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Seismic Verification of Nuclear Plant Equipment Anchorage (Revision 1)

Volume 2: Anchorage Inspection Workbook

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Seismic Verification of Nuclear Plant Equipment Anchorage (Revision 1)

The anchorage guidelines provide utility engineers with comprehensive procedures and criteria for evaluating the seismic adequacy of a wide variety of equipment anchorage types, including expansion anchors, welds, cast-in-place (CIP) bolts, and other types of fasteners. These guidelines are the basis and principal reference for the anchorage evaluation procedures in the Seismic Qualification Utility Group (SQUG) Generic Implementation Procedure for resolution of Unresolved Safety Issue (USI) A-46.

INTEREST CATEGORIES

Nuclear seismic risk, design, and qualification
Nuclear component reliability

KEYWORDS

Earthquakes
Seismic effects
Seismic qualification
Electrical equipment
Mechanical equipment
Equipment anchorage

BACKGROUND Seismic evaluations of older nuclear power plants have indicated that equipment anchorage is one of the most important engineering features by which plant seismic capacity can be readily and practically improved. Equipment anchorage has become the focal point of walkdown procedures developed by SQUG and EPRI for resolution of both USI A-46 and seismic aspects of NRC Severe Accident Policy issues. Because of the variety of available anchorage devices, a generic assessment procedure is needed for resolution of each of these issues.

OBJECTIVE To develop guidelines for the seismic evaluation of equipment anchorage in existing nuclear power plants.

APPROACH For the original report, the research team collected test data on shear and pullout capacities of expansion anchors and developed allowable loads with appropriate safety factors. For CIP bolts and welds, they adopted existing industry guidelines. The team developed capacity reduction factors for various installation parameters such as close spacing and edge distance. They also formulated two alternative procedures for inspecting and evaluating bolts in a plant, including checklists and screening tables for different types of components. In the revision, the same team expanded the database to include a wider variety of bolt types and used recent test results to update and improve the capacity reduction factors. They also developed a computer program for rapid in-plant evaluation of anchor systems and added consideration of phenomena such as prying action, preload relaxation, and overall anchorage system stiffness.

RESULTS Report NP-5228-M, revision 1, summarizes the guidelines. Report NP-5228-SL, revision 1, consists of four volumes. Volume 1 contains the guidelines. Volume 2 provides a workbook for field evaluation. Volume 3 offers a user's manual for the computer program, EPRI/Blume Anchorage Computer Program (EBAC), used for comparison of demand and capacity. Volume 4 describes a major change to the guidelines, the addition of comprehensive calculation and inspection procedures for tank and heat exchanger anchorage. The anchorage criteria and procedures in these four volumes have been incorporated into the SQUG Generic Implementation Procedure for resolution of USI A-46. The guidelines have been successfully used in their original form in seismic evaluations of the Catawba, Maine Yankee, and E. I. Hatch nuclear power plants.

EPRI PERSPECTIVE It has long been a widely held opinion in the technical community that equipment anchorage should be the focus of any plant evaluation to assess seismic adequacy or improve plant seismic safety. This has been reflected to date in trial evaluations showing that (1) most "outlier" conditions are anchorage-related and relatively easy and inexpensive to resolve and (2) upon resolution, the anchorage capacity can be substantially in excess of design basis earthquake loads. This report, along with reports NP-5223, revision 1, and NP-7147, which provide generic equipment ruggedness spectra (GERS), and report NP-7148, which describes procedures to assess electrical relay seismic functionality, complements the seismic experience data collected by SQUG and EPRI to form the basis for cost-effective resolution of USI A-46.

PROJECT
RP2925-1
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Seismic Verification of Nuclear Plant Equipment Anchorage (Revision 1)

Volume 2: Anchorage Inspection Workbook

NP-5228-SL, Revision 1, Volume 2
Research Project 2925-1

Final Report, June 1991

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Revision Notice

This is Revision 1 of the EPRI Report NP-5228, Seismic Verification of Nuclear Plant Equipment Anchorage. The original version of NP-5228 was issued in May 1987 and consisted of Volume 1 and Volume 2. The present revision has changes to Volume 1 and Volume 2, which are indicated in the introduction section of Volume 1. The original version of NP-5228 should be discarded. Revision 1 also adds two new Volumes; Volume 3 titled, "EPRI/Blume Anchorage Computer Program EBAC", and Volume 4 titled, "Guidelines on Tanks and Heat Exchangers". Volumes 3 and 4 are new and did not exist in the original version of NP-5228.

ABSTRACT

Guidelines have been developed to evaluate the seismic adequacy of the anchorage of various classes of electrical and mechanical equipment in nuclear power plants covered by NRC Unresolved Safety Issue A-46. The guidelines consist of anchorage strength capacities as a function of key equipment and installation parameters. The strength criteria for expansion anchor bolts were developed by collecting and analyzing a large quantity of test data. The strength criteria for Cast-in-Place bolts and welds to embedded steel plates and channels were taken from existing nuclear-industry design guidelines. For anchorage used in low strength concrete and in concrete with cracks, appropriate strength reduction factors were developed. Reduction factors for parameters such as edge distance, spacing and embedment depth are also included. Based on the anchorage capacity and equipment configuration, inspection checklists for field verification of anchorage adequacy were developed, and provisions for outliers that can be used to further investigate anchorages that cannot be verified in the field were prepared. The screening tables are based on an analysis of the anchorage forces developed by common equipment types and on strength criteria to quantify the holding power of anchor bolts and welds. A computer code EBAC was developed for the evaluation of the adequacy of the equipment anchorage. Guidelines to evaluate anchorage adequacy for vertical and horizontal tanks and horizontal heat exchangers were also developed.

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INTRODUCTION

This volume, Volume 2, of the four-volume report "Seismic Verification of Nuclear Plant Equipment Anchorage", provides inspection checklists and screening criteria that can be used as tools for verifying the adequacy of the anchorage of various types of equipment during plant inspections. The screening criteria are the tables and charts that give the seismic capacity as a function of key anchorage parameters. The inspection checklists provide a field procedure for recording and documenting the verification of anchorage adequacy. The major elements of the checklists include determining anchorage capacity (by reference to the screening criteria), determining the seismic demand, comparison of capacity and demand, and inspection of fasteners for proper installation.

For proper use of the inspection checklists provided here, one should be familiar with the development of the guidelines described in Volume 1. In addition to the checks provided herein, structure load path including base stiffness and prying action must also be evaluated. Use of engineering judgement as discussed in Section 3, Volume 1, is recommended for structural load path evaluation. The following general assumptions have been made in developing the screening criteria and the inspection checklists:

- Concrete strength is assumed to be 4,000 psi or greater in the case of expansion anchors and 3,500 psi or greater for cast-in-place (C-I-P) bolts. (See Section 2 of Volume 1 for guidelines for lower strength concrete).
- Concrete is assumed to be sound concrete, i.e, with structural cracks 10 mills or smaller in width.
- Expansion anchor capacities are based on mean ultimate values given in Volume 1, Table 2-6 ($f_c' \geq 4$ ksi) with a knock-down factor (KDF) of 1.0. See discussion in Section 2, Volume 1, on KDFs for expansion anchors by manufacturer and type.
- For equipment anchored by expansion anchors that contains safety-related relays, use screening tables based on factor of safety of 4 (i.e.; those based on mean/4 capacity values).

- Welds are assumed to be fillet welds meeting the minimum length criteria (weld length ≥ 4x weld size).

- All dimensions and anchor locations shown in sketches are approximate. Field verification of actual equipment dimensions and anchor locations can be accomplished by visual observation. Field measurements are recommended in situations where visual observation leads to inconclusive results.

Inspection Checklist 1

MOTOR CONTROL PANELS

Use this checklist as follows, in conjunction with Section 6 of Volume 1:

- For "yes" answers proceed to the next line.
- For "no" answers proceed either to the provisions for outliers or to the section number indicated in parentheses.
- If any expansion anchor bolts do not pass the inspection procedure, reevaluate the anchorage using the bolts that pass.
- Check the appropriate box after completion of the checklist:

  [ ] Anchorage adequacy verified

  [ ] Additional evaluation required

Plant:_____ Location in Plant:_____

EquipmentDescription:_____

By/Date:_____ Checked/Date:_____

A. Conservative Anchorage

Determine the conservative anchorage. Use the following table if demand $\leq$ 0.8g.

Number of Cabinets	Number of Bolts Required per Side for Conservative Anchorage		
	3/8"	1/2"	5/8"
4	6	5	3
6	9	6	5
8	12	8	6
10	15	9	6

B. Existing Anchorage Conditions

B.1 Does existing anchorage exceed conservative anchorage given in A? ..... Yes_____ No_____ (B.3)

B.2 Do all bolts pass the following visual inspection? ..... Yes_____ No_____

- All bolts have nuts and washers.
- The concrete is sound.
- There are no large gaps between the equipment base and the concrete.
- The edge distance and spacing of all bolts are adequate (see Supplementary Table).
- There are no safety-related relays in equipment anchored by expansion anchors

STOP: Anchorage is adequate.

B.3 List type and size of fasteners (see Note 1).

Expansion Anchor Bolts

Manuf: _____ Type: _____ Unknown: _____ Diameter: _____

Number of bolts per side..... NB = _____

Welds to Embedded Steel

Number of welds per side..... NW = _____

Area of weld (fillet size x length)..... AW = _____

Number of studs per side..... NS = _____

Stud diameter..... DS = _____

None or Other: Go to provisions for outliers.

B.4 Number of cabinets in lineup ..... NC = _____

B.5 Is depth of cabinet $\geq$ 20"? ..... Yes_____ No_____

Is height of cabinet $\leq$ 90"? ..... Yes_____ No_____

Is the center of gravity approximately at midheight? ..... Yes_____ No_____

Note 1: If values vary, use minimum.

B.6 Are all adjacent cabinets in the lineup bolted together? ..... Yes_____ No_____

C. Demand

Record demand for this location in the plant ..... D = _____

D. Screening Procedure for Expansion Anchor Bolt Anchorage

D.1 Using NB and NC values from Section B, determine anchorage capacity, G, from screening tables:

- Screening Table 1.1 based on Mean/4 (equipment with safety-related relays)
- Screening Table 1.2 based on Mean/3

G =_____

D.2 Is demand less than capacity? ..... Yes_____ No_____

D.3 Are edge distance and spacing of bolts adequate? (see Supplementary Table) ..... Yes_____ No_____

D.4 Do bolts pass the attached inspection guidelines? ..... Yes_____ No_____

STOP: Anchorage is adequate.

E. Screening Procedure for Welded Anchorage

E.1 Determine weld capacity, GW, from Screening Table 1.3, using NW, NC, and AW values from Section B ..... GW = _____

E.2 Determine stud capacity, GS, from Screening Table 1.4, using NS, NC, and DS values from Section B ..... GS = _____

E.3 Determine anchorage capacity, G, which is the lesser of GW and GS ..... G = _____

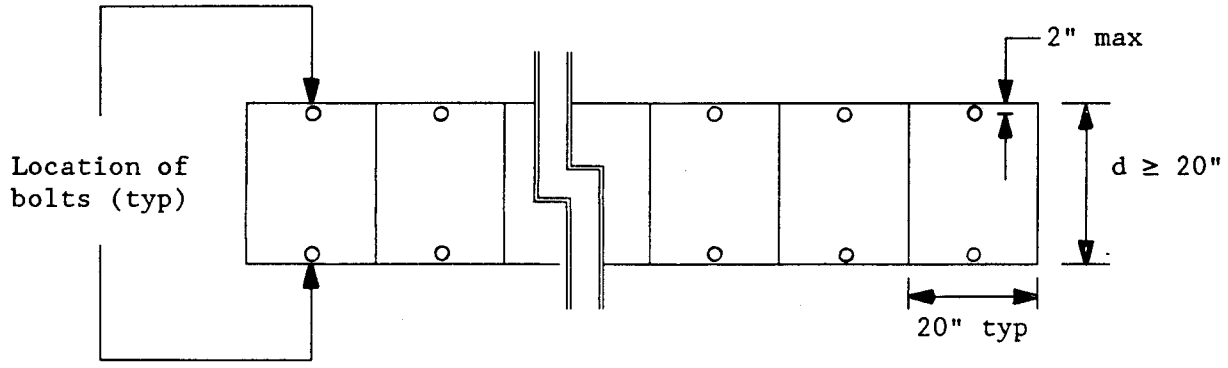
E.4 Is demand less than capacity? ..... Yes_____ No_____

STOP: Anchorage is adequate.

Screening Table 1.1

SCREENING CRITERIA FOR MOTOR CONTROL CENTERS
ANCHORED WITH EXPANSION ANCHOR BOLTS USING MEAN/4 CRITERION

Number of Cabinets (NC)	Number of Bolts per side (NB)	Seismic Capacity (g)		
		3/8" Bolts	1/2" Bolts	5/8" Bolts
2	2	0.8	1.2	1.5
	4	1.4	2.2	2.7
4	4	0.8	1.2	1.5
	8	1.4	2.2	2.7
6	4	0.6	0.9	1.1
	6	0.8	1.2	1.6
	12	1.4	2.2	2.7
8	6	0.7	1.0	1.3
	8	0.8	1.2	1.6
	16	1.4	2.2	2.7
10	6	0.6	0.8	1.0
	8	0.7	1.0	1.3
	10	0.8	1.2	1.6
	20	1.4	2.2	2.7



MCC Base Plan

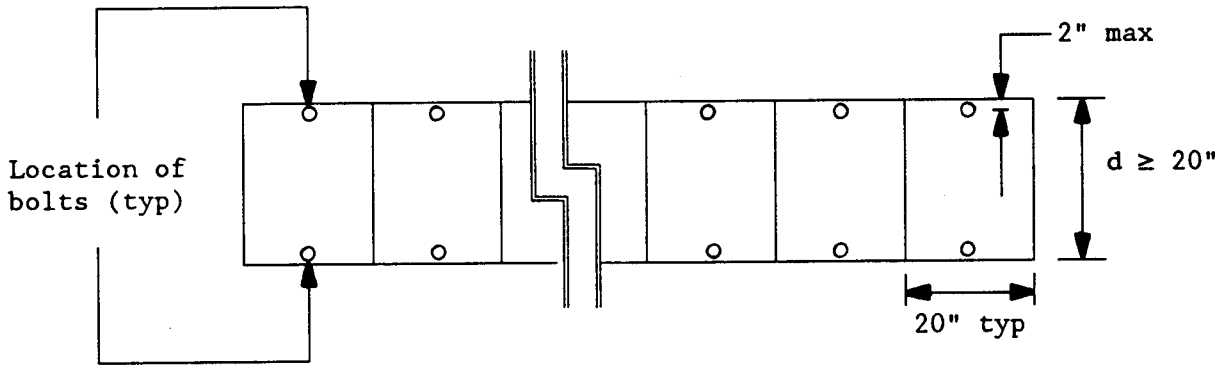
Weight ≤ 625 lb/unit
Height of center of gravity ≤ 45"

Notes:
1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum
2. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 6.

Screening Table 1.2

SCREENING CRITERIA FOR MOTOR CONTROL CENTERS
ANCHORED WITH EXPANSION ANCHOR BOLTS USING MEAN/3 CRITERION

Number of Cabinets (NC)	Number of Bolts per side (NB)	Seismic Capacity (g)		
		3/8" Bolts	1/2" Bolts	5/8" Bolts
2	2	1.1	1.6	2.0
	4	1.9	2.9	3.6
4	4	1.1	1.6	2.0
	8	1.9	2.9	3.6
6	4	0.8	1.2	1.5
	6	1.1	1.6	2.1
	12	1.9	2.9	3.6
8	6	0.9	1.3	1.7
	8	1.1	1.6	2.1
	16	1.9	2.9	3.6
10	6	0.8	1.1	1.3
	8	0.9	1.3	1.7
	10	1.1	1.6	2.1
	20	1.9	2.9	3.6



MCC Base Plan

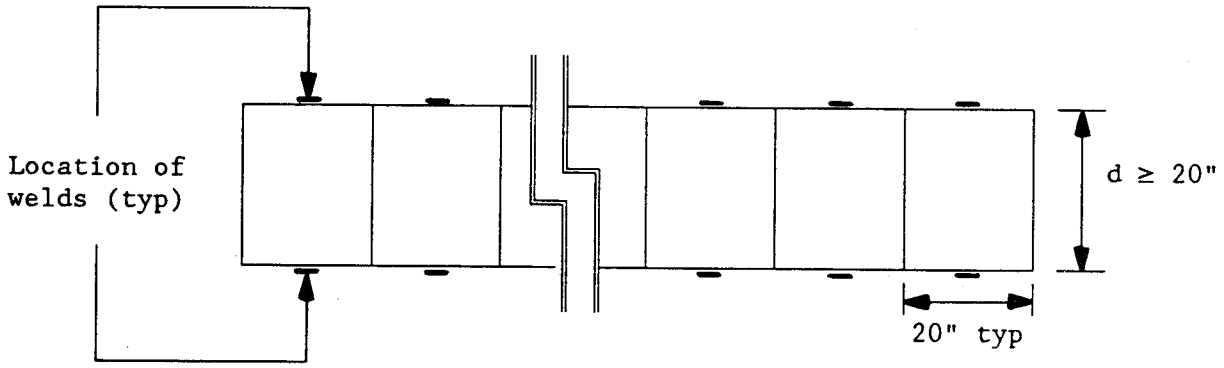
Weight ≤ 625 lb/unit
Height of center of gravity ≤ 45"

Notes:
1. $f'_c \geq 3{,}500$ psi; uncracked concrete; embedment, spacing and edge distance ≥ recommended minimum
2. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 6.

Screening Table 1.3

SCREENING CRITERIA FOR MOTOR CONTROL CENTERS ANCHORED WITH WELDS

Number of Cabinets (NC)	Number of Welds per Side (NW)	Seismic Capacity, GW (g)	
		Welds = 0.064 in.^{2}	Welds > 0.125 in.^{2}
2	2	0.9	1.6
	4	1.7	3.0
4	4	0.9	1.6
	8	1.7	3.0
6	4	0.7	1.1
	6	0.9	1.6
	12	1.7	2.9
8	6	0.8	1.3
	8	1.0	1.6
	16	1.7	2.9
10	6	0.7	1.1
	8	0.8	1.3
	10	1.0	1.6
	20	1.7	2.9



MCC Base Plan

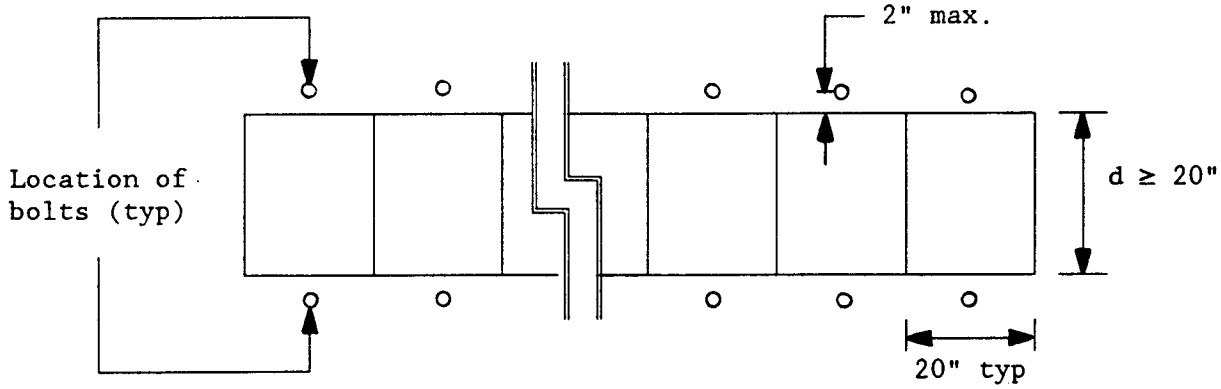
Weight ≤ 625 lb/unit
Height of center of gravity ≤ 45"

Notes: 1. For assumptions on anchor layout, equipment base, etc., see Volume 1, Section 6.

Screening Table 1.4

SCREENING CRITERIA FOR MOTOR CONTROL CENTERS
ANCHORED WITH HEADED STUDS ANCHORING EMBEDDED PLATES

Number of Cabinets (NC)	Number of Studs per Side (NS)	Seismic Capacity, GS (g)	
		1/4" Studs	Studs 3/8" and larger
2	2	1.0	1.6
	4	1.9	3.0
4	4	1.0	1.6
	8	1.9	3.0
6	4	0.8	1.1
	6	1.1	1.6
	12	1.9	2.9
8	6	0.8	1.2
	8	1.1	1.6
	16	1.9	2.9
10	6	0.7	1.1
	8	0.9	1.3
	10	1.1	1.6
	20	1.9	2.9



MCC Base Plan

Weight ≤ 625 lb/unit
Height of center of gravity ≤ 45"

Notes:
1. $f'_c \geq 3{,}500$ psi; uncracked concrete; embedment, spacing and edge distance ≥ recommended minimum
2. For other assumptions on anchor layout,equipment base, etc., see Volume 1, Section 6.

Supplementary Table

REQUIRED EDGE DISTANCE, SPACING, AND EMBEDMENT FOR BOLTS

REQUIREMENTS FOR CAST-IN-PLACE BOLTS AND HEADED STUDS:

Bolt Diameter (in.)	Minimum Edge Distance (in.)	Minimum Spacing (in.)	Minimum Embedment (in.)
3/8	3-3/8	4-3/4	3-3/4
1/2	4-3/8	6-1/4	5
5/8	5-1/2	7-7/8	6-1/4
3/4	6-5/8	9-1/2	7-1/2
7/8	7-3/4	11	8-3/4
1	8-3/4	12-5/8	10
1-1/8	9-7/8	14-1/4	11-1/4
1-1/4	11	15-3/4	12-1/2
1-3/8	12-1/8	17-3/8	13-3/4

REQUIREMENTS FOR EXPANSION ANCHOR BOLTS:

Bolt Diameter (in.)	Minimum Edge Distance and Spacing (in.)
3/8	3-3/4
1/2	5
5/8	6-1/4
3/4	7-1/2
7/8	8-3/4
1	10

INSPECTION GUIDELINES FOR EXPANSION ANCHOR BOLTS

If the answers to all the following questions are yes, the bolts pass inspection. As discussed in Section 2 of Volume 1, only a sample of bolts need be inspected for tightness unless safety-related relays are present in the equipment. Other inspections requirements are visual in nature and should be applied to all bolts.

1. Are the nut and anchor bolt tight (not turning in the hole)? ..... Yes_____ No_____
2. Is there a washer between the equipment base and the bolt head or nut? ..... Yes_____ No_____
3. Is the concrete sound? ..... Yes_____ No_____
4. Is the gap between the equipment base and the concrete surface less than or equal to 1/4"? ..... Yes_____ No_____
5. Is the bolt installed with at least the minimum required embedment shown below? ..... Yes_____ No_____

   For shell bolts, the minimum embedment is ensured if the shell does not protrude above the surface of the concrete. For nonshell bolts, the minimum embedment is ensured if the projection of the bolt above the concrete surface conforms with the following:

Bolt Diameter (in.)	Range of Bolt Projection (in.)
3/8	1/2 - 3/4
1/2	1/2 - 3/4
5/8	1/2 - 7/8
3/4	7/8 - 1-1/2
7/8	1-1/2 - 2
1	1-1/2 - 2

For further elaboration, see Step 8 of "Expansion Anchor Inspection Procedure" in Section 2 of Volume 1.

Inspection Checklist 2

FLOOR-MOUNTED BATTERY CHARGERS AND INVERTERS

Use this checklist as follows, in conjunction with Section 7 of Volume 1:

- For "yes" answers proceed to the next line.
- For "no" answers proceed either to the provisions for outliers or to the section number indicated in parentheses.
- If any expansion anchor bolts do not pass the inspection procedure, reevaluate the anchorage using the bolts that pass.
- Check the appropriate box after completion of the checklist:

  [ ] Anchorage adequacy verified

  [ ] Additional evaluation required

Plant:_____ Location in Plant:_____

Equipment Description:_____

By/Date:_____ Checked/Date:_____

A. Conservative Anchorage

Determine the conservative anchorage. Use Table 2.1 if demand $\leq$ 0.8g.

Type: _____ Size: _____ Number per Side: _____

B. Existing Anchorage Conditions

B.1 Does existing anchorage exceed conservative anchorage given in A? ..... Yes_____ No_____ (B.3)

B.2 Do all bolts pass the following visual inspection? ..... Yes_____ No_____

- All bolts have nuts and washers.
- The concrete is sound.
- There are no large gaps between the equipment base and the concrete.

- Edge distance and spacing of all bolts are adequate (see Supplementary Table)

- There are no safety-related relays in equipment anchored by expansion anchors.

STOP: Anchorage is adequate.

B.3 Type and size of fasteners (see Note 1):

Expansion Anchor Bolts

Manuf: _____ Type: _____ Unknown: _____ Diameter: = _____

Does each cabinet in the lineup have at least two bolts per side (see Note 2)? .....Yes_____ No_____

None or Other: Go to provisions for outliers.

B.4 Dimension of one cabinet in the lineup (see Notes 2 and 3):

Height ..... H = _____

Depth ..... B = _____

Length ..... L = _____

Aspect Ratio ..... H/B = _____

B.5 Are $L \leq 64"$, $B \leq 40"$, and $H/B \leq 4$? ..... Yes_____ No_____

B.6 Is the center of gravity approximately at midheight? ..... Yes_____ No_____

C. Demand

Record demand for this location in the plant ..... D = _____

D. Screening Procedure for Expansion Anchor Bolt Anchorage

D.1 Using Band H/B values from Section B, determine anchorage capacity, G, from Screening Figure 2.1 or 2.2 ..... G = _____

D.2 Is demand less than capacity? ..... Yes_____ No_____

D.3 Are edge distance and spacing of all bolts adequate (see Supplementary Table)? .... Yes_____ No_____

D.4 Do bolts pass the attached inspection guidelines? ..... Yes_____ No_____

STOP: Anchorage is adequate.

Notes:

1. If values vary, use minimum.
2. See Section 7 of Volume 1 for an alternative approach for multicabinet lineups.
3. If values vary, use maximum.

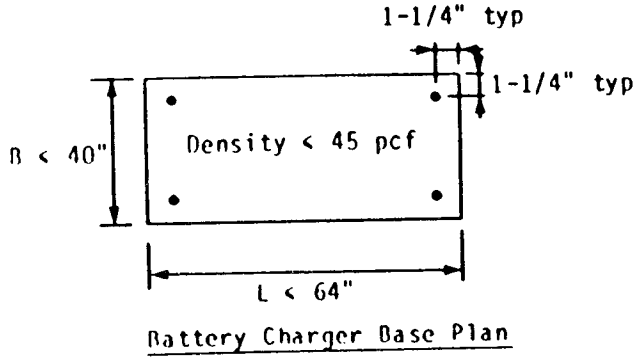
Screening Table 2.1

CONSERVATIVE ANCHORAGE FOR BATTERY CHARGERS
AND INVERTERS FOR DEMAND ≤ 0.8g

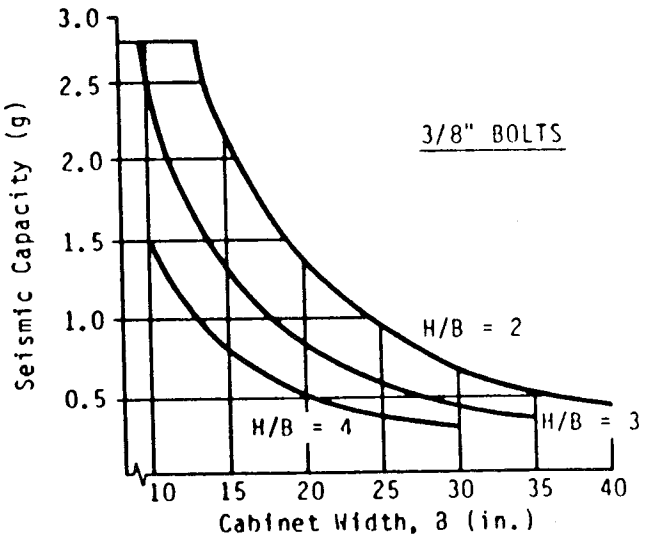
Cabinet Width* (in.)	Cabinet Height (in.)	Conservative Anchorage	
		Number of Bolts	Diameter of Bolts (in.)
15	60	6	3/8
	45	6	3/8
20	80	6	1/2
	60	6	3/8
	40	6	3/8
25	100	6	5/8
	75	6	1/2
	50	6	3/8
30	90	6	5/8
	60	6	1/2
35	70	6	5/8
40	80	6	5/8

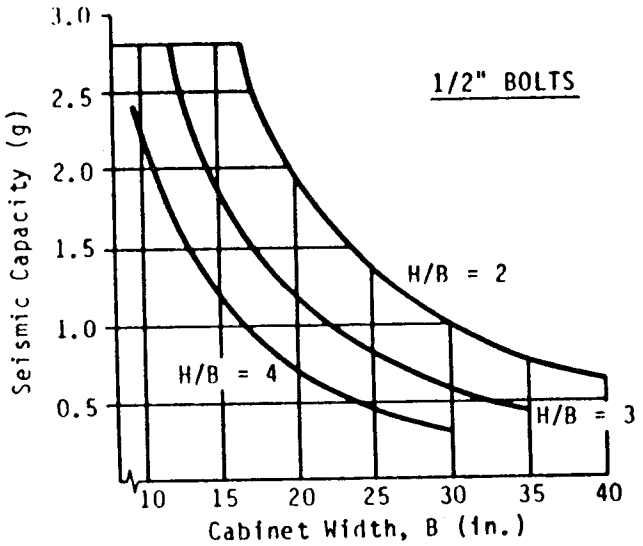
*See Screening Figure 2.1

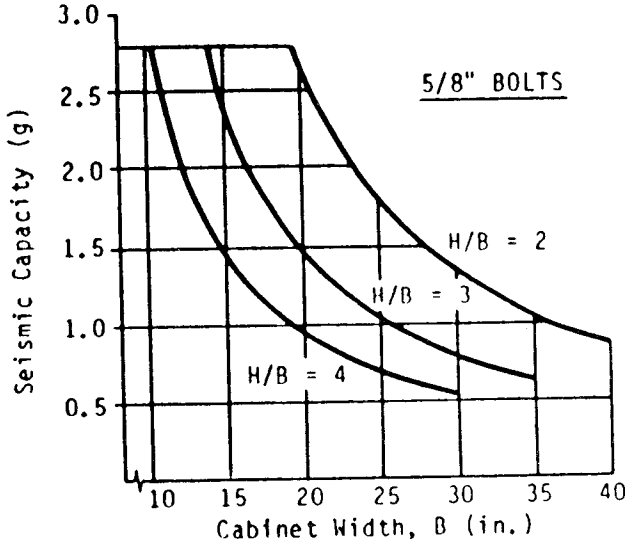
Notes: 1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum.
2. For other assumptions on layout, equipment base, etc., see Volume 1, Section 7.



Battery Charger Base Plan



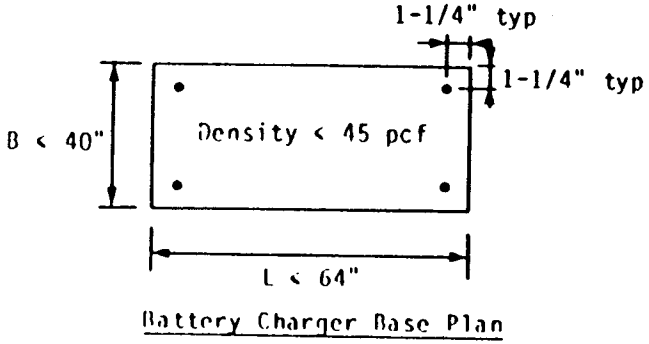




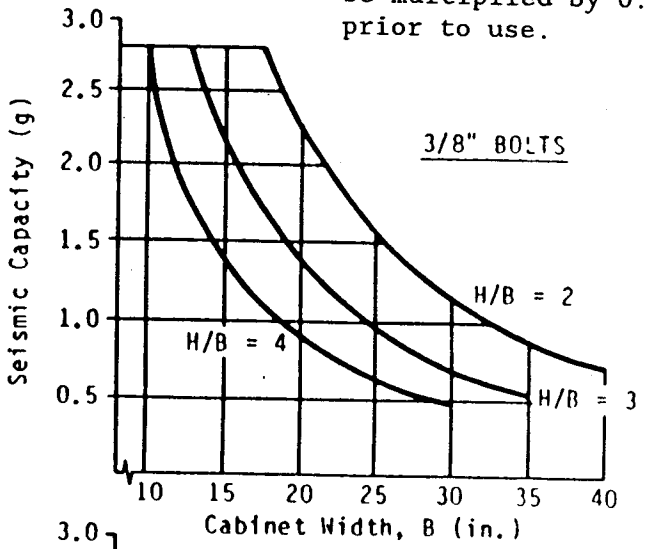
Screening Figure 2.1 Screening Criteria for Floor-Mounted Battery Chargers and Inverters Anchored by Expansion Anchors Using Mean/4 Criterion

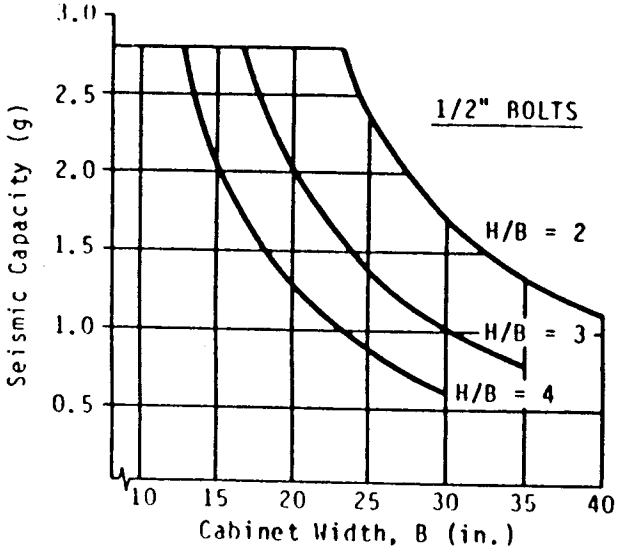
Notes: 1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum.
2. For other assumptions on layout, equipment base, etc., see Volume 1, Section 7.

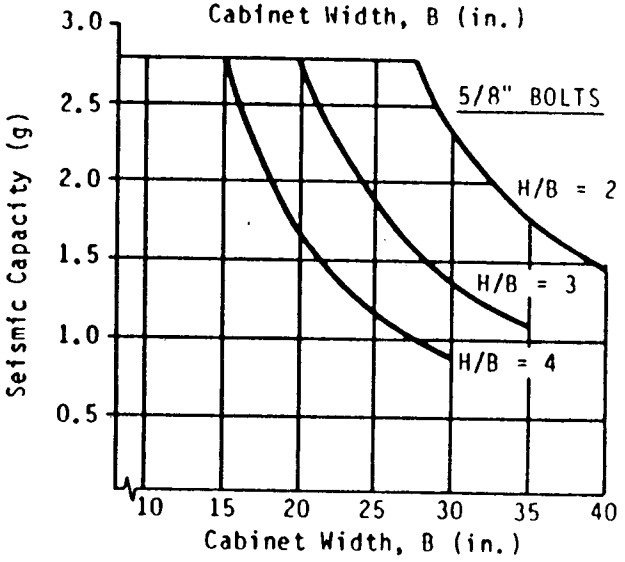
NOTE: These curves are based upon Mean/2 and need to be multiplied by 0.67 prior to use.



Battery Charger Base Plan







Screening Figure 2.2 Screening Criteria for Floor-Mounted Battery Chargers and Inverters Anchored by Expansion Anchors Using Mean/3 Criterion

Supplementary Table

REQUIRED EDGE DISTANCE, SPACING, AND EMBEDMENT FOR BOLTS

REQUIREMENTS FOR CAST-IN-PLACE BOLTS AND HEADED STUDS

Bolt Diameter (in.)	Minimum Edge Distance (in.)	Minimum Spacing (in.)	Minimum Embedment (in.)
3/8	3-3/8	4-3/4	3-3/4
1/2	4-3/8	6-1/4	5
5/8	5-1/2	7-7/8	6-1/4
3/4	6-5/8	9-1/2	7-1/2
7/8	7-3/4	11	8-3/4
1	8-3/4	12-5/8	10
1-1/8	9-7/8	14-1/4	11-1/4
1-1/4	11	15-3/4	12-1/2
1-3/8	12-1/8	17-3/8	13-3/4

REQUIREMENTS FOR EXPANSION ANCHOR BOLTS

Bolt Diameter (in.)	Minimum Edge Distance and Spacing (in.)
3/8	3-3/4
1/2	5
5/8	6-1/4
3/4	7-1/2
7/8	8-3/4
1	10

INSPECTION GUIDELINES FOR EXPANSION ANCHOR BOLTS

If the answers to all the following questions are yes, the bolts pass inspection. Only a sample of bolts need be inspected, as discussed in Section 2 of Volume 1.

1. Are the nut and anchor bolt tight (not turning in the hole)? ..... Yes_____ No_____
2. Is there a washer between the equipment base and the bolt head or nut? ..... Yes_____ No_____
3. Is the concrete sound? ..... Yes_____ No_____
4. Is the gap between the equipment base and the concrete surface less than or equal to 1/4"? ..... Yes_____ No_____
5. Is the bolt installed with at least the minimum required embedment shown below? ..... Yes_____ No_____

   For shell bolts, the minimum embedment is ensured if the shell does not protrude above the surface of the concrete. For nonshell bolts, the minimum embedment is ensured if the projection of the bolt above the surface conforms with the following:

Bolt Diameter (in.)	Range of Bolt Projection (in.)
3/8	1/2 - 3/4
1/2	1/2 - 3/4
5/8	1/2 - 7/8
3/4	7/8 - 1-1/2
7/8	1-1/2 - 2
1	1-1/2 - 2

For further elaboration, see Step 8 of "Expansion Anchor Inspection Procedure" in Section 2 of Volume 1.

Inspection Checklist 3

HORIZONTAL PUMPS AND MOTORS

Use this checklist as follows, in conjunction with Section 8 of Volume 1:

- For "yes" answers proceed to the next line.
- For "no" answers proceed either to the provisions for outliers or to the section number indicated in parentheses.
- If any cast-in-place bolts do not pass the inspection procedure, reevaluate the anchorage using the bolts that pass.
- Check the appropriate box after completion of the checklist:

  [ ] Anchorage adequacy verified

  [ ] Additional evaluation required

Plant:_____ Location in Plant:_____

Equipment Description:_____ Horsepower:_____

By/Date:_____ Checked/Date:_____

A. For Conditions Where ZPA ≤ 0.2g.

A.1 Is the existing anchorage equal to or greater than four 1/2-in. cast-in-place bolts? ..... Yes_____ No_____ (B.1)

A.2 Is the anchorage detail free of any vibration isolation spring mounts, friction clips, and expansion bolts? ..... Yes_____ No_____

A.3 Are the edge distance, embedment, and spacing of bolts adequate (see Supplementary Table)? ..Yes_____ No_____

A.4 Is the concrete around bolts sound? ..... Yes_____ No_____

A.5 Are the pump and motor rigidly bolted or welded to the steel skid (not with over-sized or slotted holes)? ..... Yes_____ No_____

STOP: Anchorage is adequate.

B. For Conditions Where $0.2g < ZPA \leq 0.75g$

B.1 Number and size of cast-in-place bolts (with fully engaged, tight nuts) per side attaching steel skid to concrete ..... Number:_____

Size:_____

B.2 Overall dimensions (see Screening Table 3.1) D1 = _____

D2 = _____

D3 = _____

B.3 Dimensional ratios ..... D1/D2 = _____

D1/D3 = _____

C. Required Anchorage

Determine required anchorage from Screening Table 3.1.

C.1 Number of bolts per side ..... _____

C.2 Size ..... _____

D. Screening Procedure

D.1 Are the number and size of bolts adequate? .... Yes_____ No_____

D.2 Are edge distance, embedment, and spacing of bolts adequate (see Supplementary Table)? .. Yes_____ No_____

D.3 Is the concrete around the bolts sound? ..... Yes_____ No_____

D.4 Does attached piping on both the suction and the discharge sides of the pump have a rigid anchor within 10 to 15 ft of the nozzles? ..... Yes_____ No_____

D.5 Are the pump and motor rigidly bolted or welded to the steel skid (not with oversized or slotted holes)? ..... Yes_____ No_____

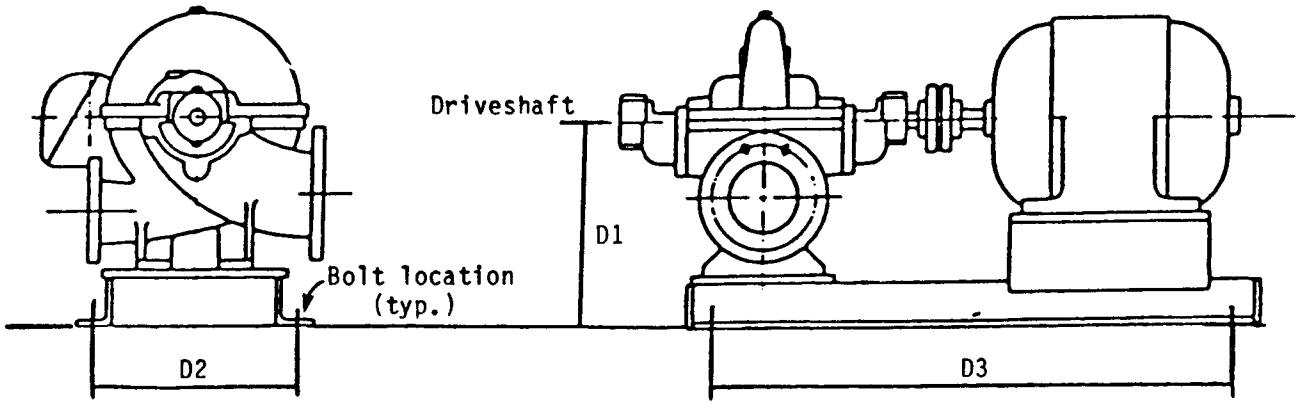
D.6 Is the center of gravity approximately at the centerline of the drive shaft? ..... Yes_____ No_____

STOP: Anchorage is adequate.

Screening Table 3.1

SCREENING CRITERIA FOR HORIZONTAL PUMPS AND MOTORS ON A COMMON STEEL SKID

Motor Horsepower	Maximum D1/D2	Maximum D1/D3	Required Bolt Size			
			2/side	3/Side	4/Side	5/Side
1,000	1.67	0.6	1-1/8"	1"	7/8"	3/4"
600	1.33	0.5	1"	7/8"	3/4"	5/8"
500	1.33	0.5	3/4"	5/8"	5/8"	1/2"
400	1.33	0.5	5/8"	5/8"	1/2"	1/2"
200	0.83	0.63	1/2"	1/2"	1/2"	1/2"
100 or less	1.43	0.63	1/2"	1/2"	3/8"	3/8"



Typical Installation

Notes: 1. $f'_c \geq 3{,}500$ psi; uncracked concrete; embedment, spacing and edge distance ≥ recommended minimum

2. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 8.

Supplementary Table

REQUIRED EDGE DISTANCE, SPACING, AND EMBEDMENT FOR BOLTS

REQUIREMENTS FOR CAST-IN-PLACE BOLTS AND HEADED STUDS

Bolt Diameter (in.)	Minimum Edge Distance (in.)	Minimum Spacing (in.)	Minimum Embedment (in.)
3/8	3-3/8	4-3/4	3-3/4
1/2	4-3/8	6-1/4	5
5/8	5-1/2	7-7/8	6-1/4
3/4	6-5/8	9-1/2	7-1/2
7/8	7-3/4	11	8-3/4
1	8-3/4	12-5/8	10
1-1/8	9-7/8	14-1/4	11-1/4
1-1/4	11	15-3/4	12-1/2
1-3/8	12-1/8	17-3/8	13-3/4

REQUIREMENTS FOR EXPANSION ANCHOR BOLTS

Bolt Diameter (in.)	Minimum Edge Distance and Spacing (in.)
3/8	3-3/4
1/2	5
5/8	6-1/4
3/4	7-1/2
7/8	8-3/4
1	10

Inspection Checklist 4

VERTICAL PUMPS AND MOTORS

To use this checklist:

- For "yes" answers proceed to the next line.
- For "no" answers proceed either to the provisions for outliers.
- Determine type of pump (i.e., 1, 2, or 3) using the guidelines given in Section 9 of Volume 1.
- If any cast-in-place bolts do not pass the inspection procedure, reevaluate the anchorage using the bolts that pass.
- Check both pump and motor if pump and motor are independently mounted.
- Check the appropriate box after completion of the checklist:

  [ ] Anchorage adequacy verified

  [ ] Additional evaluation required

Plant:_____ Location in Plant:_____

Pump Type:_____ Horsepower:_____

By/Date:_____ Checked/Date:_____

A. For Conditions Where Seismic Demand $\leq$ 0.16g

A.1 Is the existing anchorage equal to or greater than four 3/4-in. cast-in-place bolts or four 1/2-in^2 welds? ..... Yes_____ No_____

A.2 Is the anchorage detail free of any vibration isolation spring mounts? ..... Yes_____ No_____

A.3 Are the edge distance, embedment, and spacing of bolts adequate? (See Supplementary Table).... Yes_____ No_____

A.4 Is the concrete around bolts sound? ..... Yes_____ No_____

A.5 Attached Piping:

- For Pump Types 1 and 3, is the discharge piping anchored within 30 ft of the pump nozzle? ..... Yes_____ No_____

- For Pump Type 2, is both suction and discharge piping anchored within 15 ft of nozzles? ..... Yes_____ No_____

If all answers are yes, anchorage is adequate.

B. <u>For Conditions Where Seismic Demand > 0.16g</u>

B.1 Record demand for this location in plant

- For Type 1 pumps, record the demand from the appropriate demand spectrum, 5%-damped, at calculated or measured frequency of the pump, or record peak of demand spectrum ..... _____
- For Type 2 or Type 3 pumps, record the ZPA from the appropriate demand spectrum ..... _____

B.2 Number and size of cast-in-place bolts (with fully engaged, tight nuts) or number and size of welds ..... Number:_____

Size:_____

B.3 Horsepower of motor driving pump ..... _____

B.4 Determine anchorage capacity using Screening Table 4.1 ..... _____

C. <u>Screening Procedure</u>

C.1 Is demand less than capacity? ..... Yes_____ No_____

C.2 Are conditions A.2 to A.5 above satisfied? ... Yes_____ No_____

If all answers are yes, then anchorage is adequate. If any are no, see provisions for outliers.

Screening Table 4.1

SCREENING CRITERIA FOR VERTICAL PUMPS AND MOTORS

Pump Type	Number and Diameter (in.) of Cast-in-Place Bolts						Number and Area (in.²) of Welds					
	4 1/2	8 1/2	4 5/8	4 3/4	4 1	4 1-1/4	4 1/4	8 1/4	4 3/8	4 1/2	4 1	4 1-1/2
1. Vertical immersion pumps up to 150 hp with total weight up to 4,000 lb (note 1).	1.0g	1.6g	1.6g	2.0g	--	--	1.0g	1.6g	1.6g	2.0g		
2. Single-stage centrifugal pumps (note 2)												
• up to 500 hp with total weight up to 9,000 lb	--	--	0.20g	0.25g	0.5g	0.5g	--	--	0.20g	0.25g	0.5g	0.5g
• up to 2,000 hp with total weight up to 48,000 lb	--	--	0.12g	0.16g	0.3g	0.4g	--	--	0.12g	0.16g	0.3g	0.4g
3. Deep-well vertical turbine pumps with motor and impeller at different elevations (notes 2,3)												
• motors up to 500 hp with weights up to 9,000 lb	--	--	1.0g	1.4g	2.5g	3.7g	--	--	1.0g	1.4g	2.5g	3.7g
• impellers up to 14,000 lb	--	--	>0.3g	>0.3g	>0.3g	>0.3g	--	--	>0.3g	>0.3g	>0.3g	>0.3g

Notes:
1. Compare capacity with demand at calculated frequency or peak of demand spectrum (at 5% damping).
2. Compare capacity with demand spectrum ZPA.
3. Evaluate pump and motor independently.
4. $f'_c \geq 3{,}500$ psi; uncracked concrete; embedment, spacing and edge distance ≥ recommended minimum
5. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 9.

Supplementary Table

REQUIRED EDGE DISTANCE, SPACING, AND EMBEDMENT FOR BOLTS

REQUIREMENTS FOR CAST-IN-PLACE BOLTS AND HEADED STUDS

Bolt Diameter (in.)	Minimum Edge Distance (in.)	Minimum Spacing (in.)	Minimum Embedment (in.)
3/8	3-3/8	4-3/4	3-3/4
1/2	4-3/8	6-1/4	5
5/8	5-1/2	7-7/8	6-1/4
3/4	6-5/8	9-1/2	7-1/2
7/8	7-3/4	11	8-3/4
1	8-3/4	12-5/8	10
1-1/8	9-7/8	14-1/4	11-1/4
1-1/4	11	15-3/4	12-1/2
1-3/8	12-1/8	17-3/8	13-3/4

REQUIREMENTS FOR EXPANSION ANCHOR BOLTS

Bolt Diameter (in.)	Minimum Edge Distance and Spacing (in.)
3/8	3-3/4
1/2	5
5/8	6-1/4
3/4	7-1/2
7/8	8-3/4
1	10

Inspection Checklist 5

FLOOR-MOUNTED TRANSFORMERS

Use this checklist as follows, in conjunction with Section 10 of Volume 1:

- For "yes" answers proceed to the next line.
- For "no" answers proceed either to the provisions for outliers or to the section number indicated in parentheses.
- If any expansion anchor bolts do not pass the inspection procedure, reevaluate the anchorage using the bolts that pass.
- Check the appropriate box after completion of the checklist:

  [ ] Anchorage adequacy verified

  [ ] Additional evaluation required

Plant:_____ Location in Plant:_____

Equipment Description:_____

By/Date:_____ Checked/Date:_____

A. Conservative Anchorage

Determine the conservative anchorage. Use the table below for demand ≤ 0.8g.

	Conservative Anchorage	
Transformer kVA	Number of Bolts	Size of Bolts (in.)
Less than 100	6	3/8
Between 100 and 1,000	6	5/8
Between 1,000 and 3,000	6	7/8

B. Existing Anchorage Conditions

B.1 List type and size of fasteners.

Is the number of fasteners greater than or equal to four? ..... Yes_____ No_____

Expansion Anchor Bolts

Manuf: _____ Type: _____ Unknown: _____ Diameter: _____

Weld to Embedded Steel

Area of weld (filet size x length) ..... AW = _____

Headed stud diameter ..... DS = _____

Cast-in-Place Bolts

Diameter ..... DB = _____

None or Other: Go to provisions for outliers.

B.2 Determine kVA rating of transformer ..... kVA = _____

B.3 Is depth of transformer $\leq$ 70"? ..... Yes_____ No_____

Is height of transformer $\leq$ 90"? ..... Yes_____ No_____

Is width of transformer $\leq$ 125"? ..... Yes_____ No_____

B.4 If transformer is bolted to another cabinet, is the other cabinet properly anchored? ..... Yes_____ No_____

B.5 Does existing transformer anchorage consist of at least six fasteners of the type and size given in Section A above? ..... Yes_____ No_____
(C)

B.6 For bolted anchorages, do all fasteners pass the following inspection? ..... Yes_____ No_____

- All bolts have nuts and washers.
- The concrete is sound.
- There are no gaps between the equipment base and the concrete.
- The edge distance, spacing, and embedment of bolts are adequate (See Supplementary Table)
- There are no safety-related relays in equipment anchored by expansion anchors.

STOP: Anchorage is adequate

C. Demand

Record demand for this location in the plant ..... D = _____

D. Screening Procedure for Expansion Anchor Bolt Anchorage

D.1 Determine anchorage capacity, G, from Screening Table 5.1 using the appropriate kVA rating and factor of safety (Mean/3 or Mean/4) ..... G = _____

D.2 Is demand less than capacity? ..... Yes_____ No_____

D.3 Are edge distance and spacing of bolts adequate (see Supplementary Table)?..... Yes_____ No_____

D.4 Do bolts pass the attached inspection guidelines? ..... Yes_____ No_____

STOP: Anchorage is adequate.

E. Screening Procedure for Welded Anchorage

E.1 Determine weld capacity, GW, from Screening Table 5.2 using the appropriate kVA rating and weld size ..... GW =_____

E.2 Determine stud capacity, GS, from Screening Table 5.3 using the appropriate kVA rating and stud diameter ..... GS =_____

E.3 Determine anchorage capacity, G, which is the lesser of GW and GS ..... G = _____

E.4 Is demand less than capacity? ..... Yes_____ No_____

STOP: Anchorage is adequate.

F. Screening Procedure for Cast-in-Place Bolts

F.1 Determine anchorage capacity, G, from Screening Table 5.3 using the appropriate kVA rating and cast-in-place bolt diameter ..... G = _____

F.2 Is demand less than capacity? ..... Yes_____ No_____

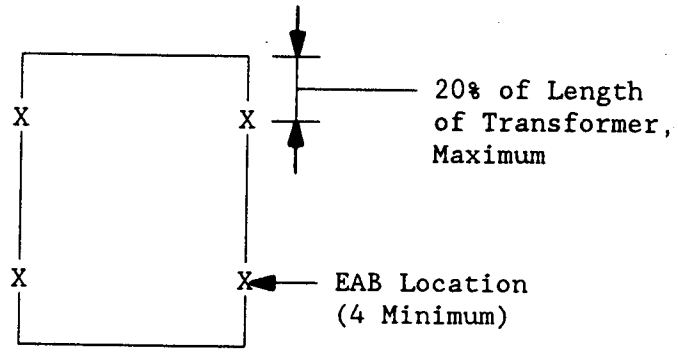
F.3 Are edge distance, embedment and spacing of bolts adequate? (See Supplementary Table) Yes_____ No_____

STOP: Anchorage is adequate.

Screening Table 5.1

SCREENING CRITERIA FOR FLOOR-MOUNTED TRANSFORMERS
ANCHORED WITH EXPANSION ANCHOR BOLTS

Anchor Diameter (in.)	Seismic capacity (g)					
	Transformers Rated kVA ≤ 100		Transformers Rated 100 < kVA ≤ 1,000		Transformers Rated 1,000 < kVA ≤ 3,000	
	Mean/4	Mean/3	Mean/4	Mean/3	Mean/4	Mean/3
3/8	1.6	2.1	0.5	0.7	0.2	0.3
1/2	2.4	3.2	0.7	0.9	0.3	0.4
5/8	3.3	4.4	0.9	1.2	0.5	0.7
3/4	4.7	6.3	1.2	1.6	0.7	0.9
7/8	6.1	8.1	1.5	2.0	0.9	1.2
1	7.0	9.3	1.7	2.3	1.0	1.3



Plan of Base of Transformer

Notes:

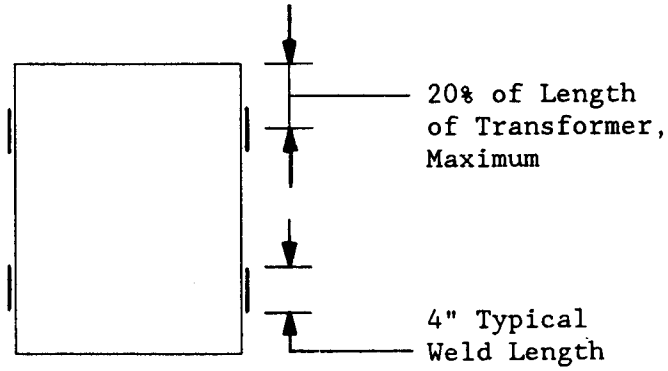
1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum

2. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 10.

Screening Table 5.2

SCREENING CRITERIA FOR FLOOR-MOUNTED TRANSFORMERS
ANCHORED WITH WELDS

Area of Weld ($in.^2$)	Seismic Capacity (g)		
	Transformers Rated kVA $\leq$ 2,000	Transformers Rated 2,000 < kVA $\leq$ 2,500	Transformers Rated 2,500 < kVA $\leq$ 3,000
0.1875	0.8	0.7	0.7
0.25	1.0	0.9	0.8
0.3125	1.3	1.1	1.0
0.375	1.5	1.2	1.1
0.5	1.9	1.5	1.4
0.625	2.2	1.8	1.7
0.75	2.6	2.2	2.0



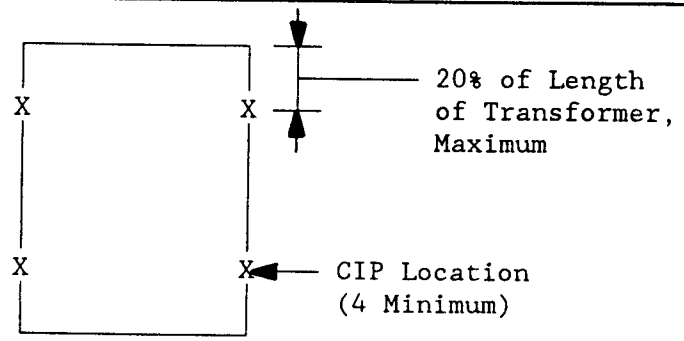
Plan of Base of
Transformer

Notes: 1. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 10.

Screening Table 5.3

SCREENING CRITERIA FOR FLOOR-MOUNTED TRANSFORMERS ANCHORED WITH CAST-IN-PLACE (CIP) BOLTS OR HEADED STUDS

Bolt or Stud Diamter (in.)	Seismic Capacity		
	Transformers Rated kVA ≤ 2,000	Transformers Rated 2,000 < kVA ≤ 2,500	Transformers Rated 2,500 < kVA ≤ 3,000
3/8	0.5	0.5	0.3
1/2	0.9	0.8	0.6
5/8	1.3	1.1	0.9
3/4	1.9	1.6	1.3
7/8	2.5	2.1	1.7
1	3.2	2.7	2.2
1-1/4	5.0	4.1	3.4
1-3/8	6.0	4.9	4.1



Plan of Base of Transformer

Notes: 1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum

2. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 10.

Supplementary Table

REQUIRED EDGE DISTANCE, SPACING, AND EMBEDMENT FOR BOLTS

REQUIREMENTS FOR CAST-IN-PLACE BOLTS AND HEADED STUDS

Bolt Diameter (in.)	Minimum Edge Distance (in.)	Minimum Spacing (in.)	Minimum Embedment (in.)
3/8	3-3/8	4-3/4	3-3/4
1/2	4-3/8	6-1/4	5
5/8	5-1/2	7-7/8	6-1/4
3/4	6-5/8	9-1/2	7-1/2
7/8	7-3/4	11	8-3/4
1	8-3/4	12-5/8	10
1-1/8	9-7/8	14-1/4	11-1/4
1-1/4	11	15-3/4	12-1/2
1-3/8	12-1/8	17-3/8	13-3/4

REQUIREMENTS FOR EXPANSION ANCHOR BOLTS

Bolt Diameter (in.)	Minimum Edge Distance and Spacing (in.)
3/8	3-3/4
1/2	5
5/8	6-1/4
3/4	7-1/2
7/8	8-3/4
1	10

INSPECTION GUIDELINES FOR EXPANSION ANCHOR BOLTS

If the answers to all the following questions are yes, the bolts pass inspection. As discussed in Section 2 of Volume 1, only a sample of bolts need be inspected for tightness unless safety-related relays are present in the equipment. Other inspections requirements are visual in nature and should be applied to all bolts.

1. Are the nut and anchor bolt tight (not turning in the hole)? ..... Yes_____ No_____
2. Is there a washer between the equipment base and the bolt head or nut? ..... Yes_____ No_____
3. Is the concrete sound? ..... Yes_____ No_____
4. Is the gap between the equipment base and the concrete surface less than or equal to 1/4"? ..... Yes_____ No_____
5. Is the bolt installed with at least the minimum required embedment shown below? ..... Yes_____ No_____

   For shell bolts, the minimum embedment is ensured if the shell does not protrude above the surface of the concrete. For nonshell bolts, the minimum embedment is ensured if the projection of the bolt above the concrete surface conforms with the following:

Bolt Diameter (in.)	Range of Bolt Projection (in.)
3/8	1/2 - 3/4
1/2	1/2 - 3/4
5/8	1/2 - 7/8
3/4	7/8 - 1-1/2
7/8	1-1/2 - 2
1	1-1/2 - 2

For further elaboration, see Step 8 of "Expansion Anchor Inspection Procedure" in Section 2 of Volume 1.

Inspection Checklist 6

AIR COMPRESSOR ASSEMBLIES

Use this checklist as follows, in conjunction with Section 11 of Volume 1:

- For "yes" answers proceed to the next line.
- For "no" answers proceed either to the provisions for outliers.
- If any cast-in-place bolts do not pass the inspection procedure, reevaluate the anchorage using the bolts that pass.
- Check the appropriate box after completion of the checklist:
  - [ ] Anchorage adequacy verified
  - [ ] Additional evaluation required

Plant:_____ Location in Plant:_____

EquipmentDescription:_____

_____

By/Date:_____ Checked/Date:_____

A. For Conditions where ZPA $\leq$ 0.16g

A.1	Is the existing anchorage equal to or greater than four 3/8-in. cast-in-place bolts?	Yes_____	No_____
A.2	Is the anchorage detail free of any friction clips, expansion anchor bolts, or vibration isolation spring mounts?	Yes_____	No_____
A.3	Are the edge distance, embedment, and spacing of bolts adequate (see Supplementary Table)? .	Yes_____	No_____
A.4	Is the concrete around the bolts sound?	Yes_____	No_____
A.5	Is the center of gravity of the entire compressor assembly less than about 3.0 ft to 3.5 ft above the concrete anchorage?	Yes_____	No_____
A.6	If a skid is used, are the components bolted or welded to it (i.e. not oversized or slotted holes)?	Yes_____	No_____

A.7 If the motor and compressor are independently anchored:

- Are condition A.1 to A.5 met for each unit? ..... Yes_____ No_____
- Is each unit anchored directly to the concrete without the use of a flexible supporting steel structure or skid? .... Yes_____ No_____

STOP: Anchorage is adequate.

B. For conditions where ZPA > 0.16g

B.1 Record demand (ZPA) for this location in plant ..... _____

B.2 Number and size of cast-in-place bolts (with fully engaged, tight nuts) attaching the compressor or the steel skid to the concrete ..... Number: _____

Size: _____

B.3 Horsepower of motor driving pump ..... _____

B.4 Determine anchorage capacity using Screening Table 6.1 ..... _____

C. Screening Procedure

C.1 Is demand less than Capacity? ..... Yes_____ No_____

C.2 Are conditions A.2 to A.6 above met for the compressor or the steel skid? ..... Yes_____ No_____

C.3 If the motor and compressor are separately anchored:

- Do the motor and compressor anchorages each meet conditions C.1 and C.2 above? ..... Yes_____ No_____
- Is each unit anchored directly to the concrete without the use of a flexible supporting steel structure? ..... Yes_____ No_____

C.4 Is the attached length of unsupported piping less than 40 ft at both the supply and discharge nozzles? ..... Yes_____ No_____

STOP: Anchorage is adequate.

Screening Table 6.1

SCREENING CRITERIA FOR AIR COMPRESSOR ASSEMBLIES

Type of Assembly	Number and Diameter of Bolts						
	4				6		
	3/8"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"
Assemblies with motors up to 50 hp	0.5g	0.9g	1.4g	--	--	--	--
Assemblies with motors between 50 and 200 hp	0.16g	0.25g	0.37g	0.5g	0.33g	0.5g	0.7g

Notes:

1. Capacities given are for anchorage of the compressor of skid to concrete with cast-in-place bolts.

2. $f'_c \geq 3{,}500$ psi; uncracked concrete; embedment, spacing and edge distance $\geq$ recommended minimum

3. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 11.

Supplementary Table

REQUIRED EDGE DISTANCE, SPACING, AND EMBEDMENT FOR BOLTS

REQUIREMENTS FOR CAST-IN-PLACE BOLTS AND HEADED STUDS:

Bolt Diameter (in.)	Minimum Edge Distance (in.)	Minimum Spacing (in.)	Minimum Embedment (in.)
3/8	3-3/8	4-3/4	3-3/4
1/2	4-3/8	6-1/4	5
5/8	5-1/2	7-7/8	6-1/4
3/4	6-5/8	9-1/2	7-1/2
7/8	7-3/4	11	8-3/4
1	8-3/4	12-5/8	10
1-1/8	9-7/8	14-1/4	11-1/4
1-1/4	11	15-3/4	12-1/2
1-3/8	12-1/8	17-3/8	13-3/4

REQUIREMENTS FOR EXPANSION ANCHOR BOLTS:

Bolt Diameter (in.)	Minimum Edge Distance and Spacing (in.)
3/8	3-3/4
1/2	5
5/8	6-1/4
3/4	7-1/2
7/8	8-3/4
1	10

Inspection Checklist 7

LATERALLY BRACED INSTRUMENT RACKS

Use this checklist as follows, in conjunction with Section 12 of Volume 1:

- For "yes" answers proceed to the next line.
- For "no" answers proceed either to the provisions for outliers or to the section number indicated in parentheses.
- If any expansion bolts do not pass the inspection procedure, reevaluate the anchorage using the bolts that pass.
- Structural members of the rack should have physical properties similar to the 3-in. by 5-in. channel described in Section 12 of Volume 1.
- Check the appropriate box after completion of the checklist:

  [ ] Anchorage adequacy verified

  [ ] Additional evaluation required

Plant:_____ Location in Plant:_____

Equipment Description:_____

_____

By/Date:_____ Checked/Date:_____

A. Existing Anchorage Conditions

A.1 Type and size of fasteners:

Expansion Anchor Bolts

Diameter.....·_____

Is the number of bolts in the anchorage at least two per upright vertical leg for each span in the line up? ..... Yes_____ No_____

None or other: Go to provisions for outliers.

A.2 Dimensions of controlling span in rack lineup:

Total Height H = _____ Span Length L = _____

Brace Height H_b = _____ Brace Depth D_b = _____

A.3 Are $H \leq 90"$, $L \leq 72"$, $H_b \geq 45"$, $D_b \geq 12"$, and $H_{db} \geq 24"$ (for double-braced rack)? ..... Yes_____ No_____

B. DEMAND

Record demand for this location in the plant ..... D = _____

C. Screening Procedure for Expansion Anchor Bolt Anchorage

C.1 Does the instrument rack support safety-related relays? ..... Yes_____No____(C.4)

C.2 Determine the seismic capacity using Screening Figure 7.1(b) for single-braced racks or Screening Figure 7.2(b) for double-braced racks ..... G =_____

C.3 Go to C.5

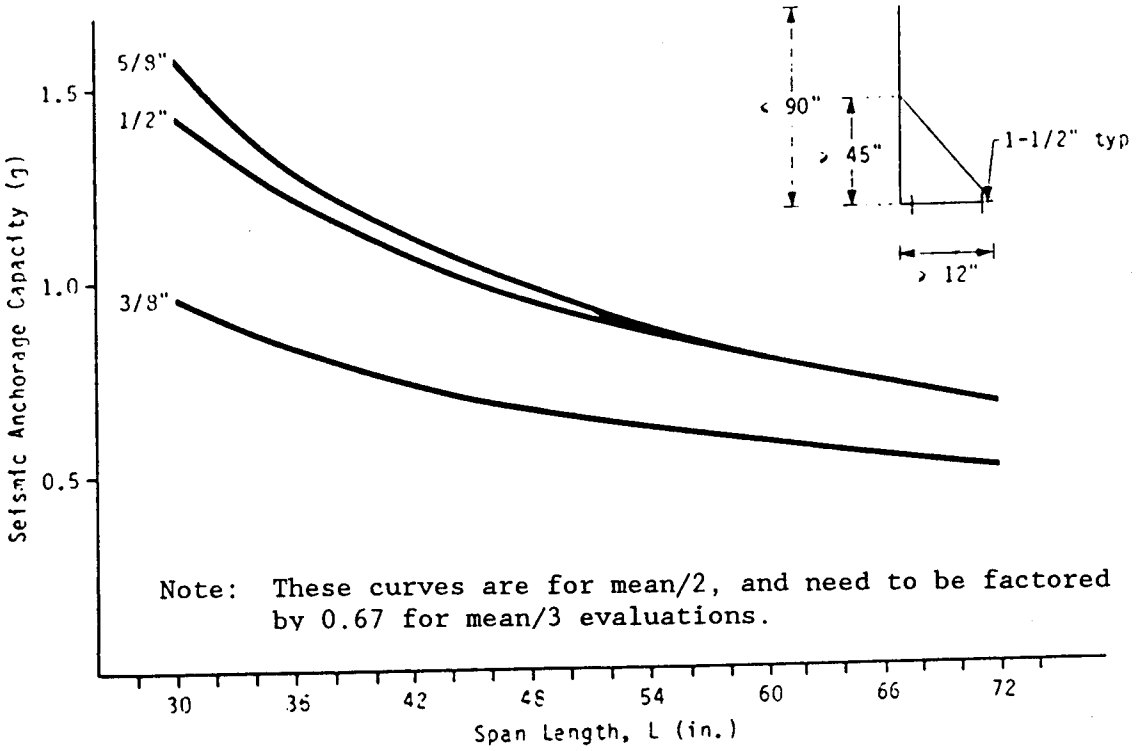
C.4 Determine the seismic capacity using Screening Fig. 7.1(a) or 7.2(a)..... G =_____

C.5 Is demand less than capacity? ..... Yes_____ No_____

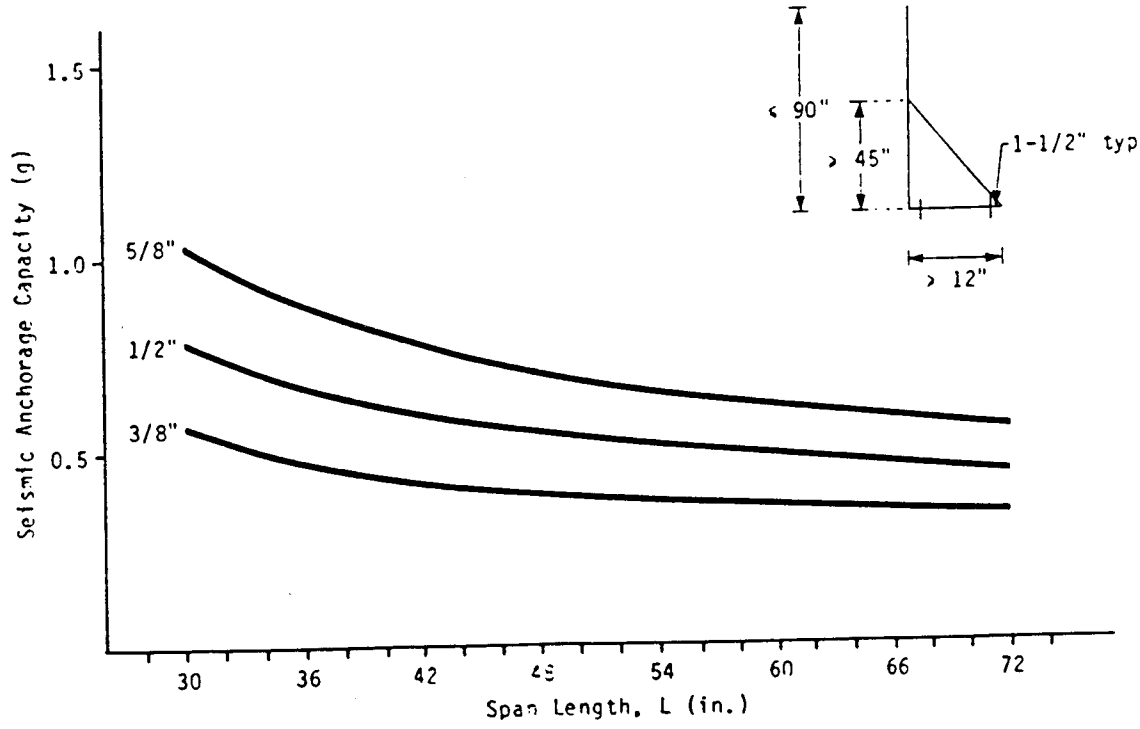
C.6 Are edge distance and spacing of bolts adequate (see Supplementary Table)? ..... Yes_____ No_____

C.7 Do bolts pass the attached inspection guidelines? ..... Yes_____ No_____

STOP: Anchorage is adequate.



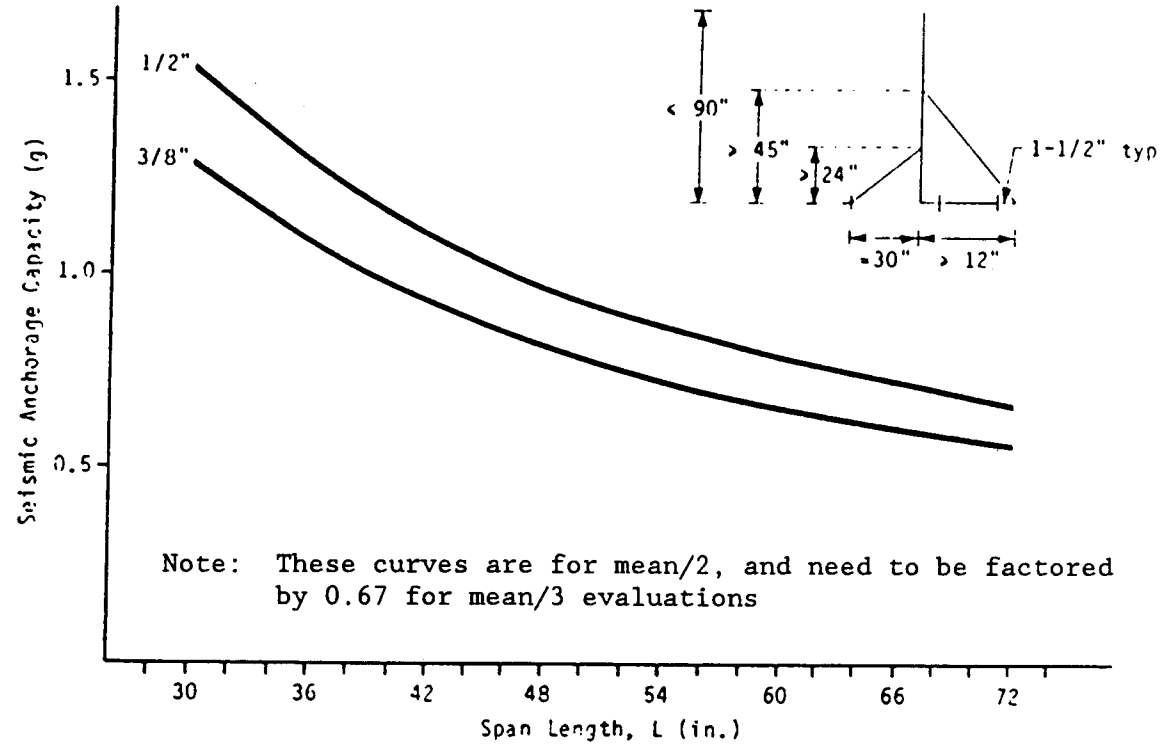
a. For Mean/3 Evaluations



b. For Mean/4 Evaluations

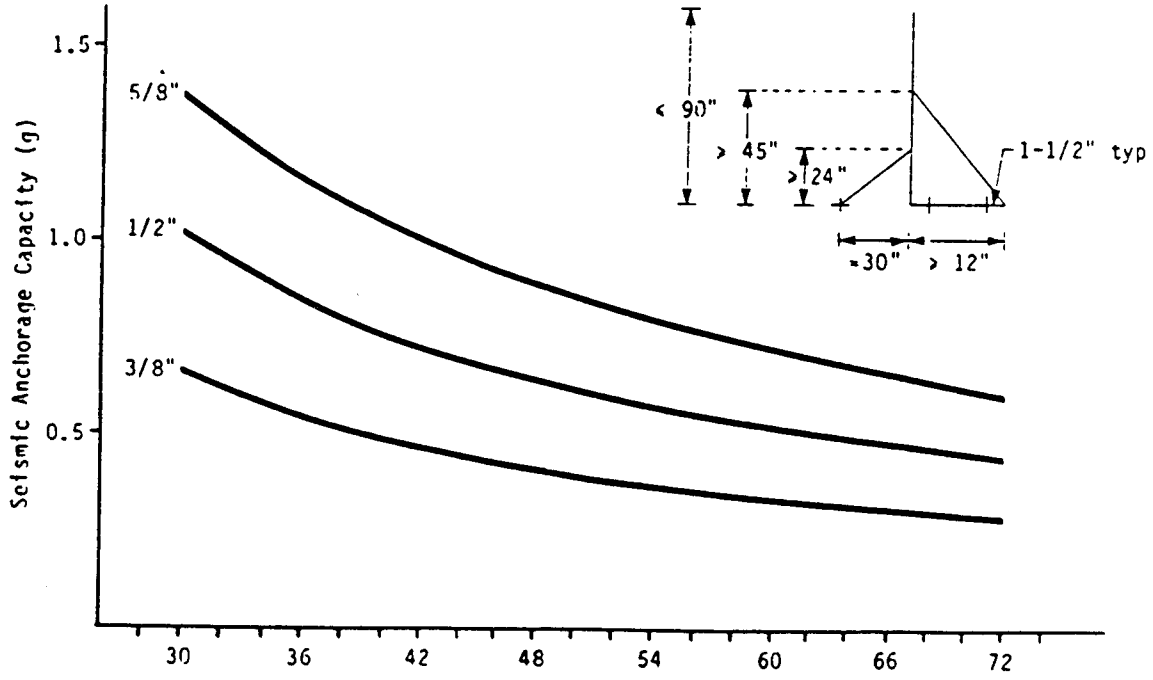
Notes: 1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum.
2. For other assumptions on layout, equipment base, etc., see Volume 1, Section 12.

Screening Figure 7.1 Screening Criteria for Single-Braced Racks Anchored by Expansion Anchors



Note: These curves are for mean/2, and need to be factored by 0.67 for mean/3 evaluations

a. For Mean/3 Evaluations



b. For Mean/4 Evaluations

Notes: 1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum.
2. For other assumptions on layout, equipment base, etc., see Volume 1, Section 12.

Screening Figure 7.2 Screening Criteria for Double-Braced Racks Anchored by Expansion Anchors

Supplementary Table

REQUIRED EDGE DISTANCE, SPACING, AND EMBEDMENT FOR BOLTS

REQUIREMENTS FOR CAST-IN-PLACE BOLTS AND HEADED STUDS

Bolt Diameter (in.)	Minimum Edge Distance (in.)	Minimum Spacing (in.)	Minimum Embedment (in.)
3/8	3-3/8	4-3/4	3-3/4
1/2	4-3/8	6-1/4	5
5/8	5-1/2	7-7/8	6-1/4
3/4	6-5/8	9-1/2	7-1/2
7/8	7-3/4	11	8-3/4
1	8-3/4	12-5/8	10
1-1/8	9-7/8	14-1/4	11-1/4
1-1/4	11	15-3/4	12-1/2
1-3/8	12-1/8	17-3/8	13-3/4

REQUIREMENTS FOR EXPANSION ANCHOR BOLTS

Bolt Diameter (in.)	Minimum Edge Distance and Spacing (in.)
3/8	3-3/4
1/2	5
5/8	6-1/4
3/4	7-1/2
7/8	8-3/4
1	10

INSPECTION GUIDELINES FOR EXPANSION ANCHOR BOLTS

If the answers to all the following questions are yes, the bolts pass inspection. Only a sample of bolts need be inspected, as discussed in Section 2 of Volume 1.

1. Are the nut and anchor bolt tight (not turning in the hole)? ..... Yes_____ No_____
2. Is there a washer between the equipment base and the bolt head or nut? ..... Yes_____ No_____
3. Is the concrete sound? ..... Yes_____ No_____
4. Is the gap between the equipment base and the concrete surface less than or equal to 1/4"? ..... Yes_____ No_____
5. Is the bolt installed with at least the minimum required embedment shown below? ..... Yes_____ No_____

   For shell bolts, the minimum embedment is ensured if the shell does not protrude above the surface of the concrete. For nonshell bolts, the minimum embedment is ensured if the projection of the bolt above the surface conforms with the following:

Bolt Diameter (in.)	Range of Bolt Projection (in.)
3/8	1/2 - 3/4
1/2	1/2 - 3/4
5/8	1/2 - 7/8
3/4	7/8 - 1 1/2
7/8	1-1/2 - 2
1	1-1/2 - 2

For further elaboration, see Step 8 of "Expansion Anchor Inspection Procedure" in Section 2 of Volume 1.

INSPECTION GUIDELINES FOR EXPANSION ANCHOR BOLTS

If the answers to all the following questions are yes, the bolts pass inspection. Only a sample of bolts need be inspected, as discussed in Section 2 of Volume 1.

1. Are the nut and anchor bolt tight (not turning in the hole)? ..... Yes_____ No_____

2. Is there a washer between the equipment base and the bolt head or nut? ..... Yes_____ No_____

3. Is the concrete sound? ..... Yes_____ No_____

4. Is the gap between the equipment base and the concrete surface less than or equal to 1/4"? ..... Yes_____ No_____

5. Is the bolt installed with at least the minimum required embedment shown below? ..... Yes_____ No_____

   For shell bolts, the minimum embedment is ensured if the shell does not protrude above the surface of the concrete. For nonshell bolts, the minimum embedment is ensured if the projection of the bolt above the surface conforms with the following:

Bolt Diameter (in.)	Range of Bolt Projection (in.)
3/8	1/2 - 3/4
1/2	1/2 - 3/4
5/8	1/2 - 7/8
3/4	7/8 - 1 1/2
7/8	1-1/2 - 2
1	1-1/2 - 2

For further elaboration, see Step 8 of "Expansion Anchor Inspection Procedure" in Section 2 of Volume 1.

Inspection Checklist 8

LOW-VOLTAGE AND METAL-CLAD SWITCHGEARS

Use this checklist as follows, in conjunction with Section 13 of Volume 1:

- For "yes" answers proceed to the next line.
- For "no" answers proceed either to the provisions for outliers or to the section number indicated in parentheses.
- If any expansion anchor bolts do not pass the inspection procedure, reevaluate the anchorage using the bolts that pass.
- Check the appropriate box after completion of the checklist:

  [ ] Anchorage adequacy verified
  [ ] Additional evaluation required

Plant:_____ Location in Plant:_____

Equipment Description:_____

By/Date:_____ Checked/Date:_____

A. Conservative Anchorage

Determine the conservative anchorage. Use the following table if demand $\leq 0.8g$.

Total Length of Switchgear Lineup (in.)	Number of Bolts Required per side for Conservative Anchorage		
	3/8"	1/2"	5/8"
100	11	8	6
125	13	9	6
150	16	11	8
200	N/A	13	11

B. Existing Anchorage Conditions

B.1 Does existing anchorage exceed conservative anchorage given in A? ..... Yes_____ No_____ (B.3)

B.2 Do all bolts pass the following visual inspection? ..... Yes_____ No_____

- All bolts have nuts and washers.
- The concrete is sound.
- There are no large gaps between the equipment base and the concrete.
- The edge distance and spacing of all bolts are adequate (see Supplementary Table).
- There are no safety-related relays in equipment anchored by expansion anchors.

STOP: Anchorage is adequate.

B.3 Type and size of fasteners:

Expansion Anchor Bolts

Manuf: _____ Type: _____ Unknown: _____ Diameter: _____

Number of bolts per side..... NB = _____

Welds to Embedded Steel

Number of welds per side..... NW = _____

Area of weld (fillet size x length)..... AW = _____

Number of studs per side..... NS = _____

Stud diameter..... DS = _____

None or Other: Go to provisions for outliers.

B.4 Total length of lineup ..... L = _____

B.5 For low-voltage switchgears:

Is height of cabinet $\leq$ 90"? ..... Yes_____ No_____

Is length of switchgear line up $\geq$ 100" ..... Yes_____ No_____

Is depth of cabinet $\geq$ 55" and $\leq$ 70"? ..... Yes_____ No_____

Is the center of gravity approximately at midheight? ..... Yes_____ No_____

B.6 Go to B.8.

B.7 For metal-clad switchgears:

Is height of cabinet $\leq$ 90"? ..... Yes_____ No_____

Is the number of cabinets in the lineup $\geq$ 5? ..... Yes_____ No_____

Is the center of gravity approximately at midheight? ..... Yes_____ No_____

Is the depth of the cabinets within the following limits? ..... Yes_____ No_____

For 26"-wide cabinets: depth between 56" and 74"?

For 36"-wide cabinets: depth between 64" and 114"?

B.8 Are all adjacent cabinets in the lineup bolted together? ..... Yes_____ No_____

C. Demand

Record demand for this location in the plant ..... D =_____

D. Screening Procedure for Expansion Anchor Bolt Anchorage

D.1 Determine anchorage capacity, G, from Screening Table 8.1 ..... G =_____

D.2 Is demand less than capacity? ..... Yes_____ No_____

D.3 Are edge distance and spacing of bolts adequate? (see Supplementary Table)..... Yes_____ No_____

D.4 Do bolts pass the attached inspection guidelines? ..... Yes_____ No_____

STOP: Anchorage is adequate.

E. Screening Procedure for Welded Anchorage

E.1 Determine weld capacity, GW, from Screening Table 8.2 ..... GW =_____

E.2 Determine stud capacity, GS, from Screening Table 8.3 ..... GS =_____

E.3 Determine anchorage capacity, G, which is the lesser of GW and GS ..... G =_____

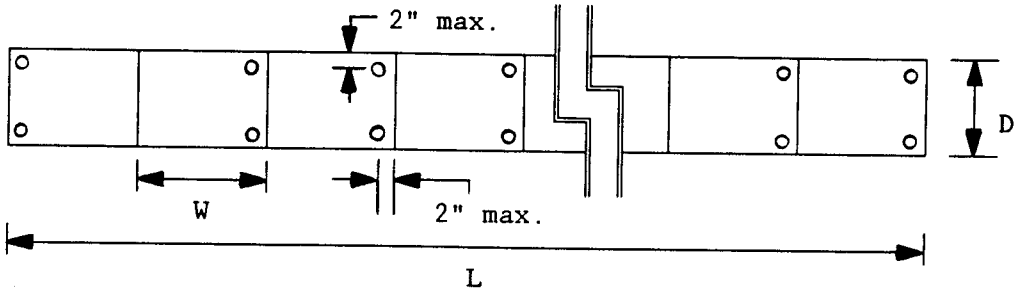
E.4 Is demand less than capacity? ..... Yes_____ No_____

STOP: Anchorage is adequate.

Screening Table 8.1

SCREENING CRITERIA FOR LOW-VOLTAGE SWITCHGEARS
AND METAL-CLAD SWITCHGEARS ANCHORED WITH EXPANSION ANCHOR BOLTS

L. (in.)	Number of Bolts per Side	Seismic Capacity (g)					
		3/8" Bolts		1/2" Bolts		5/8" Bolts	
		Mean/3	Mean/4	Mean/3	Mean/4	Mean/3	Mean/4
100	3 (W=36" only)	0.4	0.3	0.8	0.6	0.9	0.7
	4	0.5	0.4	0.9	0.7	1.2	0.9
	5	0.8	0.6	1.2	0.9	1.5	1.1
	6	0.9	0.7	1.3	1.0	1.9	1.4
125	4 (W=36" only)	0.4	0.3	0.8	0.6	1.1	0.8
	5	0.5	0.4	0.9	0.7	1.2	0.9
	6	0.8	0.6	1.2	0.9	1.5	1.1
	7	0.8	0.6	1.2	0.9	1.6	1.2
	8	0.9	0.7	1.3	1.0	1.9	1.4
150	4 (W=36" only)	0.4	0.3	0.7	0.5	0.9	0.7
	5 (W=36" only)	0.5	0.4	0.8	0.6	1.1	0.8
	6	0.5	0.4	0.9	0.7	1.2	0.9
	7	0.7	0.5	1.1	0.8	1.5	1.1
	8	0.8	0.6	1.2	0.9	1.6	1.2
	9	0.8	0.6	1.3	1.0	1.7	1.3
	10	0.9	0.7	1.5	1.1	1.9	1.4
200	5 (W=36" only)	0.4	0.3	0.7	0.5	0.9	0.7
	6 (W=36" only)	0.4	0.3	0.8	0.6	0.9	0.7
	7 (W=36" only)	0.5	0.4	0.8	0.6	1.1	0.8
	8	0.5	0.4	0.9	0.7	1.2	0.9
	9	0.7	0.5	1.1	0.8	1.3	1.0
	10	0.8	0.6	1.2	0.9	1.5	1.1
	11	0.8	0.6	1.2	0.9	1.6	1.2
	12	0.8	0.6	1.3	1.0	1.7	1.3



Notes:

1. This table applies to low-voltage and metal-clad switchgears with height ≤ 90in.
2. For metal-clad switchgears, this table applies to the following conditions:

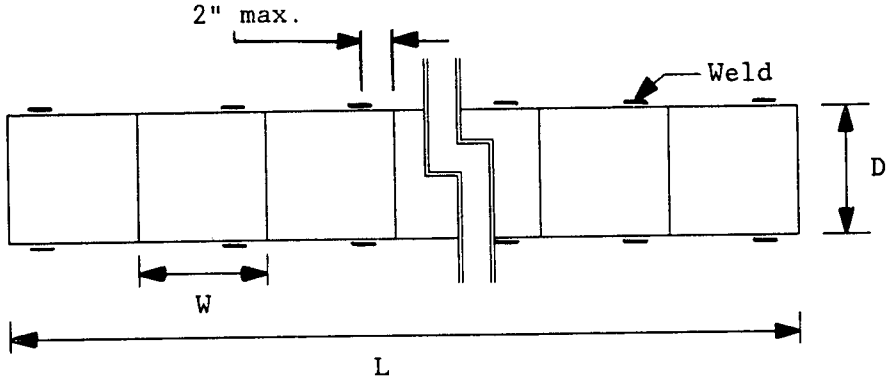
   a. W = 26"; 56" ≤ D ≤ 74"
   b. W = 36"; 64" ≤ D ≤ 114"

3. f'_c ≥ 4,000 psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum
4. For assumptions on anchor layout, equipment base, etc., see Volume 1, Section 13.

Screening Table 8.2

SCREENING CRITERIA FOR LOW-VOLTAGE SWITCHGEARS
AND METAL-CLAD SWITCHGEARS WITH WELDED ANCHORAGE

L (in.)	Number of Welds Per Side	Seismic Capacity (g) by Area of Weld (in^2)			
		0.0625	0.125	0.1875	0.5
100	3 (W=36" only)	0.4	0.7	1.0	2.4
	4	0.5	0.9	1.3	3.1
	5	0.7	1.2	1.6	3.8
	6	0.8	1.4	1.8	3.8
125	4 (W=36" only)	0.4	0.7	1.1	2.5
	5	0.5	0.9	1.3	3.1
	6	0.6	1.1	1.5	3.6
	7	0.8	1.3	1.8	3.6
	8	0.8	1.4	2.0	3.6
150	4 (W=36" only)	0.4	0.7	1.0	2.2
	5 (W=36" only)	0.5	0.8	1.2	2.6
	6	0.5	0.9	1.3	3.1
	7	0.6	1.1	1.5	3.6
	8	0.8	1.3	1.8	3.8
	9	0.8	1.4	1.8	3.8
	10	0.9	1.5	2.1	3.8
200	5 (W=36" only)	0.4	0.6	0.9	2.1
	6 (W=36" only)	0.4	0.7	1.0	2.4
	7 (W=36" only)	0.5	0.8	1.2	2.7
	8	0.5	0.9	1.3	3.1
	9	0.6	1.0	1.5	3.4
	10	0.7	1.2	1.6	3.8
	11	0.8	1.3	1.8	3.8
	12	0.8	1.4	1.8	3.8



Notes:
1. This table applies to low-voltage and metal-clad switchgears with height ≤ 90in.
2. For metal-clad switchgears, this table applies to the following conditions:

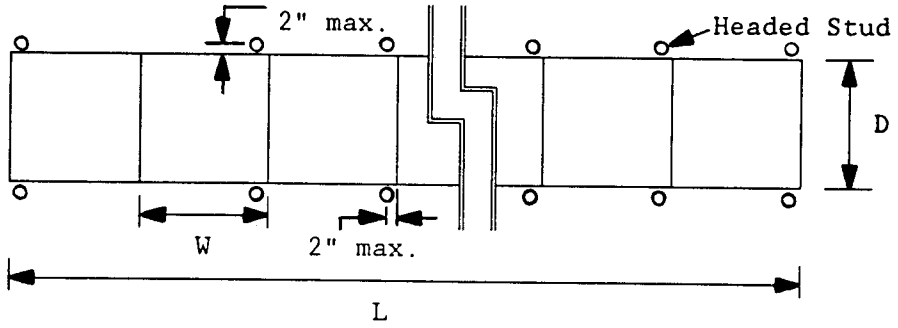
   a. W = 26"; 56" ≤ D ≤ 74"
   b. W = 36"; 64" ≤ D ≤ 114"

3. For assumptions on anchor layout, equipment base, etc., see Volume 1, Section 13.

Screening Table 8.3

SCREENING CRITERIA FOR LOW-VOLTAGE SWITCHGEARS AND METAL-CLAD SWITCHGEARS WITH CAST-IN-PLACE OR HEADED STUD ANCHORS

L (in.)	Number of Bolts Per Side	Seismic Capacity (g)		
		3/8" Studs	1/2" Studs	5/8" Studs
100	3 (W=36" only)	0.6	1.1	1.6
	4	0.8	1.4	2.2
	5	1.0	1.8	2.8
	6	1.3	2.2	3.5
125	4 (W=36" only)	0.7	1.1	1.7
	5	0.8	1.4	2.2
	6	1.0	1.7	2.7
	7	1.2	2.0	3.1
	8	1.3	2.2	3.5
150	4 (W=36" only)	0.6	0.9	1.4
	5 (W=36" only)	0.7	1.2	1.8
	6	0.8	1.4	2.2
	7	1.0	1.7	2.7
	8	1.1	1.9	2.9
	9	1.2	2.1	3.3
	10	1.4	2.4	3.7
200	5 (W=36" only)	0.5	0.9	1.3
	6 (W=36" only)	0.6	1.1	1.6
	7 (W=36" only)	0.7	1.2	1.8
	8	0.8	1.4	2.2
	9	0.9	1.6	2.5
	10	1.0	1.8	2.8
	11	1.2	2.0	3.1
	12	1.3	2.2	3.5



Notes:

1. This table applies to low-voltage and metal-clad switchgears with height ≤ 90in.
2. For metal-clad switchgears, this table applies to the following conditions:

   a. W = 26"; 56" ≤ D ≤ 74"
   b. W = 36"; 64" ≤ D ≤ 114"

3. $f'_c \geq 3{,}500$ psi; uncracked concrete; embedment, spacing and edge distance > recommended minimum
4. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 13.

Supplementary Table

REQUIRED EDGE DISTANCE, SPACING, AND EMBEDMENT FOR BOLTS

REQUIREMENTS FOR CAST-IN-PLACE BOLTS AND HEADED STUDS:

Bolt Diameter (in.)	Minimum Edge Distance (in.)	Minimum Spacing (in.)	Minimum Embedment (in.)
3/8	3-3/8	4-3/4	3-3/4
1/2	4-3/8	6-1/4	5
5/8	5-1/2	7-7/8	6-1/4
3/4	6-5/8	9-1/2	7-1/2
7/8	7-3/4	11	8-3/4
1	8-3/4	12-5/8	10
1-1/8	9-7/8	14-1/4	11-1/4
1-1/4	11	15-3/4	12-1/2
1-3/8	12-1/8	17-3/8	13-3/4

REQUIREMENTS FOR EXPANSION ANCHOR BOLTS:

Bolt Diameter (in.)	Minimum Edge Distance and Spacing (in.)
3/8	3-3/4
1/2	5
5/8	6-1/4
3/4	7-1/2
7/8	8-3/4
1	10

INSPECTION GUIDELINES FOR EXPANSION ANCHOR BOLTS

If the answers to all the following questions are yes, the bolts pass inspection. Only a sample of bolts need be inspected, as discussed in Section 2 of Volume 1.

1. Are the nut and anchor bolt tight (not turning in the hole)? ..... Yes_____ No_____
2. Is there a washer between the equipment base and the bolt head or nut? ..... Yes_____ No_____
3. Is the concrete sound? ..... Yes_____ No_____
4. Is the gap between the equipment base and the concrete surface less than or equal to 1/4"? ..... Yes_____ No_____
5. Is the bolt installed with at least the minimum required embedment shown below? ..... Yes_____ No_____

   For shell bolts, the minimum embedment is ensured if the shell does not protrude above the surface of the concrete. For nonshell bolts, the minimum embedment is ensured if the projection of the bolt above the surface conforms with the following:

Bolt Diameter (in.)	Range of Bolt Projection (in.)
3/8	1/2 - 3/4
1/2	1/2 - 3/4
5/8	1/2 - 7/8
3/4	7/8 - 1/2
7/8	1-1/2 - 2
1	1-1/2 - 2

For further elaboration, see Step 8 of "Expansion Anchor Inspection Procedure" in Section 2 of Volume 1.

Inspection Checklist 9

BATTERY RACKS

Use this checklist as follows, in conjunction with Section 14 of Volume 1:

- For "yes" answers proceed to the next line.
- For "no" answers proceed either to the provisions for outliers or to the section number indicated in parentheses.
- If any expansion anchor bolts do not pass the inspection procedure, reevaluate the anchorage using the bolts that pass.
- Check the appropriate box after completion of the checklist:

  [ ] Anchorage adequacy verified
  [ ] Additional evaluation required

Plant:_____ Location in Plant:_____

Equipment Description:_____

_____

By/Date:_____ Checked/Date:_____

A. Conservative Anchorage

Determine the conservative anchorage according to Section 14 of Volume 1.

Record the rack parameters:

Rack width ..... W = _____

Battery size .....b = h x d =_____ x _____ = _____

Spacing between transverse frames ..... L = _____

Diameter of expansion anchor bolt required
for conservative anchorage ..... _____

B. Existing Anchorage Conditions

B.1 Number, diameter, and type of existing expansion anchor bolts..... Number: _____

Diameter:_____

Manuf: _____ Type: _____

B.2 Is height of top tier $h_2 \leq 24"$?.....Yes_____ No_____

Is height of bottom tier $h_1 \leq 12"$?.....Yes_____ No_____

B.3 Is the diameter of bolts determined in Step B.1 equal to or greater than the conservative anchorage? .....Yes_____ No_____ (C)

B.4 For bolted anchorages, do all fasteners pass the following inspection? .....Yes_____ No_____

- All bolts have nuts and washers.
- The concrete is sound.
- There are no gaps between the equipment base and the concrete.
- The edge distance, spacing, and embedment of bolts are adequate (See Supplementary Table).

STOP: Anchorage is adequate.

C. Anchorage Capacity

Determine anchorage capacity using Screening Figure 9.1 through 9.6 from bolt diameter and dimensional data recorded in Sections A and B and appropriate factor of safety (Mean/3 or Mean/4)..... C = _____

D. Demand

Determine the seismic demand..... D = _____

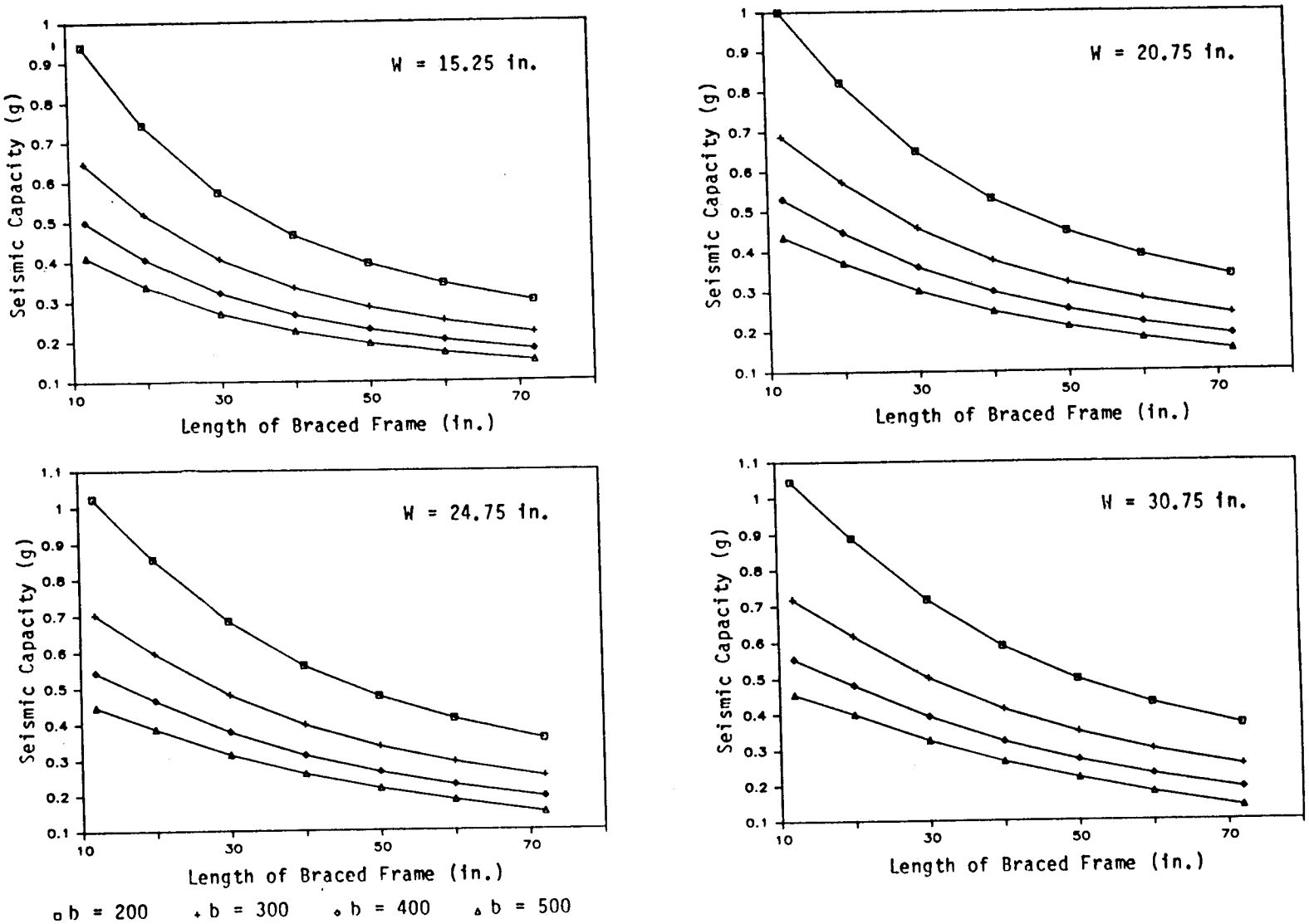
E. Screening Procedure

E.1 Is seismic capacity, C, greater than seismic demand? ..... Yes_____ No_____

E.2 Are edge distance and spacing of bolts adequate (see Supplementary Table)? ..... Yes_____ No_____

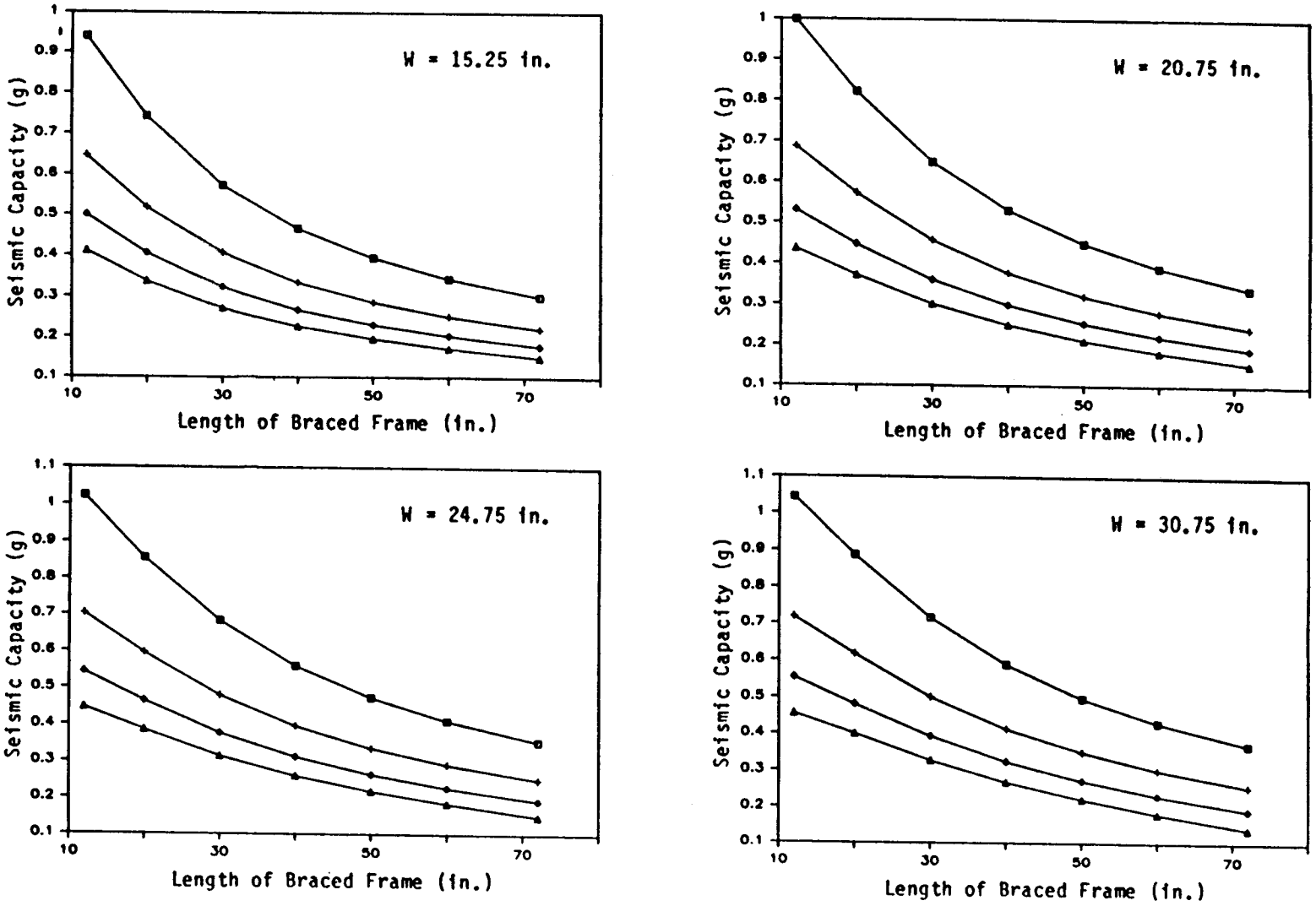
E.3 Do bolts pass the attached inspection guidelines? ..... Yes_____ No_____

STOP: Anchorage is adequate.



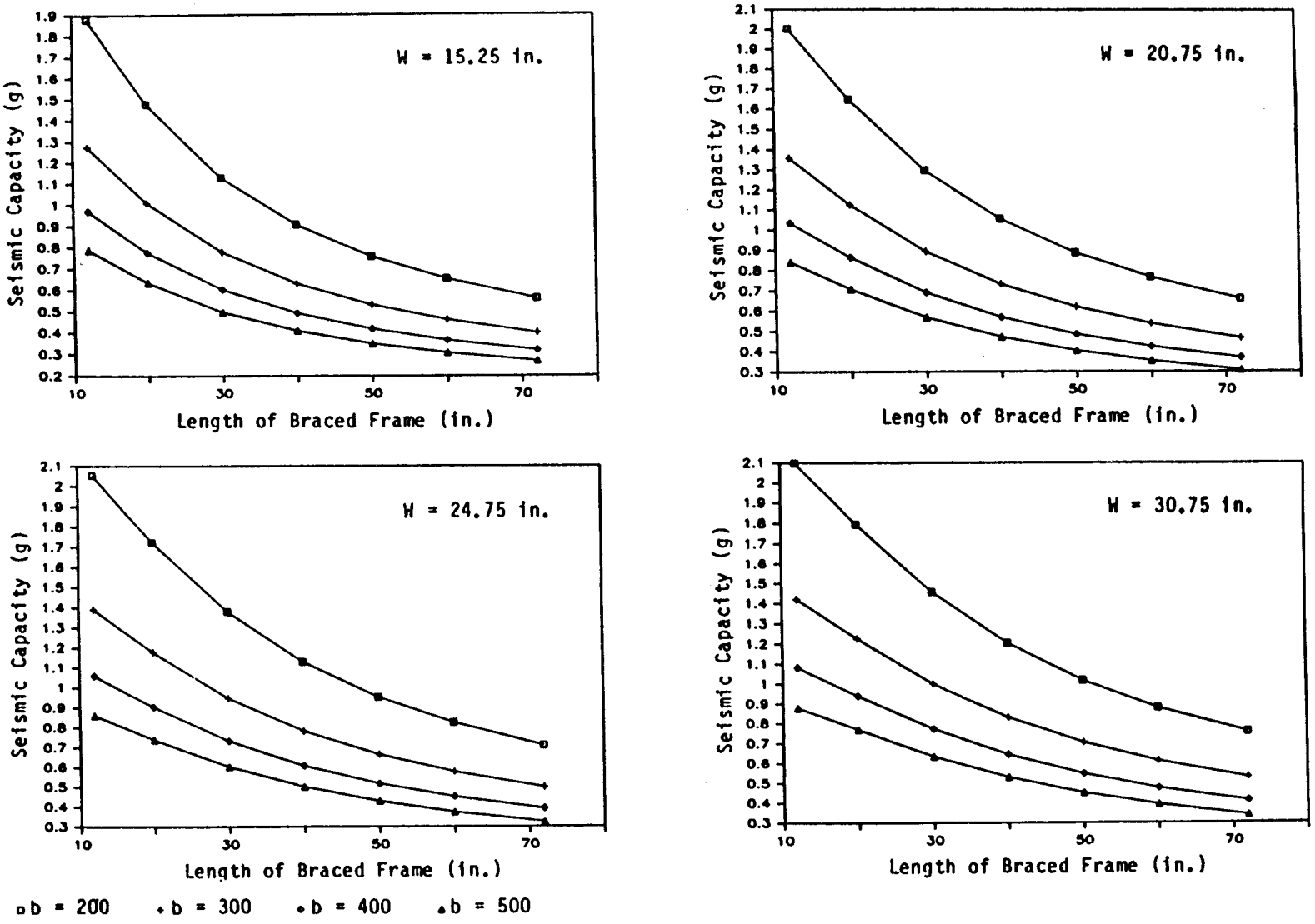
Notes: 1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum.
2. For other assumptions on layout, equipment base, etc., see Volume 1, Section 14.

Screening Figure 9.1 Screening Criteria for Battery Racks Anchored with 1/2 inch Expansion Anchor Bolts Using Mean/4 Criterion



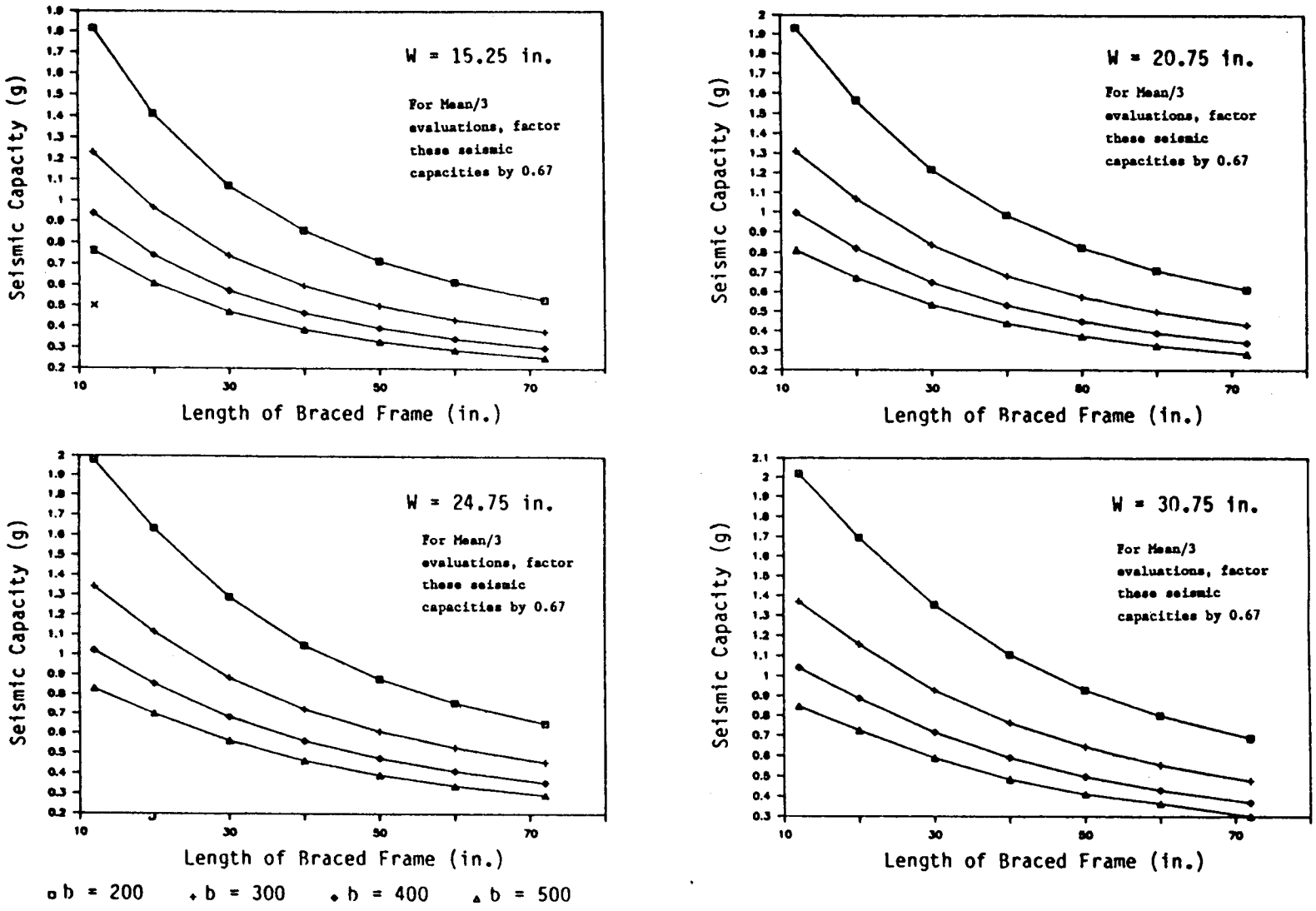
Notes: 1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum.
2. For other assumptions on layout, equipment base, etc., see Volume 1, Section 14.

Screening Figure 9.2 Screening Criteria for Battery Racks Anchored With 5/8 inch Expansion Anchor Bolts Using Mean/4 Criterion



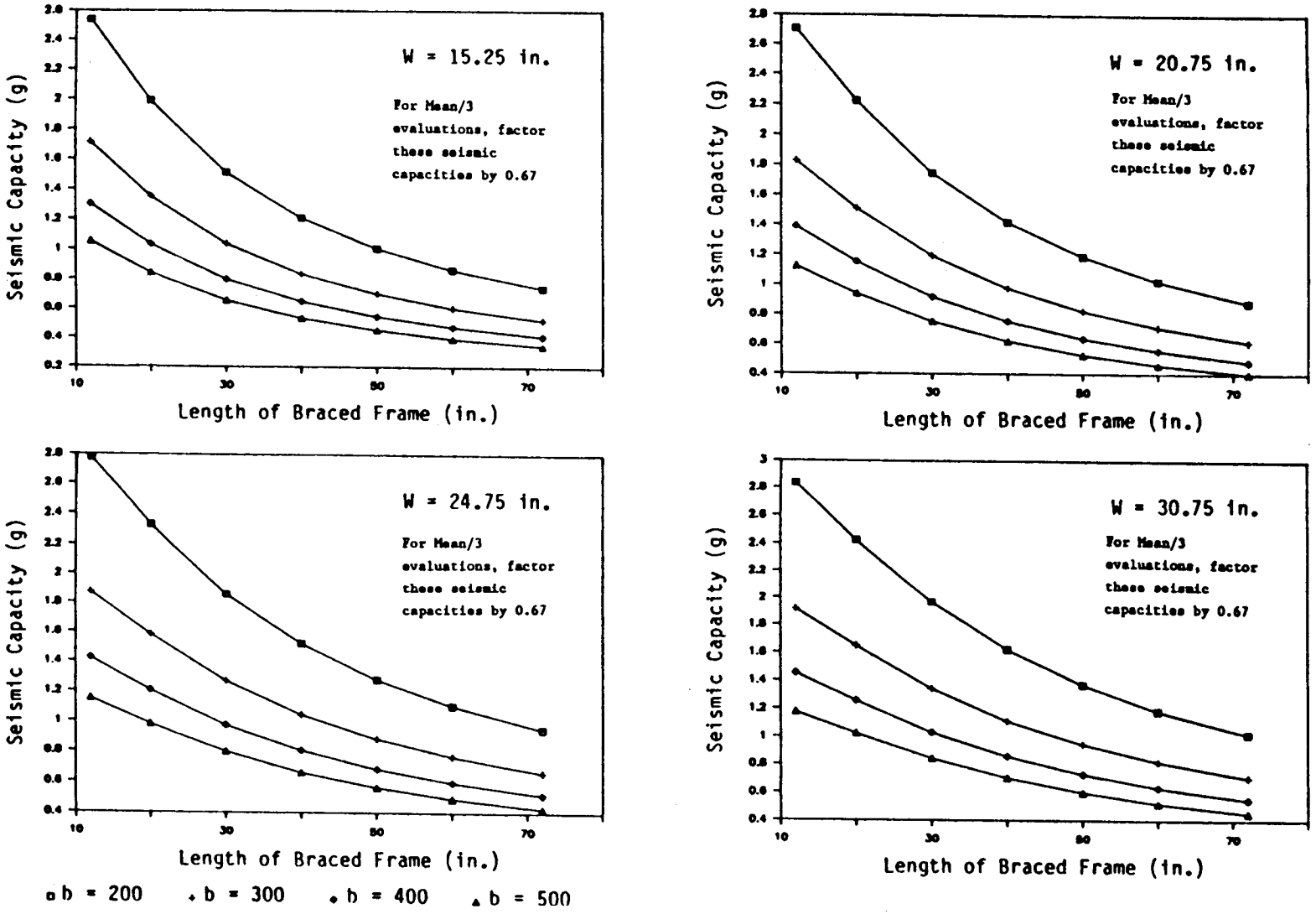
Notes: 1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum.
2. For other assumptions on layout, equipment base, etc., see Volume 1, Section 14.

Screening Figure 9.3 Screening Criteria for Battery Racks Anchored With 3/4 inch Expansion Anchor Bolts Using Mean/4 Criterion



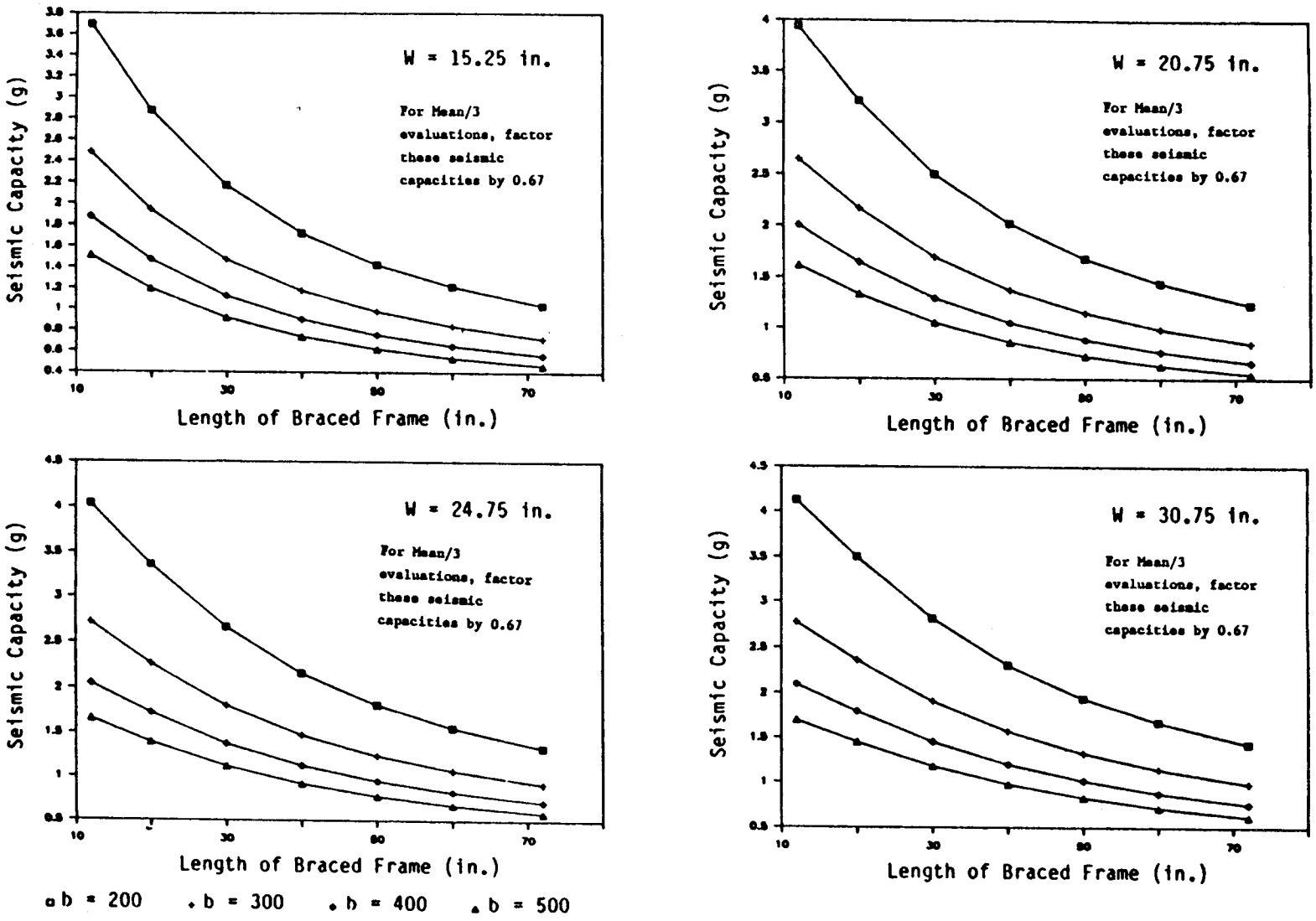
Notes: 1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum.
2. For other assumptions on layout, equipment base, etc., see Volume 1, Section 14.

Screening Figure 9.4 Screening Criteria for Battery Racks Anchored with 1/2 inch Expansion Anchor Bolts Using Mean/3 Criterion



Notes: 1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum.
2. For other assumptions on layout, equipment base, etc., see Volume 1, Section 14.

Screening Figure 9.5 Screening Criteria for Battery Racks Anchored With 5/8 inch Expansion Anchor Bolts Using Mean/3 Criterion



Notes: 1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum.
2. For other assumptions on layout, equipment base, etc., see Volume 1, Section 14.

Screening Figure 9.6 Screening Criteria for Battery Racks Anchored With 3/4 inch Expansion Anchor Bolts Using Mean/3 Criterion

Supplementary Table

REQUIRED EDGE DISTANCE, SPACING, AND EMBEDMENT FOR BOLTS

REQUIREMENTS FOR CAST-IN-PLACE BOLTS AND HEADED STUDS

Bolt Diameter (in.)	Minimum Edge Distance (in.)	Minimum Spacing (in.)	Minimum Embedment (in.)
3/8	3-3/8	4-3/4	3-3/4
1/2	4-3/8	6-1/4	5
5/8	5-1/2	7-7/8	6-1/4
3/4	6-5/8	9-1/2	7-1/2
7/8	7-3/4	11	8-3/4
1	8-3/4	12-5/8	10
1-1/8	9-7/8	14-1/4	11-1/4
1-1/4	11	15-3/4	12-1/2
1-3/8	12-1/8	17-3/8	13-3/4

REQUIREMENTS FOR EXPANSION ANCHOR BOLTS

Bolt Diameter (in.)	Minimum Edge Distance and Spacing (in.)
3/8	3-3/4
1/2	5
5/8	6-1/4
3/4	7-1/2
7/8	8-3/4
1	10

INSPECTION GUIDELINES FOR EXPANSION ANCHOR BOLTS

If the answers to all the following questions are yes, the bolts pass inspection. Only a sample of bolts need be inspected, as discussed in Section 2 of Volume 1.

1. Are the nut and anchor bolt tight (not turning in the hole)? ..... Yes_____ No_____
2. Is there a washer between the equipment base and the bolt head or nut? ..... Yes_____ No_____
3. Is the concrete sound? ..... Yes_____ No_____
4. Is the gap between the equipment base and the concrete surface less than or equal to 1/4"? ..... Yes_____ No_____
5. Is the bolt installed with at least the minimum required embedment shown below? ..... Yes_____ No_____

   For shell bolts, the minimum embedment is ensured if the shell does not protrude above the surface of the concrete. For nonshell bolts, the minimum embedment is ensured if the projection of the bolt above the surface conforms with the following:

Bolt Diameter (in)	Range of Bolt Projection (in.)
3/8	1/2 - 3/4
1/2	1/2 - 3/4
5/8	1/2 - 7/8
3/4	7/8 - 1 1/2
7/8	1-1/2 - 2
1	1-1/2 - 2

For further elaboration, see Step 8 of "Expansion Anchor Inspection Procedure" in Section 2 of Volume 1.

Inspection Checklist 10

GENERIC EQUIPMENT CABINETS

Use this checklist as follows, in conjunction with Section 15 of Volume 1:

- For "yes" answers proceed to the next line.
- For "no" answers proceed either to the provisions for outliers or to the section number indicated in parentheses.
- If any expansion anchor bolts do not pass the inspection procedure, reevaluate the anchorage using the bolts that pass.
- Check the appropriate box after completion of the checklist:

  [ ] Anchorage adequacy verified
  [ ] Additional evaluation required

Plant:_____ Location in Plant:_____

Equipment Description:_____

_____

By/Date:_____ Checked/Date:_____

A. Conservative Anchorage

Determine the conservative anchorage according to Section 15, Volume 1.

Cabinet parameters:

Width ..... W =_____

Length ..... L =_____

Height ..... H =_____

Number and diameter of expansion anchor bolts required for conservative anchorage from Table 15.7, Section 15, Volume 1 ..... Number:_____

Diameter:_____

B. Existing Anchorage Conditions

B.1 Number and diameter of existing expansion anchor bolts..... Number:_____

Diameter:_____

Manuf:_____ Type:_____

B.2 Is the diameter of bolts determined in Step B.1 equal to or greater than the conservative anchorage? ..... Yes_____ No_____ (C)

B.3 For bolted anchorages, do all fasteners pass the following inspection?..... Yes_____ No_____

- All bolts have nuts and washers.
- The concrete is sound.
- There are no gaps between the equipment base and the concrete.
- The edge distance, spacing, and embedment of bolts are adequate (See Supplementary Table).
- There are no safety-related relays in equipment anchored by expansion anchors.

STOP: Anchorage is adequate.

C. Anchorage Capacity

Determine anchorage capacity using Screening Tables 10.1 through 10.6 for the bolt diameter and dimensional data recorded in Section A ..... _____

D. Demand

Determine the seismic demand..... D = _____

E. Screening Procedure

E.1 Is seismic capacity, C, greater than seismic demand? ..... Yes_____ No_____

E.2 Are edge distance and spacing of bolts adequate (see Supplementary Table)? ..... Yes_____ No_____

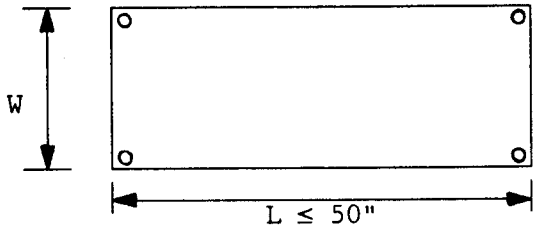
E.3 Do bolts pass the attached inspection guidelines? ..... Yes_____ No_____

STOP: Anchorage is adequate.

Screening Table 10.1

SCREENING CRITERIA FOR GENERIC EQUIPMENT CABINETS (L ≤ 50 IN.) ANCHORED WITH FOUR EXPANSION ANCHOR BOLTS USING MEAN/4 CRITERION

Cabinet Dimensions (in.)		Seismic Capacity (g)			
Width, W	Height, H	3/8-in. Bolts	1/2-in. Bolts	5/8-in. Bolts	3/4-in. Bolts
20	60	1.52	2.34	3.35	4.76
25	60	1.51	2.32	3.33	4.72
30	60	1.47	2.25	3.24	4.58
35	60	1.42	2.17	3.11	4.39
40	60	1.36	2.08	2.98	4.20
20	65	1.36	2.09	2.98	4.24
25	65	1.36	2.08	2.98	4.22
30	65	1.33	2.03	2.91	4.11
35	65	1.29	1.96	2.80	3.96
40	65	1.24	1.89	2.69	3.79
20	70	1.23	1.88	2.67	3.79
25	70	1.23	1.88	2.68	3.80
30	70	1.21	1.84	2.63	3.71
35	70	1.18	1.78	2.54	3.58
40	70	1.13	1.72	2.44	3.44
20	75	1.12	1.70	2.37	3.36
25	75	1.13	1.71	2.43	3.44
30	75	1.11	1.68	2.39	3.37
35	75	1.08	1.63	2.31	3.26
40	75	1.04	1.57	2.23	3.13
20	80	1.02	1.55	2.12	2.99
25	80	1.03	1.56	2.21	3.13
30	80	1.02	1.54	2.18	3.07
35	80	0.99	1.50	2.12	2.98
40	80	0.96	1.45	2.04	2.87



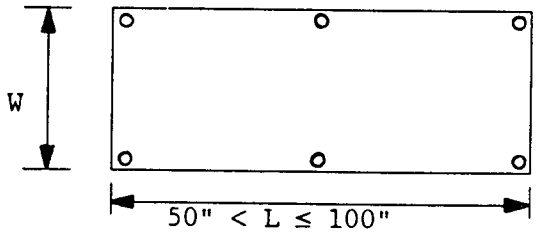
Plan View of a Cabinet Showing Location of Bolts

Notes:
1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum
2. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 15.

Screening Table 10.2

SCREENING CRITERIA FOR GENERIC EQUIPMENT CABINETS (50 < L ≤ 100 IN.) ANCHORED WITH SIX EXPANSION ANCHOR BOLTS USING MEAN/4 CRITERION

Cabinet Dimensions (in.)		Seismic Capacity (g)			
Width, W	Height,H	3/8-in. Bolts	1/2-in. Bolts	5/8-in. Bolts	3/4-in. Bolts
20	60	1.02	1.53	2.17	3.05
25	60	1.06	1.59	2.26	3.16
30	60	1.07	1.61	2.29	3.19
35	60	1.07	1.61	2.28	3.17
40	60	1.06	1.58	2.25	3.12
20	65	0.92	1.38	1.95	2.73
25	65	0.97	1.45	2.04	2.85
30	65	0.98	1.47	2.08	2.90
35	65	0.99	1.47	2.08	2.89
40	65	0.98	1.46	2.06	2.85
20	70	0.84	1.25	1.76	2.46
25	70	0.89	1.32	1.86	2.59
30	70	0.91	1.35	1.90	2.64
35	70	0.91	1.36	1.91	2.65
40	70	0.91	1.35	1.90	2.62
20	75	0.77	1.14	1.60	2.23
25	75	0.82	1.21	1.69	2.36
30	75	0.84	1.24	1.74	2.42
35	75	0.85	1.25	1.76	2.43
40	75	0.85	1.25	1.75	2.42
20	80	0.71	1.04	1.46	2.03
25	80	0.75	1.11	1.55	2.16
30	80	0.78	1.15	1.60	2.22
35	80	0.79	1.16	1.62	2.24
40	80	0.79	1.16	1.62	2.24



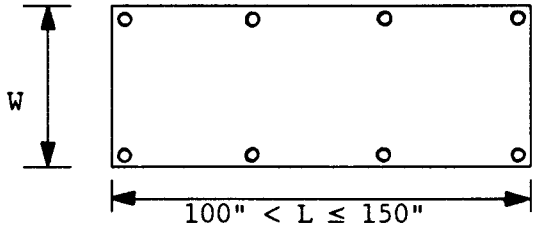
Plan View of a Cabinet Showing Location of Bolts

Notes:
1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum
2. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 15.

Screening Table 10.3

SCREENING CRITERIA FOR GENERIC EQUIPMENT CABINETS (100 < L ≤ 150 IN.) ANCHORED WITH EIGHT EXPANSION ANCHOR BOLTS USING MEAN/4 CRITERION

Cabinet Dimensions (in.)		Seismic Capacity (g)			
Width, W	Height, H	3/8-in. Bolts	1/2-in. Bolts	5/8-in. Bolts	3/4-in. Bolts
20	60	0.78	1.15	1.61	2.23
25	60	0.83	1.21	1.70	2.35
30	60	0.85	1.25	1.75	2.41
35	60	0.86	1.26	1.77	2.42
40	60	0.86	1.26	1.76	2.41
20	65	0.71	1.04	1.45	2.00
25	65	0.76	1.11	1.54	2.13
30	65	0.78	1.14	1.60	2.19
35	65	0.80	1.16	1.62	2.22
40	65	0.80	1.17	1.63	2.22
20	70	0.65	0.95	1.31	1.81
25	70	0.70	1.01	1.41	1.94
30	70	0.73	1.05	1.46	2.01
35	70	0.74	1.08	1.49	2.04
40	70	0.75	1.08	1.51	2.05
20	75	0.60	0.87	1.19	1.65
25	75	0.65	0.93	1.29	1.77
30	75	0.68	0.98	1.35	1.85
35	75	0.70	1.00	1.38	1.89
40	75	0.71	1.01	1.40	1.90
20	80	0.55	0.80	1.09	1.50
25	80	0.60	0.86	1.19	1.63
30	80	0.63	0.91	1.25	1.70
35	80	0.65	0.93	1.28	1.75
40	80	0.66	0.95	1.30	1.77



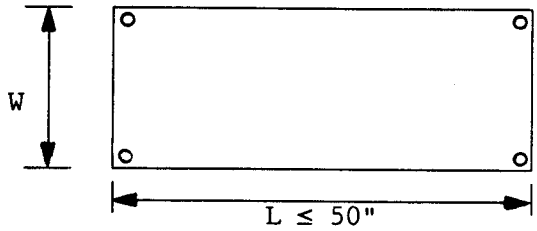
Plan View of a Cabinet Showing Location of Bolts

Notes:
1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum
2. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 15.

Screening Table 10.4

SCREENING CRITERIA FOR GENERIC EQUIPMENT CABINETS (L ≤ 50 IN.)
ANCHORED WITH FOUR EXPANSION ANCHOR BOLTS USING MEAN/3 CRITERION

Cabinet Dimensions (in.)		Seismic Capacity (g)			
Width, W	Height, H	3/8-in. Bolts	1/2-in. Bolts	5/8-in. Bolts	3/4-in. Bolts
20	60	2.03	3.12	4.46	6.35
25	60	2.01	3.09	4.44	6.29
30	60	1.96	3.00	4.32	6.11
35	60	1.89	2.89	4.15	5.85
40	60	1.81	2.77	3.97	5.60
20	65	1.81	2.79	3.97	5.65
25	65	1.81	2.77	3.97	5.63
30	65	1.77	2.71	3.88	5.48
35	65	1.72	2.61	3.73	5.28
40	65	1.65	2.52	3.57	5.05
20	70	1.64	2.51	3.56	5.05
25	70	1.64	2.51	3.57	5.07
30	70	1.61	2.45	3.51	4.95
35	70	1.57	2.37	3.39	4.77
40	70	1.51	2.29	3.25	4.59
20	75	1.49	2.27	3.16	4.48
25	75	1.51	2.28	3.24	4.59
30	75	1.48	2.24	3.19	4.49
35	75	1.44	2.17	3.08	4.35
40	75	1.39	2.09	2.97	4.17
20	80	1.36	2.07	2.83	3.99
25	80	1.37	2.08	2.95	4.17
30	80	1.36	2.05	2.91	4.09
35	80	1.32	2.00	2.83	3.97
40	80	1.28	1.93	2.72	3.83



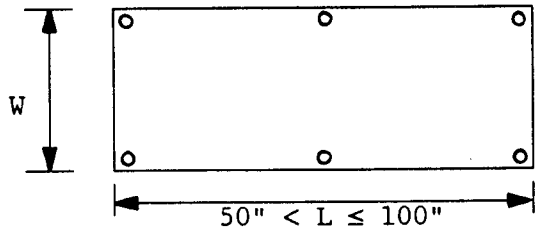
Plan View of a Cabinet Showing Location of Bolts

Notes:
1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum
2. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 15.

Screening Table 10.5

SCREENING CRITERIA FOR GENERIC EQUIPMENT CABINETS (50 < L ≤ 100 IN.) ANCHORED WITH SIX EXPANSION ANCHOR BOLTS USING MEAN/3 CRITERION

Cabinet Dimensions (in.)		Seismic Capacity (g)			
Width, W	Height, H	3/8-in. Bolts	1/2-in. Bolts	5/8-in. Bolts	3/4-in. Bolts
20	60	1.36	1.15	2.89	4.06
25	60	1.41	2.12	3.01	4.21
30	60	1.43	2.15	3.05	4.25
35	60	1.43	2.15	3.04	4.23
40	60	1.41	2.11	3.00	4.16
20	65	1.23	1.84	2.60	3.64
25	65	1.29	1.93	2.72	3.80
30	65	1.31	1.96	2.77	3.87
35	65	1.32	1.96	2.77	3.85
40	65	1.31	1.95	2.75	3.80
20	70	1.12	1.67	2.35	3.28
25	70	1.87	1.76	2.48	3.45
30	70	1.21	1.80	2.53	3.52
35	70	1.21	1.81	2.55	3.53
40	70	1.21	1.80	2.53	3.49
20	75	1.03	1.52	2.13	2.97
25	75	1.09	1.61	2.25	3.15
30	75	1.12	1.65	2.32	3.23
35	75	1.13	1.67	2.35	3.24
40	75	1.13	1.67	2.33	3.23
20	80	0.95	1.39	1.95	2.71
25	80	1.00	1.48	2.07	2.88
30	80	1.04	1.53	2.13	2.96
35	80	1.05	1.55	2.16	2.99
40	80	1.05	1.55	2.16	2.99



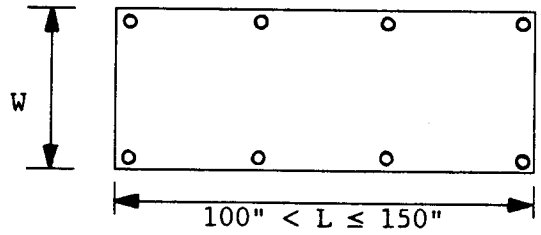
Plan View of a Cabinet Showing Location of Bolts

Notes:
1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum
2. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 15.

Screening Table 10.6

SCREENING CRITERIA FOR GEMERIC EQUIPMENT CABINETS (100 < L ≤ 150 IN.)
ANCHORED WITH EIGHT EXPANSION BOLTS USING MEAN/3 CRITERION

Cabinet Dimensions (in.)		Seismic Capacity (g)			
Width, W	Height, H	3/8-in. Bolts	1/2-in. Bolts	5/8-in. Bolts	3/4-in. Bolts
20	60	1.04	1.53	2.15	2.97
25	60	1.12	1.61	2.27	3.13
30	60	1.13	1.67	2.33	3.21
35	60	1.15	1.68	2.36	3.23
40	60	1.15	1.68	2.35	3.21
20	65	0.95	1.39	1.93	2.67
25	65	1.01	1.48	2.05	2.84
30	65	1.04	1.52	2.13	2.92
35	65	1.07	1.55	2.16	2.96
40	65	10.7	1.56	2.17	2.96
20	70	0.87	1.27	1.75	2.41
25	70	0.93	1.35	1.88	2.59
30	70	0.97	1.40	1.95	2.68
35	70	0.99	1.44	1.99	2.72
40	70	1.00	1.44	2.01	2.73
20	75	0.80	1.16	1.59	2.20
25	75	0.87	1.24	1.72	2.36
30	75	0.91	1.31	1.80	2.47
35	75	0.93	1.33	1.54	2.25
40	75	0.95	1.35	1.87	2.53
20	80	0.73	1.07	1.45	2.00
25	80	0.80	1.15	1.59	2.17
30	80	0.84	1.21	1.67	2.27
35	80	0.87	1.24	1.71	2.33
40	80	0.88	1.27	1.73	2.36



Plan View of a Cabinet Showing Location of Bolts

Notes:
1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum
2. For other assumptions on anchor layout, equipment base, etc., see Volume 1, Section 15.

Supplementary Table

REQUIRED EDGE DISTANCE, SPACING, AND EMBEDMENT FOR BOLTS

REQUIREMENTS FOR CAST-IN-PLACE BOLTS AND HEADED STUDS

Bolt Diameter (in.)	Minimum Edge Distance (in.)	Minimum Spacing (in.)	Minimum Embedment (in.)
3/8	3-3/8	4-3/4	3-3/4
1/2	4-3/8	6-1/4	5
5/8	5-1/2	7-7/8	6-1/4
3/4	6-5/8	9-1/2	7-1/2
7/8	7-3/4	11	8-3/4
1	8-3/4	12-5/8	10
1-1/8	9-7/8	14-1/4	11-1/4
1-1/4	11	15-3/4	12-1/2
1-3/8	12-1/8	17-3/8	13-3/4

REQUIREMENTS FOR EXPANSION ANCHOR BOLTS

Bolt Diameter (in.)	Minimum Edge Distance and Spacing (in.)
3/8	3-3/4
1/2	5
5/8	6-1/4
3/4	7-1/2
7/8	8-3/4
1	10

INSPECTION GUIDELINES FOR EXPANSION ANCHOR BOLTS

If the answers to all the following questions are yes, the bolts pass inspection. Only a sample of bolts need be inspected, as discussed in Section 2 of Volume 1.

1. Are the nut and anchor bolt tight (not turning in the hole)? ..... Yes_____ No_____
2. Is there a washer between the equipment base and the bolt head or nut? ..... Yes_____ No_____
3. Is the concrete sound? ..... Yes_____ No_____
4. Is the gap between the equipment base and the concrete surface less than or equal to 1/4"? ..... Yes_____ No_____
5. Is the bolt installed with at least the minimum required embedment shown below? ..... Yes_____ No_____

   For shell bolts, the minimum embedment is ensured if the shell does not protrude above the surface of the concrete. For nonshell bolts, the minimum embedment is ensured if the projection of the bolt above the surface conforms with the following:

Bolt Diameter (in.)	Range of Bolt Projection (in.)
3/8	1/2 - 3/4
1/2	1/2 - 3/4
5/8	1/2 - 7/8
3/4	7/8 - 1 1/2
7/8	1-1/2 - 2
1	1-1/2 - 2

For further elaboration, see Step 8 of "Expansion Anchor Inspection Procedure" in Section 2 of Volume 1.

Inspection Checklist 11

WALK-THROUGH CONTROL PANELS

Use this checklist in conjunction with Section 16 of Volume 1:

Plant:_____ Location in Plant:_____

Equipment Description:_____

By/Date:_____ Checked/Date:_____

A. Demand

A.1 Determine the maximum seismic demand ..... A = _____

A.2 Determine the weight of panel per foot ..... W = _____kip/ft

A.3 Determine panel height, H, depth, D, and fastener spacing, S ..... H = _____ft

D = _____ft

S = _____ft

A.4 Determine shear per foot,

$$\frac{WG}{2}\sqrt{2} \quad \text{..... V =\_\_\_\_\_kip/ft}$$

A.5 Determine pullout per foot,

$$\frac{WGH}{2}\left[\left(\frac{1}{D}\right)^2+\left(\frac{1}{2S}\right)^2+\left(\frac{2}{3H}\right)^2\right]^{1/2}-\frac{W}{2} \quad \text{..... P = \_\_\_\_\_kip/ft}$$

B. Screening Procedure For Expansion Anchor Bolts

B.1 Using Screening Figure 11.1 for 1/2-in. bolts, Screening Figure 11.2 for 5/8-in. bolts, and Screening Figure 11.3 for 3/4-in. bolts, plot the point corresponding to V and P determined in Steps A.4 and A.5.

B.2 Is the point plotted in Step B.1 inside the appropriate curve for the bolt diameter, mean/3 or mean/4 (for safety-related relays), and spacing used in the anchorage being evaluated? . . . . . Yes_____ No____

B.3 Are edge distance and spacing of all bolts adequate (see Supplementary Table)? . . . . . Yes_____ No____

B.4 Do bolts pass the attached inspection guidelines? . . . Yes_____ No____

Stop: Anchorage is adequate.

C. Screening Procedure For Welds to Embedded Steel

C.1 Using Screening Figure 11.4, plot the point corresponding to V and P determined in Steps A.4 and A.5.

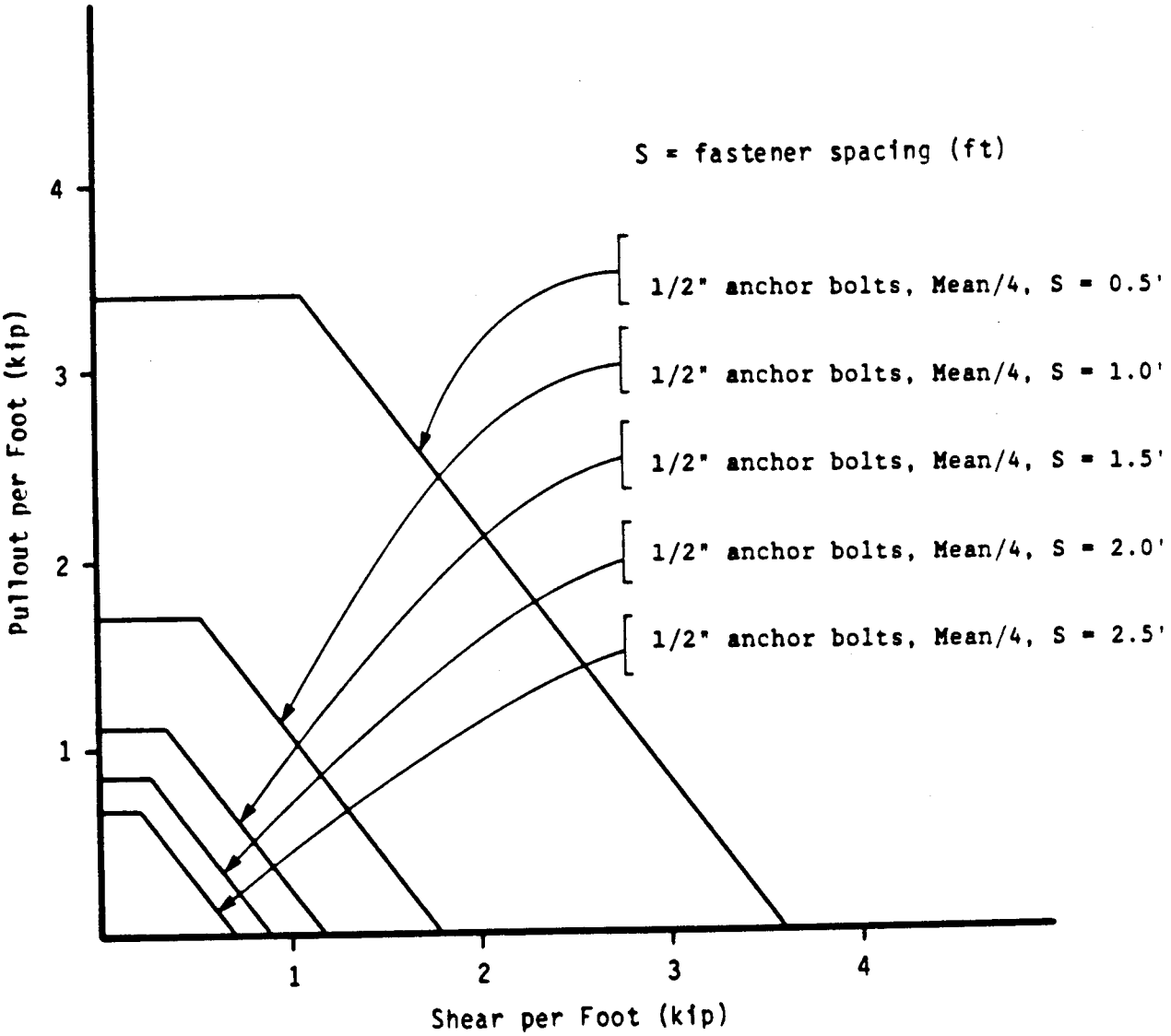
C.2 Is the point plotted in Step C-1 within the curve drawn for the weld category used in the anchorage being evaluated? . . . . . Yes_____ No____

C.3 Determine the diameter and spacing, S, of the headed stud or cast-in-place (CIP) bolt used to anchor the embedded steel plate.

C.4 Using Screening Figure 11.5, plot the point corresponding to V and P determined in Steps A.4 and A.5.

C.5 Is the point plotted in Step C.4 within the curve drawn for the headed stud or CIP bolt diameter and spacing used in this anchorage? . . . . . Yes_____ No____

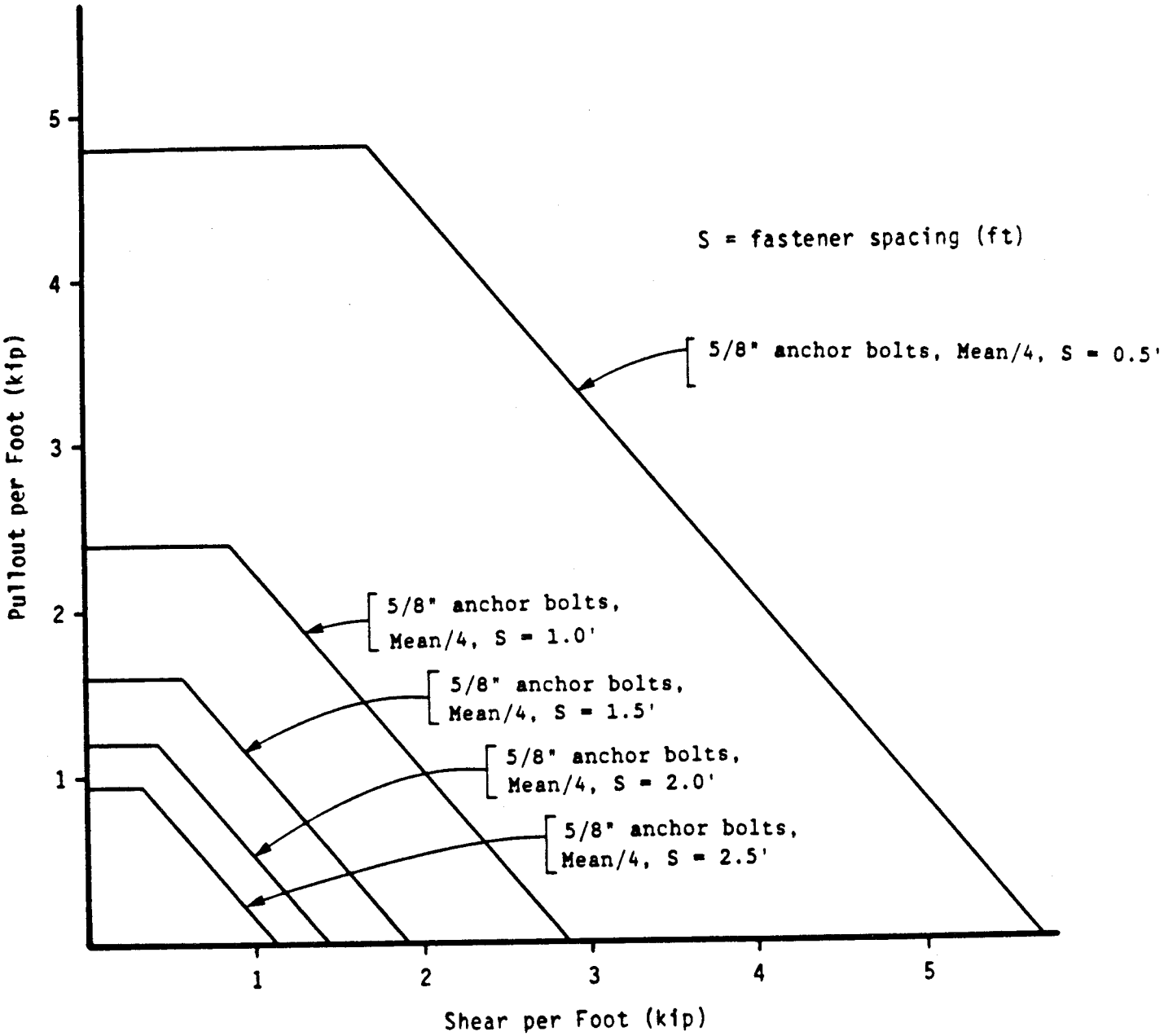
C.6 Are the edge distance and spacing adequate for the cast-in-place bolts or headed studs (see Supplementary Table) . . . . . Yes_____ No____



Notes: 1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum.

2. For other assumptions on layout, equipment base, etc., see Volume 1, Section 16.

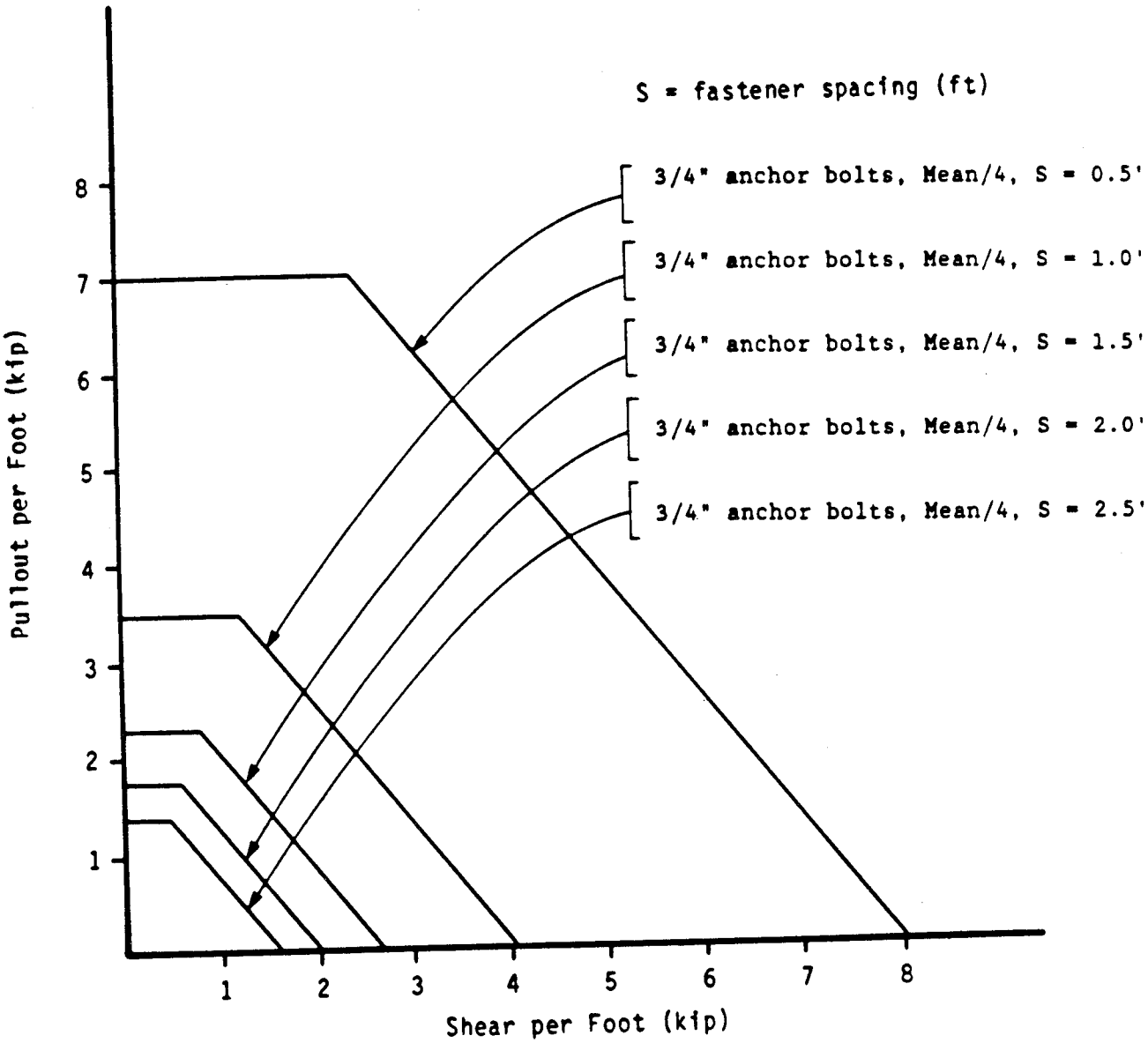
Screening Figure 11.1 Screening Criteria for Control Panels with 1/2-inch Expansion Anchor Bolts



Notes: 1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum.

2. For other assumptions on layout, equipment base, etc., see Volume 1, Section 16.

Screening Figure 11.2 Screening Criteria for Control Panels with 5/8-inch Expansion Anchor Bolts



Notes: 1. $f'_c \geq 4{,}000$ psi; KDF = 1.0; uncracked concrete; spacing and edge distance ≥ recommended minimum.

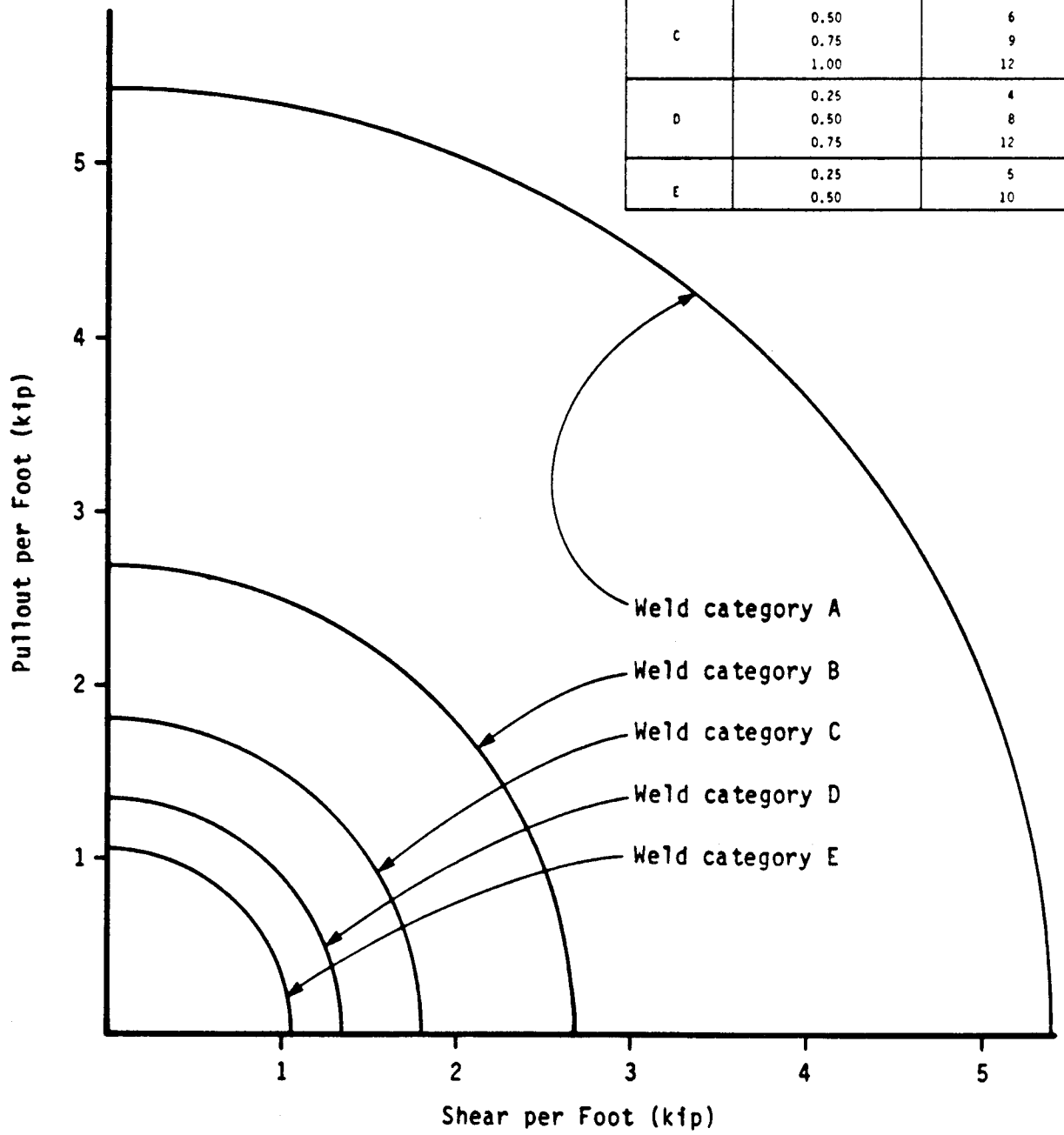
2. For other assumptions on layout, equipment base, etc., see Volume 1, Section 16.

Screening Figure 11.3 Screening Criteria for Control Panels with 3/4-inch Expansion Anchor Bolts

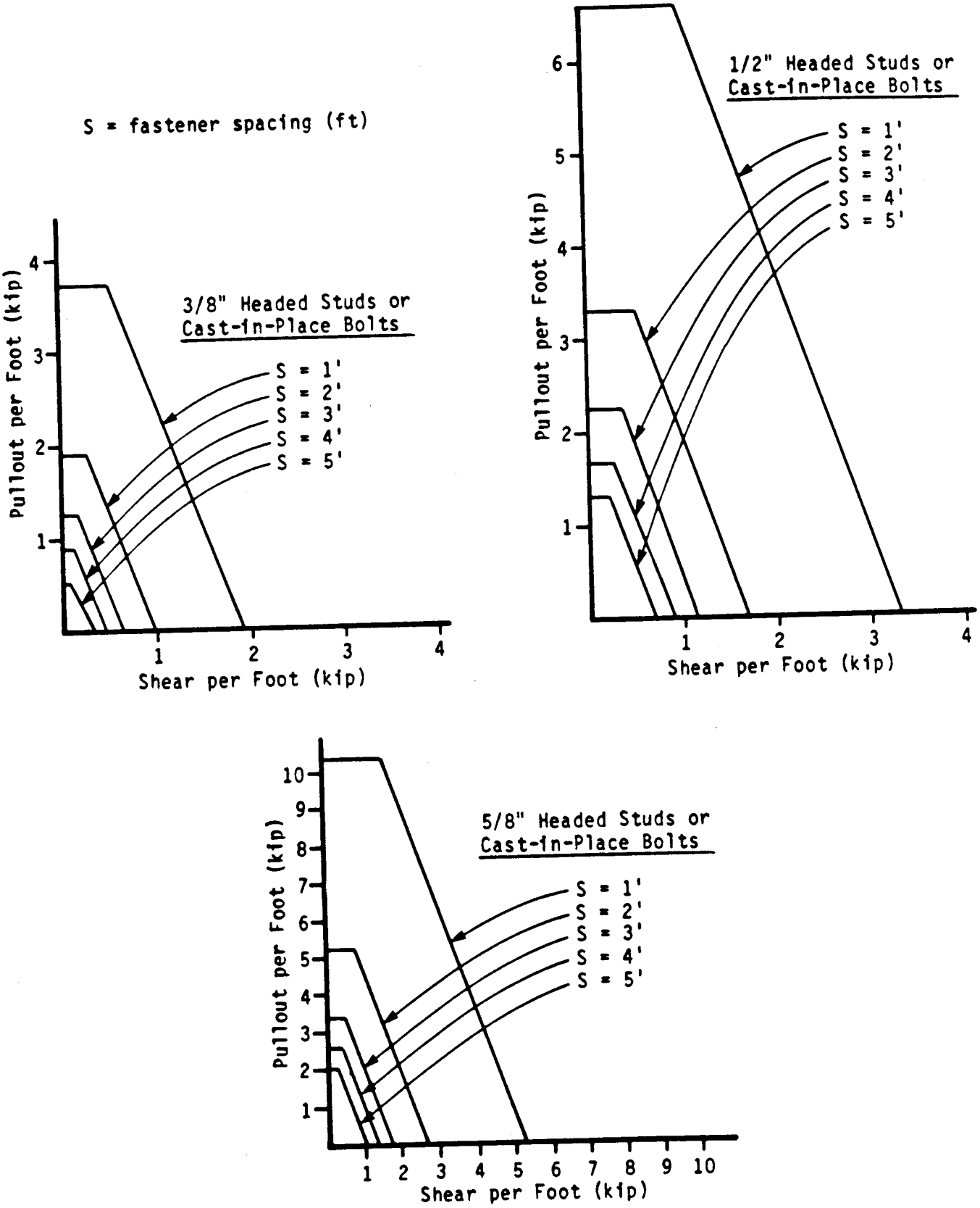
Notes: For other assumptions on layout, equipment base, etc., see Volume 1, Section 16.

DEFINITION OF WELD CATEGORIES

Weld Category	Area of Weld = Thickness x Length ($in.^2$)	Spacing of Welds (ft)
A	0.25	1
	0.50	2
	0.75	3
	1.00	4
	1.25	5
B	0.25	2
	0.50	4
	0.75	6
	1.00	8
	1.25	10
C	0.25	3
	0.50	6
	0.75	9
	1.00	12
D	0.25	4
	0.50	8
	0.75	12
E	0.25	5
	0.50	10



Screening Figure 11.4 Screening Criteria for Weld Evaluation for Panels Welded to Embedded Steel Plates



Notes: For other assumptions on layout, equipment base, etc., see Volume 1, Section 16.

Screening Figure 11.5 Screening Criteria for Anchorage of Embedded Steel for Control Panels Welded to Embedded Steel

Supplementary Table

REQUIRED EDGE DISTANCE, SPACING, AND EMBEDMENT FOR BOLTS

REQUIREMENTS FOR CAST-IN-PLACE BOLTS AND HEADED STUDS:

Bolt Diameter (in.)	Minimum Edge Distance (in.)	Minimum Spacing (in.)	Minimum Embedment (in.)
3/8	3-3/8	4-3/4	3-3/4
1/2	4-3/8	6-1/4	5
5/8	5-1/2	7-7/8	6-1/4
3/4	6-5/8	9-1/2	7-1/2
7/8	7-3/4	11	8-3/4
1	8-3/4	12-5/8	10
1-1/8	9-7/8	14-1/4	11-1/4
1-1/4	11	15-3/4	12-1/2
1-3/8	12-1/8	17-3/8	13-3/4

REQUIREMENTS FOR EXPANSION ANCHOR BOLTS:

Bolt Diameter (in.)	Minimum Edge Distance and Spacing (in.)
3/8	3-3/4
1/2	5
5/8	6-1/4
3/4	7-1/2
7/8	8-3/4
1	10

INSPECTION GUIDELINES FOR EXPANSION ANCHOR BOLTS

If the answers to all the following questions are yes, the bolts pass inspection. Only a sample of bolts need be inspected, as discussed in Section 2 of Volume 1.

1. Are the nut and anchor bolt tight (not turning in the hole)? ..... Yes_____ No_____

2. Is there a washer between the equipment base and the bolt head or nut? ..... Yes_____ No_____

3. Is the concrete sound? ..... Yes_____ No_____

4. Is the gap between the equipment base and the concrete surface less than or equal to 1/4"? ..... Yes_____ No_____

5. Is the bolt installed with at least the minimum required embedment shown below? ..... Yes_____ No_____

   For shell bolts, the minimum embedment is ensured if the shell does not protrude above the surface of the concrete. For nonshell bolts, the minimum embedment is ensured if the projection of the bolt above the surface conforms with the following:

Bolt Diameter (in.)	Range of Bolt Projection (in.)
3/8	1/2 - 3/4
1/2	1/2 - 3/4
5/8	1/2 - 7/8
3/4	7/8 - 1-1/2
7/8	1-1/2 - 2
1	1-1/2 - 2

For further elaboration, see Step 8 of "Expansion Anchor Inspection Procedure" in Section 2 of Volume 1.

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