

Integrity evaluation for elbows based on TES collapse load

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Introduction

➤ Mihama-3 Accident (2004.8.9)



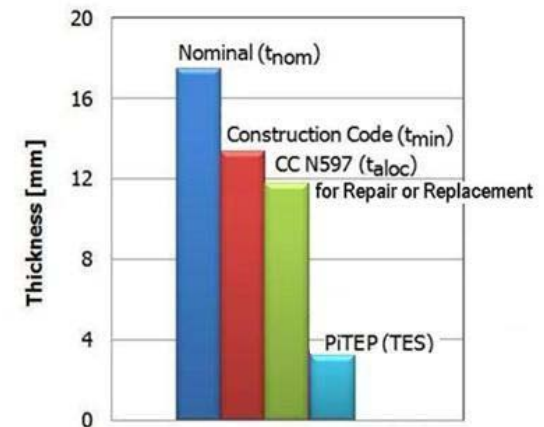
OD = 560 mm, $t_n=10$ mm, P = 1.27 MPa

$t_{min}=4.7$ mm, $\text{Min}\{t_{mea}\}=0.4$ mm

Piping integrity evaluation program recommended to develop
- to reduce the possibility of unexpected pipe failure

➤ ASME CC N-597

- ✓ Originally suggested to apply to safety-related piping
- ✓ Some limitations existed in evaluation of elbows and branch connections
- ✓ Large discrepancy found to exist between
 - thickness criteria in CC N597 for repair and
 - actual thickness at limit load obtained from tests
- ✓ Excessive inspection required
- ✓ Components still deserved to use may be replaced



Needs to Develop an Alternative Integrity Evaluation Criteria

- Applicable to non safety-related piping system
- To resolve the limitations and discrepancy between CC N597 and the actual cases
- To reduce the inspection and replacement quantities



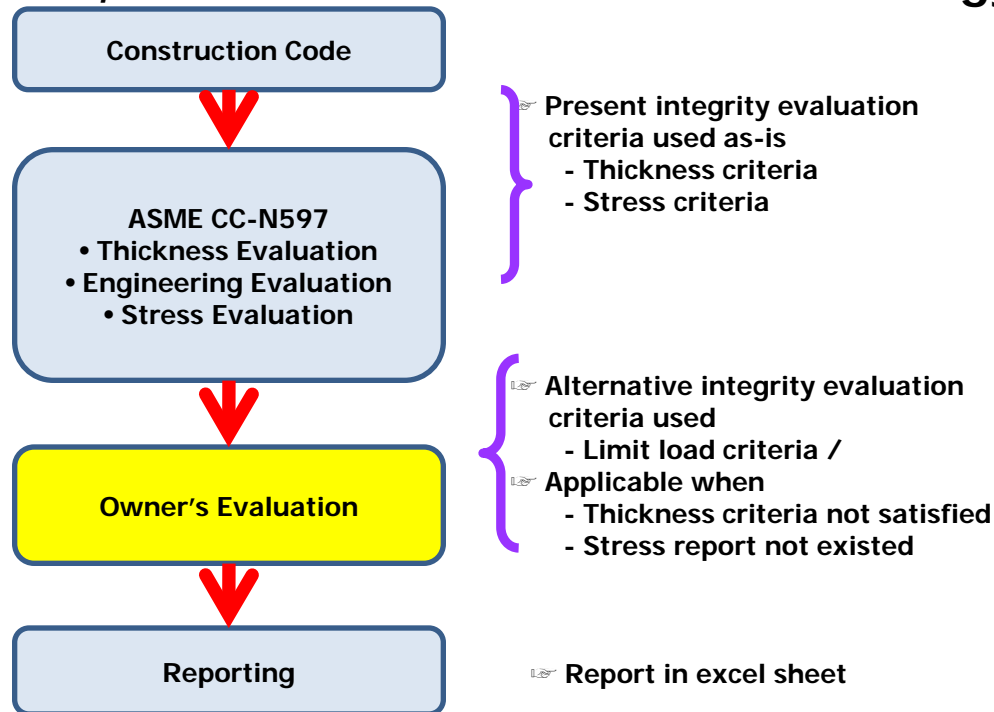
Engineering Program
for Integrity Evaluation

PiTEP®



PiTEP[®] Structure

- PiTEP[®] is composed of evaluation parts by construction code, ASME CC-N597, and owner's evaluation methodology



Alternative Integrity Evaluation Criteria - Limit Load Equations

❖ Elbow (bending moment applied)

$$\frac{M_L}{M_o} = 1.0 - (\alpha - \beta\lambda) \left(\frac{d}{t} \right)$$

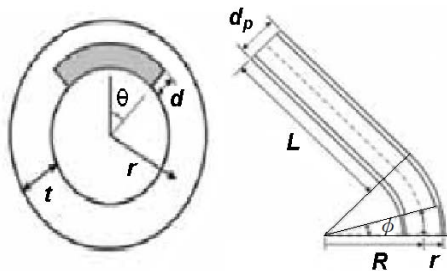
where
extrac $\alpha = 2.9 \left(\frac{\theta}{\pi} \right)^2$ $\beta = 0.29 + 0.9 \left(\frac{\theta}{\pi} \right)^2$

$$\alpha = 2.2 \left(\frac{\theta}{\pi} \right)^2 \quad \beta = 0.1 + 2.9 \left(\frac{\theta}{\pi} \right) - 3.6 \left(\frac{\theta}{\pi} \right)^2$$

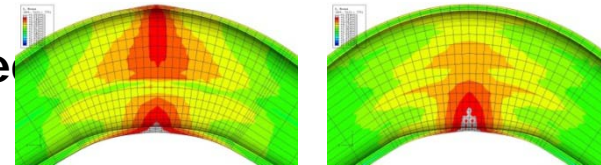
intrados

when flaw at

and



$$\lambda = \frac{Rt}{r^2} \quad \text{Bend characteristic parameter}$$



when flaw at

and closing moment

when flaw at

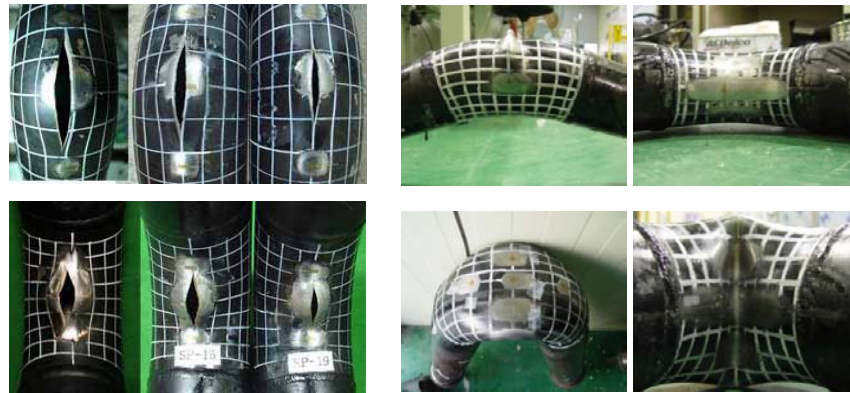
and

Verification Test for Elbow

- To verify the FE models and evaluation criteria
- Burst Pressure Test : Hydrostatic pressure up to 40MPa
- Bending Test : Open & Close Mode, Intrados & Extrados
- ➔ Limit load : Much higher than operating pressure and allowable moment even at 82% thinned



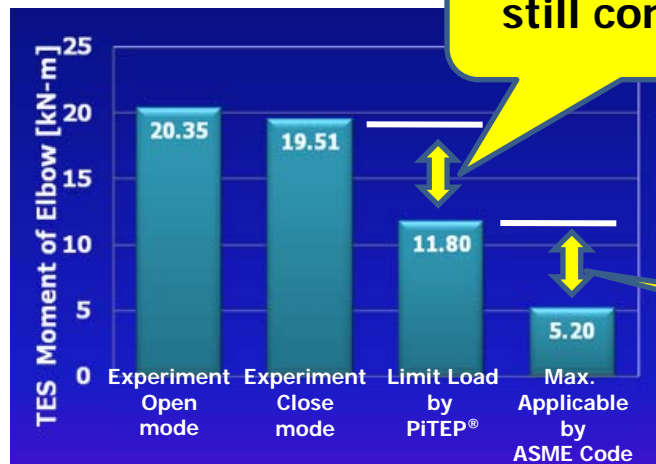
Bending Load Test



Test Results

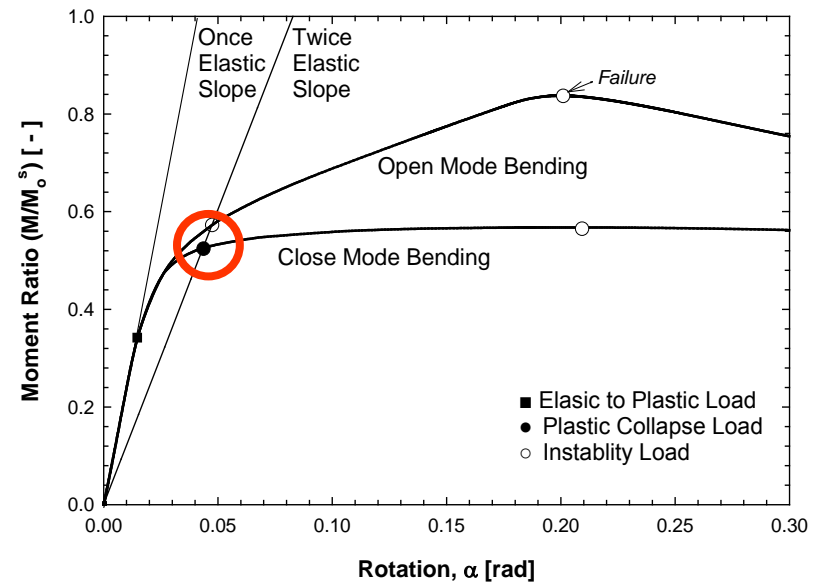
Comparison of Limit Moments

- Reduce excessive conservatism
- Confirm safety margin



Safety margin still confirmed

Excessive conservatism can be reduced



Owner's Evaluation Results & Report

Owner's Evaluation Result

Owner's Evaluation Result, Elbow And Pipe Bends

Error Message

No-Error

Result

Case 1 $M_a / M_d = 222272965.4859 / 45359712 = 4.900228764357$

Case 2 $P_{bst} / P_d = 24.95599210106 / 8.819999694824 = 2.829477562479$

Case 3 $t_p / t_{aloc} = 11.90049552917 / 3.187850713729 = 3.732922717587$

Main Previous Screen **Report** Exit

Results displayed in safety margin

Results Display Window

PITEP 배관감육손상 건전성 평가 보고서 PITEP

본 보고서는 배관의 감육결함에 대한 건전성을 평가한 보고서로서, ASME Code Case N-597에 근거한 공학적 평가 및 사용자 입력 자료의 정확성을 목적으로 한다.

1. 일반 사항
 - a. 호기
 - b. 계통
 - c. 배관 번호
 - d. 배관 종류 Elbow
 - e. 재질
 - f. 안전등급
2. 입력 자료
 - a. 배관 형상 및 운전 정보

Nominal Thickness	17.475 mm	Out Diameter(Do)	323.85 mm
Design Pressure	9.32 Mpa	Design Temperature	
Total Operation Tim	9578	Time to Next Outtag	7963
 - b. 배관 두께 및 물성치 정보

Allowable Stress	103.42 Mpa	Yield Stress	206.843 Mpa
Ultimate Tensile Str	413.69 Mpa		
Initial Thickness	20.041 mm	Measured Thickness	15.596 mm
 - c. 결함형상 정보

Bending Radius	485.78 mm	Max. Angle	15 degree
Lml(a)	42.932 mm	Lm	168.0139 mm
Lm(b)	162.578 mm	Predicted Thickness	11.9006 mm
 - d. 기타 정보

Extrados
3. 평가 결과
 - a. Construction Code

Required Minimum Thickness (tmin)	13.35395 mm	판정결과	N
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 - b. Code Case N-597

The 1st Step(0.9 tmin)	12.01956 mm	판정결과	N
Engineering Evaluation Cutoff Thickness	11.77899 mm	판정결과	Y
Cutoff Thickness	3.495 mm		
 - c. 음력 평가

기준	기준	판정결과
음력상계요건-I	0	none
음력상계요건-II	0	none
음력상계요건-III	0	none
음력상계요건-IV		
 - d. 사용자 공학적 평가

KEPRI Fitna for Fitness		판정결과	
User Load Evaluation	3.189615 mm	Y	
4. 안전 여유도 분석

모멘트 기준	압력 기준	두께 기준	
KEPRI Fitna for Fitness	4.90005	2.829491	3.734487
User Load Evaluation			

평가일시 년 월 일
평가자 소속 과명 서명

Reports generated in excel sheet

Reporting

Conclusions

- ➔ **PiTEP[®] successfully developed based on TES collapse load**
 - includes three-part integrity assurance (by construction code, ASME CC N597, and owner's methodology)
 - implemented to all domestic NPPs from 2007

- ➔ **Limitation of ASME CC N597 overcome**

- ➔ **PiTEP[®] confirmed to have enough conservatism by verification test using mock-ups**