ASME Responses to Proposed USNRC Rule Making

As it affects the

ASME Boiler and Pressure Vessel Code, Section III, Division 1

Subsection NB-3600, Subsection NC-3600 and Subsection ND-3600 Piping Design Rules

February 23, 2004

Presented 2-23-04

ATTACHMENT 3

ASME Responses to Proposed USNRC Rule Making

Introduction

Introduction

- Proposed USNRC Rulemaking:
  - Allowable Bending Stresses[(NC-3653.2(d) and ND-3653.2(d)]
  - Allowable B_2' Stress Indices for Tees and Elbows [(NB-3656(b)(3), NC-3655(b)(3), and ND-3655(b)(4)]
  - Evaluation of Anchor Motions [NB-3656(b)(4), NC-3655-(b)(4), and ND-3655(b)(4)]

Introduction

- Proposed USNRC Rulemaking (cont..)
  - Linear Elastic Response Spectrum Analysis [(NB-3056(b)(3), NC-3655(b)(3), and ND-3655(b)(3)]
  - Reflected Waves caused by Flow Transients [NB/NC/NB-3622]
  - Removal of Inelastic Analysis for Evaluating Reversing Dynamic Loads (NB-3228.6)

Introduction

- Subject of this Presentation:
  - Strain Rate and Dynamic Strain Aging - Dr. Hiroe Kobayashi
  - 2/3 vs 3/4 B_2' - John Minichiello
  - Level B & Level D SAM - John Minichiello & Tim Adams
  - Control by the OBE - Tim Adams
  - Conclusion - Don Landers

Introduction

Comparison of Current Code and Proposed USNRC Rule Making		
NC/ND Section	**Current Code**	**USNRC Rule Changes**
NC/ND-3653.1	$B_1 \frac{P \max Do}{2t_N} + B_2\left(\frac{M_A + M_B}{Z}\right) < 1.8S_h$	$B_1 \frac{P \max Do}{2t_N} + B_2\left(\frac{M_A + M_B}{Z}\right) < 1.8S_h$ and $B_1 \frac{P \max Do}{2t_N} + B_2'\left(\frac{M_E'}{Z}\right) < 1.8S_h$ (1)
NC/ND-3653.2 (a)	$\frac{iM_C}{Z} < S_A$	$\frac{iM_C'}{Z} < S_A$
NC/ND-3653.2 (d)	$\frac{iM_R}{Z} < 2.0S_A$ (5)	*Disallowed*
NC/ND-3655.b (3)	$B_1 \frac{P_D D_O}{2t} + B_2' \frac{M_E}{Z} \leq 3.0S_M$	$B_1 \frac{P_D D_O}{2t} + B_2' \frac{M_E}{Z} \leq 3.0S_M$
NC/ND-3655.b (4)	$C_2 \frac{M_{SAM}}{Z} < 6.0S_M$	$C_2 \frac{M_{SAM}}{Z} < 6.0S_M$ or $C_2 \frac{M_{SAM}}{Z} < 3.0S_M$ (4)

ASME Responses to Proposed USNRC Rule Making

Strain Rate Evaluation

and

Occurrence of Dynamic Strain Aging

STRAIN RATE EVALUATION
of
TEST#37 & JAPANESE COMPONENT TESTS
and
OCCUERENCE of DYNAMIC STRAIN AGING

Feb. 23, 2004
at NRC Public Meeting

Japanese Seismic Team
Hiro Kobayashi

BACK GROUND & OBJECTIVES

One of NRC's Concerns on Revised ASME Seismic stress Criteria
(Input from Dr. Wilkowski, NUREG/CR-5361,III-F-3)

Dynamic Strain Aging in carbon steel
(Ratio of Yield-to-Ultimate strength raise to 0.77)
at LWR operating Temp. (300-700F)
at High Strain Rate (1-10/sec.)

⇩

Strain Rate Evaluation by Elasto-Plastic FEM Analysis
Estimation of Yield-to-Ultimate strength Ratio for Carbon Steel

Input by Dr. Wilkowski

Dr. Wilkowski pointed out in the page III-F-3 of NUREG /CR-5361 that:

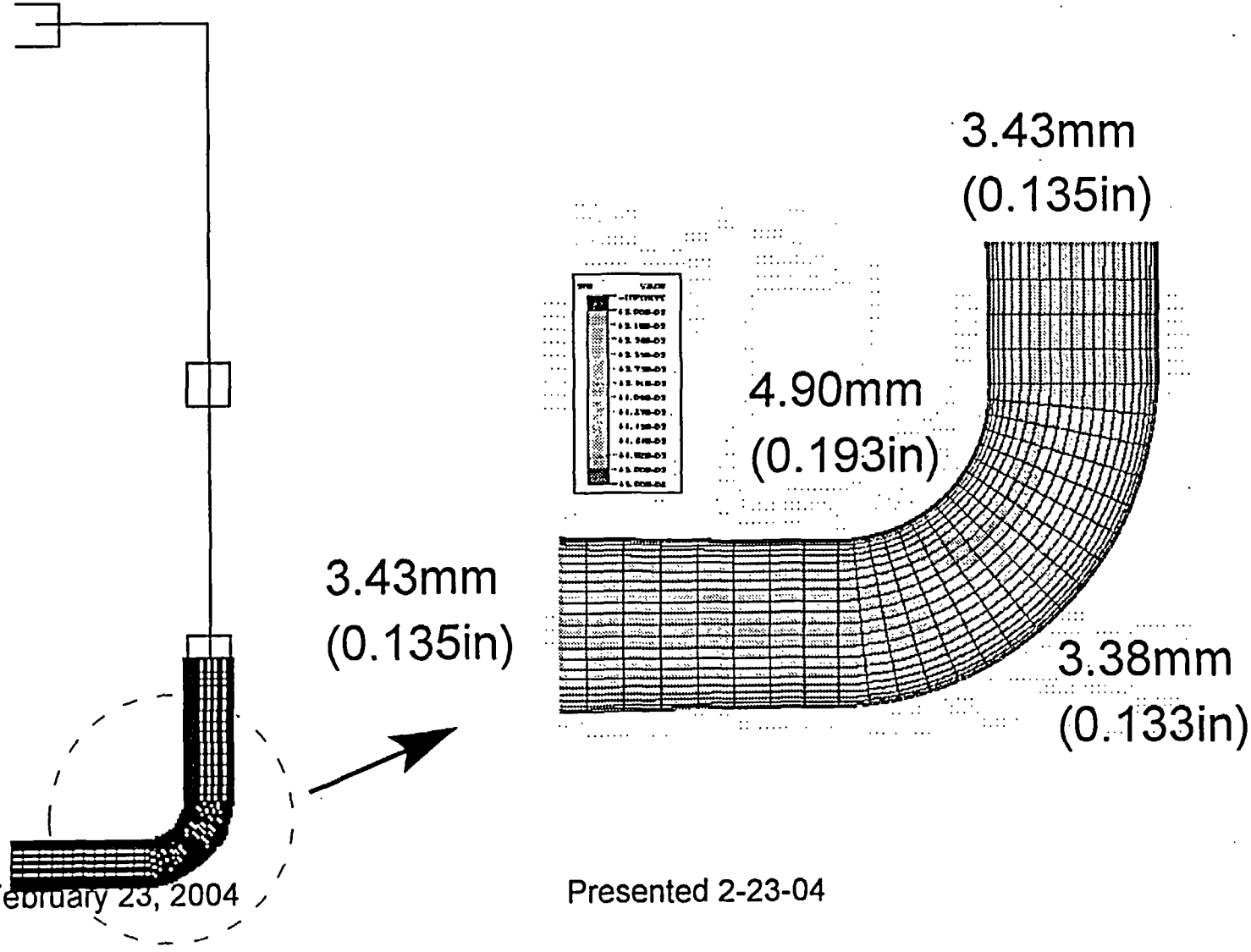
.....Low carbon steels at 300-600F. These materials experience dynamic strain aging, also known as blue embrittlement. This causes changes in the ultimate strength, strain hardening and toughness of the material as a function of temperature and strain rate.....At higher strain rates and LWR temperatures, all of the ferritic steels tested to date in the IPIRG-I & II have had slightly higher yield strengths but much lower ultimate strengths. Typically, the ultimate strengths of ferritic base metal **at 1 /sec to 10 /sec** strain rate are lower by about 15-30 percent than at quasi-static rates. Thus, the yield-to-ultimate strengths can change from 0.45.at quasi-static rate to **0.77 at the 1 to 10 sec^{-1} strain rate**.....

ANALYSIS CONDITION FOR STRAIN RATE EVALUATION

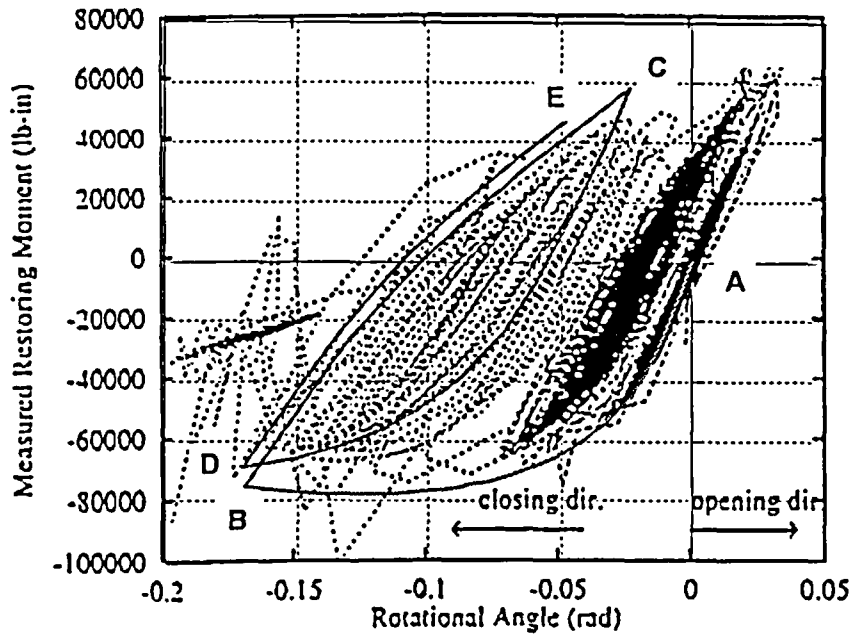
CASE1: Test#37, RUN5

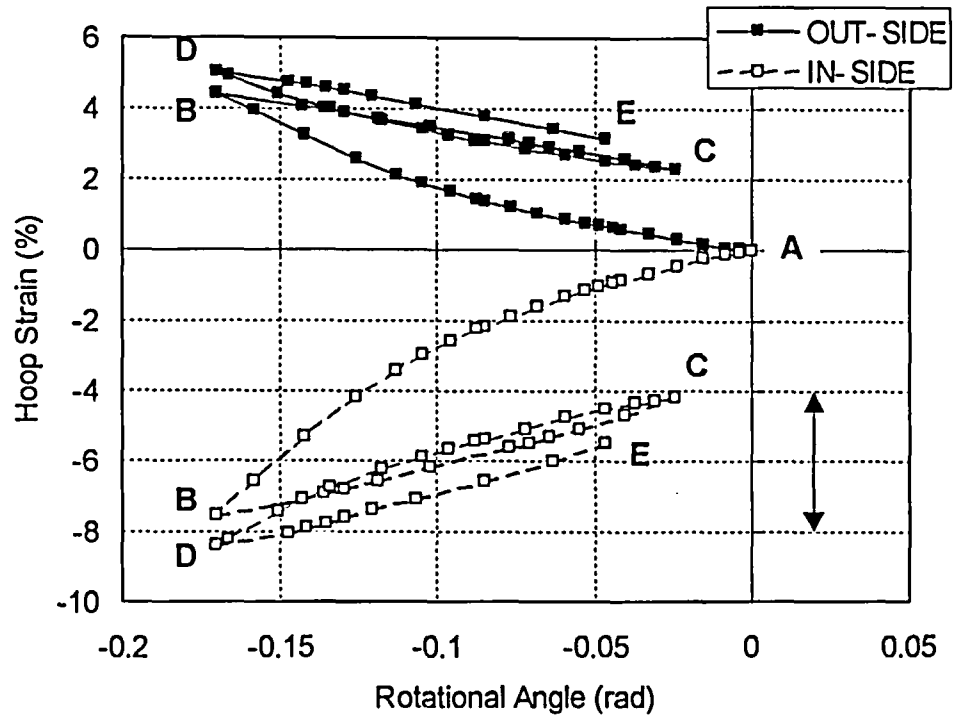
CASE2: JAPANESE COMPONENT TEST MODEL
(BEND PIPE, TEE)

ANALYSIS MODEL for TEST#37, RUN5



ANALYSIS RESULTS TEST#37, RUN5





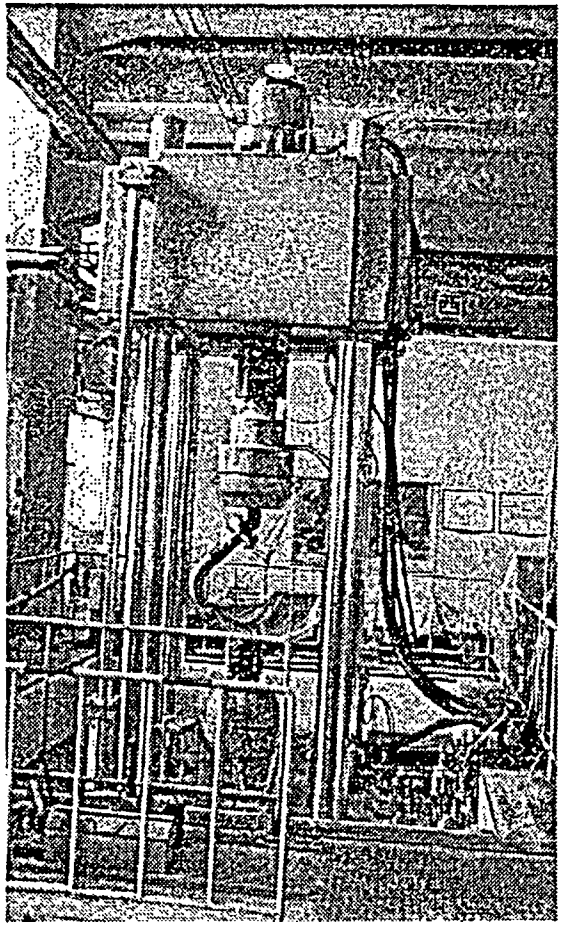
Average strain rate: 0.32/sec. (=0.04/0.125 for 4Hz)

..0.11/sec. (=0.04/0.357 for 1.4Hz; Natural Freq.)

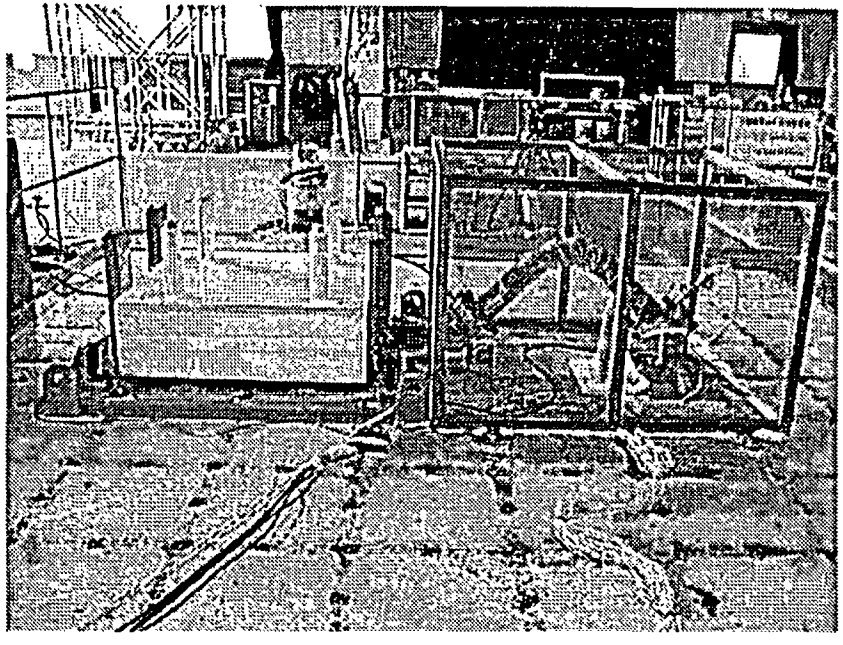
.....Not 2/sec (=Peak strain rate estimated by NRC for 4Hz)

JAPANESE COMPONENT TEST MODEL

In-plane Bending Test for Pipe Bends

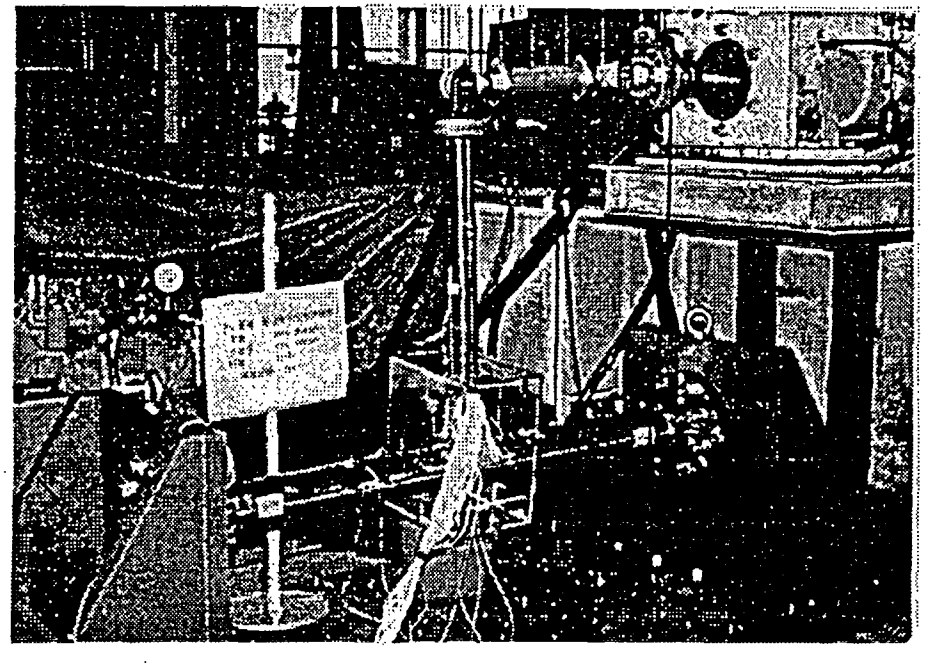


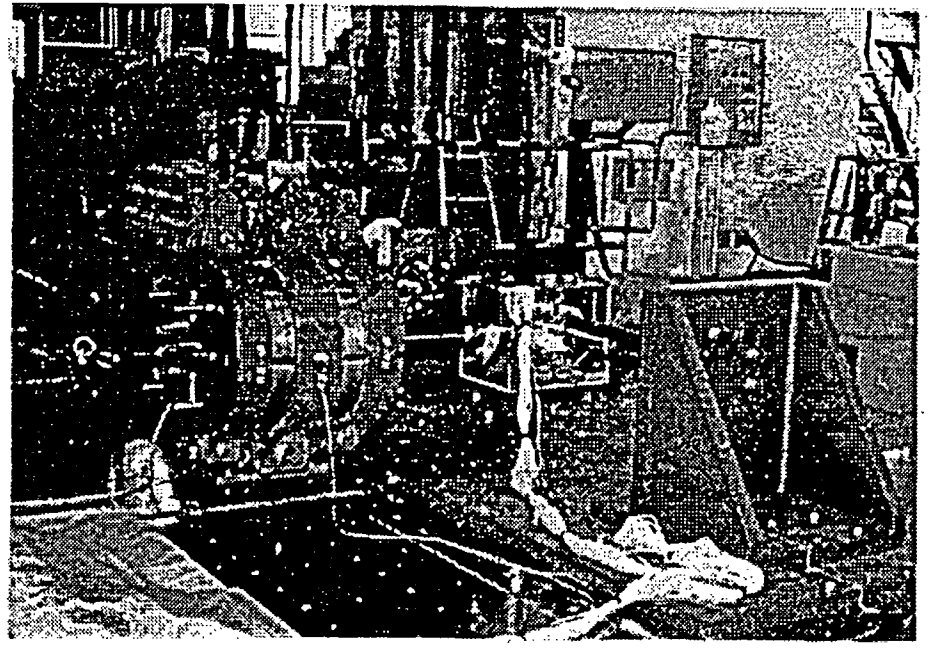
[Cyclic Test]



[Dynamic Test]

In-plane Bending Test for Tee





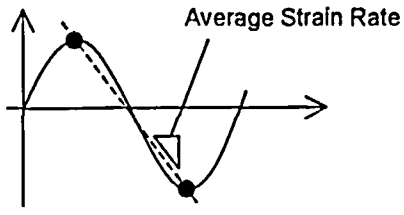
Cyclic Test

Vibration Test

Test Summary & Calculated Strain Rate

Type	Test Condition				Static Cyclic Test					Dynamic Test (Shaking Table)					
	OD	t	Mat.	Int. P*1 (MPa)	Exp. No.	Load Displ. (mm)	Mud *2 (kNm)	Mcode *3 (kNm)	Strain Range*4 ε(%)	Exp. No.	Res-ponse Displ. (mm)	Mud *2 (kNm)	Mcode *3 (kNm)	Res-ponse Freq. f (Hz)	Average Strain Rate*5 ε/(1/2f) (1/s)
Bend	4B	S40	C/S	13.7	1	±33	32.9	12.1	4.84	1	±33	31.8	12.1	4.7	0.45
Bend	4B	S40	S/S	15.0	2	±33	34.3	13.3	3.53	2	±33	45.2	13.3	4.7	0.33
Tee	4B/4B	S40	C/S	13.7	12	±50	26.0	12.7	3.4	11	±50	24.2	12.7	3.5	0.24

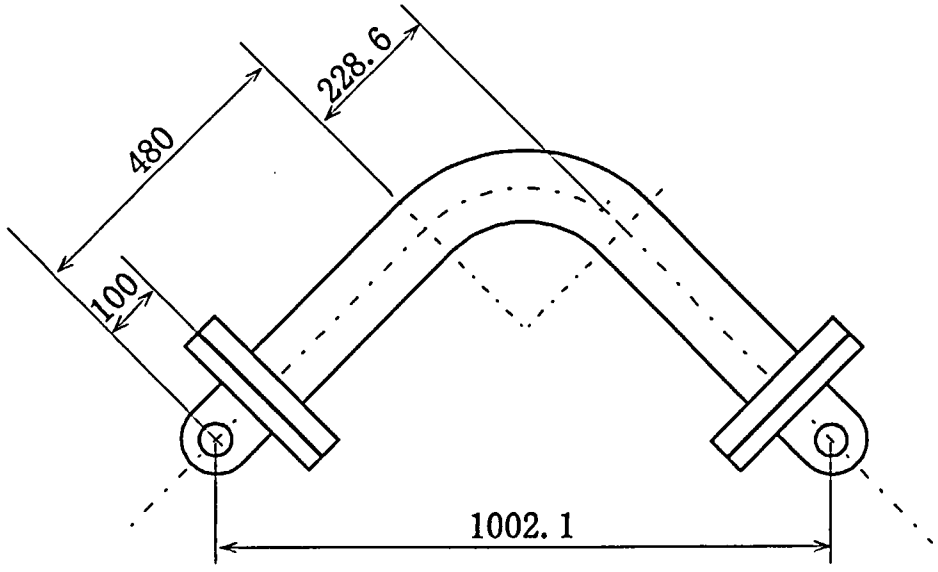
*1 : Sm equivalent (Hoop Stress)
*2 : Mud was calculated from the experimentally measured moment.
*3 : Calculated Code allowable moment by using nominal diameter, thickness and Code Sm value.
*4 : Calculated max. strain range at crack penetration point by FEM which methodology was verified by the comparison with experiment.
*5 :



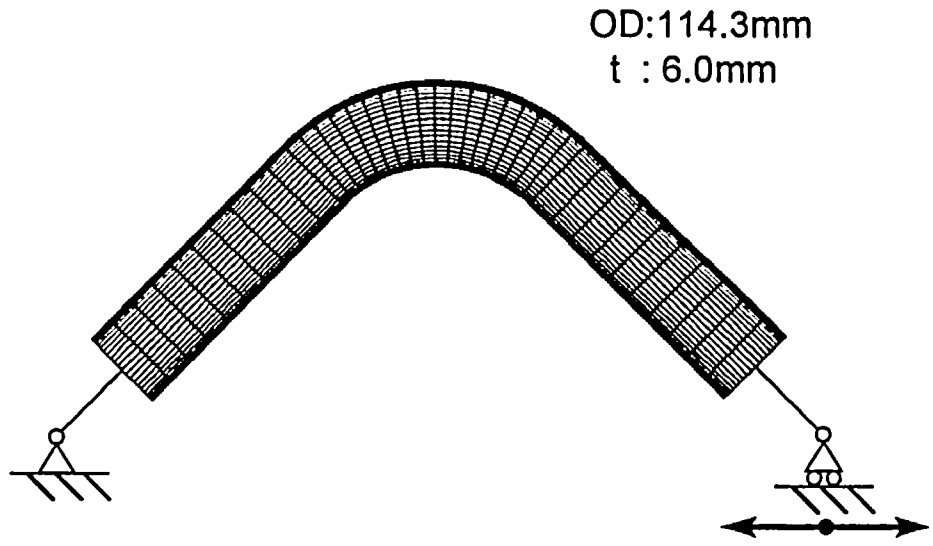
Seismic Capacity margin Rcp=Fs Fnl Fred
Fs : Strength Factor of component
Fs = Mud / Mcode (should be greater than 1.5)
Fred : Redundancy Factor
Fnl : Additional factor due to Nonlinear dynamic behavior

ANALYSIS MODEL for JAPANESE MODELS

- In-plane Bending Model for Bend



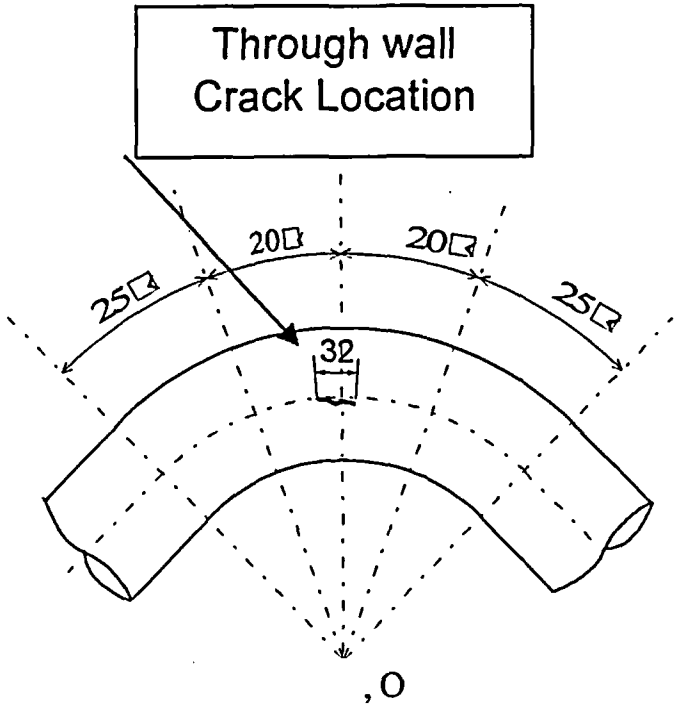
[Test Model]



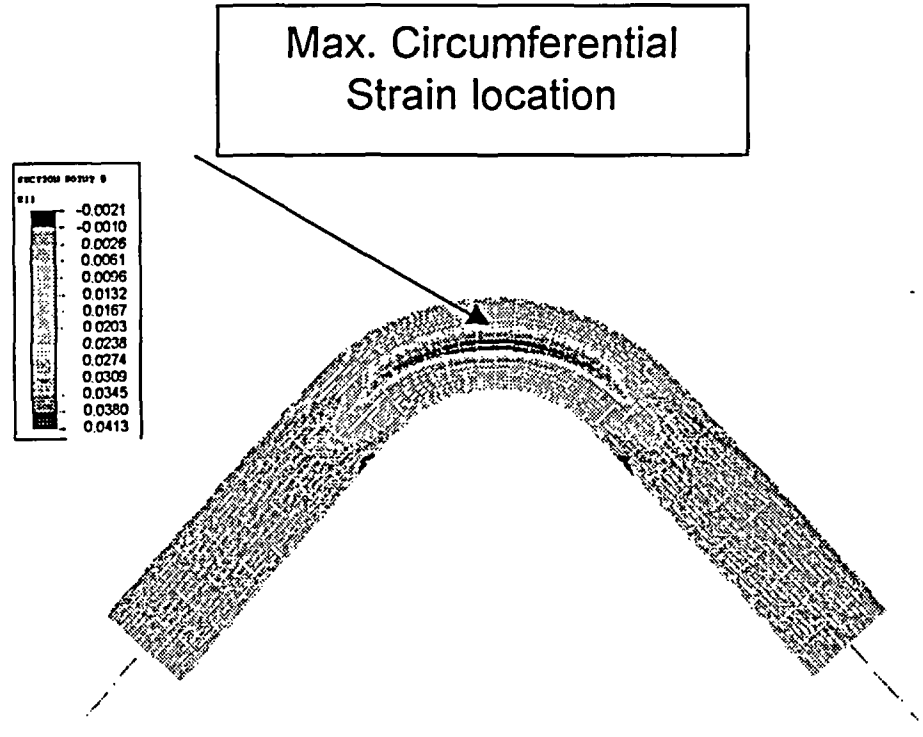
[Analysis Model]

Analysis Results - Pipe Bends

- Comparison between Failure Location and Max. Strain Location Obtained from the Analysis



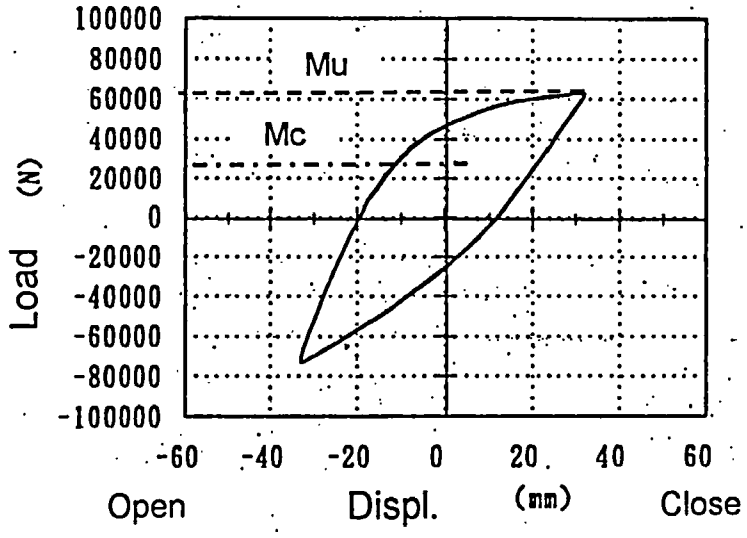
[Test Result]



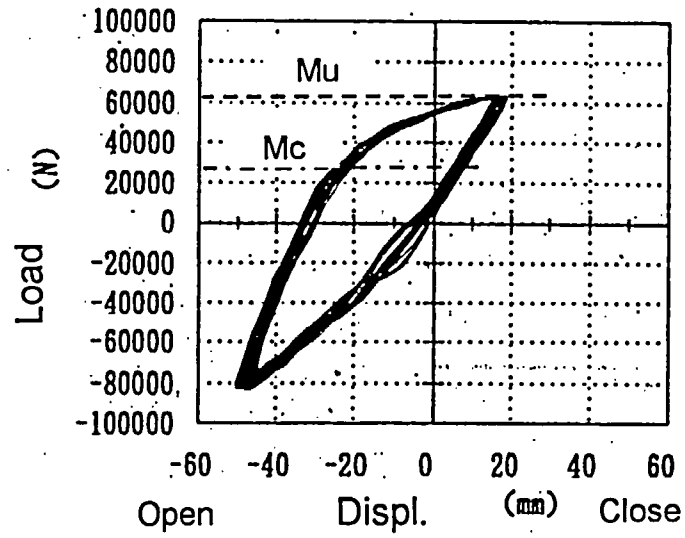
[Analysis Result]

Both results are good agreement.

Measured Load – Displacement Relationship: C/S Bend



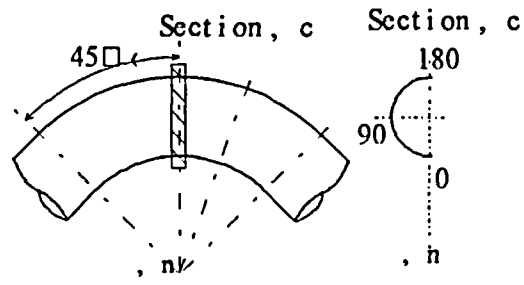
STATIC TEST□□□□□□□□□□□



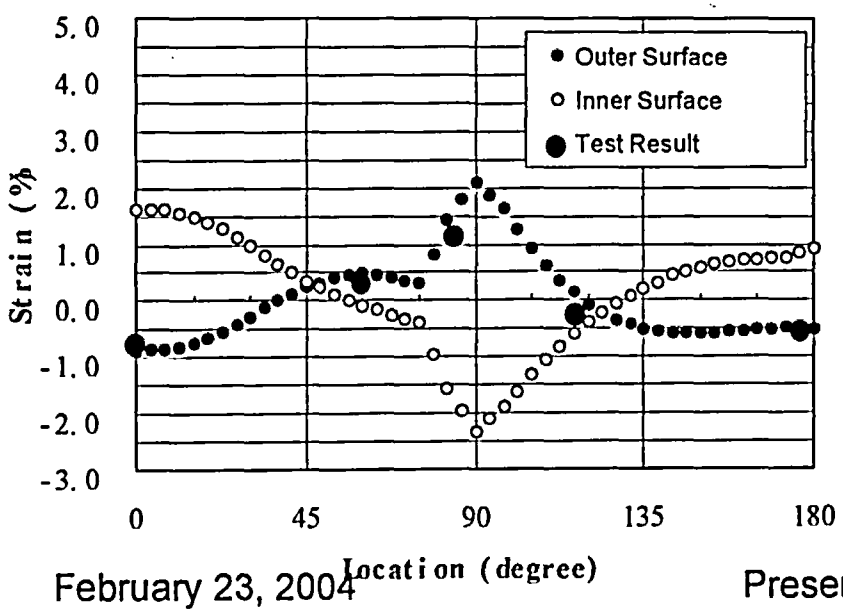
□□DYNAMIC TEST

Analysis Results

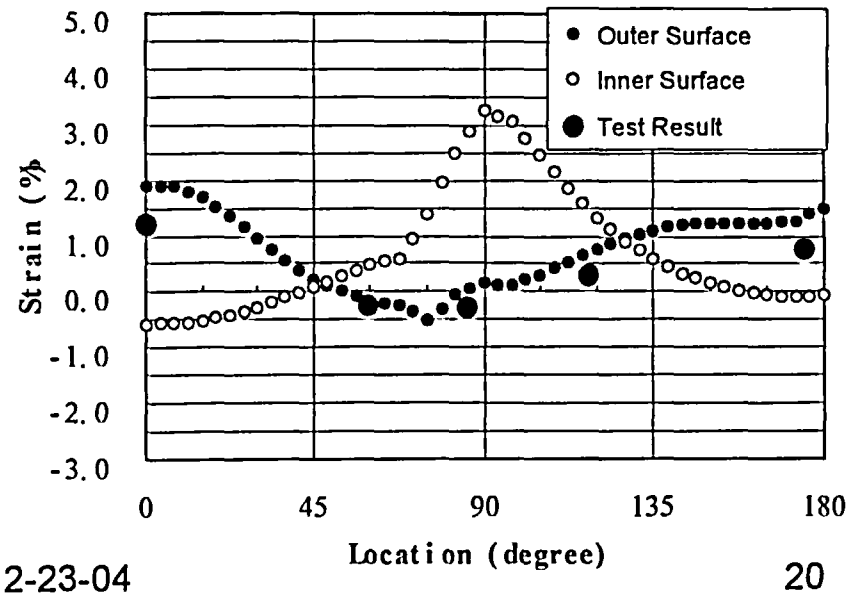
Hoop Strain Distribution correspond to fictitious stress at Mud (10Sm)



Closing

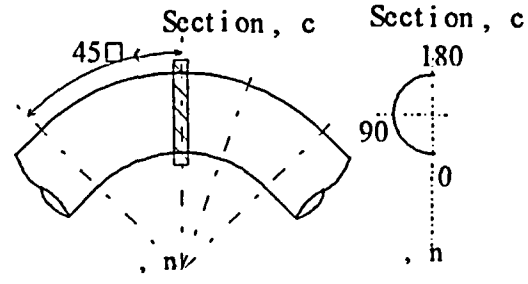


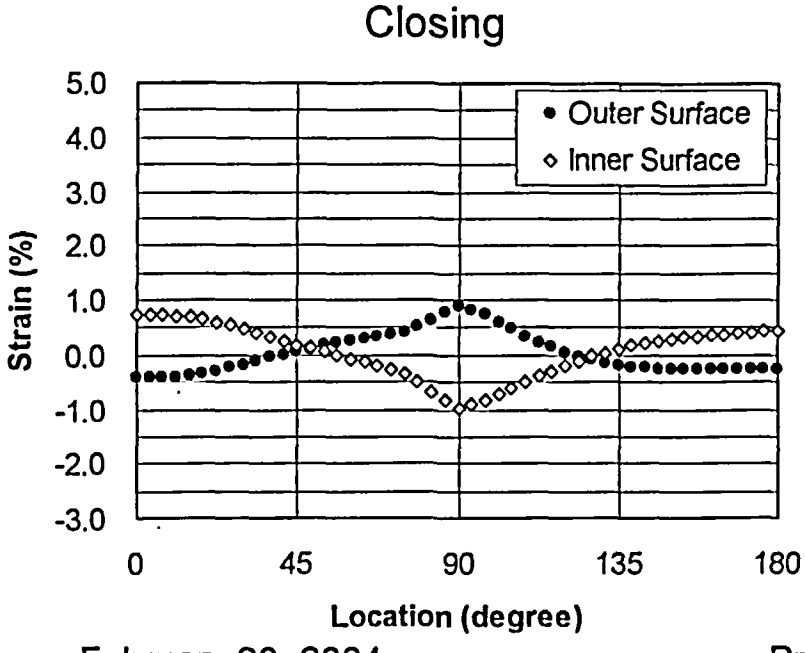
Opening

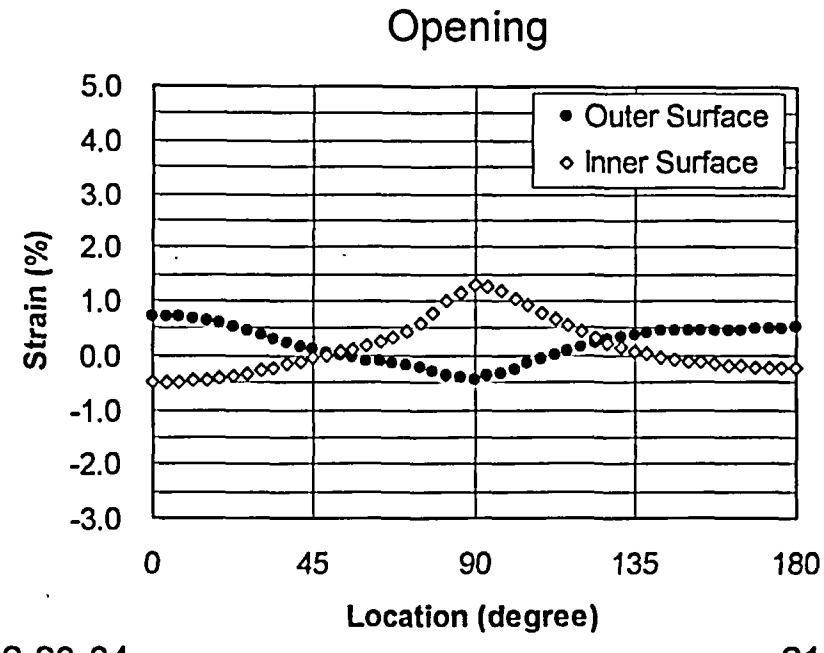


Analysis Results

- Hoop Strain Distribution correspond to fictitious stress of 6.5Sm

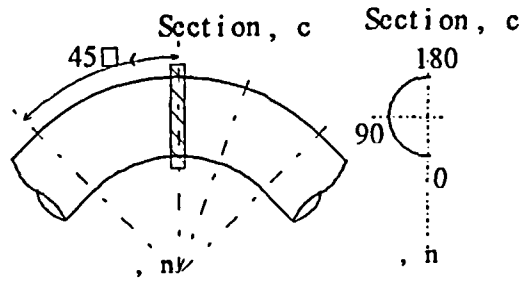


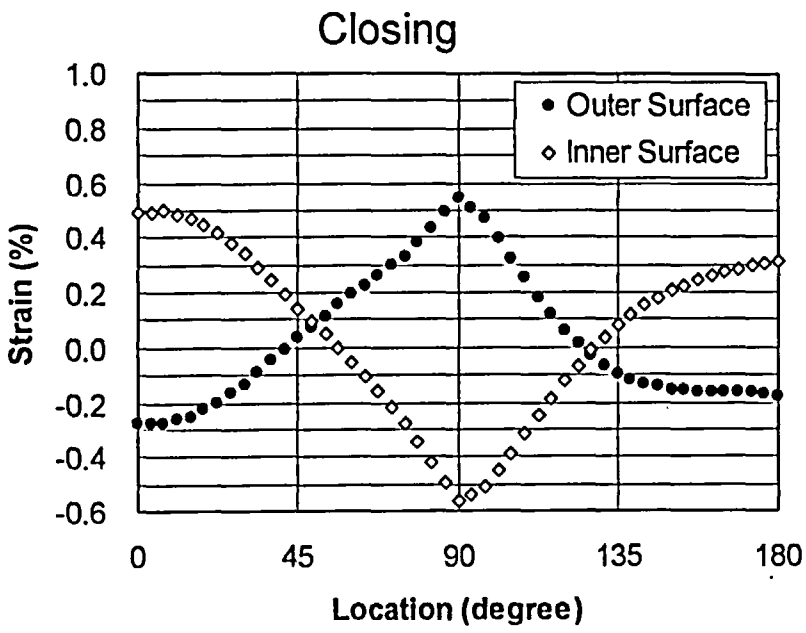


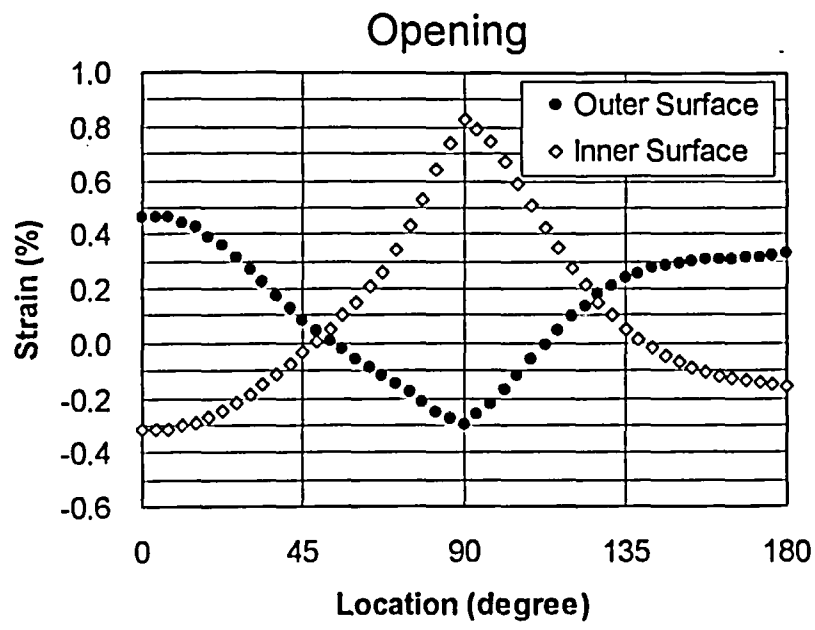


Analysis Results

- Hoop Strain Distribution correspond to fictitious stress of 4.5Sm







STRAIN RATE EVALUATION (CS, BEND)

At Mud (10Sm)

Strain range = 4.8%(0.048)

Strain rate = $0.048 \times \frac{1}{0.106}$ = 0.45/sec. at 4.7Hz

At 6.5Sm

Strain range = 1.3 + 1.0 = 2.3%(0.023)

Strain rate = $0.023 \times \frac{1}{0.125}$ = 0.18/sec. at 4Hz

At 4.5Sm

Strain range = 0.8 + 0.6 = 1.4%(0.014)

Strain rate = $0.014 \times \frac{1}{0.125}$ = 0.11/sec. at 4Hz

STRAIN RATE EVALUATION AT Mud

Carbon Steel Bent at Mud(Fs=3.1, fn=4.7Hz)

Strain range = 4.84%(0.048)

Strain rate = $0.048 \times \frac{1}{0.106} = 0.45$/sec.

Stainless Steel BENT at Mud (Fs=3.4, fn=4.7Hz)

Strain range = 3.53%(0.035)

Strain rate = $0.035 \times \frac{1}{0.106} = 0.33$/sec.

Carbon Steel Tee at Mud (Fs=1.9, fn=3.5Hz)

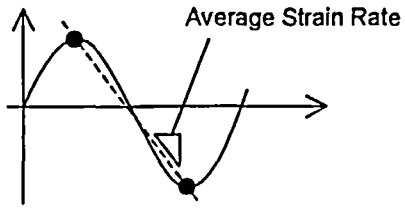
Strain range = 3.4%(0.034)

Strain rate = $0.034 \times \frac{1}{0.143} = 0.24$/sec.

Test Summary & Calculated Strain Rate

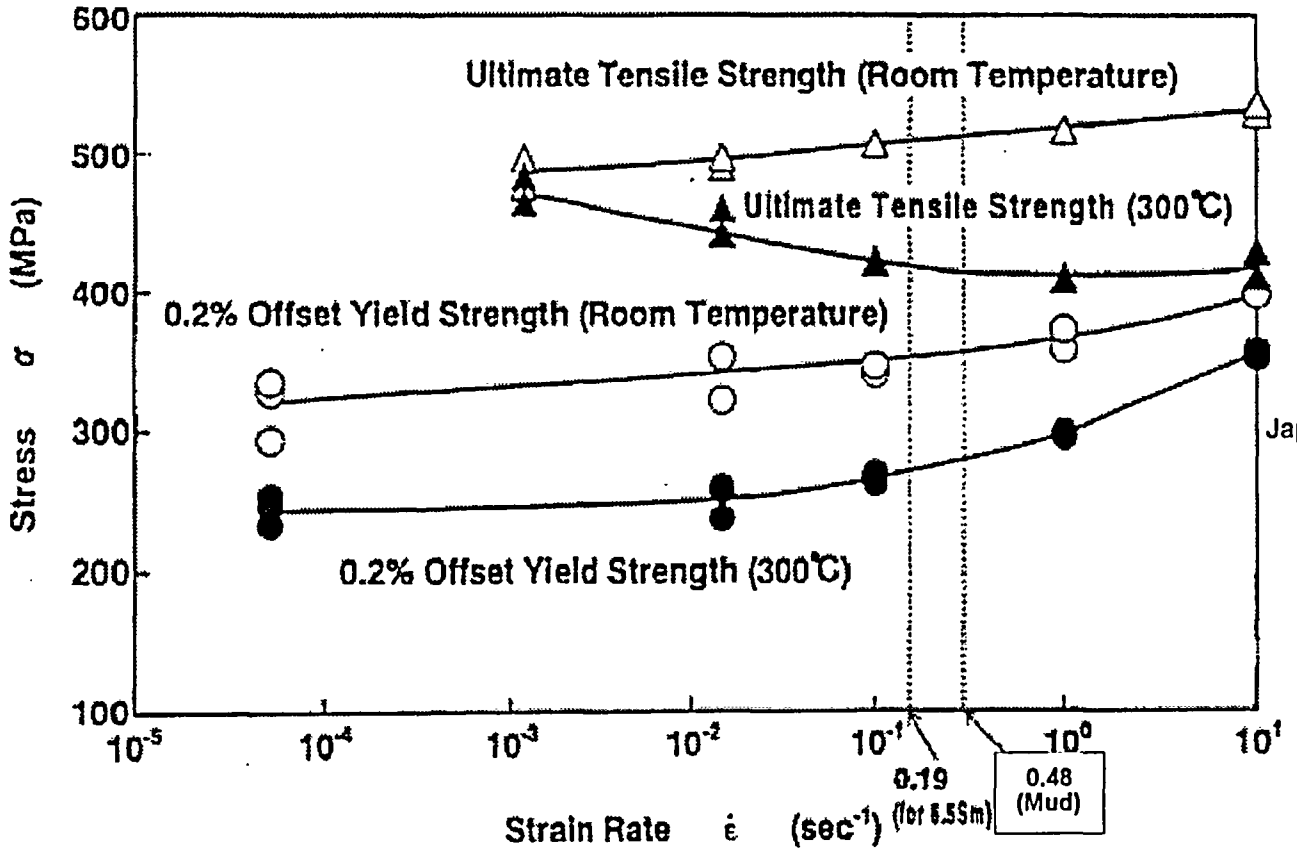
Type	Test Condition				Static Cyclic Test					Dynamic Test (Shaking Table)					
	OD	t	Mat.	Int. P*1 (MPa)	Exp. No.	Load Displ. (mm)	Mud *2 (kNm)	Mcode *3 (kNm)	Strain Range*4 ε(%)	Exp. No.	Res-ponse Displ. (mm)	Mud *2 (kNm)	Mcode *3 (kNm)	Res-ponse Freq. f (Hz)	Average Strain Rate*5 ε/(1/2f) (1/s)
Bend	4B	S40	C/S	13.7	1	±33	32.9	12.1	4.84	1	±33	31.8	12.1	4.7	0.45
Bend	4B	S40	S/S	15.0	2	±33	34.3	13.3	3.53	2	±33	45.2	13.3	4.7	0.33
Tee	4B/4B	S40	C/S	13.7	12	±50	26.0	12.7	3.4	11	±50	24.2	12.7	3.5	0.24

*1 : Sm equivalent (Hoop Stress)
*2 : Mud was calculated from the experimentally measured moment.
*3 : Calculated Code allowable moment by using nominal diameter, thickness and Code Sm value.
*4 : Calculated max. strain range at crack penetration point by FEM which methodology was verified by the comparison with experiment.
*5 :



Seismic Capacity margin Rcp=Fs Fnl Fred
Fs : Strength Factor of component
Fs = Mud / Mcode (should be greater than 1.5)
Fred : Redundancy Factor
Fnl : Additional factor due to Nonlinear dynamic behavior

Stress Ratio Change (Japanese STS410)



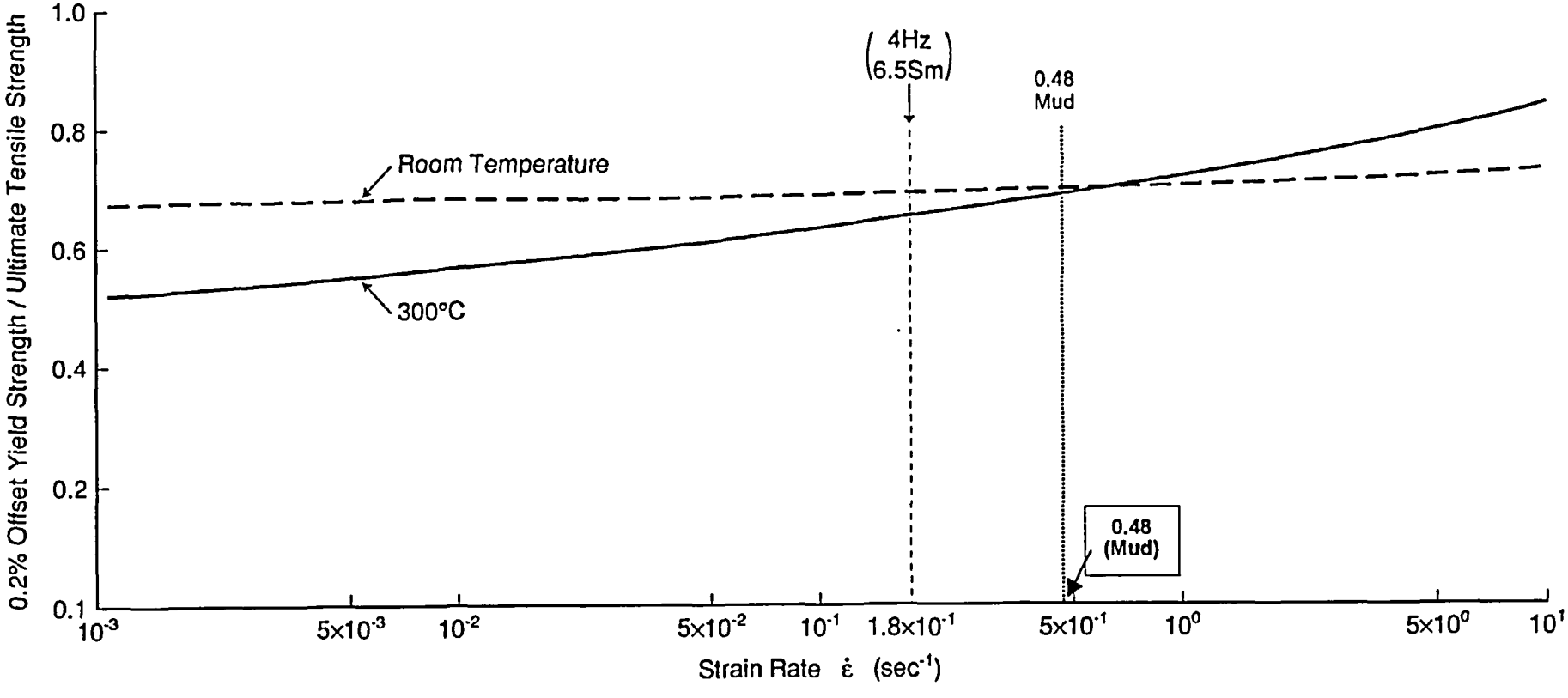
Japanese Code Requirement

	RT	300C
Su	410	404
Sy	245	183

(Mpa)

From CRIEPI Report T92044 (1993), "Evaluation of Dynamic Fracture Strength of Dynamic Flawed Carbon Steel Piping under High Temperature"

Stress Ratio Change (Japanese STS410)



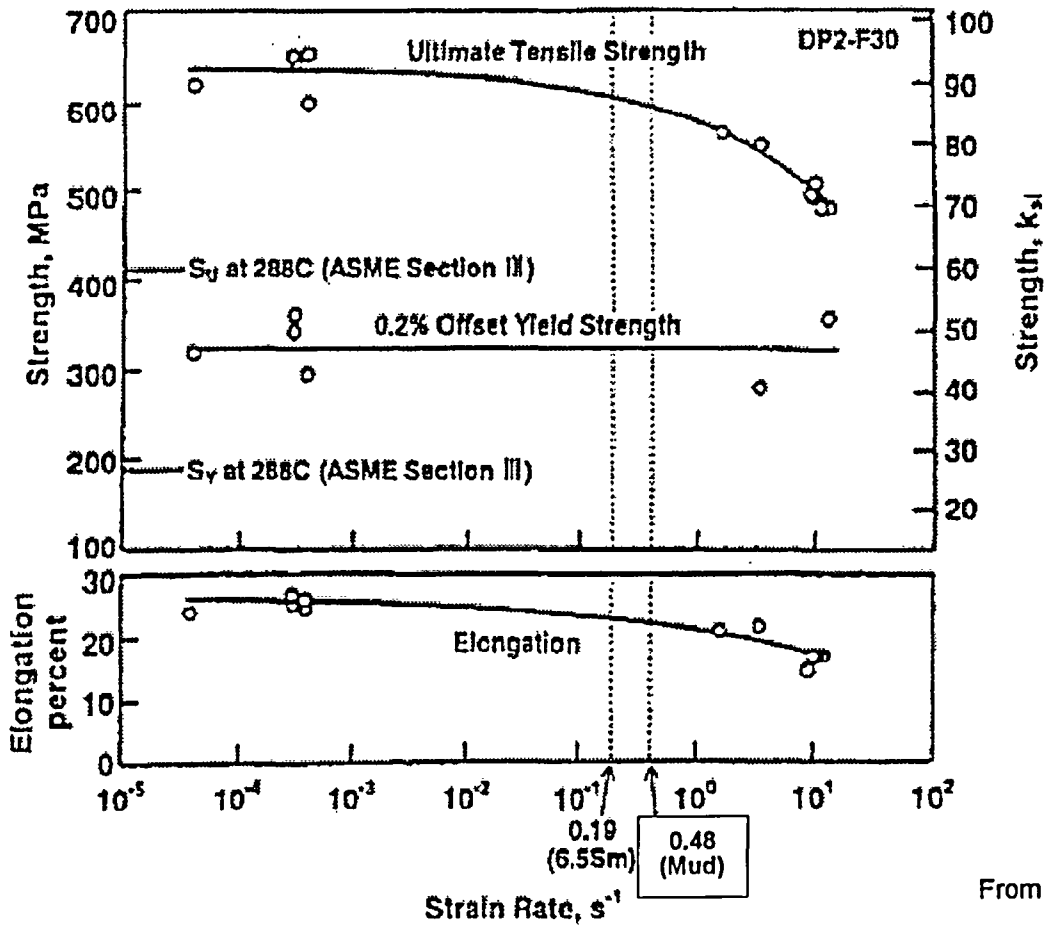
Effect of Dynamic Strain Aging on the Stress

STS410 Carbon Steel□Japanese Material)

Model		JST Bend		Test #37	
Freq.		4Hz	4.7Hz	1.7Hz	4Hz
Response Level		6.5Sm	Fs G.T 1.5	Run5	Run5
Strain Rate		0.18	0.45(Max)	0.11	0.32
Stress Ratio	RT	0.70	0.71	0.69	0.70
	300C	0.66	0.70	0.64	0.68

Stress Ratio=0.2% Offset Yield Strength/ Ultimate Tensile Strength

Tensile Property at 288C(550F) vs. Strain Rate for PipeDP2-F30 (A106 Gr.B)

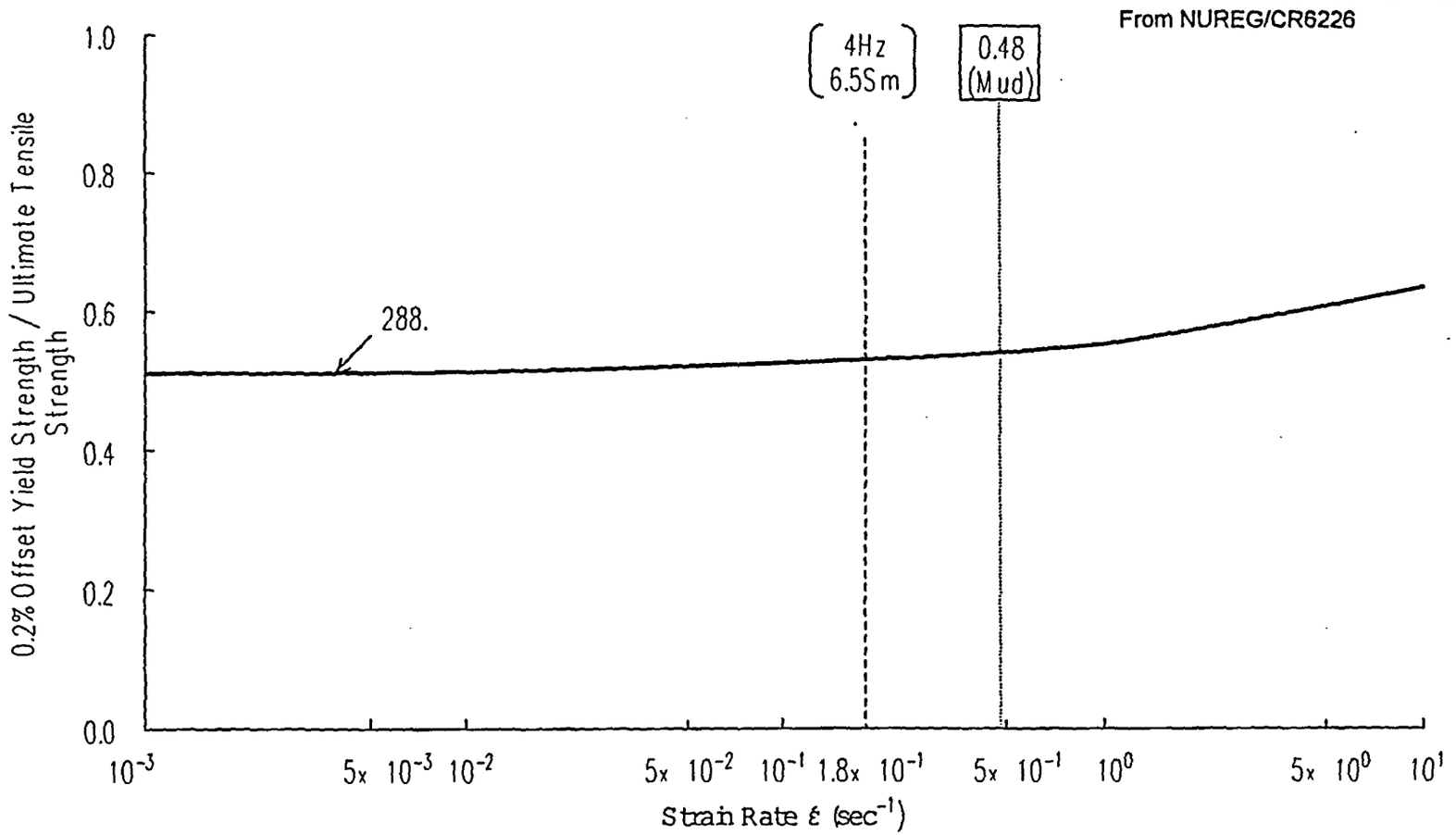


From NUREG/CR6226

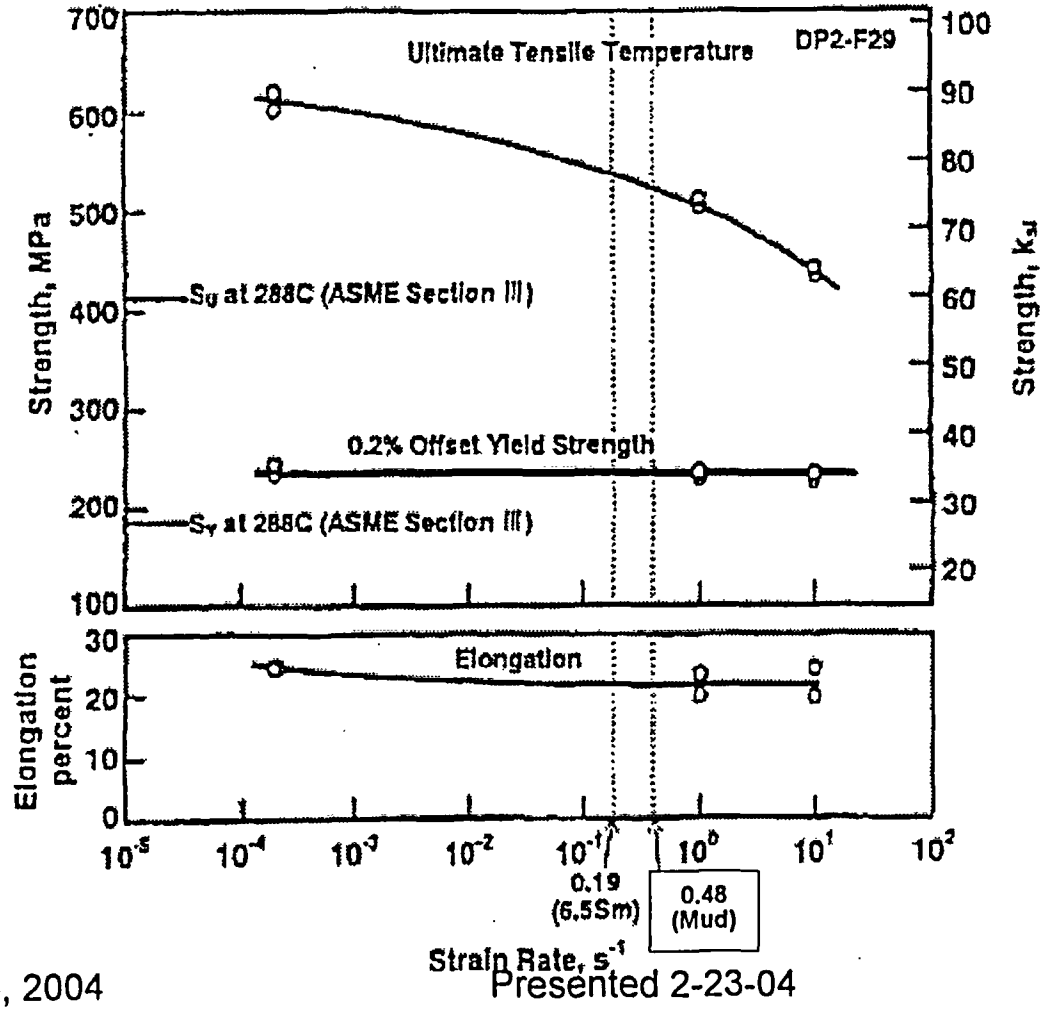
Stress Ratio Change (A106 Grade B)

Tensile Property at 288C(550F) vs. Strain Rate for PipeDP2-F30 (A106 Gr.B)

From NUREG/CR6226



Tensile Property at 288C(550F) vs. Strain Rate for PipeDP2-F29 (A106 Gr.B)

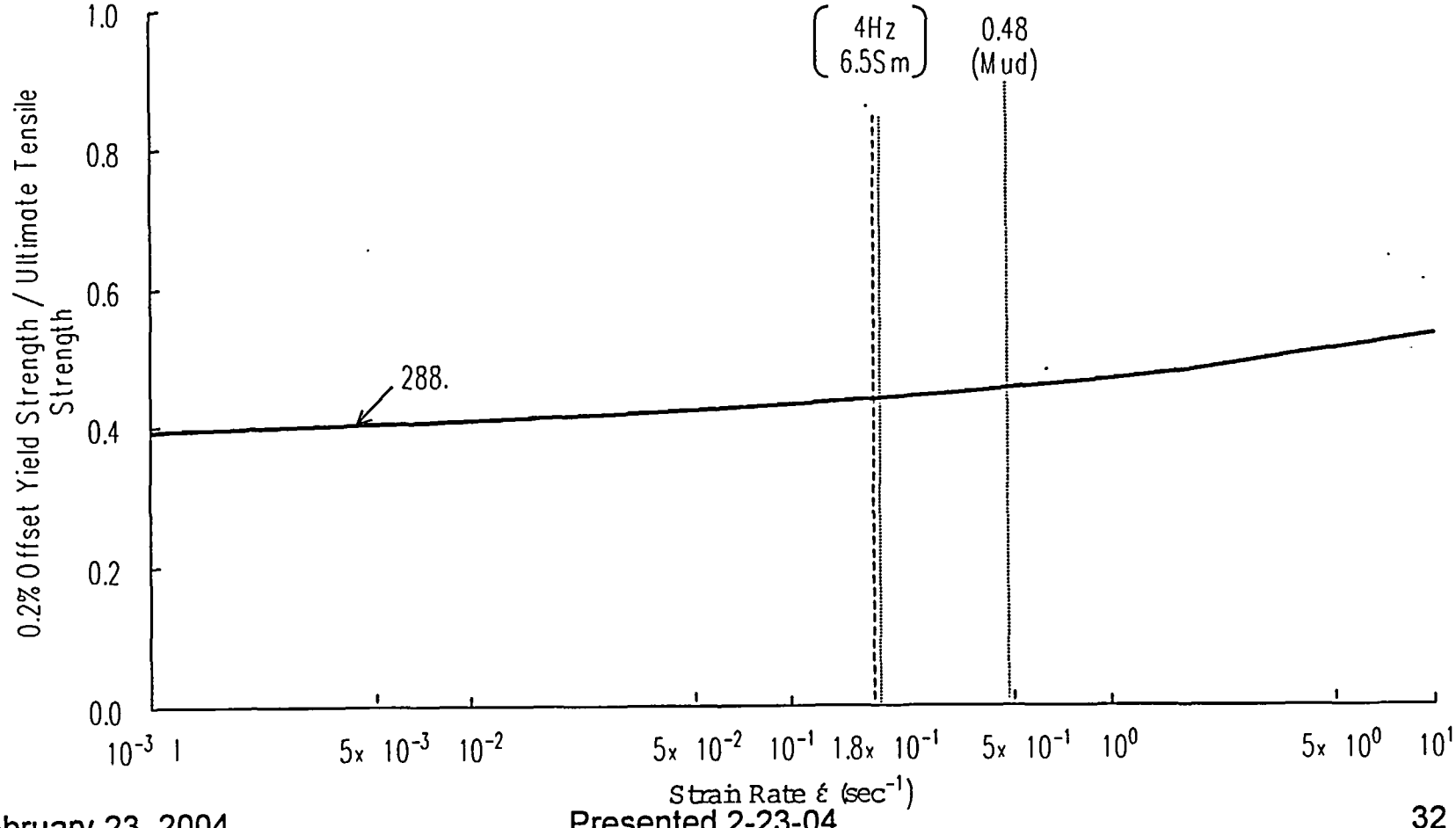


From NUREG/CR6226

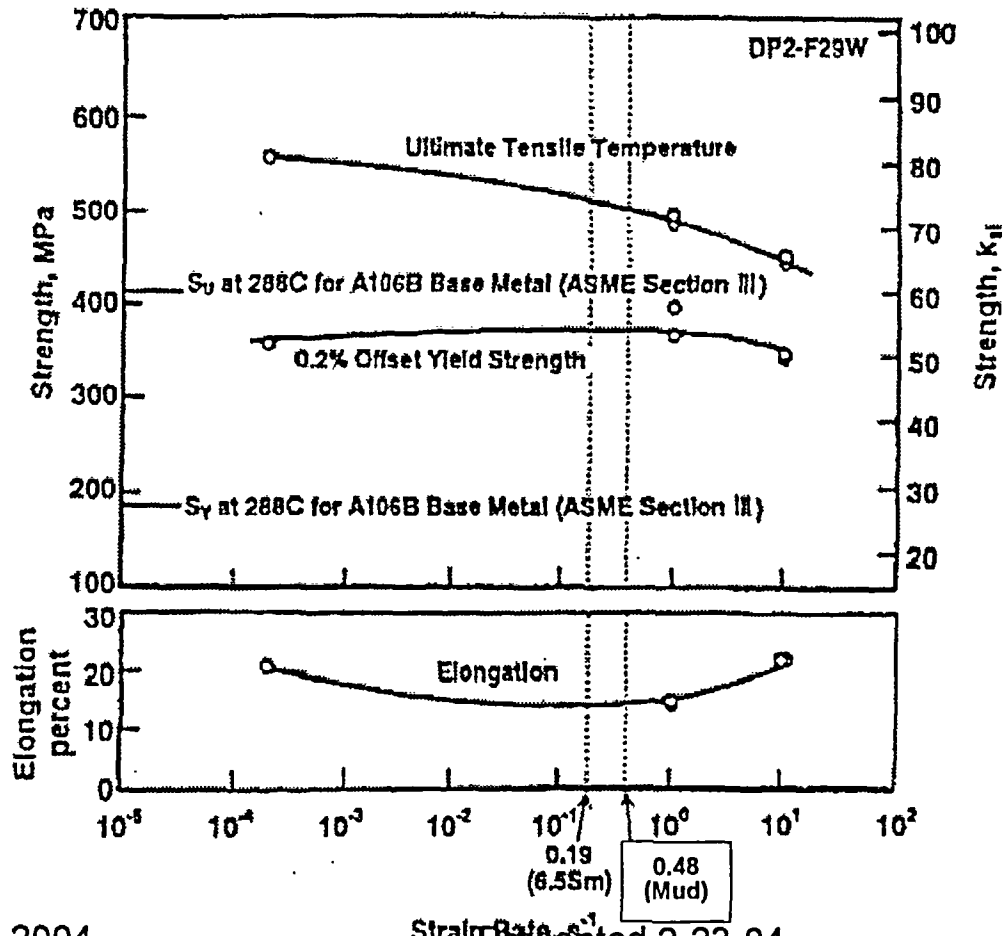
Stress Ratio Change (A106 Grade B)

Tensile Property at 288C(550F) vs. Strain Rate for PipeDP2-F29 (A106 Gr.B)

From NUREG/CR6226



Tensile Property at 288C(550F) vs. Strain Rate for Submerged arc weld
DP2-F29W (A106 Gr.B)

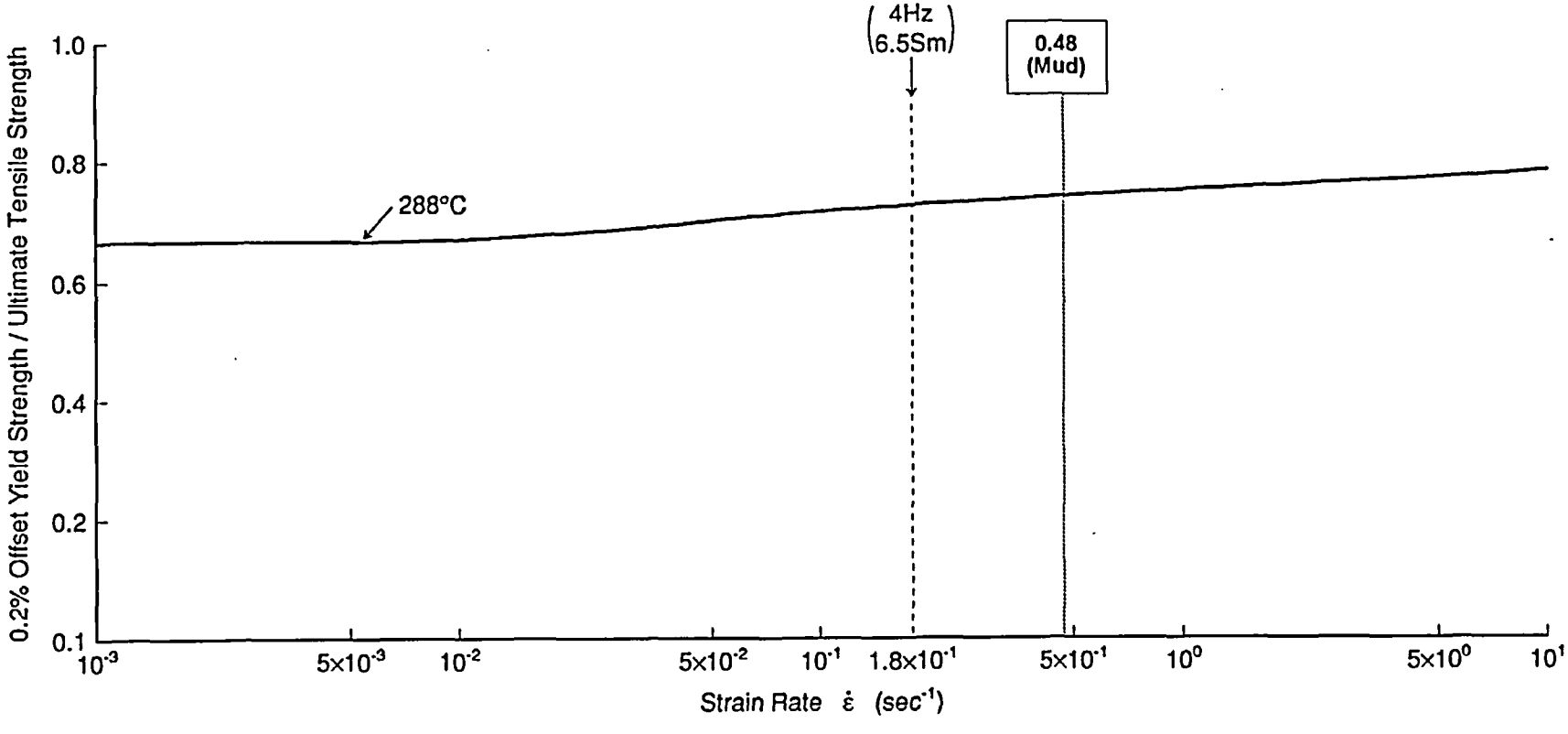


From NUREG/CR6226

Stress Ratio Change (A106 Grade B)

Tensile Property at 288C(550F) vs. Strain Rate for Submerged arc weld DP2-F29W (A106 Gr.B)

From NUREG/CR6226



CONCLUSIONS (1)

Dr. Wilkowski pointed out in the page III-F-3 of NUREG /CR-5361 that:

.....Low carbon steels at 300-600F. These materials experience dynamic strain aging, also known as blue embrittlement. This causes changes in the ultimate strength, strain hardening and toughness of the material as a function of temperature and strain rate.....At higher strain rates and LWR temperatures, all of the ferritic steels tested to date in the IPIRG-I & II have had slightly higher yield. strengths but much lower ultimate strengths. Typically; the ultimate strengths of ferritic base metal at 1 /sec to 10 /sec strain rate are lower by about 15-30 percent than at quasi-static rates. Thus, the yield-to-ultimate strengths can change from 0.45at quasi-static rate to **0.77 at the 1 to 10 sec^{-1} strain rate**.....

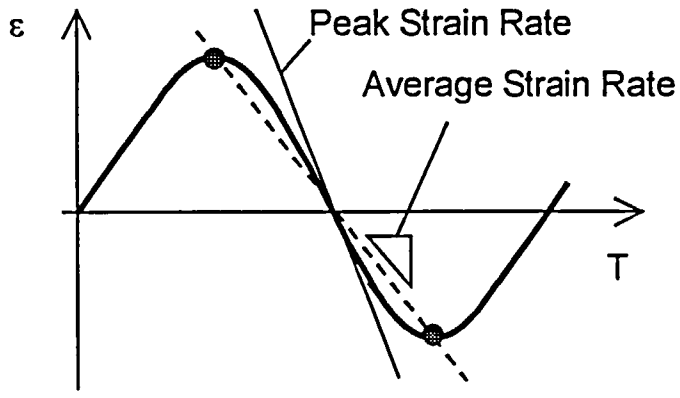
CONCLUSIONS (2)

1) The evaluated strain rates of piping components such as elbow and tee tested both in USA (Test#37) and in Japan at Mud condition with sufficient margin is much lower than 1/sec that is the lowest limit of dynamic strain aging by Dr. Wilkowski.

2) Dynamic strain aging never occur in piping components in operating NPP of LWR temperature and at seismic event.

3) Dynamic strain aging issue does not disturb to set 3.0Sm and B2'=2/3B2 as the allowable primary stress intensity limit for seismic evaluation of nuclear piping systems.

PEAK VS. AVERAGE STRAIN RATE



Combination of peak strain rate and peak strain is too much conservative.
Actually, strain becomes zero at peak strain rate and strain rate becomes zero at peak strain. So, average strain rate is reasonable for the evaluation of dynamic strain aging.

Input on strain rate from Dr. Wilkowski

Subj: RE: 2-00 minutes (w/o attachments)
Date: 3/6/2000 8:28:16 AM Central Standard Time
From: gwilkows@columbus.rr.com (Gery Wilkowski)
To: Minicjc@aol.com

Hence if the strain to maximum load is 5% and a typical piping frequency is 4 Hz, then the period of the first natural frequency (larger amplitude cycles) is 0.25 seconds, and one quarter of the period is 0.0625 seconds. Then the effective seismic strain rate would then be between 0.8/second (0.05/0.0625 seconds) and 0.4/second (effect of factor of 2 on time for multiple cycles). If the strain to reach the Mud (or Muc) limit is less than 5%, then scale these estimated strain rates back linearly. If the frequency is higher or lower, then also adjust the time accordingly.

Seismic Analysis of Piping Peer Review Group Report

Submitted by G. M. Wilkowski and R. J. Olson
Battelle-Columbus

Low carbon steels at 300 to 600 F. These materials experience dynamic strain aging, also known as blue embrittlement. This causes changes in the ultimate strength, strain hardening and toughness of the material as a function of temperature and strain rate. For instance, the ANCO tests done on the ferritic components had yield-to-ultimate strengths of approximately 0.58 to 0.68 at room temperature. At higher strain rates and LWR temperatures, all of the ferritic steels tested to date in the NRC's International Piping Integrity Research Group programs (IPIRG-1 and IPIRG-2) have had slightly higher yield strengths, but much lower ultimate strengths. Typically, the ultimate strengths of ferritic base metals at 1 sec^{-1} to 10 sec^{-1} strain rates are lower by about 15 to 30 percent than at quasi-static rates. Thus, the yield-to-ultimate strengths can change from 0.45 at quasi-static rates to 0.77 at the 1 to 10 sec^{-1} strain rates. The change is even more significant for ferritic weld metals. Hence, ferritic steels at LWR temperatures and dynamic loading will have less strain hardening than ferritic steels at room temperature under dynamic loading.

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CONCLUSIONS

From the various review meetings and written information supplied, we believe that the recent ASME seismic design code rules are in need of further validation before they are deemed acceptable. This statement is based on weaknesses in six technical areas, most of which are related to the EPRI/ANCO component tests that are the basis of the new seismic design rules. Some of these aspects may erode the safety margins that are thought to currently exist.

(1) Materials Considerations

The criteria are based on the tests conducted at ANCO on wrought stainless steel and low strength carbon steel pipe and components at room temperature. However, the criteria are said to be applicable to a large variety of materials (P1 to P8) at LWR temperatures. The concern here is that there may be materials where the margins experimentally determined from the limited component tests may not reach the desired levels. Materials with higher yield-to-ultimate strength ratios (i.e., lower strain hardening) or materials that may be less flaw tolerant at operating conditions may have lower margins than determined from the room temperature tests. Some specific materials that are of concern are:

- Low carbon steels at 300 to 600 F. These materials experience dynamic strain aging, also known as blue embrittlement. This causes changes in the ultimate strength, strain hardening and toughness of the material as a function of temperature and strain rate. For instance, the ANCO tests done on the ferritic components had yield-to-ultimate strengths of approximately 0.58 to 0.68 at room temperature. At higher strain rates and LWR temperatures, all of the ferritic steels tested to date in the NRC's International Piping Integrity Research Group programs (IPIRG-1 and IPIRG-2) have had slightly higher yield strengths, but much lower ultimate strengths. Typically, the ultimate strengths of ferritic base metals at 1 sec^{-1} to 10 sec^{-1} strain rates are lower by about 15 to 30 percent than at quasi-static rates. Thus, the yield-to-ultimate strengths can change from 0.45 at quasi-static rates to 0.77 at the 1 to 10 sec^{-1} strain rates. The change is even more significant for ferritic weld metals. Hence, ferritic steels at LWR temperatures and dynamic loading will have less strain hardening than ferritic steels at room temperature under dynamic loading.

- Other higher strength materials that have been used in ASME-designed nuclear power plants. Some additional examples are:
  - A106 Grade C,
  - cast stainless steel that has experienced thermal aging, and may be low in toughness at reactor start-up temperatures (i.e., 300 F), and
  - low alloy steel (i.e., A508) used in forgings for nozzles (i.e., surge line nozzles into cold leg piping) or pipe in German, Swiss, future Japanese PWR's, and perhaps the future European Pressurized Water Reactor (EPR).

ASME Responses to Proposed USNRC Rule Making

Background Discussion on B_2'

Background Discussion on B_2'

- Correct Equations:
  - B_2' = 0.87/*h*2/3 for curved pipe and butt-welding elbows…
  - B_{2b}' = 0.27(Rm/Tt)2/3 and
  - B_{2r}' = 0.33(Rm/Tr)2/3 for ANSI B16.9 or MSS-SP-87 butt-welding tees
- ND-3655(b)(3) correct; errata issued for NB/NC
- Basis was work by Dr. Kennedy

Background Discussion on B_2'

- Dr. Kennedy discussion:
  - $F_s F_{nl} F_{red} \sim 2.0$
  - $F_{nl} F_{red} > 1.33$ for reasonable systems
  - Thus, $F_s \sim 1.5$
- Reduction of EPRI and JST tests shows 1.5
  - Use $3S_m$ allowable
  - Use B_2' indices:
    - Elbows, Bends, and tees: $B_2' = 2/3\ B_2$
    - Welds at location of abrupt stiffness changes: $B_2' = 4/3\ B_2$
    - Other fittings where a reduction is unavailable: $B_2' = B_2$

Background Discussion on B_2'

- JST Static "Markl" vs dynamic tests
  - Similar cycles for similar displacement
  - Cantilever tests represent maximum follow-up
  - JST and EPRI tests were cantilever tests
  - Predominant failure fatigue; B_2' similar to SIF

Background Discussion on B_2'

- SWG-SR recommended 2/3 factor
  - Compromised to ¾ to address dynamic strain aging temperature effect (DSATE)
  - Received negatives at MC
  - JST data showed (and shows) there was little DSATE at the levels of strain in our tests, even at M_{ud}
  - Reballoted in September 2001 with 2/3 and passed

ASME Responses to Proposed USNRC Rule Making

Equation 11a ($2S_a$)

Equation 11a ($2S_a$)

- Code Equation: $S_R = iM_R/Z \leq 2S_a$
  - M_R = <u>range</u> of SAM <u>and</u> inertia
  - Similar to Class 1 "primary plus secondary" and fatigue checks
  - No separate primary check, same as Class 1
- Based on typical OBE events and cycles

Equation 11a ($2S_a$)

- Objectives
  - Keep usage low (Markl's equation with SF)
  - Ensure elastic cycling ($2S_a \sim 1.5\text{-}2Sy$)
- Similar to New Reactor Criteria:
  - $iM_c/Z < 3S_h$
  - M_c = range of thermal plus amplitude of SAM, or the range of SAM
  - $2S_a \sim 3S_h$

Equation 11a ($2S_a$)

- ASME check includes inertia with SAM, and takes range
- If thermal is equal to S_a (~$1.5S_h$), ASME check is the same stress allowable as that used for new reactors

- Conclusion: ASME check:
  - Consistent with Class 1 check
  - Consistent with new reactor stress level
  - Reasonable stress limit

ASME Responses to Proposed USNRC Rule Making

SSE SAM Limit

SSE SAM Limit

- ASME Equation: $C_2M_{SAM}/Z \leq 6S_m$
  - M_{SAM} = range of SAM moment stresses
- NRC Proposal:
  - Can use ASME, but only if the user
    - "… demonstrated that the global piping response … does not create significant inelastic strain concentrations"
  - Otherwise, use ASME with $3S_m$ limit

SSE SAM Limit

- JST inelastic work on elbows at $10.5S_m$
  - Combined inertia and SAM absolutely
  - Maximum strain of 1.2%
  - Actual stress level < $3S_m$
  - Appears to meet the "…does not create significant inelastic strain concentrations…", however, this would have to be done each time!!

SSE SAM Limit

- ASME Limit again similar to SSE SAM limit for new reactors
  - SIF = $C_2/2$ for dominant fitting (elbow)
  - $C_2 M_{SAM}/Z = 2iM_{SAM}/Z \leq 6S_m$
  - $iM_{SAM}/Z \leq 3S_m \sim 3S_h$

SSE SAM Limit

- Additional Effect of the 3 S_m Limit:
- Consider:
  - C_2=2i for most Components
  - S_m approximately .72 S_A on Average
- Then:

$$2i\frac{M_{AM}}{Z} \leq 3.0(.72S_A)$$

or

$$i\frac{M_{AM}}{Z} < 1.08S_A \text{ or } \approx 1.0S_A$$

This is Level B Limit on Secondary Stress!

SSE SAM Limit

- Prior to 1994 No Limit on Level D SAM's
- Implicit Limit:
  - OBE SAM's 3 S_m to 1.4 SA
  - OBE = .6 SSE
  - SSE SAM's 5 S_m or 1.6 to 2.3 S_A
- New Rules Geared Toward Part 52 Plants
  - No Explicit OBE Analysis Required
  - Only SSE Analysis

SSE SAM Limit

- ASME Felt Some SAM Limit Required
- Explicit Limit Added to Level D
  - No OBE, Only SSE
- Essentially the Same Previous Implicit Limit on SSE Sam's

ASME Responses to Proposed USNRC Rule Making

Control Shifted to the OBE (Level B)

Control Shifted to the OBE

Comparison Level B to Level D at 500 °F (Inertial Loads)					
	S_H	S_M	1.8 S_H	3.0 S_M	$\frac{1.8S_h}{3.0S_M}$
SA-106B	17.1	18.9	30.8	56.0	.54
SA-376, Type 304	16.6	17.5	30.0	51.0	.58
SA-312, Type 304	17.5	17.5	31.5	51.0	61

Control Shifted to the OBE

Comparison Level B to Level D at AMB (70 °F) (Inertial Loads)					
	S_H	S_M	1.8 S_H	3.0 S_M	$\frac{1.8S_h}{3.0S_M}$
SA-106B	17.1	20.	30.8	60	.5
SA-376, Type 304	20.	20.	36	60	.6
SA-312, Type 304	20.	20.	36	60	.6

Control Shifted to the OBE

- Items that will Cause OBE to Control
  - Pressure Stress
  - Deadweight Stress
  - Damping

Control Shifted to the OBE

- Pressure Deadweight Example
  - Cold 4" Sch 40 pipe
  - A106B
  - Design Pressure: 500 psig
  - Deadweight Support at NF Spans
  - Water-filled, not Insulated
  - Straight Pipe $B_2 = B_2' = 1.0$

Control Shifted to the OBE

$$B_1 \frac{PDo}{2t} = .5 \frac{(500)*(4.5)}{2*(.237)} = 2373 \text{ psi}$$

$$M_W = \frac{wL^2}{8} = \frac{(1.36)*(168)^2}{8} = 4800 \text{ in-lbs}$$

$$B_2 \frac{M_W}{Z} = 1.0 \frac{(4800)}{(3.21)} = 1500 \text{ psi}$$

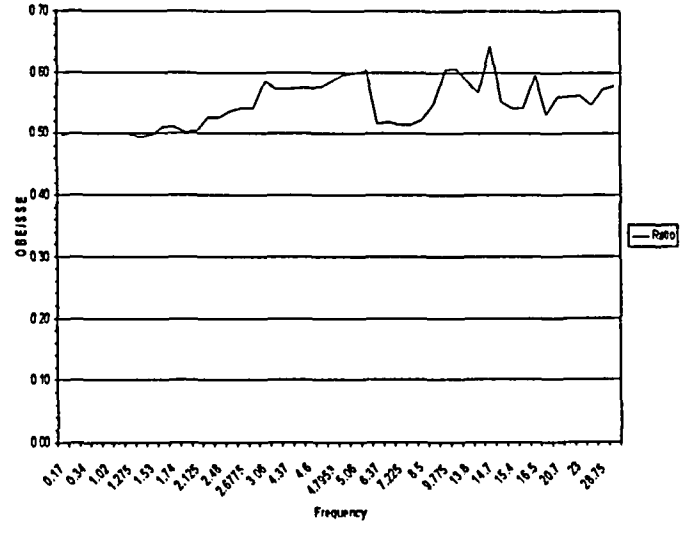
OBE capacity = 1.8 (17100) – [(2373) + (1500)] = 26,900 psi
SSE capacity = 3.0 (20000) – [(2373) + (1500)] = 56,127 psi

$$\frac{OBEcapacity}{SSEcapacity} = \frac{(26900)}{(56127)} = .48 \qquad (< .5)$$

Control Shifted to the OBE

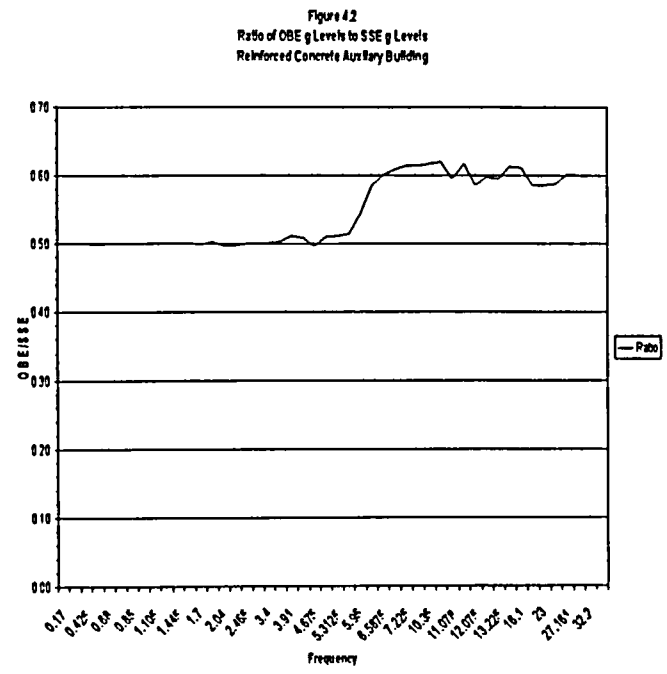
- Ground Motion
  - OBE = 1/2 SSE
  - Reguide 1.60 Spectra
- Reinforced Concrete Building
- Structural Damping
  - Reguide 1.61
  - OBE: 4%, SSE 7%
- Equip Damping
  - OBE, SSE: N-411
- OBE/SSE = .6 or >

Figure 4.1
Ratio of OBE g Levels to SSE g Levels
Re-Inforced Concrete Reactor Building



Control Shifted to the OBE

- Ground Motion
  - OBE = 1/2 SSE
  - Reguide 1.60 Spectra
- Reinforced Concrete Building
- Structural Damping
  - Reguide 1.61
  - OBE: 4%, SSE 7%
- Equip Damping
  - OBE, SSE: N-411
- OBE/SSE = .6 or >



Control Shifted to the OBE

- Capacity
  - Initial Margins on Capacity
    - OBE/SSE = .5 to .6
  - Pressure, Deadweight Reduce Capacity
    - OBE/SSE = .48 or <
- Demand
  - Damping Causes: OBE/SSE =.6
- Capacity .5 or <, Demand .6 or >

OBE (Level B) will Control Primary Stress !

ASME Responses to Proposed USNRC Rule Making

Conclusion

Conclusion

- The ASME has Significant Concerns with the following proposed USNRC Rulemaking:
  - Allowable Bending Stresses[(NC-3653.2(d) and ND-3653.2(d)]
  - Allowable B_2' Stress Indices for Tees and Elbows [(NB-3656(b)(3), NC-3655(b)(3), and ND-3655(b)(4)]
  - Evaluation of Anchor Motions [NB-3656(b)(4), NC-3655-(b)(4), and ND-3655(b)(4)]

Conclusion

- The ASME has Concerns With But Would Not Oppose:
  - Linear Elastic Response Spectrum Analysis [(NB-3056(b)(3), NC-3655(b)(3), and ND-3655(b)(3)]
  - Reflected Waves caused by Flow Transients [NB/NC/NB-3622]

Conclusion

- The ASME Supports the following proposed USNRC Rulemaking
  - Removal of Inelastic Analysis for Evaluating Reversing Dynamic Loads (NB-3228.6)

Table 1 Testing Conditions of Pipe Fracture Experiments

	Experiment 1.2-4	Experiment 1.2-6
Pipe Materials	A106 Gr.B Carbon Steel	A106 Gr.B Carbon Steel
Actual Outside Diameter	168mm (6.60inches)	168mm (6.60inches)
Actual Wall Thickness	14.0mm (0.550inches)	13.0mm (0.501inches)
Crack Length/Pipe Circumference	0.36	0.36
Crack Depth/Pipe Thickness	1.0	1.0
Test Temperature	288℃ (550° F)	288℃ (550° F)
Load-Line Displacement Rate	0.051 to 0.102mm/sec (0.002 to 0.004in/sec)	12.5mm/sec (0.50in/sec)
4-Point Bending Inner Span	610mm (24inches)	610mm (24inches)
4-Point Bending Outer Span	1524mm (60inches)	1524mm (60inches)
Experimental Moment at Crack Initiation	34.57kN·m (305,930in-lb)	25.31kN·m (340,050in-lb)
Maximum Experimental Moment	42.71kN·m (377,965in-lb)	36.94kN·m (327,200in-lb)
Tensile Yield Strength	320MPa (46.4ksi)	320MPa (46.4ksi)
Ultimate Tensile Strength	621MPa (90.0ksi)	621MPa (90.0ksi)

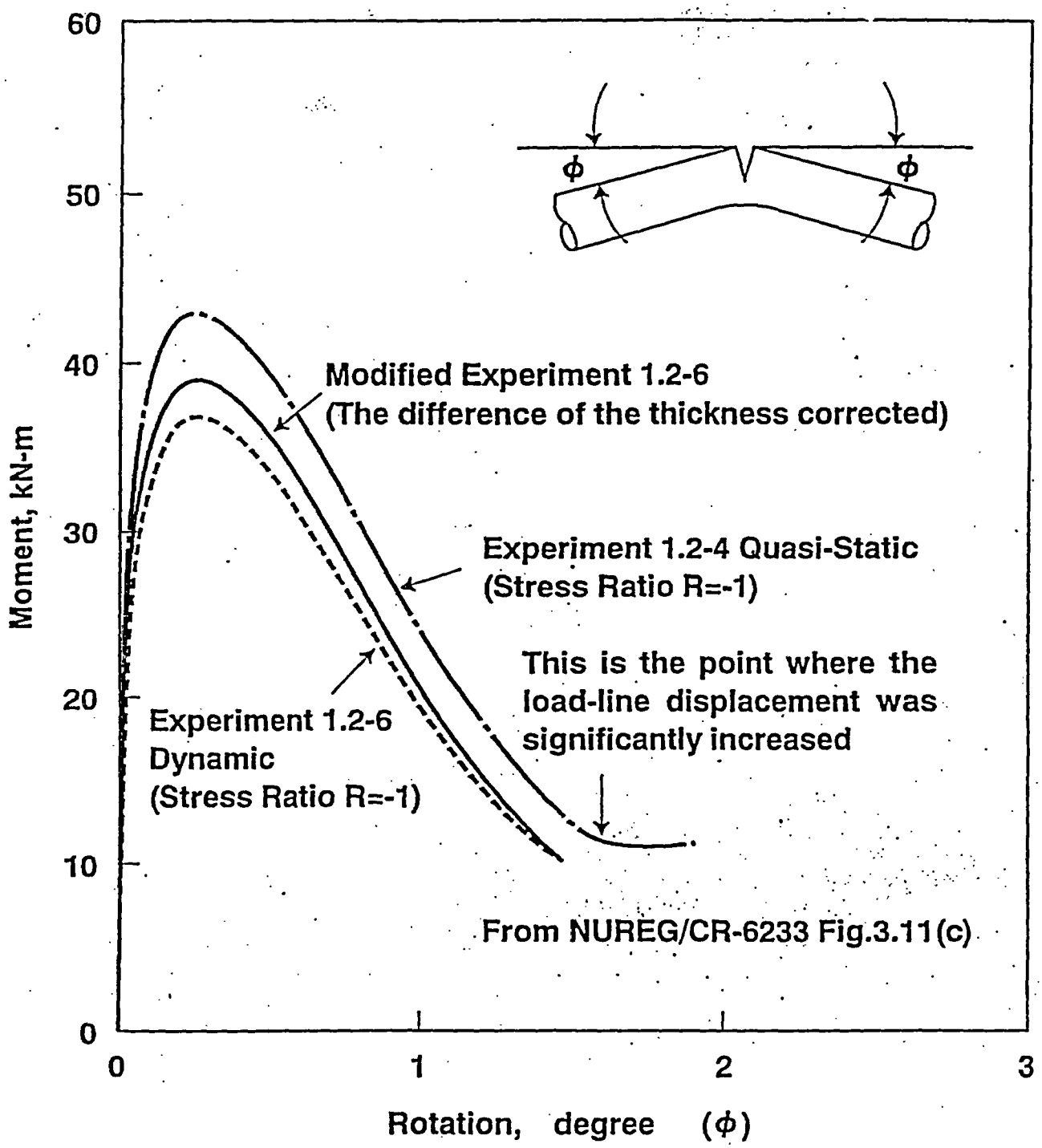


Fig.1 Moment vs. Rotation Based on Load-Line Displacement for IPIRG Experiments 1.2-4 and 1.2-6