501

CASE

(CITIZENS ASSN. FOR SOUND ENERGY)

1426 S. Polk
Dallas, Texas 75224

214/946-9446

October 13, 1984

Administrative Judge Peter B. Bloch
U. S. Nuclear Regulatory Commission
4350 East/West Highway, 4th Floor
Bethesda, Maryland 20014

Dr. Walter H. Jordan
881 W. Outer Drive
Oak Ridge, Tennessee 37830

Dr. Kenneth A. McCollom, Dean
Division of Engineering, Architecture and Technology
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Stillwater, Oklahoma 74074

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USNRC

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OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

Gentlemen:

SUBJECT: In the Matter of
Application of Texas Utilities
Generating Company, et al. for
An Operating License for
Comanche Peak Steam Electric Station
Units #1 and #2 (CPSES)
Docket Nos. 50-445 and 50-446 OL

Attachments to CASE's 10/8/84
Answer to Applicants' Motion for
Summary Disposition Regarding Consideration
of Cinching Down of U-Bolts

We are attaching four attachments which were inadvertently omitted from subject pleading; we apologize for any inconvenience:

CASE Exhibit 920, MSS Standard Practice SP-69, "Pipe Hangers and Supports - Selection and Application," pages i-iii, 1-10. -- see page 5 of pleading

CASE Exhibit 742, NUREG/CR-2137, "Realistic Seismic Design Margins of Pumps, Valves, and Piping," pages 8, 10, 11, 30, 31, B-8, B-9, and B-10. -- see page 7 of pleading

Response by Applicants to NRC Questions of Meeting of August 8-9 and August 23, 1984, A. U-bolt Cinching, pages 1-27. -- see page 14 of pleading

June 8, 1984, letter from L. M. Popplewell, TUGCO Project Engineering Manager, to Ms. Nancy Williams, Project Manager, Cygna Energy Services, Subject: Comanche Peak Steam Electric Station Cygna Review Questions (Pipe Supports), and attached pages re: Cygna Questions (42), (43), and part of (44). -- see page 15 of pleading

Respectfully submitted,

Juanita Ellis

(Mrs.) Juanita Ellis, President

cc: Service List

DS03

CASE Exhibit 920

MSS

STANDARD PRACTICE **SP-69**

1976
Edition

PIPE HANGERS AND SUPPORTS - SELECTION AND APPLICATION

Developed and Approved
by the
Manufacturers Standardization Society
of the
Valve and Fittings Industry
1815 North Fort Myer Drive
Arlington, Virginia 22209

Originally Approved July 1966

FOREWORD

The requirements of this standard were developed by a cooperative effort of representatives of pipe hanger manufacturers. They are based on the best practice current at this time and on proven results of the research and experience of this industry.

The metric units given in parenthesis were derived utilizing the following conversion factors, and rounded to appropriate accuracy.

Conversion	Factor
inches to millimeters	25.4
feet to meters	0.3048
PSI to kPa	6.89
F to C	$C = \frac{F-32}{1.8}$

First Edition	1966
Revised	1976

All MSS Standards approved and practices recommended are advisory only. There is not agreement to adhere to any MSS standard or recommended practice and their use by anyone is entirely voluntary.

CONTENTS

Specifications and standards of the following organizations appear in this standard.

AISC American Institute of Steel Construction, Inc.
1221 Avenue of the Americas
New York, N.Y. 10020

ANSI American National Standards Institute
1430 Broadway, New York, New York 10018

--- Factory Mutual Engineering Corporation
1151 Boston-Providence Turnpike, Norwood, MA 02062

--- Federal Specifications: Superintendent of Documents
United States Government Printing Office, Washington, D.C. 20402

MSS Manufacturers Standardization Society of the Valve and Fittings Industry
1815 North Fort Myer Drive, Arlington, Virginia 22209

NFPA National Fire Protection Association
470 Atlantic Avenue, Boston, MA 02210

PFI Pipe Fabrication Institute
1326 Freeport Road, Pittsburgh, PA 15238

UL Underwriters Laboratories
207 East Ohio Street, Chicago, IL 60611

PIPE HANGERS AND SUPPORTS – SELECTION AND APPLICATION

1. SCOPE AND OBJECTIVES

1.1 This standard relates to the selection and application of pipe hangers and supports for all service temperatures. Hangers and supports noted herein, are the types specified in MSS SP-58 Pipe Hangers and Supports, Material, Design and Manufacture. Reference is also made to other pipe supporting and controlling elements such as guides, restraints, and anchors.

1.2 The objectives of this standard are:

a) To serve in the engineering design, in whole or in part, as a pipe hanger and support specification by reference to this document.

b) To serve as a guide to proven industry practice during engineering design and writing of job specifications covering the hanging, supporting, and controlling the movement of piping systems.

c) To provide the erector with information on types of hanger and support components to be used for specific applications and installations, where such information is not otherwise provided.

1.3 This is a basic standard practice. However, it may be subject to changes and/or elaboration by the design engineer.

1.4 Other documents governing pipe hangers and supports may be specified to take precedence, in whole or in part, over this document. Examples:

ANSI B31 Codes for Pressure Piping.

Federal Specification WW-H-171 (latest issue) – Hangers and Supports Pipe.

Underwriters Laboratories, Inc. Standard UL-203-Pipe Hanger Equipment.

Factory Mutual Engineering Division Bulletin 2-8 - Installing Sprinkler Equipment.

2. CLASSIFICATION OF PIPING SYSTEMS –

For the purpose of pipe hanger and support selection, this document establishes an identification of piping systems according to the operating (service) temperatures of the pipe contents as follows:

2.1 Hot Systems

A-1. 120F (49C) to 450F (232C)
A-2. 451F (233C) to 750F (398C)
A-3. Over 750 F (399C)

2.2 Ambient Systems

B. 60F (16C) to 119F (48C)

2.3 Cold Systems

C-1. 33F (1C) to 59F (15C)
C-2. -2F (-29C) to 32F (0C)
C-3. Below -2F (-29C)

3. GENERAL REQUIREMENTS

3.1 The selection of pipe hangers and supports shall be based upon the overall design concept of the piping systems and any special requirements which may be called for in the specifications. The supporting systems shall provide for and control the free or intended movement of the piping including its movement in relation to that of connected equipment.

3.2 A careful study shall be made of the piping layout in relation to the surrounding structure and adjacent piping and equipment before selecting the type support to be used at each hanger point.

3.3 Hangers, supports, anchors and restraints shall be selected to withstand all static and dynamic conditions of loading to which the piping and associated equipment may be subjected.

3.4 Load calculations, where required by specification, shall give consideration to the following:

a) Weights of pipe, valves, fittings, insulating materials, suspended hanger components, and normal fluid contents.

b) Weight of hydrostatic test fluid or cleaning fluid if normal operating fluid contents are lighter.

c) Use of restraints against normal thermal movement.

d) The effects of anchors and restraints to provide for the intended operation of expansion joints.

e) Reaction forces due to operation of safety or relief valves.

f) Wind, snow or ice loadings on outdoor piping.

g) Loadings due to seismic forces when provided by the design engineer's specification.

3.5 Hanger components shall not be used for purposes other than for which they were designed. They shall not be used for rigging and erection purposes.

4. MATERIAL REQUIREMENTS

4.1 It is strongly recommended that the materials of all pipe hanging and supporting elements be in accordance with MSS SP-58.

4.2 The material in contact with the pipe shall be compatible with the piping material so that neither shall have a deteriorating action on the other.

4.3 Materials subject to corrosion or electrolysis shall be protected as specified by the engineering design and such protection shall be applied in accordance with the requirements of MSS SP-58.

5. DIMENSIONAL REQUIREMENTS

5.1 Hangers and supports shall be sized to fit the outside diameter of pipe, tubing, or, if specified, the outside diameter of insulation.

5.2 Hangers for the suspension of Size 2½ and larger pipe and tubing shall be capable of vertical adjustment under load.

6. SELECTION OF HANGERS AND SUPPORTS FOR PIPE MOVEMENT

6.1 The selection of hangers and supports shall be made to provide the piping system with the degree of control that its operating characteristics require.

6.2 Where negligible movement of pipe occurs at hanger locations, rod hangers should be used for suspended lines. For piping supported from below, bases, brackets or structural cross members should be used.

6.3 Where there is horizontal movement at a suspended type hanger location, hanger components shall be selected to allow for swing. If the vertical angle of the hanger rod is greater than 4 degrees a traveling device should be provided for horizontal movement. For piping supported from below, slides, rollers, or roller carriages should be used.

SYSTEM TEMP RANGE	INSULATION NOTE 1	HORIZONTAL PIPE ATTACHMENTS: STEEL CLIPS A	MALL IRON RINGS B	STEEL BANDS C	STEEL CLAMPS D	CAST IRON HANGING ROLLS E	CAST IRON SUPPORTING ROLLS F	STEEL TRAPEZES G	STEEL PROT. SADDLES & SHIELDS H	STEEL OR CAST IRON STANCHIONS I
HOT A-1 [illegible]	COVERED	NONE	NONE	1, 5, 7, 9, 10 W SADDLE OR SHIELD	3	41, 43 W SADDLE	44, 45, 46 W SADDLE	NOTE 3 W SADDLE	39	36, 37, 38 W/SADDLE
	BARE	24, 26	6, 11, 12	1, 5, 7, 9, 10	3, 4	41, 43	44, 45, 46	NOTE 3	NONE	36, 37, 38
HOT A-2 [illegible]	COVERED	NONE	NONE	1 W SADDLE	3	41 W SADDLE	44, 45, 46 W SADDLE	NOTE 3 W SADDLE	39	36, 37, 38 W SADDLE
	BARE	NONE	NONE	NONE	3, 4	NONE	NONE	NOTE 3	NONE	NONE
HOT A-3 [illegible]	COVERED	NONE	NONE	1 W ALLOY SADDLE	ALLOY 2, 3	41, 43 W ALLOY SADDLE	44, 45, 46 ALLOY SADDLE	NOTE 3 W ALLOY SADDLE	39 ALLOY	36, 37, 38 W ALLOY SADDLE
	BARE	NONE	NONE	NONE	ALLOY 2, 3, 4	NONE	NONE	NOTE 3	NONE	NONE
AMBIENT B [illegible]	COVERED	24, 26	NONE	1, 5, 7, 9, 10 W SADDLE OR SHIELD	3	41, 43 W SADDLE	44, 45, 46 W SADDLE	NOTE 3 W SADDLE	39, 40	36, 37, 38 W SADDLE
	BARE	24, 26	6, 11, 12	1, 5, 7, 9, 10	3, 4	41, 43	44, 45, 46	NOTE 3	NONE	36, 37, 38
COLD C-1 [illegible]	COVERED	NONE	NONE	1, 5, 7, 9, 10 W SHIELD	3	41, 43 W SHIELD NOTE 4	44, 45, 46 W SHIELD NOTE 4	NOTES 3 & 4 W/SHIELD	40	36, 37, 38 W SHIELD
	BARE	24, 26	6, 11, 12	1, 5, 7, 9, 10	3, 4	41, 43	44, 45, 46	NOTE 3	NONE	36, 37, 38
COLD C-2 [illegible]	COVERED	NONE	NONE	1, 5, 7, 9, 10 W SHIELD	NONE	41, 43 W SHIELD NOTE 4	44, 45, 46 W SHIELD NOTE 4	NOTES 3 & 4 W SHIELD	40	36, 37, 38 W SHIELD
	BARE	NONE	NONE	1, 5, 7, 9, 10	3, 4	41, 43	44, 45, 46	NOTE 3	NONE	36, 37, 38
COLD C-3 [illegible]	COVERED	NONE	NONE	1, 5, 7, 9, 10 W SHIELD	NONE	41, 43 W/SHIELD NOTE 4	44, 45, 46 W/SHIELD NOTE 4	NOTES 2, 3, 4 W SHIELD	40	36, 37, 38 W SHIELD
	BARE	NONE	NONE	NOTES 2 & 3	NOTES 2 & 3	NONE	NONE	NOTES 2 & 3	NONE	NOTES 2 & 3

SYSTEM	STEEL WELDED ATTACHMENTS J	VERTICAL PIPE ATTACHMENTS: STEEL RISER CLAMPS 2 BOLT K	STEEL RISER CLAMPS 4 BOLT L	WELDED ATTACHMENTS STEEL M	HANGER ROD FIXTURES, STEEL OR MALL IRON: TURNBUCKLES N	SWING EYES O	CLEVISES P	BUILDING STRUCTURE ATTACHMENTS, STEEL AND/OR MALL IRON: INSERTS Q	C-CLAMPS R	BEAM CLAMPS S	WELDED ATTACHMENTS T	BRACKETS U
HOT A-1	35 NOTE 3	*	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	19, 23	20, 21, 25, 27, 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
HOT A-2	35 NOTE 3	NONE	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	NONE	20, 21, 25, 27, 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
HOT A-3	35 ALLOY NOTE 3	NONE	42 ALLOY NOTE 3	ALLOY NOTE 3	13	17	14	NOTES 2 & 5	NONE	20, 21, 25, 27, 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
AMBIENT B	35 NOTE 3	*	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	19, 23	20, 21, 25, 27, 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
COLD C-1	NOTE 3	*	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	19, 23	20, 21, 25, 27, 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
COLD C-2	NOTE 3	*	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	19, 23	20, 21, 25, 27, 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
COLD C-3	NOTES 2 & 3	NOTES 2 & 3	NOTES 2 & 3	NOTES 2 & 3	13, 15	16, 17	14	18 NOTE 5	19, 23	20, 21, 25, 27, 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34

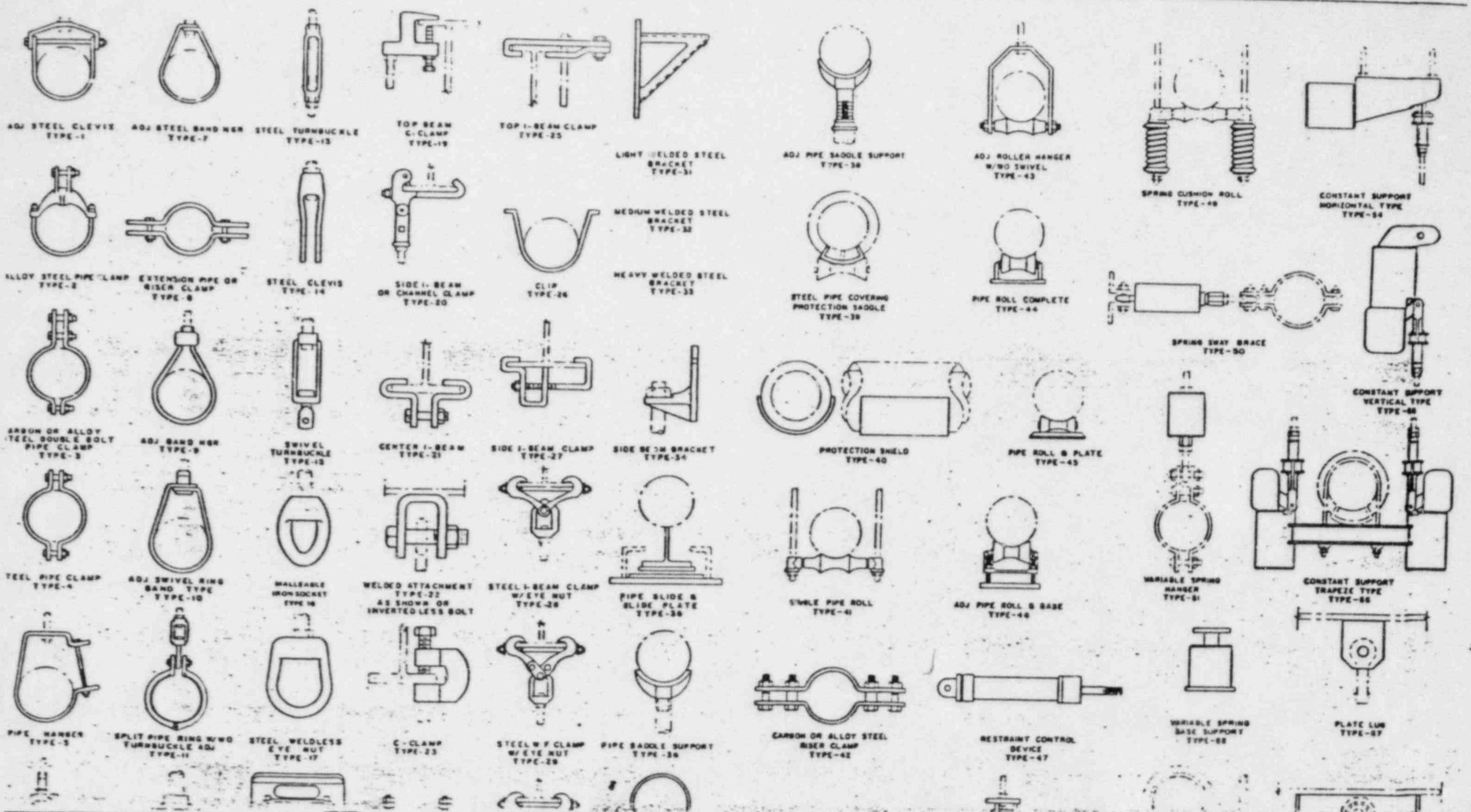
NOTE:

1. Hangers on insulated systems shall incorporate protection saddles or shields or shall be clamped or welded to the pipe and project through the insulation to provide external attachment.
2. The selection of type and material shall be made by the Design Engineer.
3. The design shall be in accordance with MSS SP-58 or as specified by the Design Engineer.
4. For shields used with rollers or subject to point loading, see table 5.
5. Continuous inserts, anchor bolts and concrete fasteners may be used as specified by the Design Engineer.

TABLE I. HANGER AND SUPPORT SELECTIONS
(For Spring Hangers, See Table 2)

To find recommended hanger or support components,
1. Locate the system temp. and insulation condition in the two columns at left.
2. Read across the column headings for the type of component to be used.
3. Numbers in boxes refer to those types shown in Figure 1, which corresponds to Figure 1 of MSS SP-58.

SYSTEM	INSULATION	HORIZONTAL PIPE ATTACHMENTS									VERTICAL PIPE ATTACHMENTS				HANGER ROD FIXTURES			BUILDING STRUCTURE ATTACHMENTS				
															STEEL OR MALL. IRON			STEEL AND OR MALL. IRON				
TEMP. RANGE DEG. F(C)	NOTE 1	STEEL CLIPS A	WALL IRON RINGS B	STEEL BANDS C	STEEL CLAMPS D	CAST IRON HANGING ROLLS E	CAST IRON SUPPORTING ROLLS F	STEEL TRAPEZES G	STEEL PROT. SADDLES & SHIELDS H	STEEL OR CAST IRON STANCHIONS I	STEEL WELDED ATTACHMENTS J	STEEL RISER CLAMPS 2-BOLT K	STEEL RISER CLAMPS 4-BOLT L	WELDED ATTACHMENTS STEEL M	TURN-BUCKLES N	SWING EYES O	CLEVISES P	INSERTS Q	C-CLAMPS R	BEAM CLAMPS S	WELDED ATTACHMENTS T	BRACKETS U
HOT A-1	COVERED	NONE	NONE	1, 5, 7, 9, 10 W SADDLE OR SHIELD	3	41, 43 W/SADDLE	44, 45, 46 W/SADDLE	NOTE 3 W SADDLE	39	36, 37, 38 W/SADDLE	35 NOTE 3	8	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	19, 23	20, 21, 25 27, 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
120(49) to 450(232)	BARE	24, 26	8, 11, 12	1, 5, 7, 9, 10	3, 4	41, 43	44, 45, 46	NOTE 3	NONE	36, 37, 38												
HOT A-2	COVERED	NONE	NONE	1 W SADDLE	3	41 W/SADDLE	44, 45, 46 W SADDLE	NOTE 3 W SADDLE	39	36, 37, 38 W/SADDLE	35 NOTE 3	NONE	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	NONE	20, 21, 25 27, 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
450(232) TO 750(399)	BARE	NONE	NONE	NONE	3, 4	NONE	NONE	NOTE 3	NONE	NONE												
HOT A-3	COVERED	NONE	NONE	1 W ALLOY SADDLE	ALLOY 2, 3	41, 43 W ALLOY SADDLE	44, 45, 46 ALLOY SADDLE	NOTE 3 W ALLOY SADDLE	39 ALLOY	36, 37, 38 W ALLOY SADDLE	35 ALLOY NOTE 3	NONE	42 ALLOY NOTE 3	ALLOY NOTE 3	13	17	14	NOTES [illegible]	NONE	20, 21, 25 27, 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
OVER 750(399)	BARE	NONE	NONE	NONE	ALLOY 2, 3, 4	NONE	NONE	NOTE 3	NONE	NONE												
AMBIENT B	COVERED	24, 26	NONE	1, 5, 7, 9, 10 W SADDLE OR SHIELD	3	41, 43 W/SADDLE	44, 45, 46 W SADDLE	NOTE 3 W SADDLE	39, 40	36, 37, 38 W/SADDLE	35 NOTE 3	8	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	19, 23	20, 21, 25 27, 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
60(16) TO 119(48)	BARE	24, 26	8, 11, 12	1, 5, 7, 9, 10	3, 4	41, 43	44, 45, 46	NOTE 3	NONE	36, 37, 38												
COLD C-1	COVERED	NONE	NONE	1, 5, 7, 9, 10 W SHIELD	3	41, 43 W SHIELD NOTE 4	44, 45, 46 W SHIELD NOTE 4	NOTES 3 & 4 W SHIELD	40	36, 37, 38 W SHIELD	NOTE 3	8	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	19, 23	20, 21, 25 27, 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
[illegible] TO [illegible]	BARE	24, 26	8, 11, 12	1, 5, 7, 9, 10	3, 4	41, 43	44, 45, 46	NOTE 3	NONE	36, 37, 38												
COLD C-2	COVERED	NONE	NONE	1, 5, 7, 9, 10 W SHIELD	NONE	41, 43 W SHIELD NOTE 4	44, 45, 46 W SHIELD NOTE 4	NOTES 3 & 4 W SHIELD	40	36, 37, 38 W SHIELD	NOTE 3	8	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	19, 23	20, 21, 25 27, 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
[illegible] TO [illegible]	BARE	NONE	NONE	1, 5, 7, 9, 10	3, 4	41, 43	44, 45, 46	NOTE 3	NONE	36, 37, 38												
[illegible]	COVERED	NONE	NONE	1, 5, 7, 9, 10 W [illegible]	NONE	41, 43 W SHIELD	44, 45, 46 W SHIELD	NOTES 3 & 4	40	36, 37, 38												


ADJ STEEL CLEVIS TYPE-1
ADJ STEEL BAND HGR TYPE-7
STEEL TURNBUCKLE TYPE-13
TOP BEAM C-CLAMP TYPE-19
TOP I-BEAM CLAMP TYPE-25
LIGHT WELDED STEEL BRACKET TYPE-31
ADJ PIPE SADDLE SUPPORT TYPE-38
ADJ ROLLER HANGER W/WO SWIVEL TYPE-43
SPRING CUSHION ROLL TYPE-49
CONSTANT SUPPORT HORIZONTAL TYPE TYPE-54
ALLOY STEEL PIPE CLAMP TYPE-2
EXTENSION PIPE OR RISER CLAMP TYPE-8
STEEL CLEVIS TYPE-14
SIDE I-BEAM OR CHANNEL CLAMP TYPE-20
CLIP TYPE-26
MEDIUM WELDED STEEL BRACKET TYPE-32
HEAVY WELDED STEEL BRACKET TYPE-33
STEEL PIPE COVERING PROTECTION SADDLE TYPE-39
PIPE ROLL COMPLETE TYPE-44
SPRING SWAY BRACE TYPE-50
CONSTANT SUPPORT VERTICAL TYPE TYPE-55
CARBON OR ALLOY STEEL DOUBLE BOLT PIPE CLAMP TYPE-3
ADJ BAND HGR TYPE-9
SWIVEL TURNBUCKLE TYPE-15
CENTER I-BEAM TYPE-21
SIDE I-BEAM CLAMP TYPE-27
SIDE BEAM BRACKET TYPE-34
PROTECTION SHIELD TYPE-40
PIPE ROLL & PLATE TYPE-45
STEEL PIPE CLAMP TYPE-4
ADJ SWIVEL RING BAND TYPE TYPE-10
MALLEABLE IRON SOCKET TYPE 16
WELDED ATTACHMENT TYPE-22 AS SHOWN OR INVERTED LESS BOLT
STEEL I-BEAM CLAMP W/EYE NUT TYPE-28
PIPE SLIDE & SLIDE PLATE TYPE-35
SINGLE PIPE ROLL TYPE-41
ADJ PIPE ROLL & BASE TYPE-46
VARIABLE SPRING HANGER TYPE-51
CONSTANT SUPPORT TRAPEZE TYPE TYPE-56
PIPE HANGER TYPE-5
SPLIT PIPE RING W/WO TURNBUCKLE ADJ TYPE-11
STEEL WELDLESS EYE NUT TYPE-17
C-CLAMP TYPE-23
STEEL W F CLAMP W/EYE NUT TYPE-29
PIPE SADDLE SUPPORT TYPE-36
CARBON OR ALLOY STEEL RISER CLAMP TYPE-42
RESTRAINT CONTROL DEVICE TYPE-47
VARIABLE SPRING BASE SUPPORT TYPE-52
PLATE LUG TYPE-57

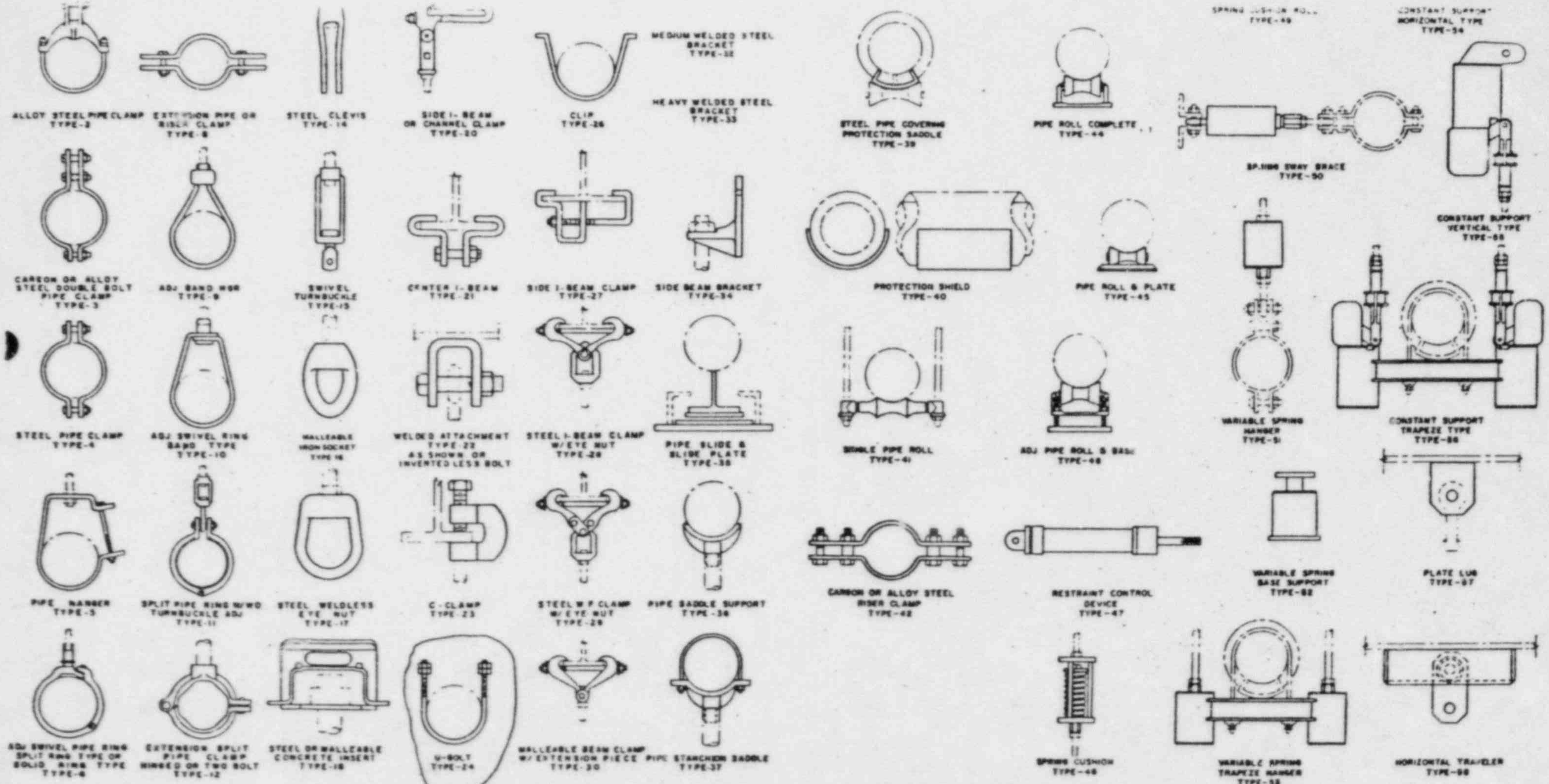


FIGURE 1. TYPE CHART

6.4 Where significant vertical movement of the pipe occurs at the hanger location, a resilient support must be used. Selection of resilient supports shall be based on permissible load variation and effects on adjacent equipment. Typical load variations are shown in Table 2. Load and movement calculations shall be made for the proper selection of spring hangers. Vertical movement and load transfer from riser expansion to horizontal runs shall be given consideration when applying spring hangers.

6.4.1 Spring Cushion Hangers may be used where vertical movement does not exceed ¼ inch (6.3 mm), and where formal load and movement calculations are not required.

TABLE 2. SPRING SUPPORT SELECTION

VERTICAL EXPANSION	ALLOWABLE VARIABILITY OR DEVIATION	SINGLE ROD HANGER	DOUBLE ROD HANGER	BASE SUPPORT
	NOTE (1)	NOTE (2) AND NOTE (3)		
MAX. 1/4 INCH (6.3mm)	25% 6%	49,51SS 51SS	48,49,51SS,53SS 51S, 53S	52SS 52S
MAX. 1 INCH (25.4mm)	25% 6%	51S 54,55	51S, 53S 54,55,56	52S 54,55
MAX. 2 INCH (50.8mm)	25% 6%	51LS 54,55	51LS,53LS 54,55,56	52LS 54,55
MAX. 3 INCH (76.2mm)	25% 6%	51LS 54,55	51LS,53LS 54,55,56	52LS 54,55
OVER 3 INCH (76.2mm)	25% 6%	54,55 54,55	54,55,56 54,55,56	54,55 54,55

NOTE (1) VARIABLE SPRING HANGERS

VARIABILITY FACTOR = $\frac{\text{Pipe Travel in. (mm) X Spring Rate lbs/in. (Kg/mm)}}{\text{Operating Load LBS (kg)}}$

CONSTANT SUPPORT HANGERS

DEVIATION = $\frac{\text{Max Reading Moving Down} - \text{Min Reading Moving Up}}{\text{Max Reading Moving Down} + \text{Min Reading Moving Up}}$

(2) NUMBERS IN COLUMNS ARE TYPE NUMBERS FROM FIGURE 1

(3) VARIABLE SPRING TYPES 51, 52, AND 53 ARE STANDARD SPRING, SHORT SPRING, AND LONG SPRING MODELS ARE IDENTIFIED AS S, SS AND LS, RESPECTIVELY

6.4.2 Variable Spring Hangers shall be used for all other resilient support requirements except as noted in Subsection 6.4.3.

6.4.3 Constant Support Hangers shall be used on piping systems where the deviation in supporting force must be limited to 6 percent and which cannot be accommodated by a Variable Spring Hanger.

7. HANGER AND SUPPORT SELECTION

7.1 Hanger and support components shall be selected from Table 1 within the system classification.

7.2 For attachment to concrete structure, poured in place anchor bolts or inserts are preferred whenever possible. When necessary, approved concrete fasteners may be used.

7.3 Where additional structural members are required, they shall be designed for the specific loads they are to support in accordance with the requirements of the American Institute of Steel Construction.

8. ATTACHMENTS MADE BY WELDING OR BOLTING

8.1 All welded type support components shall be in accordance with MSS SP-58.

8.2 All attachments welded to the pipe shall be in accordance with MSS SP-58 and Pipe Fabrication Institute, Standard ES-26.

8.3 Welded and bolted attachments to the building structural steel shall be in accordance with the requirements of AISC. There shall be no drilling or burning of holes in the building structural steel without prior approval by the design engineers.

TABLE 3. MAXIMUM HORIZONTAL PIPE HANGER AND SUPPORT SPACING

	1		2		3		4		5	6	7	8	9	10	11
NOMINAL PIPE OR TUBE DIAM.	STD WT STEEL PIPE				COPPER TUBE				FIRE PRO-TECTION	CAST IRON PRES.	CAST IRON SOIL	ASBESTOS CEMENT	GLASS	PLASTIC	FIBERGLASS REIN-FORCED
	WATER SERVICE		VAPOR SERVICE		WATER SERVICE		VAPOR SERVICE								
	ft	m	ft	m	ft	m	ft	m							
1/4	7	2.1	8	2.4	5	1.5	5	1.5	FOLLOW REQUIREMENTS OF THE NATIONAL FIRE PROTECTION ASSOCIATION. SEE SECTION 14.	12 ft (3.7m) MAX SPACING MIN OF ONE (1) HANGER PER PIPE SECTION CLOSE TO JOINT ON THE BARREL. ALSO AT CHANGE OF DIRECTION AND BRANCH CONNECTIONS.	10 ft (3.0m) MAX SPACING MIN OF ONE (1) HANGER PER PIPE SECTION CLOSE TO JOINT ON THE BARREL. ALSO AT CHANGE OF DIRECTION AND BRANCH CONNECTIONS.	FOLLOW PIPE MANUFACTURER'S RECOMMENDATIONS.	8 ft (2.4m) MAX SPACING. FOLLOW MANUFACTURER'S RECOMMENDATIONS. SEE SECTION 18.	FOLLOW PIPE MANUFACTURER'S RECOMMENDATIONS FOR MATERIAL AND SERVICE TEMPERATURE.	FOLLOW PIPE MANUFACTURER'S RECOMMENDATIONS FOR SPACING AND SERVICE CONDITION.
3/8	7	2.1	8	2.4	5	1.5	6	1.8							
1/2	7	2.1	8	2.4	5	1.5	6	1.8							
3/4	7	2.1	9	2.7	5	1.5	7	2.1							
1	7	2.1	9	2.7	6	1.8	8	2.4							
1 1/4	7	2.1	9	2.7	7	2.1	9	2.7							
1 1/2	9	2.7	12	3.7	8	2.4	10	3.0							
2	10	3.0	13	4.0	8	2.4	11	3.4							
2 1/2	11	3.4	14	4.3	9	2.7	13	4.0							
3	12	3.7	15	4.6	10	3.0	14	4.3							
3 1/2	13	4.0	16	4.9	11	3.4	15	4.6							
4	14	4.3	17	5.2	12	3.7	16	4.9							
5	16	4.9	19	5.8	13	4.0	18	5.5							
6	17	5.2	21	6.4	14	4.3	20	6.1							
8	19	5.8	24	7.3	16	4.9	23	7.0							
10	20	6.1	26	7.9	18	5.5	25	7.6							
12	23	7.0	30	9.1	19	5.8	28	8.5							
14	25	7.6	32	9.8											
16	27	8.2	35	10.7											
18	28	8.5	37	11.3											
20	30	9.1	39	11.9											
24	32	9.8	42	12.8											
30	33	10.1	44	13.4											

NOTE: (1) FOR SPACING SUPPORTS INCORPORATING TYPE 40 SHIELDS, SEE TABLE 5.
(2) DOES NOT APPLY WHERE SPAN CALCULATIONS ARE MADE OR WHERE THERE ARE CONCENTRATED LOADS BETWEEN SUPPORTS SUCH AS FLANGES, VALVES, SPECIALTIES, ETC., OR CHANGES IN DIRECTION REQUIRING ADDITIONAL SUPPORTS.

8.4 Recommended maximum applied torque for set screws in C-clamps is listed below

Thread size Inch	Torque Inch Pound
1/4	40
3/8	60
1/2	125
5/8	250
3/4	400
7/8	665

9. HANGER AND SUPPORT SPACING

9.1 The maximum spacing of hangers and supports shall be as set forth in Table 3.

9.2 Spacings less than shown in Table 3 may be required to conform with building structure loading limitations.

9.3 Minimum rod diameters for single rod hangers are listed in Table 4.

9.4 When periodic dismantling of a piping system for cleaning, etc. is anticipated, the design engineer shall specify any required additional supports.

10. PIPE ATTACHMENTS FOR INSULATED LINES

10.1 The connections to pipe attachments shall be outside the insulation so that movement of the line shall not cause damage to the insulation.

10.2 Insulation protection shields shall be provided to protect the vapor barrier of insulation on cold lines. Under no circumstances shall hangers, supports or guides be applied directly to horizontal pipe or tubing on vapor barriered lines. (See Table 5).

11. MULTIPLE SUPPORTS

11.1 Horizontal banks of piping may be supported on a common base member without regard to the pipe centerline elevation. The particular method of support to be used shall be as required by the engineering design.

11.2 In the supporting of multiple pipe runs, provisions shall be made to keep the lines in their relative lateral positions, using clamps or clips. Lines subject to thermal expansion shall be free to roll axially or slide.

12. RISER SUPPORTS

12.1 The selection and location of riser supports shall take into consideration the entire weight of the riser, hydrostatic test load conditions, line temperature and available supporting structure. On a riser subject to expansion, only one support of the rigid type shall be used.

12.2 Riser clamps, Type 42, shall have a positive means of engagement between the pipe and the clamp.

13. ANCHORS, GUIDES AND RESTRAINTS

13.1 Anchors, guides and restraints shall be located by the specifications and/or drawings. Should the need or the desirability of relocating, eliminating or adding anchors, guides or restraints arise, such changes shall be brought to the attention of the design engineer for consideration and approval.

13.2 Anchors, guides and restraints shall be designed for imposed loadings as determined by the design engineer.

13.3 The necessity for, and the location of, shock supressors and seismic control devices shall be as determined by the design engineer.

TABLE 4 MIN. ROD DIAMETER FOR SINGLE ROD HANGERS(1)(2)

	COLUMNS(3) 1, 2, 6, 7, 9		COLUMNS(3) 3, 4, 8, 10, 11	
NOMINAL PIPE OR TUBING DIA.	NOMINAL ROD DIA.		NOMINAL ROD DIA.	
in.	in	mm	in	mm
1/4	3/8	9.6	3/8	9.6
3/8	3/8	9.6	3/8	9.6
1/2	3/8	9.6	3/8	9.6
3/4	3/8	9.6	3/8	9.6
1	3/8	9.6	3/8	9.6
1 1/4	3/8	9.6	3/8	9.6
1 1/2	3/8	9.6	3/8	9.6
2	3/8	9.6	3/8	9.6
2 1/2	1/2	12.7	1/2	12.7
3	1/2	12.7	1/2	12.7
3 1/2	1/2	12.7	1/2	12.7
4	5/8	15.8	1/2	12.7
5	5/8	15.8	1/2	12.7
6	3/4	19.1	5/8	15.8
8	7/8	22.2	3/4	19.1
10	7/8	22.2	3/4	19.1
12	7/8	22.2	3/4	19.1
14	1	25.4	7/8	22.2
16	1	25.4		
18	1	25.4		
20	1 1/4	31.8		
24	1 1/4	31.8		

NOTE:

(1) For calculated loads, rod diameters may be sized in accordance with MSS SP-58, Table 3.

(2) Rods may be reduced one size for double rod hangers with 3/8 in. (9.6 mm) minimum diameter.

(3) Columns noted refer to MSS SP-69, Table 3.

13.4 The location, type and number of corrective devices which may be necessary to control any unforeseen vibrations as determined after the piping is in service are not a part of this standard.

14. FIRE PROTECTION SYSTEMS

14.1 Hangers and supports for fire protection systems shall conform to the standards published by the National Fire Protection Association in the National Fire Codes for fixed extinguishing equipment. Pamphlet forms are as follows:

NFPA-11 Foam Extinguishing Systems
NFPA-12 - Carbon Dioxide Systems
NFPA-13 Installation of Sprinkler Systems
NFPA-14 Standpipe and Hose Systems
NFPA-15 Water Spray Systems
NFPA-16 – Foam Water Systems
NFPA-17 - Dry Chemical Extinguishing Systems

14.2 Hangers in general are covered in NFPA Pamphlet 13. If the system is other than a standard water sprinkler system, the applicable pamphlet (e.g., Foam) shall also be consulted.

15. CAST IRON PRESSURE PIPING

15.1 The size of hangers shall be suitable for the O.D. of the pipe to be supported.

15.2 For exposed piping with other than bolted flanged or grooved joints, clamps and restraining rods shall be used.

15.3 In cases where movement may occur between the piping and the structure to which the hangers are attached, spring hangers shall be installed as specified.

15.4 For buried lines, supporting means that may be required due to soil conditions or settlement of terminal points, shall be specified by the design engineer.

16. CAST IRON SOIL PIPING

Requirements shall be as set forth in Subsection 15.3 and 15.4.

17. ASBESTOS CEMENT PIPING

17.1 The size of hangers shall be suitable for the O.D. of the pipe to be supported.

17.2 Support types and spacing shall be as recommended by the pipe manufacturer.

TABLE 5 TYPE 40 PROTECTION SHIELDS FOR VAPOR BARRIER INSULATED PIPE AND TUBING

NOM. PIPE SIZE	SHIELD LENGTH		U.S. STANDARD GAGE	SPACING	
	in	mm		ft	m
1/2 - 3 1/2	12	305	18	10	3.0
4	12	305	16	10	3.0
5 - 6	18	457	16	10	3.0
8 - 14	24	610	14	10	3.0
16 - 24	24	610	12	10	3.0
NOM. TUBING SIZE	**SHIELD LENGTH**		**U.S. STANDARD GAGE**	**SPACING**	
	in	mm		ft	m
1/4 - 1	12	305	18	5*	1.5
1 1/4 - 2 1/2	12	305	18	8*	2.4
3 - 3 1/2	12	305	18	10	3.0
4	12	305	16	10	3.0
5 - 6	18	457	16	10	3.0
8	24	610	14	10	3.0

NOTES: The listed spans and shield lengths are based on insulation with a compressive strength of 15 psi (103kPa). For insulation with compressive strengths greater than 15 psi (103kPa), span may be increased proportionately up to the maximum allowable as listed in Table 3. Spans marked * are the maximum allowable.

Protection shield gages listed are for use with band type hangers only, for point loading increase gage thickness and length. When shields are used with rollers shield lengths shall be increased to keep rolling point of contact within the middle one-third of the shield length.

18. GLASS PIPING

18.1 Hangers shall be provided with pads or cushions on the bearing surfaces to prevent scratching the pipe. The hangers shall fit loosely around the pipe yet contact it through the pads or cushions in a manner to distribute the load over the largest possible area. Point loading shall be avoided. The system of hangers shall be designed with the least practical number of rigid anchor points. Supports for vertical piping and all anchors shall be as recommended by the pipe manufacturer.

18.2 Hangers shall be placed approximately one foot from each side of fittings or couplings. At least two hangers shall be used for each 10-foot (3.0m) section.

19. PLASTIC PIPING

19.1 Rigid plastic piping normally shall be supported by the same type of hangers used with steel pipe.

19.2 Support spacing shall be based on the manufacturer's recommendations for the service conditions.

19.3 Flexible plastic tubing or rigid plastic pipe operating at temperatures high enough to materially lower its strength, shall be supported continuously by metal angles or channels and special hangers.

20. FIBERGLASS REINFORCED PIPE (FRP)

20.1 The size of hanger shall be suitable for the O.D. of the pipe to be supported.

20.2 Support spacing shall be based on the manufacturer's recommendations for the service condition.

20.3 FRP should not be point loaded and all shields and hangers in contact with the pipe shall be free of burrs. A suitable rubber or other pliable material is recommended for a liner in the hanger.

LIST OF MSS STANDARD PRACTICES

NUMBER	
SP- 6 1974	Standard Finishes for Contact Faces of Pipe Flanges and Connecting End Flanges of Valves and Fittings (M)
SP- 9-1970	Spot Facing for Bronze, Iron and Steel Flanges
SP-25-1964	Standard Marking System for Valves, Fittings, Flanges and Unions
SP-42-1959	150 lb. Corrosion Resistant Cast Flanged Valves
SP-43-1971	Wrought Stainless Steel Butt-Welding Fittings
SP-44-1975	Steel Pipe Line Flanges (M)
SP-45-1971	Bypass and Drain Connection Standard (formerly SP-5 and SP-28)
SP-51-1957 (R 1965)	150 lb. Corrosion Resistant Cast Flanges and Flanged Fittings
SP-53-1971	Quality Standard for Steel Castings – Dry Particle Magnetic Inspection Method
SP-54-1971	Quality Standard for Steel Castings – Radiographic Inspection Method
SP-55-1971 (R 1975)	Quality Standard for Steel Castings – Visual Method
SP-58-1975	Pipe Hangers and Supports – Materials, Design and Manufacture (M)
SP-60-1969	Connecting Flange Joint Between Tapping Sleeves and Tapping Valves
SP-61-1961	Hydrostatic Testing of Steel Valves
SP-65-1962 (R 1968)	High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets
*	
SP-67-1976	Butterfly Valves (M)
SP-69-1976	Pipe Hangers and Supports – Selection and Application (M)
SP-70-1970	Cast Iron Gate Valves, Flanged and Threaded Ends
SP-71-1970	Cast Iron Swing Check Valves, Flanged and Threaded Ends
SP-72-1970	Ball Valves with Flanged or Butt-Welding Ends for General Service
SP-73-1970	Silver Brazing Joints for Wrought and Cast Solder Joint Fittings
SP-75-1973	Specification for High Test Wrought Welding Fittings
SP-76-1970	Malleable Iron Threaded Pipe Unions – 150, 250, and 300 lb.
SP-77-1971	Guidelines for Pipe Support Contractual Relationships
SP-78-1972	Cast Iron Plug Valves
SP-79-1974	Socket-Welding Reducer Inserts (M)
SP-80-1974	Bronze Gate, Globe, Angle and Check Valves (M)
SP-81-1975	Stainless Steel, Bonnetless, Flanged, Wafer, Knife Gate Valves (M)
SP-82-1976	Valve Pressure Testing Methods (M)

(M) Metric Units Included

R-Year – Indicates year standard reaffirmed without substantive change

Prices available upon request.

A large number of former MSS Standard Practices have been approved by the ANSI as ANSI Standards. In order to maintain a single source of authoritative information, the MSS withdraws its Standard Practices when they are approved as ANSI Standards.

* MSS SP-66-1964 Pressure-Temperature Ratings for Steel Butt-Welding End Valves, has been officially withdrawn from publication in favor of ANSI B16.34-1973. However, due to time lag in piping construction, copies will remain available from the MSS office.

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY
1815 NORTH FORT MYER DRIVE
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CASE EXHIBIT 742

NUREG/CR-2137
ORNL/Sub-2913/11

Realistic Seismic Design Margins of Pumps, Valves, and Piping

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more before it breaks). The procedures are not applicable to brittle materials such as cast iron.

(2) The design procedures are applicable to operating temperatures such that time-dependent phenomena (for example, creep at high temperatures) are not significant. The design procedures are not, for example, applicable to a ferritic steel structure that operates at 900 F.

(3) The design procedures give allowable stresses for base materials, not weld materials or weldments. However, the welding procedures and qualifications are such that the basic properties of the weldment (yield strength, ultimate tensile strength, and ductility) are at least as good as the base materials.

(4) The design procedures do not provide for severe environmental effects such as stress-corrosion cracking.

2.1 ASME Code

The ASME Code gives rules for the construction of pumps, valves, and piping under subsections NB for Class 1, NC for Class 2, and ND for Class 3. The rules under these subsections are intended to ensure the integrity of the pressure boundary, but not operability or functional capability. Under these rules, yielding of the material is permitted*, provided that the yielding does not cause leakage through or rupture of the pressure boundary.

Since 1974, the ASME Code has included Subsection NF, which gives rules for component supports. The subsection NF design approach is related to that of the construction of steel buildings. It is based on the prevention of excessive deformations; yielding is a primary consideration.

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*Deformation limits, if any are necessary, must be included in the Design Specification. These may impose limits on the amount of yielding.

The ASME Code does not rule on which loading is considered to be in which category of loading, nor does it determine what combinations of loads should be in the various Code categories. These determinations are, in effect, established by NRC (for example, Regulatory Guide 1.48, "Design Limits and Loading Combinations for Seismic Category 1 Fluid Systems Components" [3]). An important consideration is whether a component is essential to obtain safe shutdown and whether it is active or passive. As a specific example, consider a PWR plant in which the main feedwater pumps (and/or the building in which they are located) are not designed to withstand the SSE. In principle, the main feedwater pumps could become useless following the SSE. The NRC requires that auxiliary feedwater pumps and their buildings be designed to withstand the SSE. These auxiliary feedwater pumps are considered as "essential" for safe shutdown. Further, they are "active" because they must operate following the SSE. Their normal function is to operate during and following various accident conditions including SSE. Accordingly, Regulatory Guide 1.48 [3] suggests that the auxiliary feedwater pumps be designed to Level B limits, not Level D.

2.2 AISC Manual

The AISC Manual is significant to this report because support structures in operating nuclear power plants and those that are to operate in the near future were designed before the development of ASME Subsection NF, "Component Supports." They were designed according to the AISC Manual.

The AISC Manual is much simpler than the ASME Code in the sense that it has no "classes," or "Categories of Loadings/Limits." However, it does contain one provision which is crudely analogous to the ASME Code Loading/Limits Level D. That provision is contained in Par. 1.5.6 of the AISC specification for the Design, Fabrication, and Erection of Structural Steel for Buildings (included in the AISC Manual). Par. 1.5.6 states, in effect, that allowable stresses may be increased by one-third in evaluating calculated stress produced by earthquake loadings combined with "normal" loadings.

In following portions of this report, we will discuss the relevance of the AISC Manual rules to Seismic Margins. We refer to the AISC Manual allowable stresses without the one-third increase as "basic allowable stresses;" those with the one-third increase are referred to as "seismic" allowable stresses.

In contrast to the ASME Code Subsections NB, NC, and ND, which are concerned with pressure boundary integrity, the AISC Manual rules are directed toward structural stability. This concern is appropriate for supports where, of course, there is no pressure boundary.

ASME Code Subsection NF, "Component Supports," follows rather closely the design philosophy of the AISC Manual. Indeed, much of the detailed guidance is identical to that given in the AISC Manual. Because the AISC Manual was developed solely for room temperature applications and covers a limited range of materials, NRC has provided additional guidance in Regulatory Guides 1.124 [4] and 1.130 [5].

4. CONCRETE ANCHOR BOLTS

A major aspect of seismic capability of pumps, valves, and piping is to assure that they are adequately held to the building structure. For pumps, this involves hold-down bolts. For piping, supports such as hangers are involved. Valves are usually supported by the attached piping; hence, piping supports are significant to valves.

Bolting connections to concrete can be made either by installing the bolts before pouring the concrete or by drilling a hole in the concrete and inserting an anchor bolt.

Bolts installed before the concrete is poured have not produced any known field-installation problems. The embedded ends of the bolts can be hooked or installed with large washers; thereby, the tensile and shear strength of bolting like SA-307 grade B can be developed. However, anchor bolts installed after pouring the concrete have given field-installation problems, and the NRC IE Bulletin 79-02 [6] was issued to address the problems.

Considerable skill and care in the installation process are required to consistantly obtain anchor bolts that, as installed, develop the tensile and shear strength indicated by Manufacturers' catalogs.

References [7] and [8] are two recent ASME publications concerning anchor bolts. The data given in Reference [9] have been abstracted in Appendix B to this report. From our review of Reference [9] data, it appears that (with one exception*) the tensile and shear strength of anchor bolts given in Manufacturers' catalogs can, with appropriate skill and care, be achieved in field installations.

Manufacturers commonly recommend (1) that design loads for anchor bolts should not exceed one-quarter of the manufacturer's tensile or shear strength, and

---

*Discussed in Appendix B.

(2) that a linear interpolation should be used for combinations of tension and shear. If the recommendation is used for both SSE and OBE and associated loadings, the <u>average</u> Nominal Margin would be 4.0. However, this Nominal Margin is not the same as the Nominal Margins for allowable stresses; these are related to minimum material properties, whereas the Nominal Margin of 4.0 is related to average strengths.

Judging from the data given in Reference [9], there is a substantial scatter of data above and below the average, even though all of these results presumably come from tests where skill and care had been used in the installations. The statistical evaluation described in Appendix B indicates that if design loads are taken as one-quarter of average loads, the probability of failure at the design load is less than 0.001, provided the expansion anchor bolts are installed with skill and care at least equivalent to that used in preparing the test installations.

The results of our statistical evaluation are summarized in the following tabulation.

Type of Load	Data Base	Avg.	σ	Avg.-2
Tension	TES only	0.9904	0.1904	0.6096
	Mfr only	0.8638	0.2403	0.3832
	Both	0.9421	0.2196	0.5029
Shear	TES only	0.9672	0.1467	0.6738
	Mfr only	1.0809	0.3368	0.4072
	Both	1.0226	0.2657	0.4912

With the assumed normal distribution, the ratio of "Avg.-2 " corresponds to a probability of failure below that load ratio of 0.023. For design loads based on 1/4 of average loads, the probability of failure at the design load is less than 0.001. Of course, this depends upon skill and care in installation that is at least equivalent to that used by TES and the manufacturers in conducting their tests. As in most aspects of constructing a nuclear power plant, lack of skill and care could lead to higher failure probabilities.

Equivalent Bolt Stresses

To correlate allowable loads on anchor bolts with allowable stresses in the bolts, it is informative to express the allowable loads on the anchor bolts as stresses in the bolts. This is simply done by dividing the loads by the cross-sectional area of the bolts. The bolt stresses so derived are shown in Table B3.

- Bolt stresses, at average failure loads, are:

Type of Load	Bolt Stress, ksi		
	Max	Min	Avg
Tension	58.6	8.3	30.65
Shear	84.8	25.4	46.49

TABLE B3. TES AVERAGE LOADS EXPRESSED AS BOLT STRESSES

Nom. Size	A_b, in^2 (a)	Type of Load	Bolt Stress (ksi) at TES Average Load										
			A	B	C	D	E	F	G	H	I	J	K
1/4	.03182	Tension	----	----	----	----	32.2	----	39.3	----	----	----	----
		Shear	----	----	----	----	84.8	----	42.4	----	----	----	----
3/8	.07749	Tension	47.1	----	45.6	----	33.6	----	18.4	----	----	----	----
		Shear	51.6	----	41.0	----	52.3	----	40.7	----	----	----	----
1/2	.1419	Tension	----	37.0	28.7	----	26.8	38.2	8.3	41.2	19.5	49.9	41.7
		Shear	----	49.3	40.5	----	56.9	47.2	25.4	47.4	44.0	56.4	42.3
5/8	.2260	Tension	44.2	45.4	23.8	----	31.0	34.8	13.1	----	26.4	58.6	24.3
		Shear	50.9	58.6	44.2	----	60.2	50.9	26.8	----	36.4	54.2	33.2
3/4	.3345	Tension	----	28.4	30.3	22.7	28.2	27.2	29.1	31.4	16.2	26.2	22.7
		Shear	----	53.1	41.9	47.1	59.4	45.6	47.6	41.1	54.9	39.5	40.4
7/8	.4617	Tension	35.2	29.0	----	----	----	----	21.6	----	25.7	----	----
		Shear	24.6	42.2	----	----	----	----	44.0	----	52.0	----	----
1	.6057	Tension	----	39.3	----	----	30.4	----	31.4	----	20.9	36.9	----
		Shear	----	66.0	----	----	45.4	----	37.1	----	31.4	68.1	----
1-1/4	.9691	Tension	----	28.9	----	----	21.9	----	17.3	----	----	----	----
		Shear	----	46.4	----	----	33.6	----	39.7	----	----	----	----

(a) A_b = Tensile stress area, = $0.7854\,[D-0.9743/n]^2$, D = nominal bolt size, n = threads per inch (UNC-series).

It can be seen that the anchor bolts developed tension loads about equal to the yield strength of SA-307 Grade B bolts. However, for shear loading, if we assume that shear failure occurs at about 0.6 times the tensile strength, the bolt stresses are greater than the capacity of SA-307 Grade B bolts, for which $0.6S_u$ = 36 ksi.

The bolt materials used with the anchor bolts are not described in the TES Report. They were presumably materials with tensile properties like SA-193 Grade B7; 125,000 psi minimum ultimate tensile strength, 100,000 psi minimum yield strength. In shear, the maximum bolt stress is up to 84.8 ksi (1/4 inch Group E). Presumably, in this particular test the failure consisted of a shear failure of the bolt (unfortunately, the TES report does not describe the type of failures). If so, and if shear failures occur at 0.6 S_u, then the bolt material S_u was about 84.8/0.6 = 141 ksi. Of course, part of the resistance to shear may have been due to friction between the fixture and the concrete pad.

These aspects bring out the point that the bolt material itself can be a significant aspect of the strength of expansion anchor bolts. To obtain some of the high shear strengths given in manufacturer's catalog, the bolt material must itself be high strength. Care must be taken that a lower strength bolt material like SA-307 Grade B is not inadvertently used.

Combined Tension and Shear

For combination of Tension and Shear loads, the usual practice is to apply the limit:

$$\frac{P_t}{P_{td}} + \frac{P_s}{P_{sd}} \leq 1.00 \qquad \text{(B1)}$$

RESPONSE TO NRC QUESTIONS OF
MEETING OF AUGUST 8-9 and August 23, 1984

A. U-bolt Cinching

a) Provide additional justification for the assessment that strain relaxation of the U-bolt ceases as the U-bolt stress reduces to approximately 1/2 of the yield strength. Justification should be provided as additional data and also provide actual properties of the U-bolt material employed.

There is scant, if any, data available on strain relaxation properties of SA-36 material. Some relevant data is reported in ASTM DS60 "Compilation of Stress-Relaxation Data for Engineering Alloys," for material having the same composition as SA-36 steel (note that this reference does not mention the material designation). The ASTM material specification for A-36 is presented as Exhibit A1. Also included as Exhibit A2 are the pertinent portions of ASTM DS60 which provide data for ferritic steels having chemical composition and physical properties similar to but varying to different degrees from those of A-36. Also provided are the definitions given in DS60, which are relevant to the question of what causes relaxation and whether creep is important. Unfortunately not much data is available directly at the temperatures of interest, i.e., less than 500°F although considerable information may be inferred from the data at the higher temperatures as will be discussed later. In fact, only materials 2 and 25 have data at room temperature. Material 2 has the proper chemical composition but its physical properties are significantly different from those of A-36. Material 25 has physical properties similar to A-36 but does not quite meet all of the chemical specifications. Figure A1 shows the stress strain curve of material 25 at various temperatures within our range of interest, i.e. less than 500°F. This curve is used to illustrate the meaning of material relaxation (as opposed to overall mechanical relaxation which will be discussed later) for monotonic loading, <u>i.e.</u> noncyclic. For the material to relax, plastic strain is required. Ferritic steels like A-36 exhibit a well defined proportional limit at which plastic strain begins. The yield strengths of these materials are given at the 0.1% or 0.2% elastic strain offset (in general it is the latter, although for material 25 the former is used). In figure A1 the details of the stress strain curve between the proportional limit and the yield point are not shown. From that figure, if the material is strained below the proportional limit no material relaxation will occur. Strains in excess of the proportional limit will result in relaxation, the amount of relaxation being proportional to the amount of plastic strain (or volume of material that has yielded). At room temperature the strain corresponding to the proportional limit is about 0.075 percent. At that level of initial strain, therefore, little or no relaxation should be expected. Figure A4, developed using the information on Material 25 of ASTM DS60, shows that the relaxation is negligible. At 532°F, the strain corresponding to the proportional limit point is 0.065 percent. Since the material 25 has been strained to .075% relaxation should be expected. Moreover, the heating of the material from room temperature to 532°F and the return to room temperature contributes to relaxation. How this happens is explained by Figure A2, obtained via private communication with M.J. Manjoine, one of the authors of ASTM DS60 and a recognized authority in materials behavior. This figure is an expanded view of a portion of Figure A3, also provided by M.J. Manjoine. Figure A3 deduces the behavior of ferritic steels like A-36 at the lower temperatures from the fact that the behavior exhibited at the higher temperatures (above 700°F) for which the data is available is the same as that exhibited for mild austenitic steels which have data available at all temperatures. The behavior of austenitic steels is shown in figure A7 which is taken directly from reference 4 (see p. 27). As figure A2 shows a material which is strained to or above the proportional limit will lose load at constant strain simply as a result of the lower yield strength at temperature and the higher modulus of elasticity at room temperature than at temperature. Thus, if material 25 had been strained to yield at 532°F, upon its return to room temperature it could exhibit 35 percent of its initial stress. This would occur upon return to room temperature regardless of whether "material" relaxation occurs. If the material is maintained at temperature, loaded for sufficient time, material relaxation would also occur. This can lead to an additional 15-20 percent loss of load. However, for the latter time is needed to redistribute the load. Although we do not know for a fact, it is fairly obvious that the material relaxation characteristics of material 25 at 532°F must have been determined at temperature, since as figure A4 indicates, there is some twenty percent relaxation. Similar significant strain relaxation should be expected at all temperatures for initial strains of 0.225 percent, and this is indeed the case.

If the applied load results in a stress below 1/2 of the yield strength at temperature, the corresponding strains would be well below those corresponding to the proportional limits, and thus no relaxation should be expected.

So far only monotonic loads have been discussed. To complete the discussion of material relaxation, it must be pointed out that the stress strain curve for steels are different between the cases of monotonic and cyclic loads. For the monotonic loads discussed so far, the point at which mild ferritic steel materials begins to yield is higher (by approximately 15 percent - private communication with M.J. Manjoine) than the point at which yielding will occur under cyclic loads.

The difference is shown in Figure A5.

It is important that a distinction be made between "cyclic" loads such as are experienced by the U-bolts, whereas the load can be cycled from a low to a high level without stress reversal, and "stress reversal" loads which are cyclic but for which the load causes the stresses to be alternatively tensile and compressive. The relaxation behavior for the two cases can be vastly different. Figure A8 (reference 5) shows that stress strain curve for ferritic steel under reversing constant amplitude loads (reversing strain). Figure A9 (reference 6) shows an idealized curve for the kind of mild steel which is characteristic of both ferritic steels like A-36 and austenitic steels like A-304. Figure A10 (reference 6) shows the static (monotonic) stress strain curve and the cyclic (strain reversal) curve for a material like A-36. The cyclic curve is the envelope of the stress-strain curves exhibited during the cycling as shown by the dashed line of figure A9. It is important to compare the type of relaxation which one can experience under cyclic loadings with no strain reversal to those which can be experienced for the latter. To do so we will utilize Figure A11, (provided by M.J. Manjoine), which combines both types of loadings. In the case of cyclic loading with no strain reversal, the second cycle will have a proportional limit PL1 which is about 15 percent lower than the monotonic proportional limit. However, if the cyclic is o. e of relatively large strain reversal (i.e., strains near yield here defined as .2% offset), then the proportional limit will be much lower as indicated by point PL2 in the figure.

For strain reversal conditions, according to Mr. Manjoine there is little difference between the stress strain curve of ferritic steels like SA-36 and austenitic stee's like SA-304. Thus, the material relaxation properties of SA-36 can be inferred for cyclic loads from those of SA-304 for which considerably more data is available.

Figure A6, reproduced from ASTM-DS60 (reference 4) shows the relaxation behavior of SA-304. It can be seen that for cyclic loading with strain reversal there can be always some material relaxation, but that for stresses below $1/2\sigma y$, the amount of relaxation is minor.

Material relaxation, however, is only one of the parameters of interest in the overall relaxation of the U-bolt assembly. Relaxation of the assembly preload can be due to a combination of material relaxation and other mechanical relaxation phenomena that may manifest themselves during the various loading cycles, such as wear, local yielding with load redistribution, etc.

It is difficult to predict the amount of relaxation that might occur as a result of wear or yielding of surface irregularities. It is for that reason that the long term, accelerated vibration test was conducted, i.e., to simulate the number of cycles that the assembly would see during its entire lifetime of operation. It is possible, however, to estimate the amount of mechanical relaxation that takes place due to local yielding, although it is impossible to tell how quickly it will occur since the time required for load redistribution depends on too many factors. Such overall estimates can proceed from a knowledge of the stress state at each location of the assembly, which permits an estimate of the volume of material that might be at yield. This volume of material will relax over time, redistributing load, and giving the appearance that the overall assembly relaxes. It is germane to estimate what amount of relaxation could occur when the shank of the U-bolt is stressed to a maximum stress of 1/2 yield strength. At such loads there are portions, however small, of the assembly which experience higher stresses and can in fact be at yield. These regions are shown in Figure A12 as points A, B, C, D and E. Points A, B and C yield at the outer fibers when the U-bolt is cinched up and preloaded to relatively low value of loads as a result of straightening the U-bolt legs. Yielding is, however, limited to the outer fibers near and opposite the pipe, and the material which yields occupies negligible volume.

For consistency with future discussion of Westinghouse test data, we will use a yield strength of the material of the U-bolt equal to 36,000 psi, even though actual material yield is about 45,000 psi. Test results obtained by strain gauges have all been referred to the 36,000 nominal yield strength. When the stress in the shank is equal to 1/2 the yield strength in the U-bolt shank area, for instance for the 10-inch assembly (refer to Attachment 1 to the Affidavit) with the 3/4 inch U-bolt, the corresponding load is 7,956 lbs., which gives a threaded area stress in excess of 1/2 of yield, i.e., 23,820 psi. However, as figure A13 indicates, the nut engagement results in stress concentration within the threaded area. Stress concentration can raise the average stress above yield. Since we have two nuts, a similar stress concentration profile will exist in the bolt within the other nut because of the nut engagement to the first one. For the 3/4-inch bolt, the nuts are 5/8 inch thick with six threads. Approximately half of the bolt volume within both nuts will have stress concentration in excess of 1.5. Thus, a total length of 5/8 inches will have stresses at or close to yield.

The same is true in the other leg of the U-bolt. Thus, about 1.25 inches of material out of a total of 31 inches will experience relaxation of the order 15 percent (relaxation from yield stress - see figure A2) if at room temperature. The remaining threaded area (approximately 5 inches) will experience less relaxation since it is more lightly stressed. The amount of relaxation that it can experience can be estimated using figure 2, suggested by M.J. Manjoine. This additional threaded material would relax approximately 7.5 percent. Thus, one can approximate the overall mechanical relaxation that would occur for loads resulting in stresses in the shank of one-half yield as

$\frac{5\ (.075) + 1.25\ (.15)}{3.25} = 1.7\%$, or very low relaxation.

Perhaps more relevant than theoretical calculations to the question of when overall (material and mechanical) relaxation ceases for the U-bolts, is the actual data taken during the various tests conducted by Applicants (see reference 1). One such test is the thermal cycling test.

Results of the thermal cycling test on the 4" Sch 160 stainless steel specimen indicated that the stress in the U-bolt was approximately 31,100 psi (or approximately 86.4% of the assumed yield strength of 36,000 psi and essentially equal to the cyclic yield strength). The total material would thus relax.

After nine cycles the residual stress was measured to be approximately 19,900 psi or 55 percent of the assumed yield strength. (Ambient temperature for pipe and U-bolt was essentially the same before cycling (105°F) and just before the 10th cycle (107.5°F). The U-bolt was heated to an average temperature of about 400°F (see page 16 of Attachment 3 to the Affidavit). From Figure A2 one can deduce that the temperature cycling would result in a relaxation of approximately 36 percent, of which the initial 25 percent would be due to the temperature cycling alone. The result of the thermal cycling test does in fact confirm that the room temperature stress before the thermal cycling, i.e., a nominal 31,100 psi, was reduced to 19,900 or a 36 percent reduction.

Another test which provides insight on the stress relaxation is the creep test which was performed immediately after completion of the thermal cycling test, without retorquing the bolts.

For the 4-inch specimen the microstrain measured in the two U-bolt legs at the ambient temperature before the creep test (77°F) were 856 and 775 microstrain for legs 1 and 2 respectively. (These microstrains correspond to a load of 4,870 and 4,409 lbs.) After the creep test with the ambient temperature being 91.4°F, the strains were measured to be 853 and 773 microstrain, respectively. When one accounts for the fact that at 91.4° there is a preload induced by the difference in thermal expansion between the stainless steel pipe and the carbon steel U-bolt, and that had the ambient temperature returned to $77^{o}F$ the preload would have been reduced by approximately 45 lbs., the final load at the completion of the creep test would be approximately 4,580 lbs. compared to 4,639 (or 1.2 percent decrease).

Since 4,580 lbs. corresponds to a stress of 23,367 psi (shank area), which is above 1/2 of the assumed yield strength of 36,000, this decrease, if real and not due to instrument uncertainty, would be due to the strain relaxation. The question of whether it may be due to creep is addressed in the answer to the next question.

For the 10" Sch 40 line, where the temperature is low (pipe $250^{o}F$ and U-bolt $150^{o}F$) creep is clearly not a concern. The strains measure prior to the creep test (after the thermal cycling test) were 283 and 280 microstrains respectively in legs 1 and 2 of the U-bolt (at an ambient temperature of $75.8^{o}F$). The initial microstrains correspond to a load of 3,625 and 3,578 lbs. respectively. These loads correspond to a stress equal to 8,200 psi in the shank or 10,800 psi in the thread area of the U-bolt. In either case the stresses are well below the 1/2 yield strength, with the exception of highly local area in the thread within the nut, and hence little, if any, relaxation should be exhibited.

The strains after the creep test were measured to be 281 and 276 microstrains respectively corresponding to an average load of 3,567 lbs.

The drop in load of approximately 39 lbs. is partly due to the lower environment temperatures after the test which was 66.9°F instead of 75.8°F.

The drop in load corresponding to the 9 degrees difference is calculated to be approximately 11 lbs. Thus, relaxation (if any) was less than 0.8 percent.

The seismic test provides further evidence of the relaxation phenomenon. Initial information provided from the test, which is attached as Exhibit A3, indicated a reduction in load from 4,484 lbs. in both U-bolt legs to about 4,291 lbs. and 4,355 lbs. in legs 1 and 2 respectively, when the assembly was vibrated at 9 Hz with a constant amplitude of 7,000 lbs. This relaxation of approximately 12 percent could not be justified on the basis of the applied load which would result, coupled with the initial preload of 4,484 lbs. (50 ft. lb. torque) in maximum load experienced by the U-bolt of approximately 6,100 lbs., and a corresponding stress of 18,200 psi in the threaded area and 13,800 psi in the shank area. This led to questioning the validity of the 7,000 lb. load, and to the realization that the actual applied vibratory load had been higher, and to the results published in the Affidavit, which are included here as Exhibit A4. As seen in the Exhibit, the actual load applied to the U-bolt was in excess of 10,000 lbs during the peak portion of the cycle and initially in excess of 8,600 lbs. during the pull portion of the cycle. On the average the force seen by the U-bolt during the cycling was in excess of 6,600 lbs. (peak load of more than 8,600 lbs. plus preload of 4,484 lbs.) which would have resulted in a stress in the thread area of about 19,800 lbs. which is 11 percent higher than the nominal 1/2 yield strength, hence justifying the relaxation seen.

Finally, the data obtained during the long term accelerated vibration test merits some attention.

As stated in our Affidavit, the initial preload stress was equal to about 9,020 psi. After the initial reposition of the assembly which occurred approximately 5.15 minutes into the test (see attached raw data - Exhibit A5), and which resulted in an average loss of preload equal to 640 lbs, the preload was seen to decrease slightly, then increase again then decrease with a final preload being about 450 less than the preload existing after the initial adjustment. During the period of time between the 4th sweep (21 minutes) and the 36th sweep (189 minutes) there was essentially no change in the preload. At the latter time is when the sudden cocking mentioned in the Affidavit on p. 30 took place, which resulted in some further preload decrease.

Relaxation of the material discussed within the context of this reply does not change the total strain of the material. (See definition in 2 of Exhibit A2.) The preload at the end of the test is still sufficient to prevent loss of contact between the pipe and backing plate (see figures 17 and 18 of Attachment 1 to the Affidavit with an applied load of 1,500 lbs. and a preload of approximately 3,200 lbs.), thus the motion which resulted in further relaxation is most likely due to accumulated strain over the more than 10^6 cycles experienced at an applied load of 1,500 lbs. These cycles represent the number that the support may experience during its lifetime, and hence the test results confirm that in spite of some relaxation, adequate preload would be retained throughout life.

Cyclic plastic strain accumulation may occur at these loads, which are abnormally high for the period of time tested. An elasto plastic finite element analyses of a similar U-bolt, backing plate, pipe arrangement, conducted per an 8-inch pipe (same size U-bolt as the 10" pipe, indicates that for sufficiently high preload, the U-bolt can experience some plasticity in the transition region between the straight shank and the curved portion and at the inner surface of the U-bolt apex. This occurs from the bending moment place on the U-bolt from the straightening action of the preload or full external load. This small amount of plasticity occurs even though the average stresses through the U-bolt cross section is low, and in fact, for the particular case examined are only 2,000 psi. Under the large number of cycles seen by the specimen the accumulated plastic strain can result in sufficient permanent deformation to permit relaxation. Also, wear and yielding of surface imperfections can accomplish the same thing.

b) Provide more information as to why creep of the U-bolt should not be a consideration, considering the result for the 4-inch pipe. Provide material of U-bolt nut. Include explanation on effect of different ambient temperatures on loss of preload shown by this test.

Relative to the possibility of creep phenomena existing in the U-bolt, the maximum temperatures measured for each of the three test specimens, during the Creep Test are listed below. It is to be noted that the temperature in the U-bolt varied along its length.

4-inch specimen

Pipe temperature:	560°F
U-bolt temperature:	445°F
Nut temperature:	340°F

10-inch specimen

Pipe temperature:	250°F
U-bolt temperature:	150°F
Nut temperature:	140°F

32-inch specimen

Pipe temperature:	560°F
U-bolt temperature:	350°F
Nut temperature:	170°F

Also note that all three U-bolts are SA-36 Carbon Steel. Reference 2 suggests a temperature of 752°F (400°C, 673°K) as the minimum used for creep tests performed for carbon steels. Finite creep is not discernable in carbon steels at temperatures lower than this. Figure A7 (from reference 4) further confirms this. Reference 3 defines the temperature below which self-diffusion is too slow to influence creep as approximately one-half of a metal's absolute melting temperature. The absolute melting temperature for SA-36 carbon steel is in excess of 1366°K (1093°C, 2000°F). Similarly, reference 4 defines the temperature below which creep is not discernable as 0.4 Tm (Tm metal absolute melting temperature) which would correspond to 524°F.

Based on the fact that none of the U-bolt temperatures exceeded 500°F it can be concluded that no finite creep occurred in the U-bolts. Since the nut material is ASTM-A563GrA and none of the temperatures exceeded 340°F, no finite creep occurred in the nuts. The curve shown in Firgure A3 for ferritic steels like SA-36, and Figure A7, taken from reference 4 for austenitic steel, confirms that relaxation is not due to creep until temperatures of approximately 800°F are available.

The small decrease in U-bolt preload experienced during the test, of the 4 inch sch 160 pipe is believed to be a result of relaxation as explained in the answer above.

Based on the above, and test results obtained, it is concluded that none of the U-bolt test specimens were subject to creep phenomena during the Creep Test.

The explanation of the effect on the loss of preload from the different ambient temperatures is given in the answer to the preceding question, namely the higher ambient temperature at the end of the test would have the effect of underestimating the loss of preload by about 45 lbs.

c) What is the thickness of the backing plate for the 4" pipe - U-bolt configuration?

The thickness of the backing plate is 3/4 of an inch. The drawing provided was a poor copy where the copying has resulted in a 3 looking like a 1. Enclosed (Enclosure A1) is a better copy of the drawing reflecting the 3/4 inch thickness.

d) Clarify the statement made in the opening remarks regarding the 32" pipe on page 42 of Attachment 3 to the Affidavit.

The statement as written: "The stresses measured in the test and calculated for the 32" pipe, cross piece and U-bolt are comparable." was not meant to state that the magnitude of the stresses calculated or measured were comparable numerically. It is quite obvious from the 32 inch pipe test data that the data scatter would make such comparison questionable. It simply meant that the very low stresses calculated by finite element analysis were confirmed to be low by test.

e) Verify that stresses in the pipe would still be acceptable if one had used the C indices rather than the B indices of the Code on p. 54 and following of the Affidavit.

This question refers to the effect on the pipe stress intensities that would be computed, had the piping moment stresses been computed utilizing the C indices (Class 2 and 3) rather than B indices (Class I).

The effect of ASME Class 2 and 3 rules on the piping stresses has been discussed in the affidavit on pages 63 to 66. On page 65 of the affidavit, a comparison is made in Tables L and M of the deadweight and seismic (Equation 9 - Class 1 rules) and the thermal (Equation 12 - Class 1 rules) piping moment stresses developed using Class 1 and Class 2/3 stress indices.

The changes in stress indicated by the results reported in these tables are given below (Table A^1). Note that a positive value implies an increase in stress, and a negative sign a decrease in stress if Class 2/3 rules are used.

TABLE A^1

CHANGE IN PIPE STRESS

		CHANGE IN STRESS (KSI)	
PIPE SIZE	MATERIAL	DEADWEIGHT+ SEISMIC	THERMAL
4" SCH 160	Stainless	2.15	4.01
10" SCH 40	Stainless	2.55	0.07
10" SCH 80	Carbon	1.97	-2.86
32" MS	Carbon	2.49	-0.32

The results of this change on the stress intensities calculated using Class 2/3 rules is given below (Tables B^1 and C^1). These tables can be compared to Tables H and I given on page 60 of the Affidavit.

TABLE B[1]

TOTAL PIPE STRESS INTENSITY

PIPE SIZE	PRELOAD TORQUE	APPLIED STRUT LOAD	TOTAL STRESS INTENSITY
4" SCH 160	60 ft/lbs	2,000 lbs	70.3 ksi
10" SCH 40S	100 ft/lbs	10,000 lbs	76.83 ksi
10" SCH 80	100 ft/lbs	10,000 lbs	53.80 ksi
32" MS	240 ft/lbs	100,000 lbs	49.34 ksi

TABLE C[1]

MAXIMUM PRIMARY AND SECONDARY STRESS INTENSITIES

PIPE SIZE	EQ. 9 PRIME STRESS INTENSITY (KSI)	EQ. 9 ALLOWABLE (KSI)	EQ. 12 SECONDARY (KSI)	EQ. 12 ALLOWABLE (KSI)
4" SCH 160	33.75	50.52	36.55	50.52
10" SCH 40S	63.16	60.00	13.67	60.00
10" SCH 80	40.12	60.00	13.68	60.00
32" MS	33.06	58.26	16.28	58.26

With the exception of Equation 9 for the 10" SCH 40S pipe size, all of the pipes evaluated meet the Equation 9 and Equation 12 allowables. The Equation 9 stresses reported for the 10" SCH 40S pipe are conservative since:

1. The pipe stress includes the secondary stress due to pressure pipe growth restriction.

2. A higher stress push load is used than seen by the Comanche Peak 10" U-bolt supports.
3. A higher mechanical primary pipe moment stress is used than seen by the 10" Comanche Peak pipes.

The significance of each of these items is given below:

1. The total circumferential pressure stress from the computer analysis is 10.51 ksi. The circumferential pipe stress due to pressure is 8.84 ksi. The secondary pressure stress is 10.51 - 8.84 = 1.67 ksi, which is presently included as primary stress.
2. The largest U-bolt strut load as determined from ITT Grinnell U-bolts loads is 8,585 pounds. In the evaluation, a 10,000 load was used. This is equivalent to a 2 ksi reduction in pipe stress.

$$= (72.71) - 58.59 \left[1- \left(\frac{8585}{10,000}\right)\right] = 2.0 \text{ ksi}$$

3. On pages 61 and 62 of the affidavit, a comparison is made between the primary piping moment stresses used in the U-bolt evaluation to actual randomly selected computer piping analysis stresses. From Table J of the affidavit, it can be seen that the mechanical primary pipe moment stress used in the U-bolt cinching evaluation is 3.3 ksi higher, (10.45 - 7.063 = 3.3 ksi).

Adjusting the 10" SCH 40S stress intensities given in Table C[1] to remove the conservatisms discussed above results in a primary stress intensity value of 56.19 ksi. Note that without consideration of item 3, 3.3 ksi, the primary stress intensity value is 59.49 ksi and is still below the allowable stress. The secondary stress intensity if 15.34 ksi. Thus, the 10" SCH 40S pipe is within the acceptable limits of 60.0 ksi for primary and secondary stress.

f) Provide an example of how the total value of stress intensity can be obtained from the finite element results and how the value can be divided into equation (9) and equation (12) stress intensities.

The easiest way to show how the stress intensity is obtained is to refer to the figure VII-2 of Attachment 3 of the Affidavit which defines it as the maximum of either the absolute difference between the major principal stress or minor principal stress and zero or the algebraic difference of the two principal stresses, and to apply this figure to an actual example. The example chosen is the 4" sch 160 pipe. For the elements having the largest circumferential and longitudinal stresses, the finite element analyses determined that the principal stresses are virtually identical to the circumferential and longitudinal stresses (see Attachment 3 of Affidavit at page 57). The longitudinal, circumferential, major and minor principal stresses for the highest stressed piping element of the 4" sch 160 pipe are given for both the inside and outside surfaces and for the maximum load case in the table of p. 58 of Attachment 3 to the Affidavit. These values are reproduced below:

	Long. Stress (ksi)	Circum. Stress (ksi)	Princ. Stress (ksi) Major	Minor
4" sch 160 inside	10.49	44.79	44.78	10.50
outside	-26.65	-34.07	-26.63	-34.08

where the negative sign denotes compressive stresses.

A confirmation of the max. circumferential stress can be found in the table of page 71 of Attachment 3 of the Affidavit for element 627. Note that on that table, there is no distinction regarding the surface at which the maximum stresses occur. For instance, the 44.79 ksi tensile circumferential stress occurs on the inside surface, while the -26.65 ksi compressive longitudinal stress occurs on the outside surface of element 627. To the local stresses computed by the finite element analysis one must add the longitudinal equation 9 pressure and piping moment stresses. These are available from the table on page 56 of attachment 3 of the Affidavit. They are:

Longitudinal Pressure Stress	4.8 ksi
EQ. 9 Piping Moment Stress	$\pm$ 12.146 ksi
EQ. 12 Piping Moment Stress	$\pm$ 22.49 ksi

Adding the longitudinal pressure to the stresses previously tabulated we obtain:

	Principal Stresses	
	Major (Circumferential)	Minor (Longitudinal)
4" sch 160 Inside	44.79	15.29
Outside	-34.07	-21.85

To add the piping moment stresses to the longitudinal (minor principal) stresses, we choose the sign which will produce the largest stress intensity.

This is seen in a Mohr circule depicted in Figure A14, where inside surface stresses are used.

Thus, the total stress intensity is given by 44.79- (-19.346) = 64.136 ksi, which is the total stress intensity given on page 59 of Attachment 3 of the Affidavit or in table H of page 60 of the Affidavit.

For comparison purposes, the stress intensity derived for the outside surface is:

Maj. Princ. (Circumferential) stress = -34.07

Minor Princ. (Longitudinal) stress = $-26.63 + 4.8 \pm 12.146 \mp 22.49 = -56.466$

The max. stress intensity is thus 56.47 ksi.
Using the alternative signs would have produced a stress intensity of 34.07 + 12.8 = 47.5 ksi which is lower.

As shown above, the highest stress intensity occurs on the inside surface.

To determine the primary and secondary stress intensities, several alternatives are available. The most straightforward determines the primary stress intensity from the principal primary stresses and derives the secondary stress intensity by subtraction of the primary from the total. For the example chosen, we proceed as follows:

(i) The secondary portion of the circumferential stress is obtained as the stress due to thermal expansion by subtracting the circumferential stress due to preload + thermal given on page 59 of Attachment 3 of the Affidavit as -39305 psi, from the circumferential stress due to preload alone, which is given in the preceding page as -26091 psi. These occur on the outside surface. The primary circumferential stress becomes -34.07 +13.21 = -20.86 ksi.

(ii) The primary longitudinal stress is similarly derived by considering only the equation 9 piping moment stress, <u>i.e.</u>, neglecting the equation 12 stress and subtracting the difference between the longitudinal stress due to preload + thermal and that due to preload only, which equals 6.5 ksi. The longitudinal stress thus becomes -21.85 -12.146 + 6.5 = -27.5 ksi.

(iii) Thus, the primary stress intensity is -27.5 ksi and the secondary stress intensity becomes 56.47 - 27.5 = 28.97 ksi.

Similarly, we obtain the primary and secondary stress intensities for the inside surface.

(i) Primary circumferential 44.79 - 10.81 = 33.98 (10.81 is the difference between preload + thermal and preload only circumferential stresses for the inside surface and these do not appear in any table, but are available from the computer output).

(ii) Primary longitudinal = 15.29 $\pm$ 12.146 - 4.24 = -1.1 where again 4.24 is the difference between the longitudinal stress due to preload + thermal and that due to preload only.

Please note that the primary stress intensity is thus 35.1 ksi instead of the value of 31.6 reported on page 59 of the Attachment 3 to the Affidavit.

(iii) The secondary stress intensity then becomes 64.14 - 35.1 = 29.04 ksi instead of the 32.54 ksi reported.

The difference between the numbers here and in the Affidavit occurred when inadvertently the outside secondary circumferential stress was subtracted from the inside total circumferential stress.

g) Define what is meant by partial preload in the tables Attachment 3 to the Affidavit.

Partial preload refers to a loading condition in which the torque of the U-bolt is a fraction of the maximum torque that is assumed to be applied to the U-bolt. For instance, for the 4" sch 160 pipe U-bolt assembly full preload corresponds to a torque of 60 ft.-lbs., and partial preload corresponds to a torque of 9 ft.-lbs.

h) Confirm the location of strain gauges S5 and S10 in Figure 21 of the Test Report SQ&T-EQT-860 (Attachment 1 of the Affidavit).

Sketch 5 on p. 58 of Attachment 1 of the Affidavit is in error. It inadvertently suggests that the same U-bolt strain gauge identification scheme used for the Torque vs. Preload, Friction and Load Distribution Tests was used for the Thermal Cycling and Creep Tests. This was not the case. Since high temperature strain gauges were required for the Thermal Cycling and Creep Tests, low temperature gauges that may have been used for previous tests were removed. The high temperature strain gauges were not instrumented to be consistent with the low temperature gauges. Also, the low temperature gauges were identified by BLH channel number. When test data for Thermal Cycling and Creep Tests was first received from the lab, the strain gauges were identified by serial number. Thus, in EQ&T-EQT-860, the strain gauges used for the Thermal Cycling and Creep Tests are not identified by the sample S1 through S5 sequence as in the other tests. Since channel numbers are directly traceable to serial numbers, any results contained in the test report are easily traceable to the appropriate test data.

The high temperature strain gauges as installed for the Thermal Cycling and Creep Tests are identified on the attached Figure A15 for each of the U-bolt sizes. The strain gauge on the three-gauge U-bolt leg that is located 90° from the two other gauges is not required to monitor U-bolt preload and, therefore, is not referenced in any of the test results.

(i) Correct typo on p. 66 of Test Report

Leg 2 (gauges S4, S11) should read 3516 instead of 5316 pounds.

(j) Provide material properties of the U-bolts and nuts used.

The mechanical properties of the U-bolts are as follows:

1/2" U-bolt	Sy = 45130, 45290 psi;	Su = 63080, 63590 psi
3/4" U-bolt	Sy = 44350;	Su = 65120 psi
2 3/4" U-bolt	Properties not provided by Vendor	
Nuts	ASTM - A563 GrA.	

References:

1. Report No. EQ&T-EQT-860, "Comanche Peak Steam Electric Station U-Bolt Support/Pipe Test Report".
2. I.A. Oding, "Creep and Stress Relaxation in Metals", Oliver and Boyd, 1965.
3. F. Garofolo, "Fundamentals of Creep and Creep-Rupture in Metals", Macmillan, 1966.
4. Compilation of Stress Relaxation Data for Engineering Alloys, "ASTM Data Service Publication DS-60."
5. ASTM Journal of T&E, Vol. 1, # 4, p. 275, 1973.
6. H.R. Jhansale and T.H. Topper "Engineering Analysis of the Inelastic Stress Response of a Structural Metal Under Variable Cyclic Strains," ASTM STP 519, 1973, pp. 246-270.

C. Wong
T. [illegible] /FF

TEXAS UTILITIES GENERATING COMPANY

P. O. BOX 1002 · GLEN ROSE, TEXAS 76043

June 8, 1984

CYGNA	
JOB NO.:	84042
DATE LOGGED:	6/12/84
LOG NO.:	#23
FILE:	2.1.1 Inc. CR (w/o att)
CROSS REF. FILE	2.1 Inc. CR Log 4.1.1 [illegible] (4128 [illegible] 136)

CYGNA Energy Services
101 California Street
Suite 1000
San Francisco, CA 94111

Attention: Ms. Nancy Williams, Project Manager

SUBJECT: COMANCHE PEAK STEAM ELECTRIC STATION
CYGNA REVIEW QUESTIONS
(Pipe Supports)

Reference: 1) May 24, 1984 Telecon Between D. Rencher (TUGCO) and J. Minichiello (CYGNA)

2) May 22, 1984 Telecon Between G. Grace (TUGCO) and J. Minichiello (CYGNA)

3) May 16, 1984 Telecon Between D. Rencher (TUGCO) and J. Minichiello (CYGNA)

Dear Ms. Williams:

Enclosed are TUGCO's responses to the above referenced telecons. The May 24th telecon (Reference 1) is all encompassing. However, the format that we have used is the following:

All questions that were new as a result of the May 24th telecon (Reference 1) are numbered 1 through 24. Questions from the May 22nd (Reference 2) and May 16th.(Reference 2) telecons are numbered as they were received originally. All CYGNA questions are written with the TUGCO response following. In addition, all CYGNA questions contain in parentheses the number referenced to the question of the May 24th telecon. The questions and answers are in date order starting from the most recent. Attached to this letter is an index of all the attachments that are referenced in our responses.

If there are any further questions, please contact Mr. George Grace (Ext. 500).

Very truly yours,

TEXAS UTILITIES GENERATING COMPANY
ENGINEERING DIVISION

L. M. Popplewell

L. M. Popplewell
Project Engineering Manager

RECEIVED

JUN 11 1984

CYGNA - SAN FRANCISCO

LMP/GG/lp
Attachments
cc: D. Wade/J. Minichiello/D. Rencher

May 24, 1984

CYGNA QUESTION (42)

13. MS-1-001-005-S72R, Rev. 4, Calc. Rev. 3
On vendor certification, Rev. 1, Sheet 1, there is a note stating "Warping of items #3 and #7 as indicated in CMC-59142 not considered or approved." Also, sheet 1 of drawing Rev. 4, Note 3, states items #3 and #7 may not warp.

Were items 3 and 7 removed (after CMC-59142 was not approved) and replaced? If not, how does TUEC resolve this position?

TUGCO RESPONSE

13. The configuration of stiffening plates on items 3 and 7 were an ITT original design. Hence, when the as-built configuration of the support was reviewed (the review was performed in the ITT-Providence office), the designer disallowed warpage and made a comment to that effect on the cover sheet.

In May, 1983, the Safeguards Task Force informed D. Rencher that some tube steel warpage had occurred on the MS hangers, and measurements as to the extent of warpage were provided. Calculations were performed to determine the effect of this warpage on the structural integrity of the tube members.

The memo to the ITT-Grinnell engineering group summarized the results of the calculations (see attachment K) and allowed the engineers to approve slightly warped members. While slight warpage is permissible on this support, the note was not removed from the drawing.

*The measurements were performed within Engineering and not verified by QC at the time.

CYGNA QUESTION (43)

14. MS-1-002-004-S72R, Dwg. Rev. 2, Calc. Rev. 1.

The pad between the U-bolt and pipe failed in SA-4123, but was accepted by a Rapid Letter. Please provide the calculation on which the Rapid Letter is based.

TUGCO RESPONSE

14. Initially the curved plate Item 4 was analyzed as a flat plate with a cylinder (the U-Bolt) bearing on it. Case 2a in Roark 5th Edition (page 517) was used. This conservative approach resulted in extremely high stresses (106807 psi). These stresses were far in excess of the allowable and hence the engineer initially failed the plate. However, upon subsequent review it was determined that the above approach neglected several important factors.

From a practical standpoint an analogy can be made between the contact stresses produced between a U-Bolt and pad and those produced between a U-Bolt and process pipe. Most U-Bolts are placed in direct contact with the process pipe without a pad. The contact stress between the

U-Bolt and pipe produces no bearing problems. Since the wrapper plate is as thick as the pipe, by comparison, there is no bearing problem. Therefore, no calculations are required to qualify the pad. However, an analytical approach can be made to substantiate the above analogy.

According to Article 13.1 in Roark, it can be said that the bearing stress is highly localized and triaxial, and can be very high without producing apparent damage. In our particular situation a reasonable amount of deformation may even be beneficial since the contact width increases, thereby reducing the bearing stress.

Since $E_1 = E_2$ & $v_1 = v_2 = .3$ from case 2a the contact width

$$b = 2.15\sqrt{\frac{pK_D}{E}} = 2.15\sqrt{\frac{3278(2.75)}{27200000}} = 0.39"$$

Since in this particular case we are not deformation controlled and some localized yielding is acceptable, and since the stress cannot exceed yield without redistributing, the stress will reduce to an acceptable level with a small increase in contact width.

Resulting contact width:

$$fp = .9Sy = .9(26950) = 24255 = \frac{104881}{32(b)}$$

$$b = .135"$$

CYGNA QUESTION (44)

15. MS-1-002-002-S72R, Rev. 3, Calc. Rev. 3

a. Joint forces at nodes 2 and 6 were referenced in SA-4284 for the design of item 20. The location of Node 2 in the computer model sketch does not correspond to location of item 20 and node 6 does not exist in the mode. Please provide model and output which have nodes 2 and 6.

b. No calculation were provided for the evaluation of member stresses and weld capacities. Buckling was not evaluated. If in a previous revision, please provide for review.

c. Forces used to qualify base plate shown on Section B-B were different from those shown in STRUDL frame output. Bolt locations assumed in the analysis were also different from the actual bolt locations shown on the drawing. Please provide justification for the as-built design.

d. Loads used to qualify through-bolts do not match the STRUDL frame output. SA-3662, Rev. 1, does not show the same values used in sheet 4 of 8 of SA-4284. Please provide justification