definition of ductility ratio being the final displacement divided by displacement at yield. Yielding occurs earlier for the loading sequence of applying SSE before thermal load. However, the final displacement results for both loading sequences are nearly identical. Parametric studies were performed on two worst case structures and the results indicated the differences are less than one percent comparing the maximum displacements on members with thermal restraint.

ATTACHMENT 1

NRC REQUEST FOR ADDITIONAL INFORMATION

ON THERMAL DESIGN METHODS