

# **Integrity evaluation for elbows based on TES collapse load**

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# Introduction

## ➤ Mihama-3 Accident (2004.8.9)



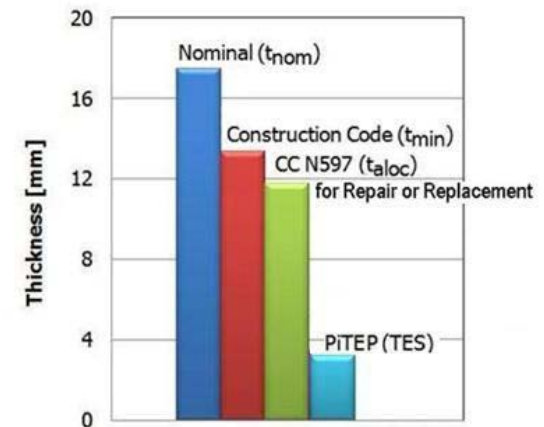
OD = 560 mm,  $t_n=10$  mm, P = 1.27 MPa

$t_{min}=4.7$  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



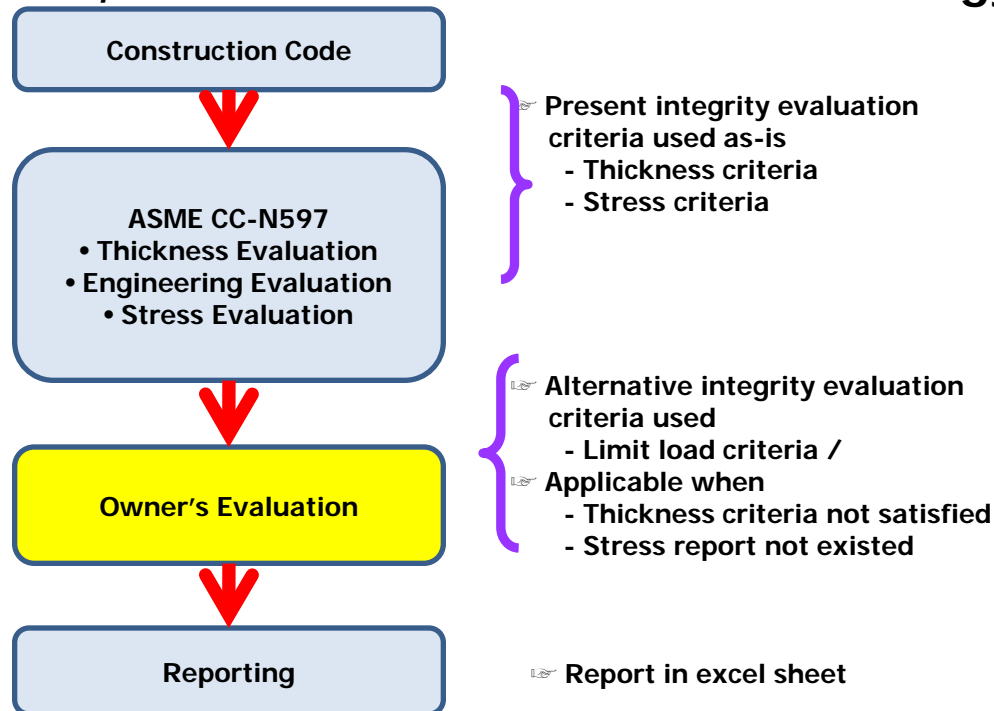
Engineering Program  
for Integrity Evaluation

# PiTEP®



# PiTEP<sup>®</sup> Structure

- PiTEP<sup>®</sup> 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  $\alpha = 2.9 \left( \frac{\theta}{\pi} \right)^2$   $\beta = 0.29 + 0.9 \left( \frac{\theta}{\pi} \right)^2$

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

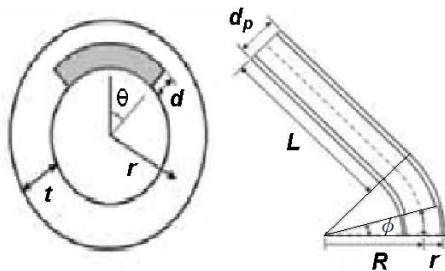
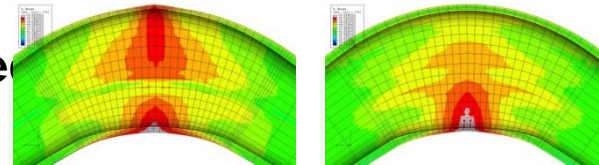
intrados

when flaw at

and closing moment

when flaw at

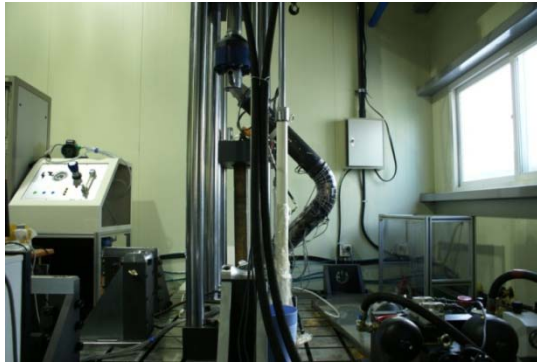
and



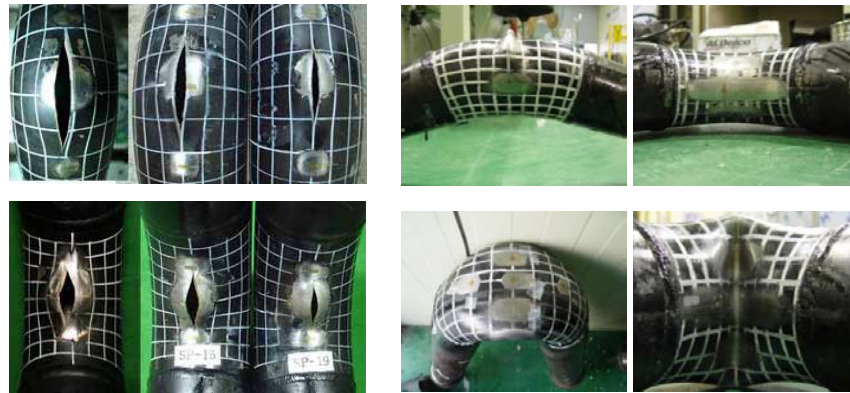
$$\lambda = \frac{Rt}{r^2} \quad \text{Bend characteristic parameter}$$

# 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



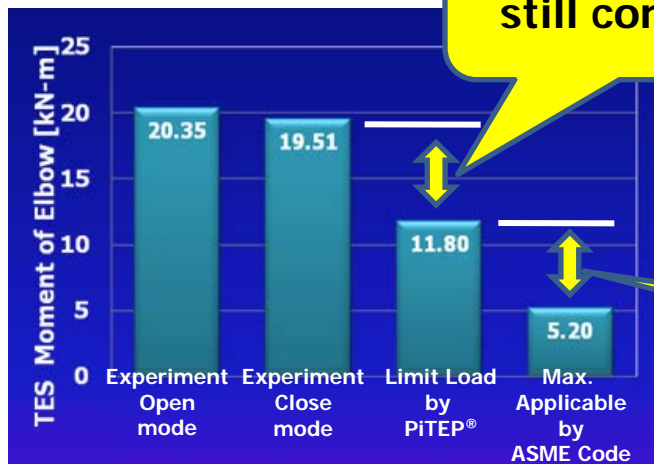
Bending Load Test



Test Results

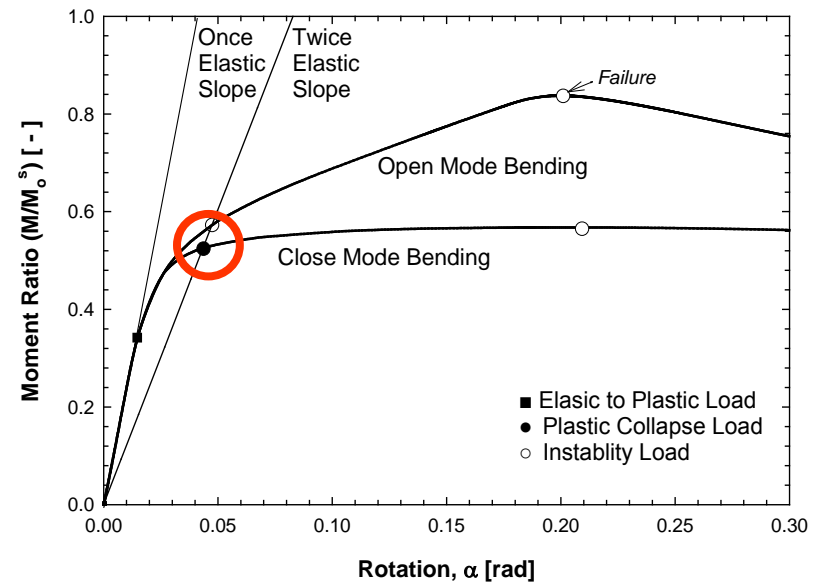
# Comparison of Limit Moments

- 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 자료만을 목적으로 한다.

1. 일반 사항
  - a. 호기
  - b. 계종
  - 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
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	
1st/ Last Evaluation	3.189615 mm	판정결과	Y
4. 안전 여유도 분석
 

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

평가일시 년 월 일  
평가자 소속 부서 직책 PITEP

Reports generated in excel sheet

Reporting



# Conclusions

- ➔ **PiTEP<sup>®</sup> 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<sup>®</sup> confirmed to have enough conservatism by verification test using mock-ups**