Integrity evaluation for elbows based on TES collapse load

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Introduction

➢ Mihama-3 Accident (2004.8.9)

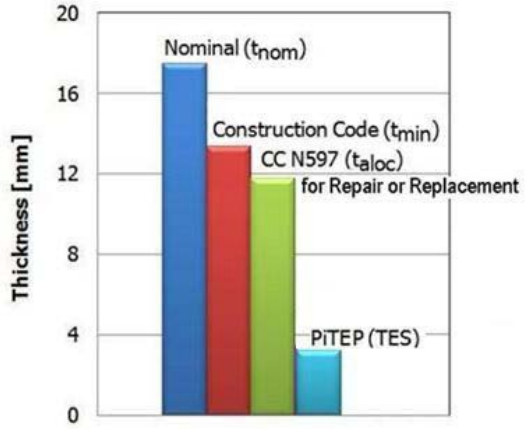
OD = 560 mm, t_n=10 mm, P = 1.27 MPa

t_{min}=4.7 mm, 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

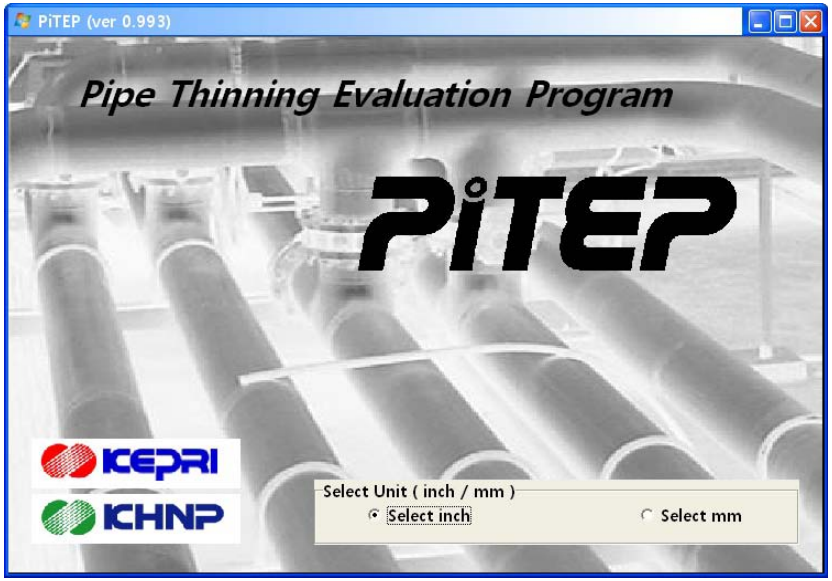


Needs to Develop an Alternative Integrity Evaluation Criteria

- 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

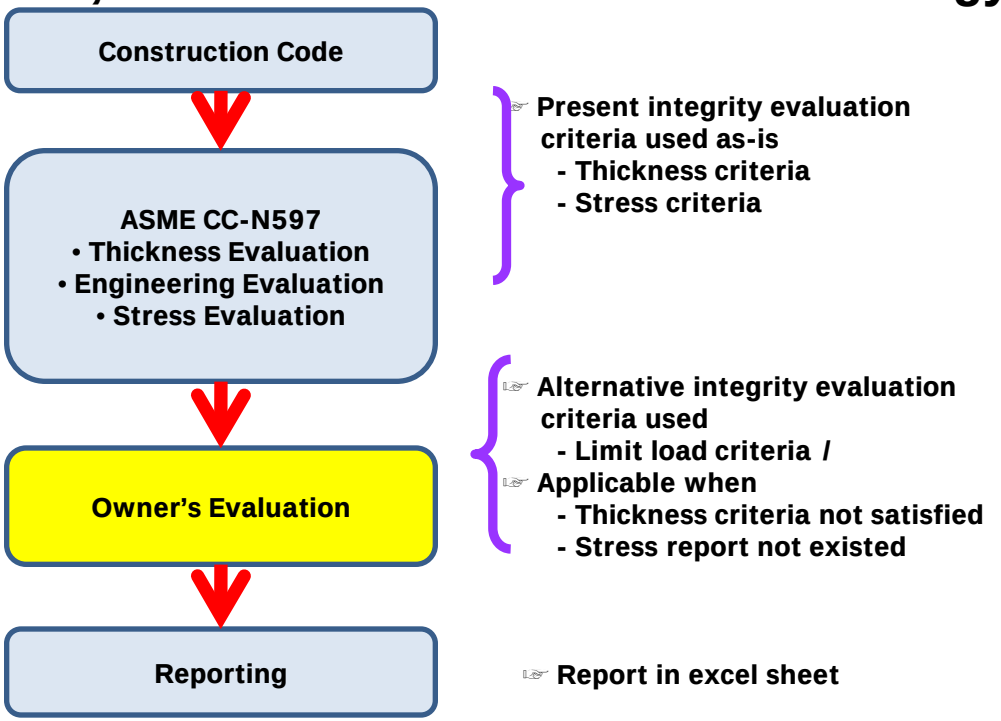
Engineering Program for Integrity Evaluation

PiTEP®



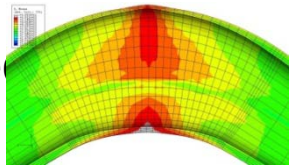
PiTEP® Structure

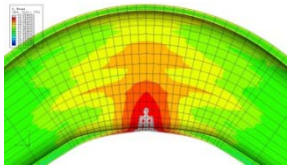
➢ **PiTEP® is composed of evaluation parts by construction code, ASME CC-N597, and owner's evaluation methodology**



Alternative Integrity Evaluation Criteria
- Limit Load Equations

❖**Elbow (bending moment applie**





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

where
extrac

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

when flaw at

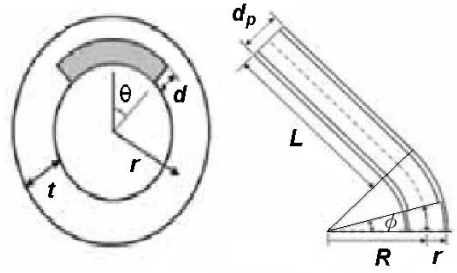
and closing moment

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

when flaw at

intrados

and



$$\lambda = \frac{Rt}{r^2}$$

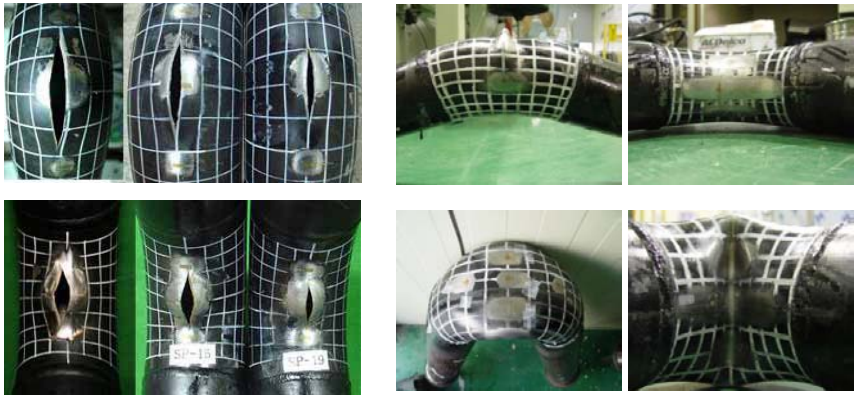
Bend characteristic parameter

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

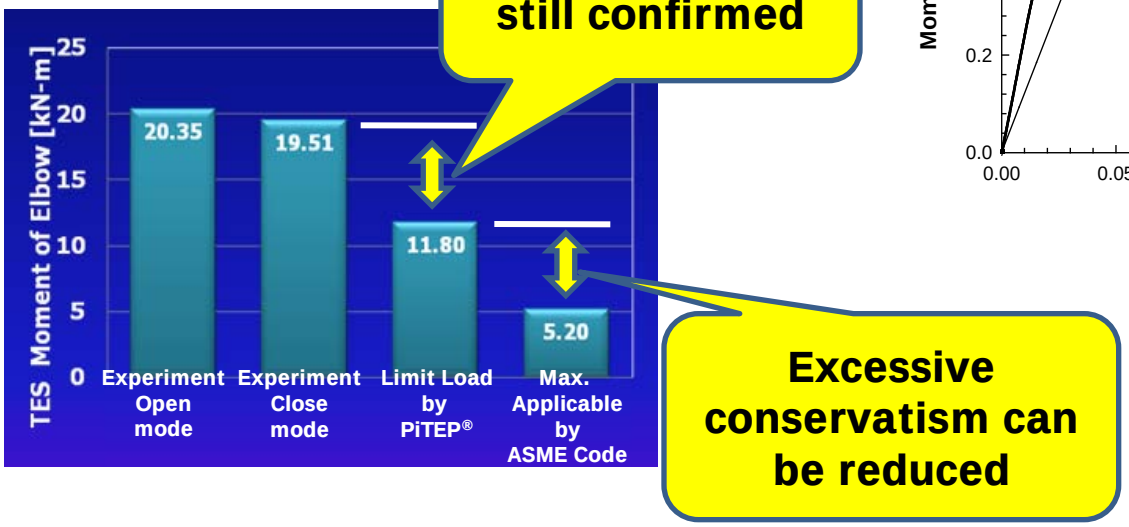
Bending Load Test

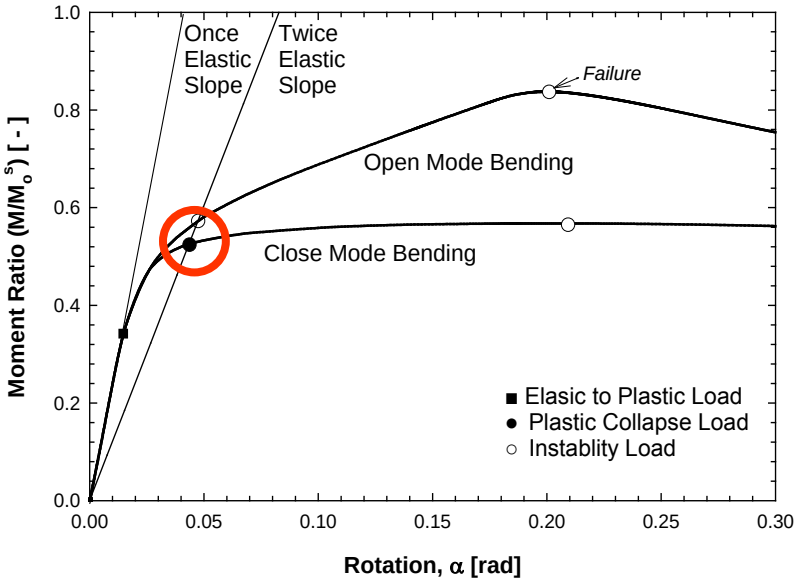


Test Results

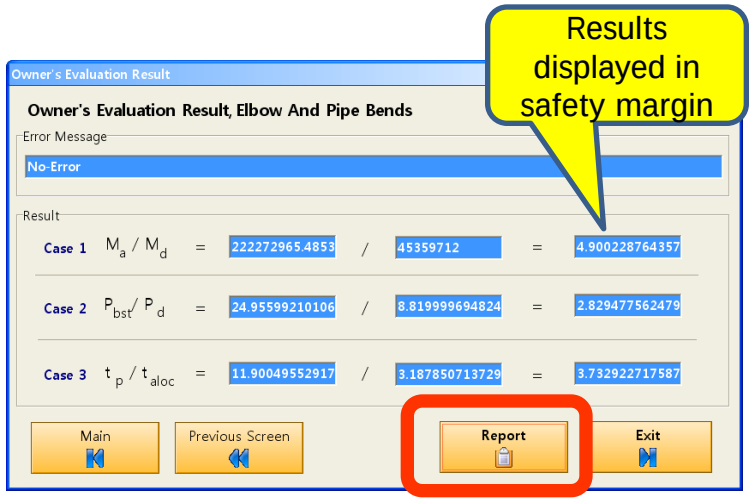
Comparison of Limit Moments

- Reduce excessive conservatism
- Confirm safety margin

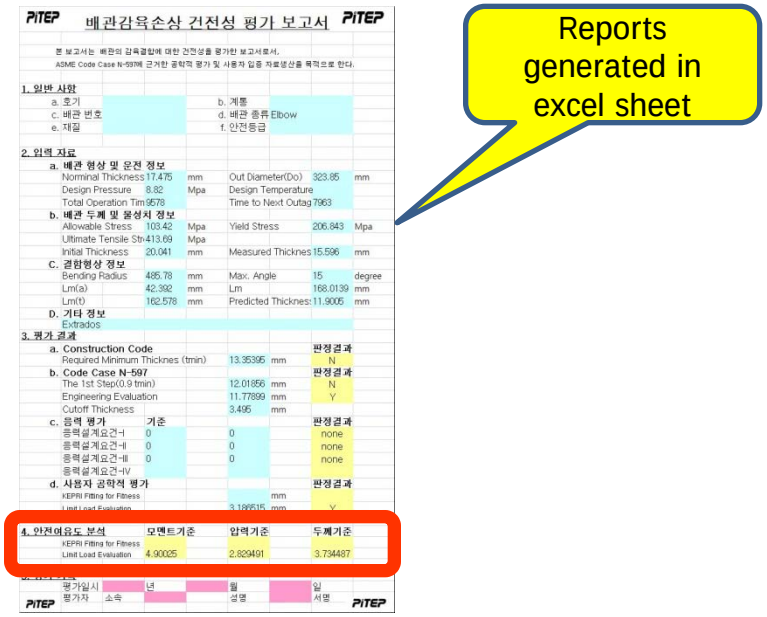




Owner's Evaluation Results & Report



Results Display Window



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**