Evaluation of Cast Iron Fittings in a Hazard Category 2 Nuclear Facility

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Presentation

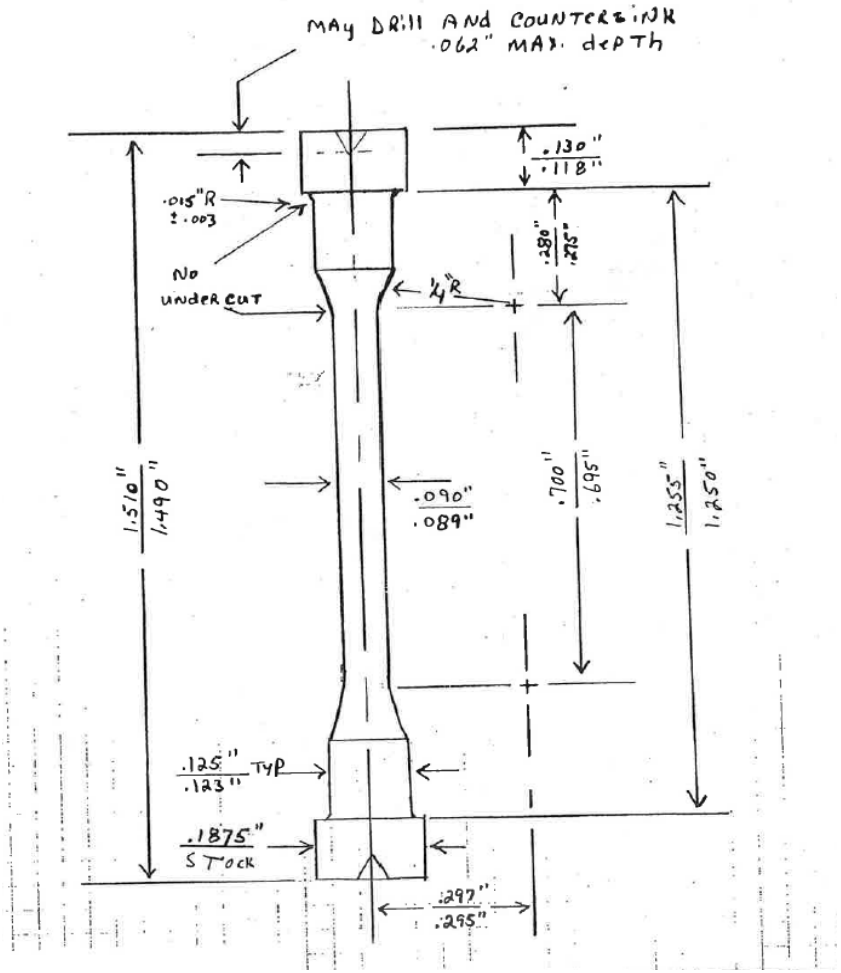
- Background
- Results of Previous Analysis
- Describe Test Program
- Discuss Analysis of Material Properties for use in Subsequent Analysis
- Present Results
- Path Forward with Recommendations and Conclusions

Background

- **Finished Analysis**
  - Analysis of existing facility Fire Suppression System piping completed as part of SAFER project
  - Results indicated that the FSS required strengthening through addition of braces to function at PC3 levels
- **Upgrades**
  - New braces were designed and a confirmatory dynamic analysis of portions (3 basement models, 1 laboratory room model) of the piping systems that were considered to be bounding
  - Assumption in analysis was that the fittings were made of carbon steel (ASTM A120)
  - This assumption was questioned by DNFSB review of analysis
  - Review of original specs and purchase documents were inconclusive
  - Undertook a sampling program to determine what type of material the fittings were made of

Test Program

- Four “G” type tees were removed from the FSS in accessible areas
- A total of 15 samples were machined from the tees for tensile testing at low strain rates (0.001 in/in/sec)
- 5 samples from specimen A
- 5 samples from specimen B
- 4 samples from specimen C
- 1 sample from specimen D
- Testing was performed at MST-8



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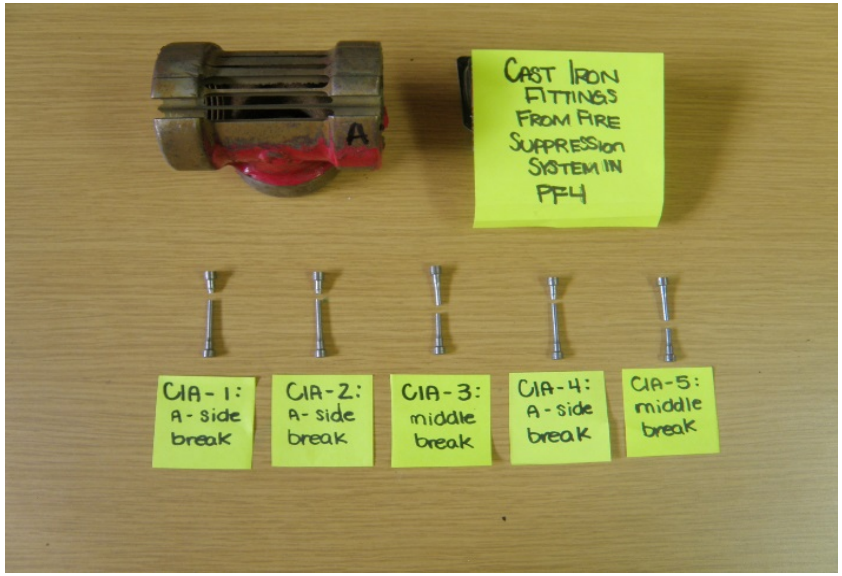
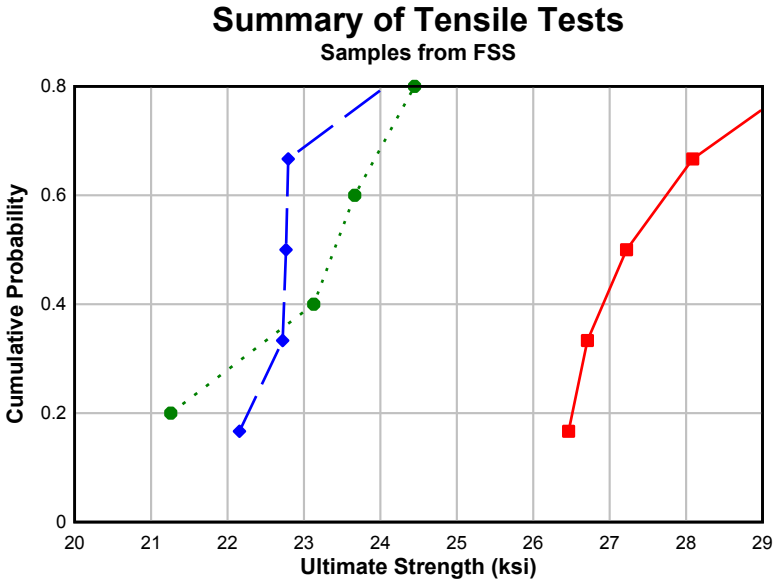


Analysis

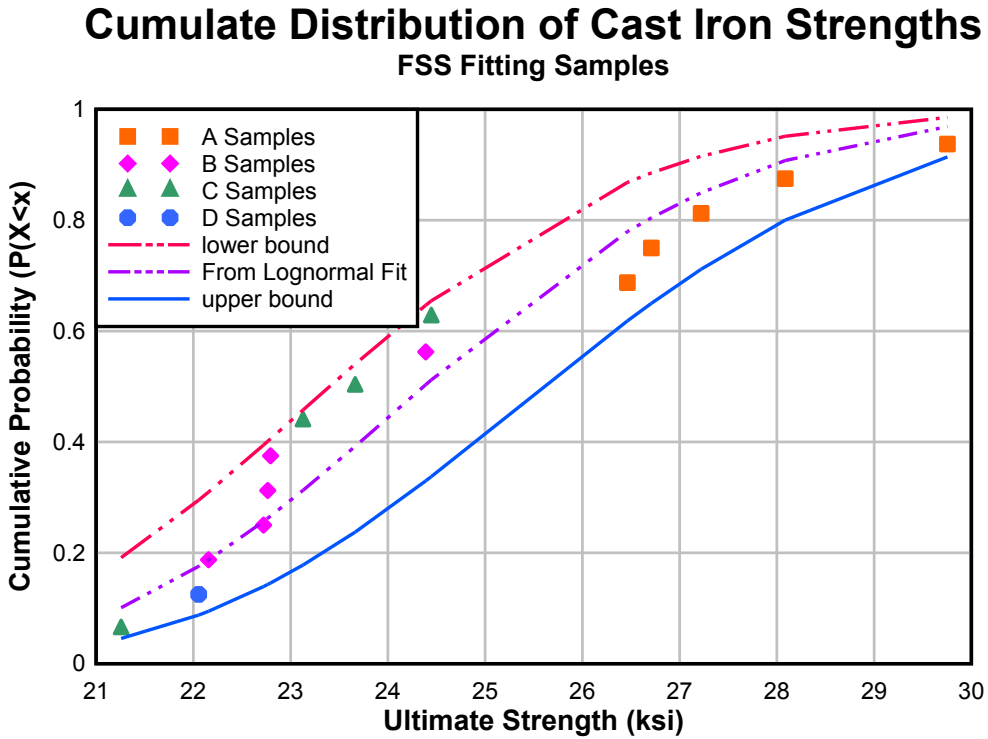
- **MST-8 Report was produced on 7/18/16**
- **Results indicate material is Class (20)**

Sample No.	Failure Stress		Reference File Name
	(MPa)	(Ksi)	
CIA-1	187.7	27.2	CIA-1_2951e-3e_295K_0.001s_S_eng.txt
CIA-2	193.7	28.1	CIA-2_2951e-3ae_295K_0.001s_S_eng.txt
CIA-3	205.2	29.8	CIA-3_2951e-3e_295K_0.001s_S_eng.txt
CIA-4	182.5	26.5	CIA-4_2951e-3e_295K_0.001s_S_eng.txt
CIA-5	184.2	26.7	CIA-5_2951e-3e_295K_0.001s_S_eng.txt
CIB-1	157.0	22.8	CIB-1_2951e-3e_295K_0.001s_S_eng.txt
CIB-2	157.2	22.8	CIB-2_2951e-3e_295K_0.001s_S_eng.txt
CIB-3	152.8	22.2	CIB-3_2951e-3e_295K_0.001s_S_eng.txt
CIB-4	156.7	22.7	CIB-4_2951e-3e_295K_0.001s_S_eng.txt
CIB-5	168.2	24.4	CIB-5_2951e-3e_295K_0.001s_S_eng.txt
CIC-1	159.5	23.1	CIC-1_2951e-3e_295K_0.001s_S_eng.txt
CIC-2	146.6	21.3	CIC-2_2951e-3e_295K_0.001s_S_eng.txt
CIC-3	168.6	24.4	CIC-3_2951e-3e_295K_0.001s_S_eng.txt
CIC-4	163.2	23.7	CIC-4_2951e-3e_295K_0.001s_S_eng.txt
CID-1	152.1	22.1	CID-1_2951e-3e_295K_0.001s_S_eng.txt
Average		24.5	
sigma		2.54	
Cov		0.10	



Analysis

- **Examined the results of failure (rupture) stress**
- **15 Data Points**
- **Assumptions**
  - Data fit a lognormal distribution
  - Sample variance is a reasonable estimator of the population variance
- **95% non-exceedance ultimate strength is 20 ksi**



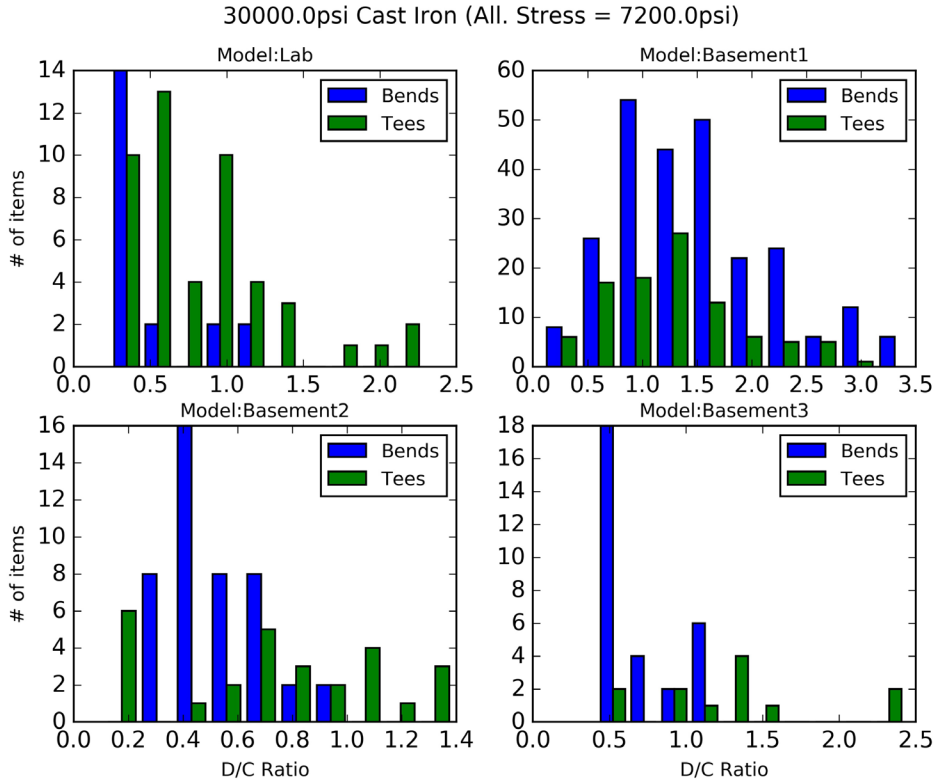
Results

- ASME B31.1 limits basic allowable stress to 1/10 ultimate for cast irons
- Allowable stress for class 20 would be 2.0 ksi
- Basic allowable stress used in existing calcs (assuming ASTM A120) was 11.85 ksi
- ASME B31E allows an increase in basic allowable stress for piping systems to be the minimum of 2.4S, 1.5 Sy or 60 ksi = 2.4(2) 4.8 ksi
- Reran stress analysis using B31E allowable

Assumed Class of Grey Iron	AUTOPIPE Model	Number of Elbows	Number of Tees	Number of Elbows Failing Code Check	Number of Tees Failing Code Check	Percentage of Elbows Failing Code Check	Percentage of Tees Failing Code Check
20	Lab Floor	20	48	4	24	20	50
	Basement 1	252	98	232	80	92	82
	Basement 2	44	27	4	17	9.1	63
	Basement 3	30	12	8	10	27	83
30	Lab Floor	20	48	2	14	10	29
	Basement 1	252	98	194	62	77	63
	Basement 2	44	27	0	8	0	30
	Basement 3	30	12	8	8	27	67

Results

- A stress intensification factor of 2.3 (per code) was used in existing stress analysis
- Section properties of pipe were used in reporting stresses at fittings
- Accounting for a slight increase in the SIF and the actual section properties may be justified (D/C < 2 may be acceptable)

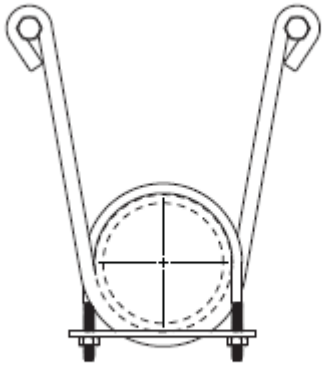


Path Forward

- **Existing stress analysis for FSS at PC3 levels is flawed (wrong material for fittings)**
- **It is very unlikely that we could show code compliance at PC3 demand levels without further modifications**
- **Defendable analysis at PC2 levels does not exist**
- **Cost for reanalysis of the existing piping models to PC2 levels is approximately $50k**
- **Options**
  - Reanalysis of existing piping system to either PC2 or PC3 levels with added bracing to bring piping within code allowable stress values
  - Strengthen/replace fittings
  - Eliminate safety class or safety significant requirements for FSS.

Path Forward

- Reran Analysis at PC3 levels with correct allowable stress and section properties
- Results show large overstress in many fittings
- Currently looking at some oversimplifying assumptions in dynamic analysis
- May look for simple fixes to vertical hangers to decrease demands



Component of State of California OSHPD Approved Seismic Restraints System

Conclusions and Recommendations

- **NFPA allows the use of cast iron fittings in sprinkler systems**
- **Be cautious when making assumptions about materials used in piping systems and stress allowables for use in dynamic analysis**

6.4 Fittings.

6.4.1 Fittings used in sprinkler systems shall meet or exceed the standards in Table 6.4.1 or be in accordance with 6.4.2 or 6.4.3.

Table 6.4.1 Fittings Materials and Dimensions

Materials and Dimensions	Standard
Cast Iron	
Cast iron threaded fittings, Class 125 and 250	ASME B16.4
Cast iron pipe flanges and flanged fittings	ASME B16.1
Malleable Iron	
Malleable iron threaded fittings, Class 150 and 300 steel	ASME B16.3
Factory-made wrought steel buttweld fittings	ASME B16.9
Buttwelding ends for pipe, valves, flanges, and fittings	ASME B16.25
Specification for piping fittings of wrought carbon steel and alloy steel for moderate and elevated temperatures	ASTM A 234
Steel pipe flanges and flanged fittings	ASME B16.5
Forged steel fittings, socket welded and threaded copper	ASME B16.11
Wrought copper and copper alloy solder joint pressure fittings	ASME B16.22
Cast copper alloy solder joint pressure fittings	ASME B16.18