Emerging Issues in the Power Generation Industry

93rd General Meeting of the NBBI

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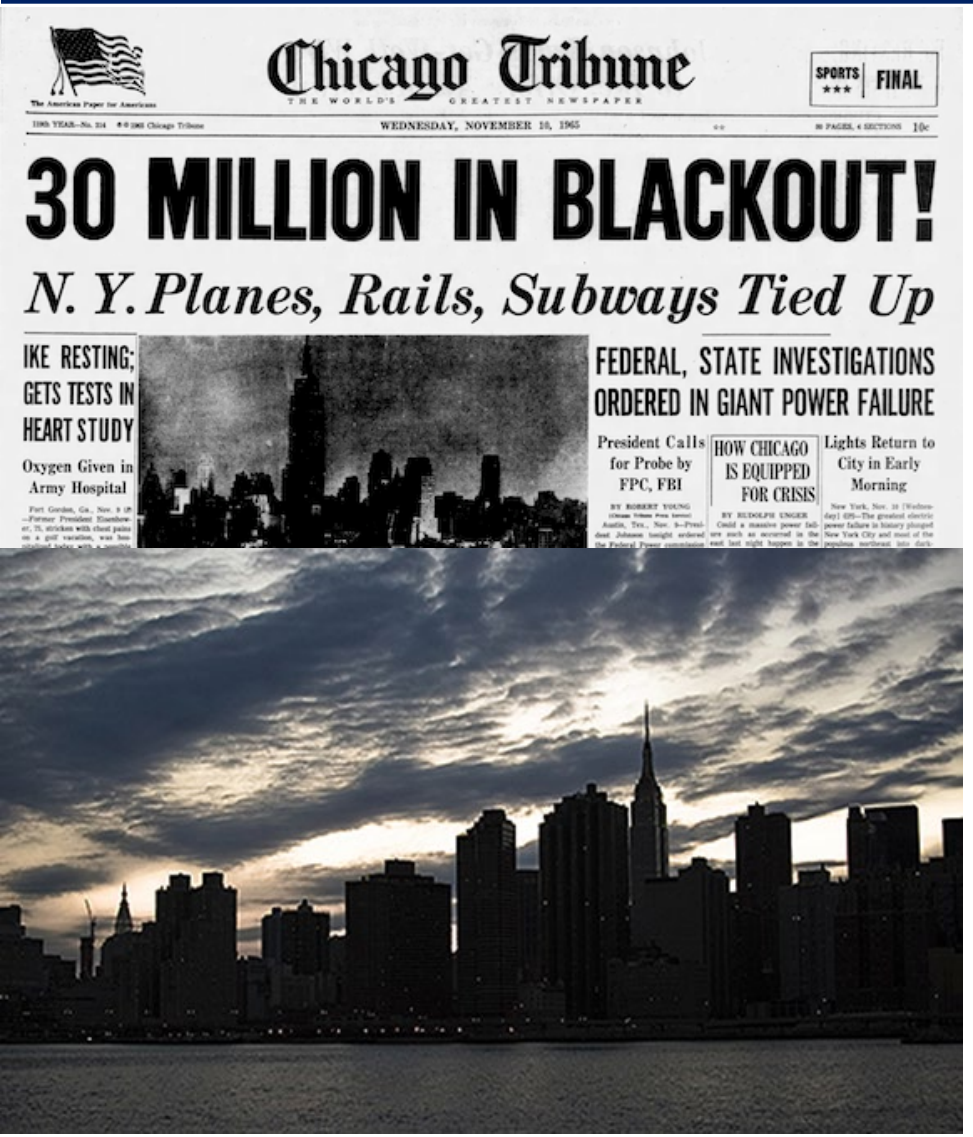
General Session
Monday, May 12

EPRI… Born in a blackout

Independent, non-profit, center for public interest research


Chicago Tribune
THE WORLD'S GREATEST NEWSPAPER
SPORTS ★★★ FINAL
WEDNESDAY, NOVEMBER 10, 1965
30 MILLION IN BLACKOUT!
N. Y. Planes, Rails, Subways Tied Up
IKE RESTING; GETS TESTS IN HEART STUDY
Oxygen Given in Army Hospital
FEDERAL, STATE INVESTIGATIONS ORDERED IN GIANT POWER FAILURE
President Calls for Probe by FPC, FBI
HOW CHICAGO IS EQUIPPED FOR CRISIS
Lights Return to City in Early Morning

Mission

Advancing safe, reliable, affordable, and clean energy for society through global collaboration, science and technology innovation, and applied research.

Power of Collaboration

Leveraging research funds (~$500M/year), industry expertise, Academia and National Labs, DOE/CEC/NYSERDA/EU Horizon 2020 etc.

Global Presence

Over 40 countries participate in EPRI research, development, and demonstration activities. International members >25% of EPRI research and as high as 50% for nuclear.

Impact

Founded in 1972: 50 Years of EPRI R&D

Underlying realities that introduce issues and uncertainty

Advanced (very efficient) new combined cycle plant

Design will include critical systems in the creep range

No design life recognized by ASME BPVC

Need to maximize use of advanced creep strength enhanced ferritic (CSEF) steels

>1,000 ft. of piping, >10 miles of tubing, >100s tons of material from worldwide suppliers

Thousands of tube-to-tube or tube-to-header welds, and 100s of thick-section pipe girth welds

Will follow the rules in ASME BPVC without appreciating these are a minimum set of requirements

Will rely on staff or engineers to interpret the rules who do not regularly attend ASME BPVC meetings

Contractual language may not allow for independent oversight by end-user/owner to perform QA/QC during fabrication or installation

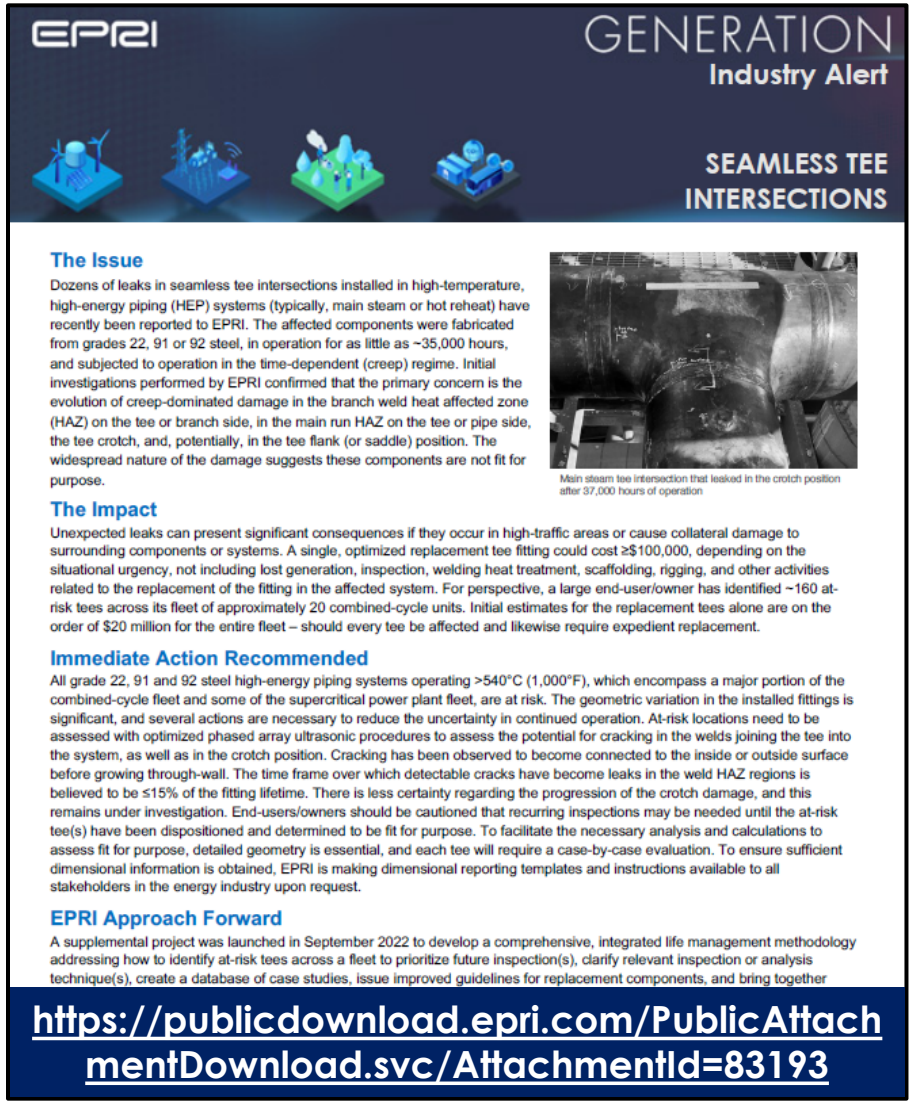
What could possibly go wrong?

New construction case study – tee fittings

Industry alert – first-of-a-kind EPRI document

- Any ‘modern’ plant constructed with a grade 22, grade 91 or grade 92 piping system. This typically includes:
  - All CCGT built after ~1998
  - All SC coal-fired plants constructed after ~1998
- More specifically:
  - Grade 22, Grade 91 and grade 92 steels **(and X20)**
  - Main steam and hot reheat systems
  - Operating >1,000°F (540°C)
  - Failures in 35,000 to 90,000 hours with many in the range of 50,000 to 70,000 hours **(now up to ~150,000 hours)**

Who should be responsible for raising awareness of emerging industry issues?



EPRI

GENERATION
Industry Alert

SEAMLESS TEE INTERSECTIONS

The Issue

Dozens of leaks in seamless tee intersections installed in high-temperature, high-energy piping (HEP) systems (typically, main steam or hot reheat) have recently been reported to EPRI. The affected components were fabricated from grades 22, 91 or 92 steel, in operation for as little as ~35,000 hours, and subjected to operation in the time-dependent (creep) regime. Initial investigations performed by EPRI confirmed that the primary concern is the evolution of creep-dominated damage in the branch weld heat affected zone (HAZ) on the tee or branch side, in the main run HAZ on the tee or pipe side, the tee crotch, and, potentially, in the tee flank (or saddle) position. The widespread nature of the damage suggests these components are not fit for purpose.

Main steam tee intersection that leaked in the crotch position after 37,000 hours of operation

The Impact

Unexpected leaks can present significant consequences if they occur in high-traffic areas or cause collateral damage to surrounding components or systems. A single, optimized replacement tee fitting could cost ≥$100,000, depending on the situational urgency, not including lost generation, inspection, welding heat treatment, scaffolding, rigging, and other activities related to the replacement of the fitting in the affected system. For perspective, a large end-user/owner has identified ~160 at-risk tees across its fleet of approximately 20 combined-cycle units. Initial estimates for the replacement tees alone are on the order of $20 million for the entire fleet – should every tee be affected and likewise require expedient replacement.

Immediate Action Recommended

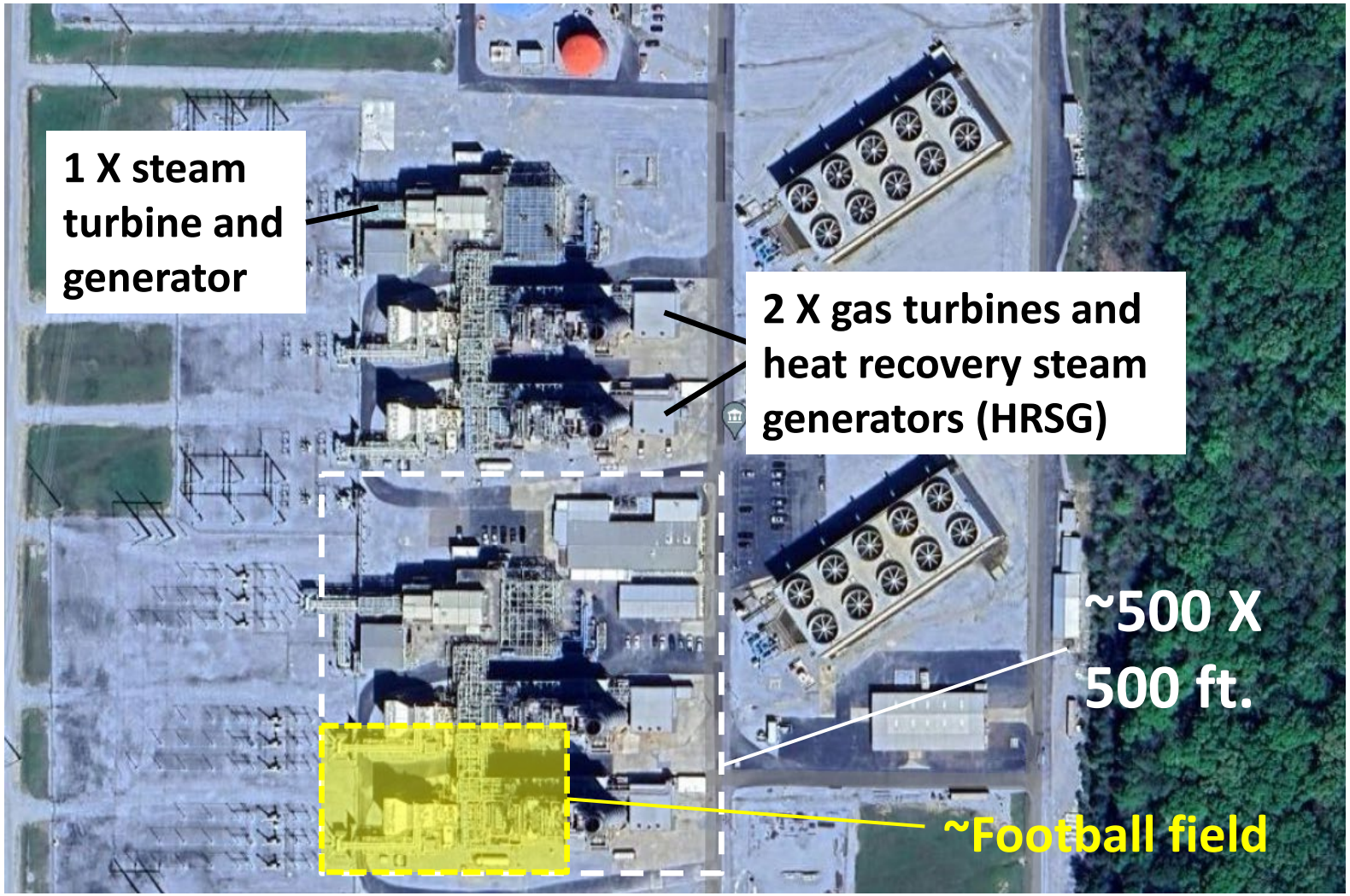
All grade 22, 91 and 92 steel high-energy piping systems operating >540°C (1,000°F), which encompass a major portion of the combined-cycle fleet and some of the supercritical power plant fleet, are at risk. The geometric variation in the installed fittings is significant, and several actions are necessary to reduce the uncertainty in continued operation. At-risk locations need to be assessed with optimized phased array ultrasonic procedures to assess the potential for cracking in the welds joining the tee into the system, as well as in the crotch position. Cracking has been observed to become connected to the inside or outside surface before growing through-wall. The time frame over which detectable cracks have become leaks in the weld HAZ regions is believed to be ≤15% of the fitting lifetime. There is less certainty regarding the progression of the crotch damage, and this remains under investigation. End-users/owners should be cautioned that recurring inspections may be needed until the at-risk tee(s) have been dispositioned and determined to be fit for purpose. To facilitate the necessary analysis and calculations to assess fit for purpose, detailed geometry is essential, and each tee will require a case-by-case evaluation. To ensure sufficient dimensional information is obtained, EPRI is making dimensional reporting templates and instructions available to all stakeholders in the energy industry upon request.

EPRI Approach Forward

A supplemental project was launched in September 2022 to develop a comprehensive, integrated life management methodology addressing how to identify at-risk tees across a fleet to prioritize future inspection(s), clarify relevant inspection or analysis technique(s), create a database of case studies, issue improved guidelines for replacement components, and bring together

https://publicdownload.epri.com/PublicAttachmentDownload.svc/AttachmentId=83193

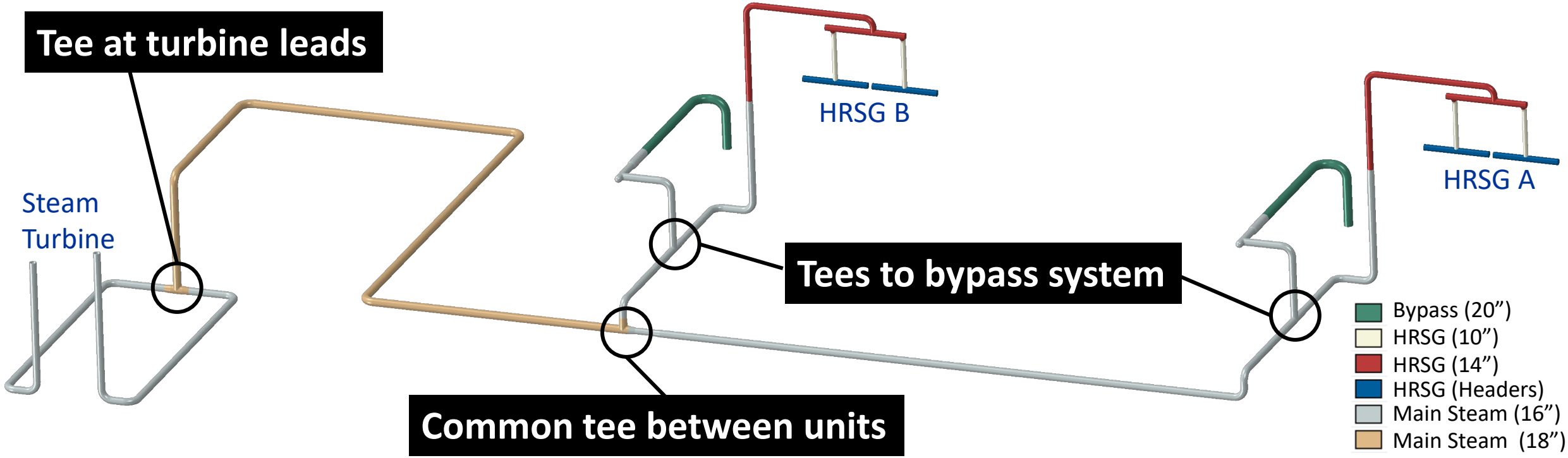
Modern combined cycle plant site



- Gas turbine exhaust heats steam in the HRSG (some models similar to aero engines)
- Steam is superheated and reheated and 'piped' to the steam turbine
  - 'Compact' CCGT plant still requires several hundred feet of piping and dozens of welds
  - This site has 2 X 2 units on 1 steam turbine (so-called 2-on-1)
- Power generation capacity for a site like this ~1 GW (about the output of a single commercial nuclear reactor)

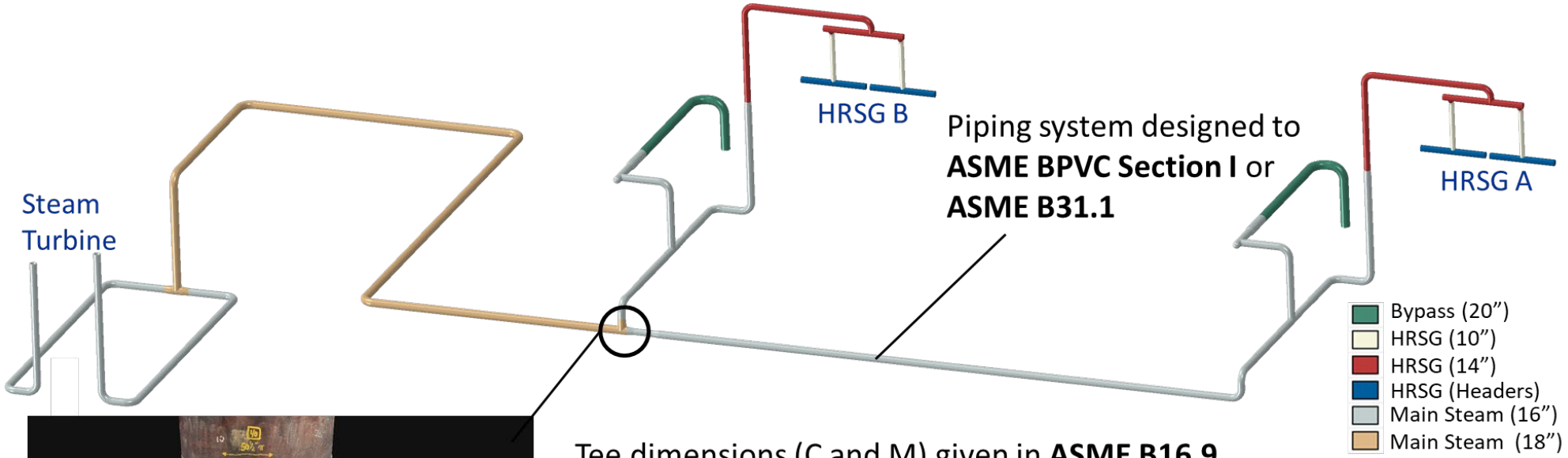
Representative combined cycle main steam piping system

- Typical 2-on-1 combined cycle main steam system
- ~3-5 tees/piping system
  - 6-10 total in creep range (excluding headers/manifolds)



16-inch (406 mm) OD X 1.6-inch (40.6 mm) WT main steam tee (~1,200 lbs)

Codes and standards



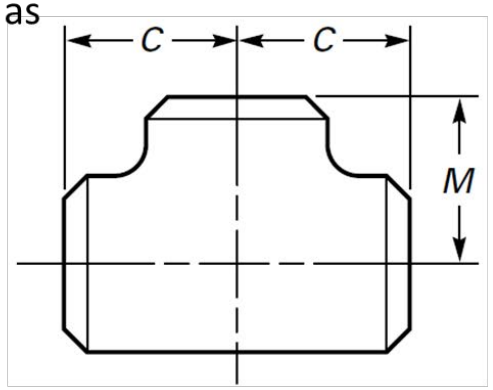
Tee stamped **A-234 WP91** or **SA-234 WP91**

Additional requirements given in **A-960/SA-960**

Composition + heat treatment
Acceptance testing + inspection
Stamping

Tee dimensions (C and M) given in **ASME B16.9**

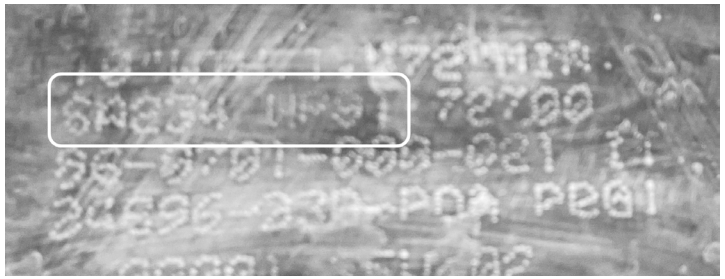
“Thickness” typically established by a room temperature burst test on a carbon steel tee as specified in ASME B16.9, Section 2.2.1 “Acceptable design methods”



At least five relevant codes or standards that play a role in designing or producing components that must be fit for purpose in the creep range for 100,000s of hours

Challenges with tee fittings

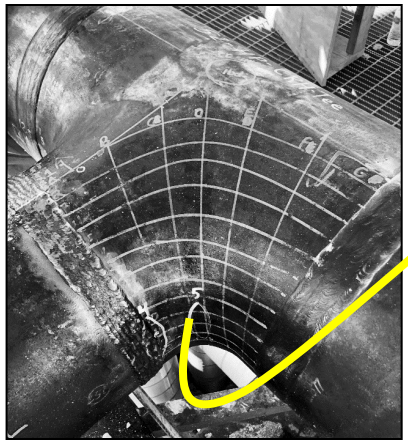
Rogue material improperly stamped A-/SA-234 WP91

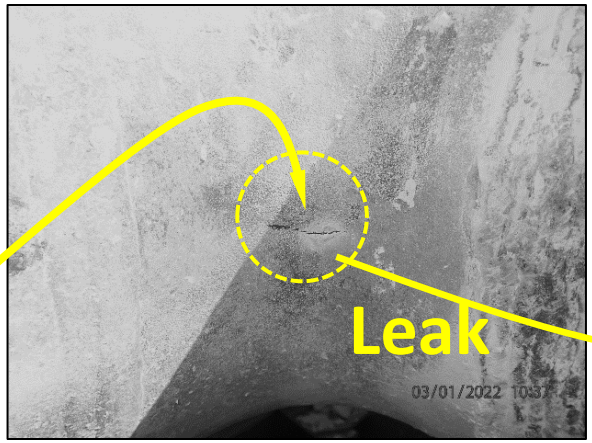


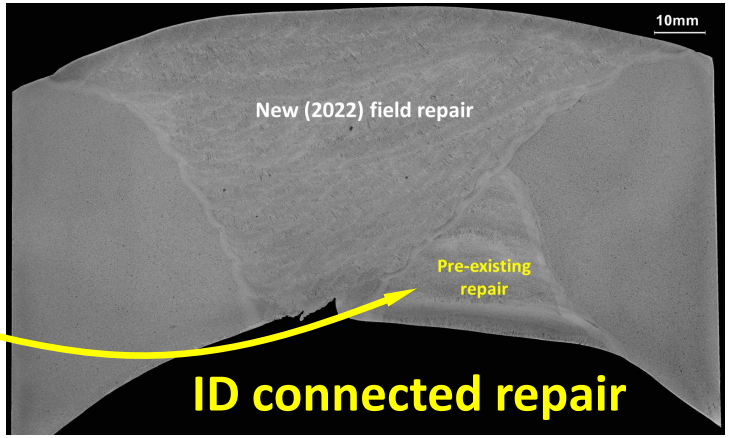
	Actual	WP91
Cr	11.00	8.0 to 9.5
Ni	0.68	0.40 max
C	0.201	0.08 to 0.12

Codes and standards do not provide sufficient safeguards; 100s of cracks and leaks worldwide

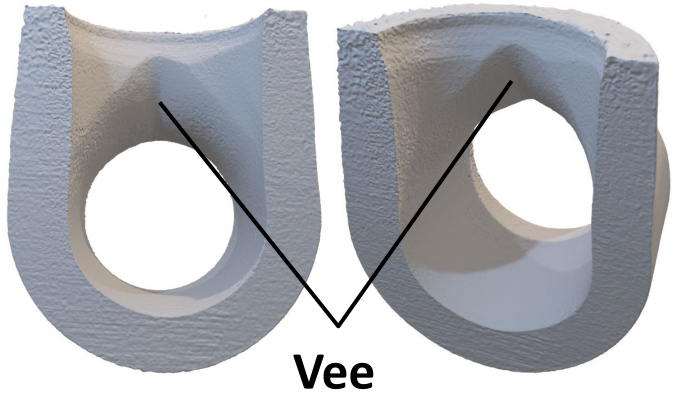
Undocumented repairs in crotch position and given inadequate PWHT



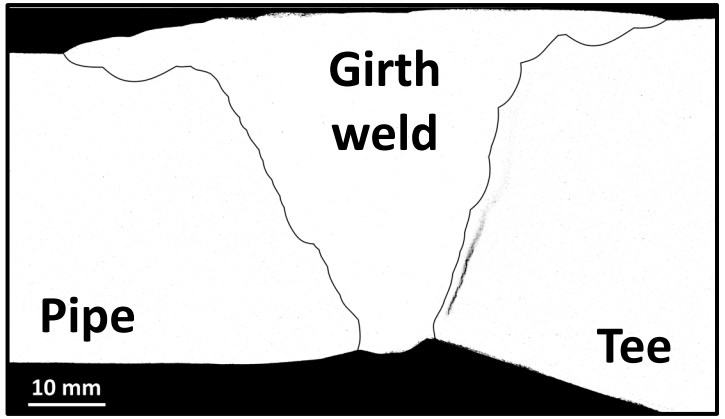


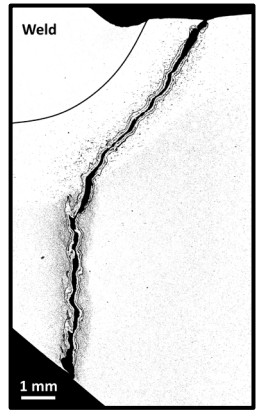


Vees in the crotch region creating elevated stress



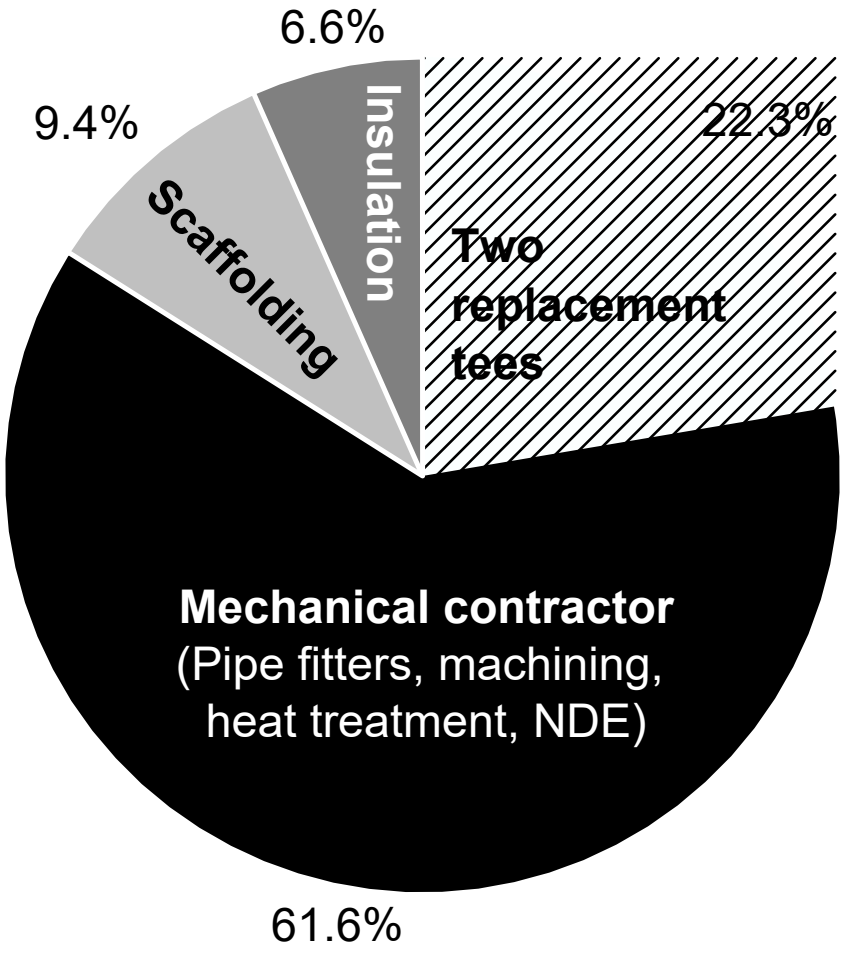
Cracks in welds due to poor geometry, proximity to crotch, inferior performance





Magnitude of the problem

- **Economic perspective**
  - Total cost to replace two hot reheat tees in a supercritical coal-fired power plant was $1.2M
  - A ‘large tee’, if procured from forging and machined to custom geometry ~$125,000/tee
  - Lead times approaching 12-months for forging + machined
- **Safety perspective**
  - Some cracks have grown relatively long in-service
  - Some analyzed configurations are at increased risk to crack instability (rupture), and particularly for seam-welded or repaired tees
  - To date, through-wall cracks have manifested as leaks
- **Total worldwide exposure could be ≥$10B**



Total replacement costs are 5-10X new construction…

Near-term solution includes EPRI spec., but will not solve all deficiencies…

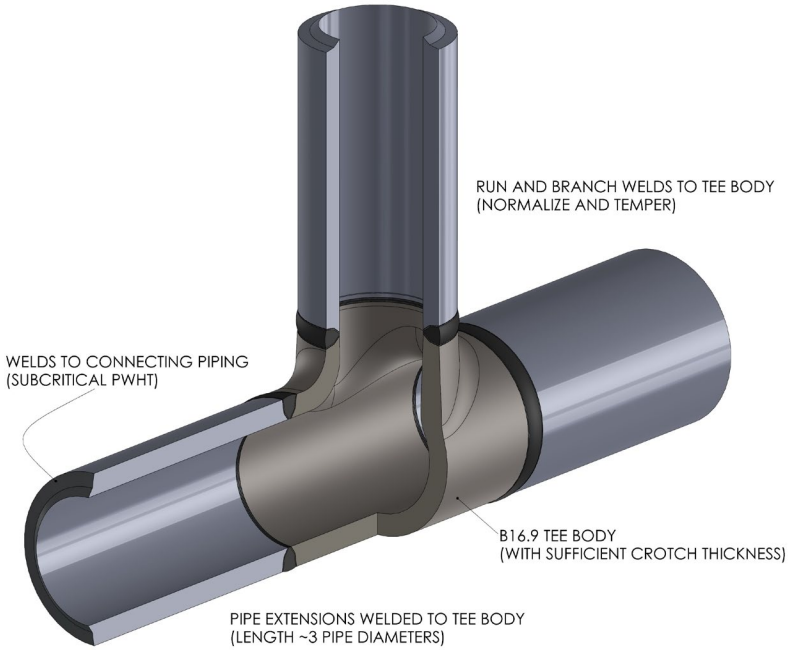
ASME B16.9
- ❑ Design requirements
- ❑ Design parameters
- ❑ Fabrication requirements
- ❑ Inspection & testing
- ❑ Documentation

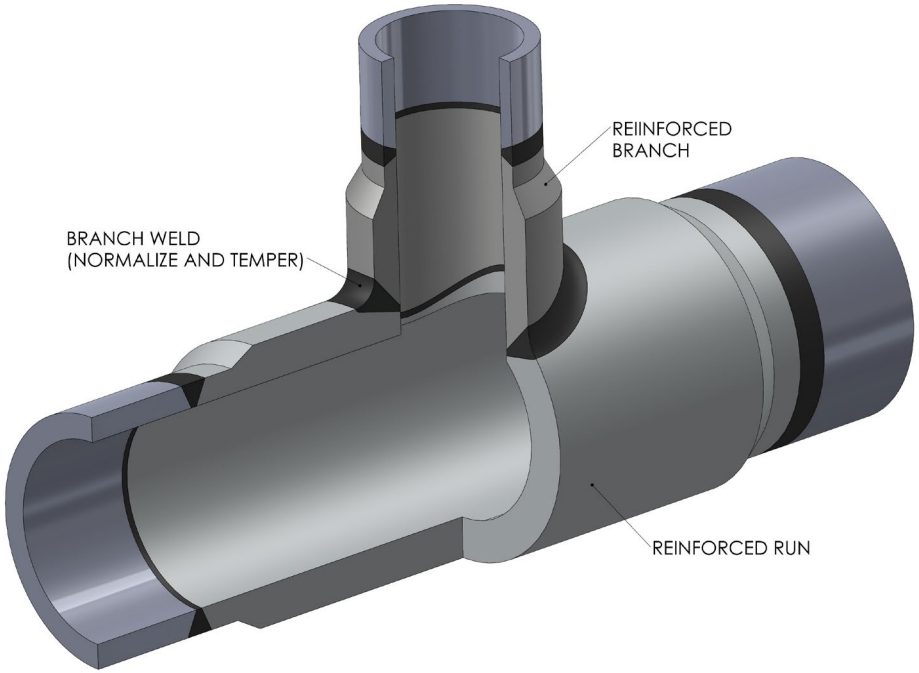
ASME B16.9++
- ❑ Design requirements
- ❑ Design parameters
- ❑ Fabrication requirements
- ❑ Inspection & testing
- ❑ Documentation

Machined forging
- ❑ Design requirements
- ❑ Design parameters
- ❑ Fabrication requirements
- ❑ Inspection & testing
- ❑ Documentation

Fabricated branch
- ❑ Design requirements
- ❑ Design parameters
- ❑ Fabrication requirements
- ❑ Inspection & testing
- ❑ Documentation

[Future] Additive
- ❑ Design requirements
- ❑ Design parameters
- ❑ Fabrication requirements
- ❑ Inspection & testing
- ❑ Documentation





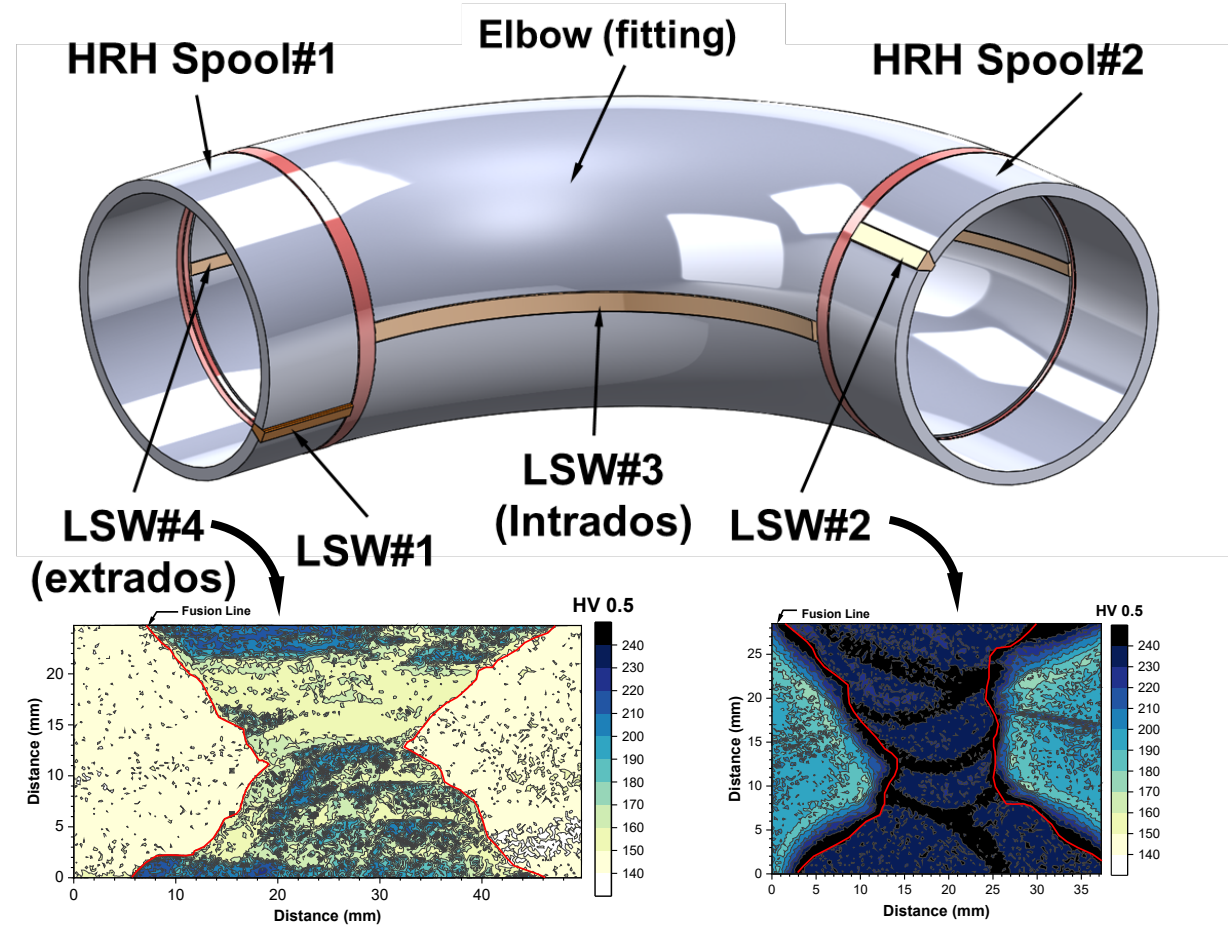
The elephant(s) in the room

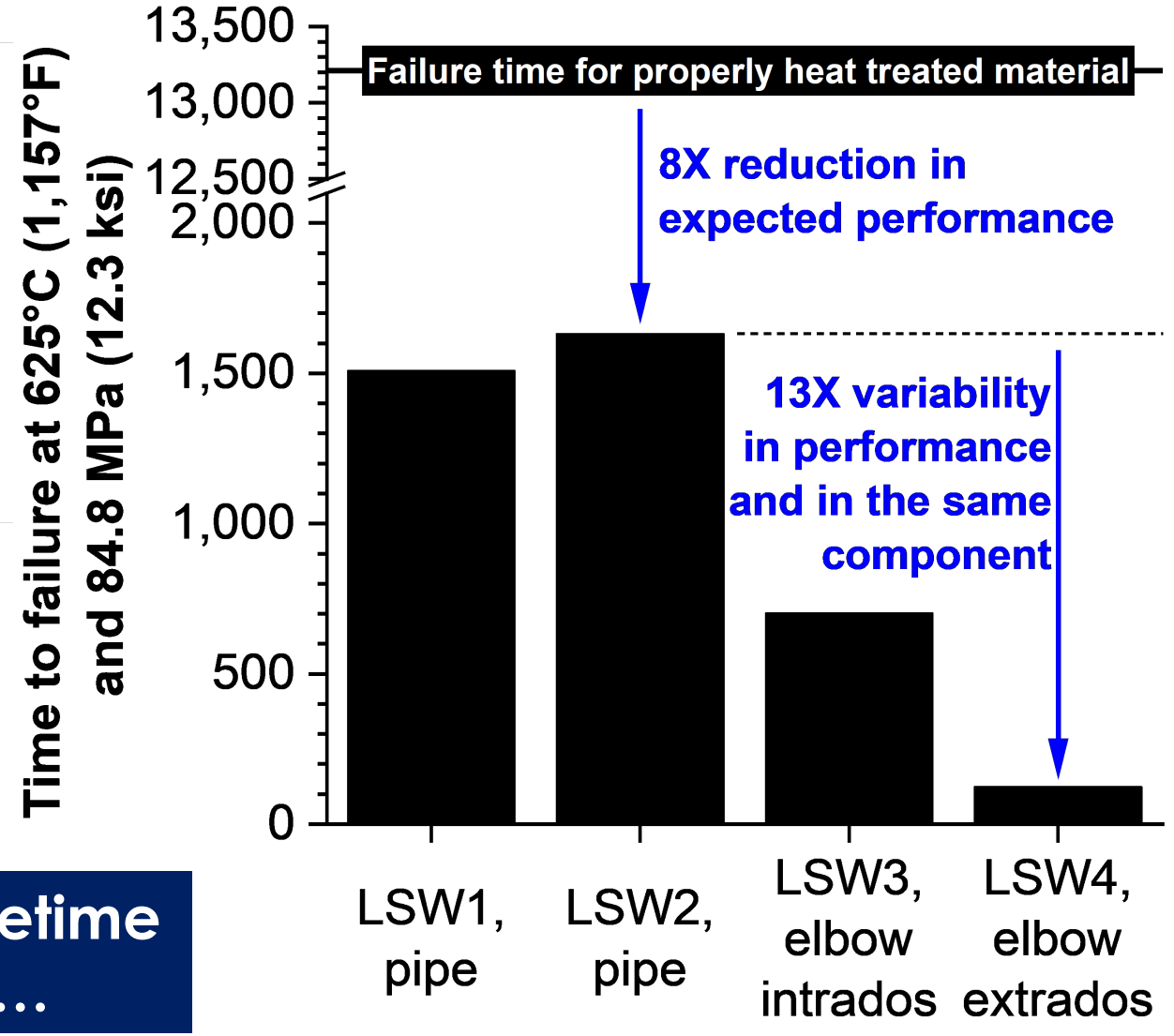
A-/SA-234 covers fittings… Fittings include tees, crosses, reducers, elbows, returns, and torispherical caps

A-/SA-234 includes seam-welded fittings

Excessive risk warrants the need for immediate investment to reduce uncertainty

Variability in seam-welded construction in fittings





Max variability of ~100X suggests a lifetime of 10,000 hours or 1,000,000 hours…

Post construction perspective

Recent announcements and insight

Southern Company extends life of coal plants to power data centers, appears to abandon net zero goal

Daniel Tait • February 20, 2025

https://energyandpolicy.org/southern-company-extends-life-of-coal-plants-to-power-data-centers-appears-to-abandon-net-zero-goal/

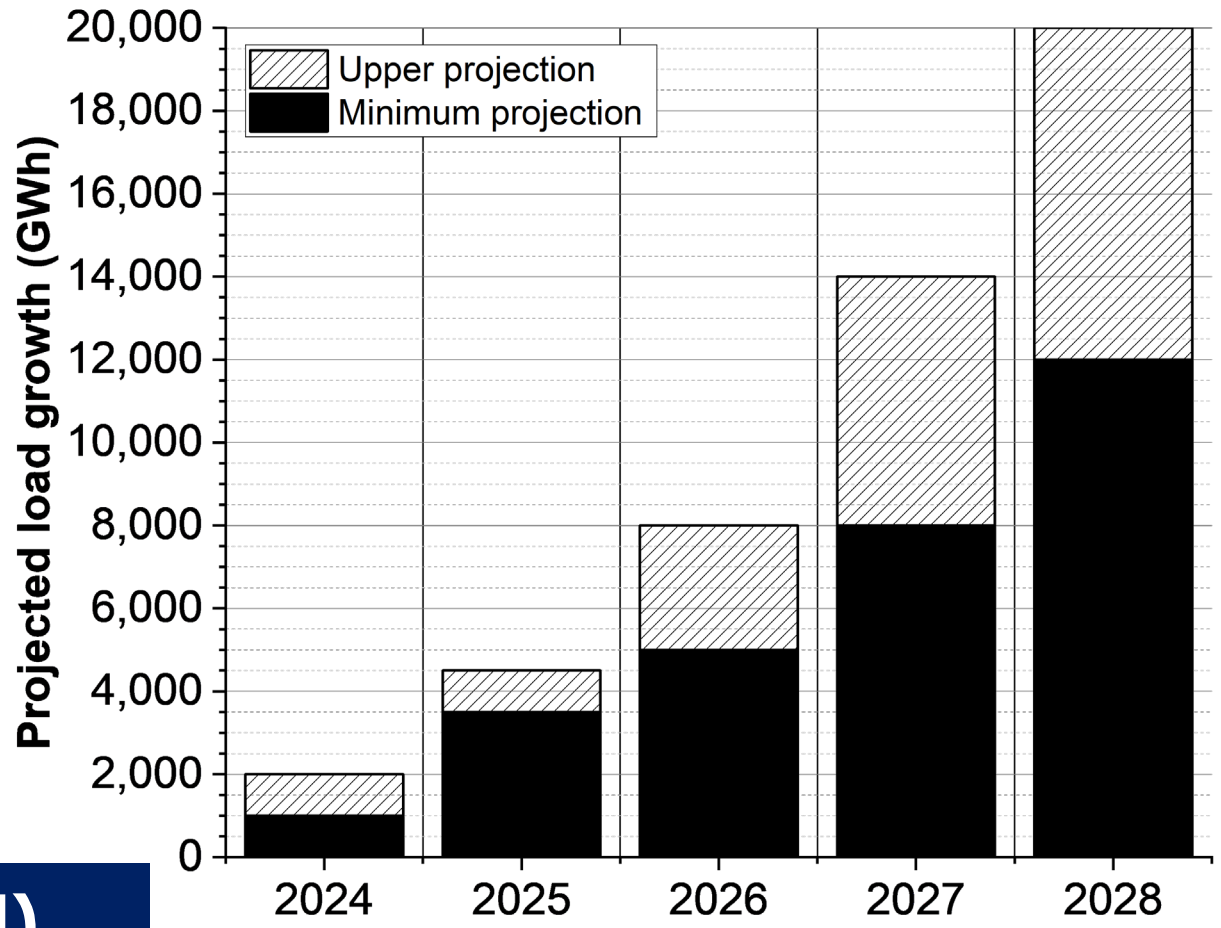
South Africa Wants to Slow Down its Coal Plant Closures in Violation of an Agreement with Western Nations

IER

SEPTEMBER 18, 2024

https://www.instituteforenergyresearch.org/fossil-fuels/coal/south-africa-wants-to-slow-down-its-coal-plant-closures-in-violation-of-an-agreement-with-western-nations/

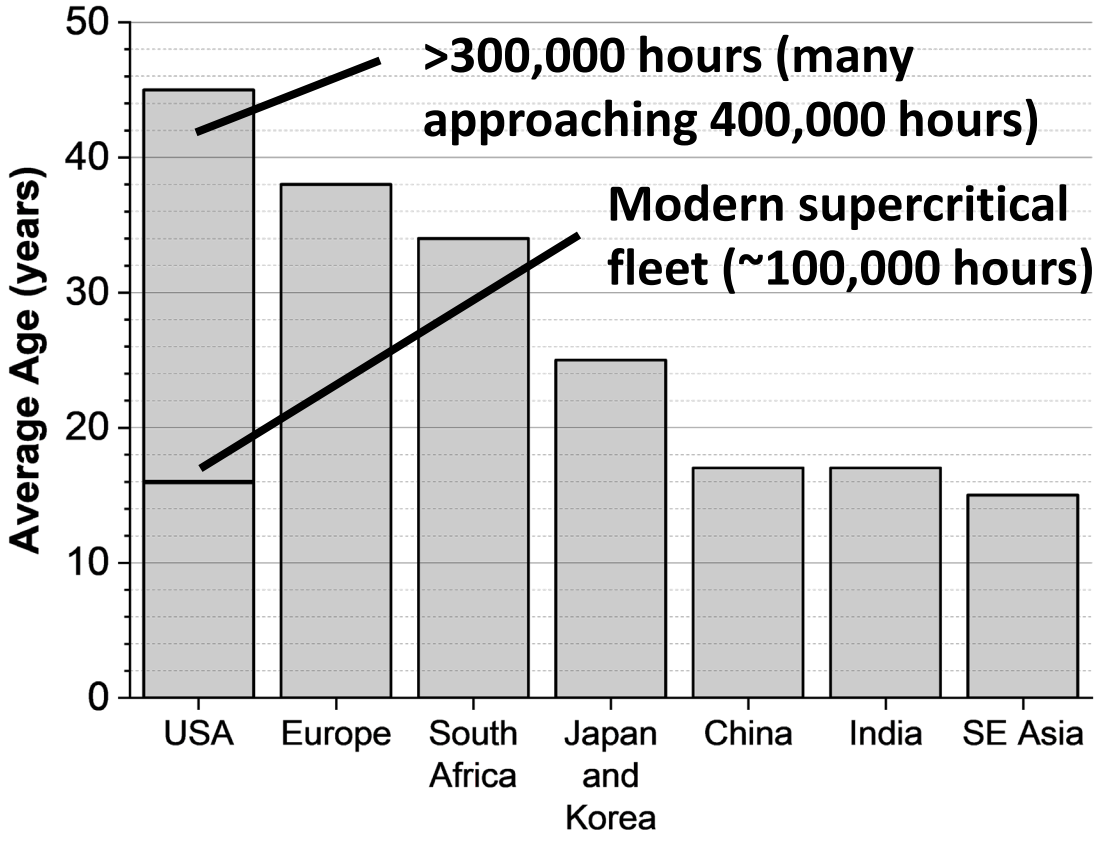
5-year projections for large USA utility



Market evolving rapidly (again!)

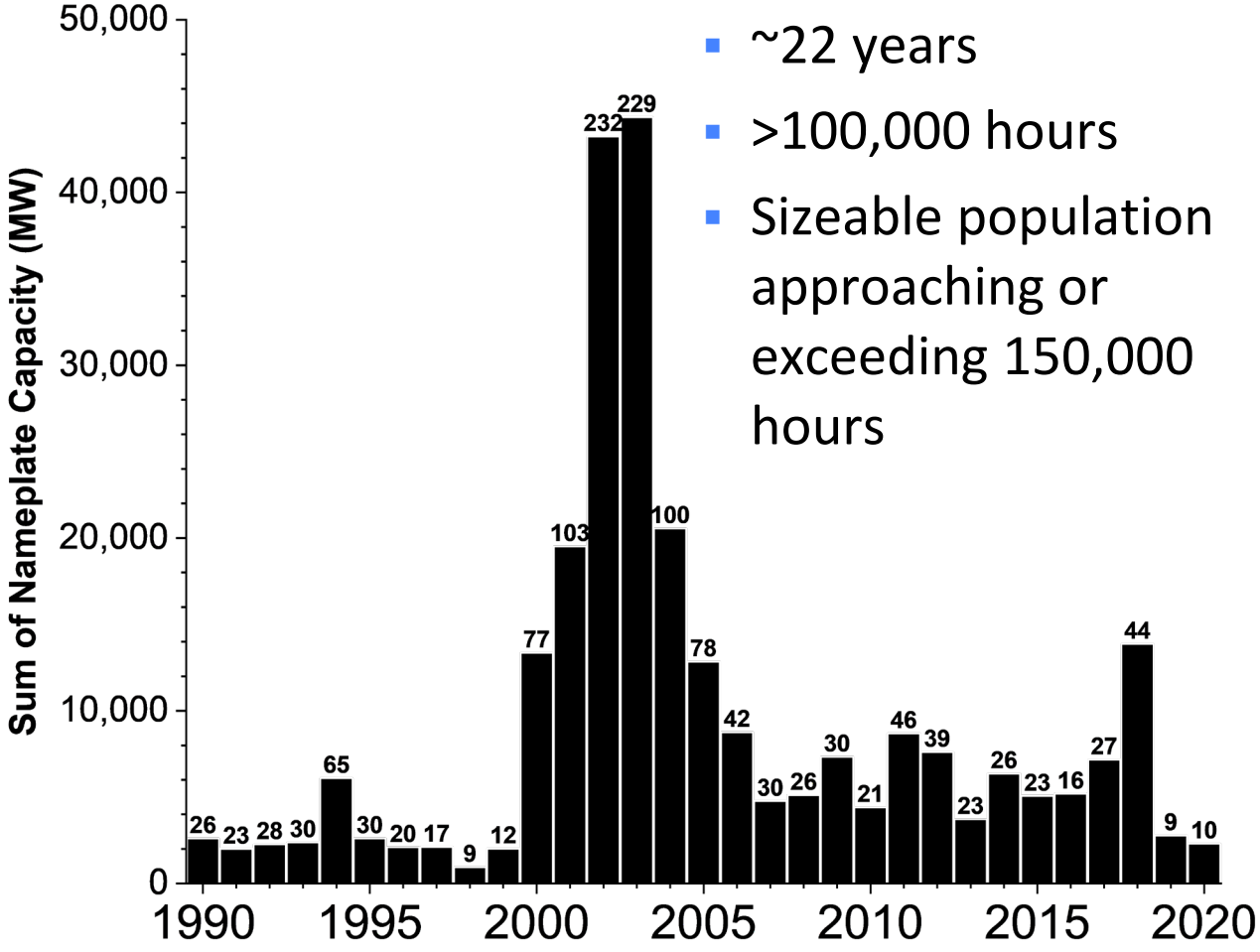
Average age of thermal assets

World coal-fired units



https://www.iea.org/data-and-statistics/charts/average-age-of-existing-coal-power-plants-in-selected-regions-in-2020

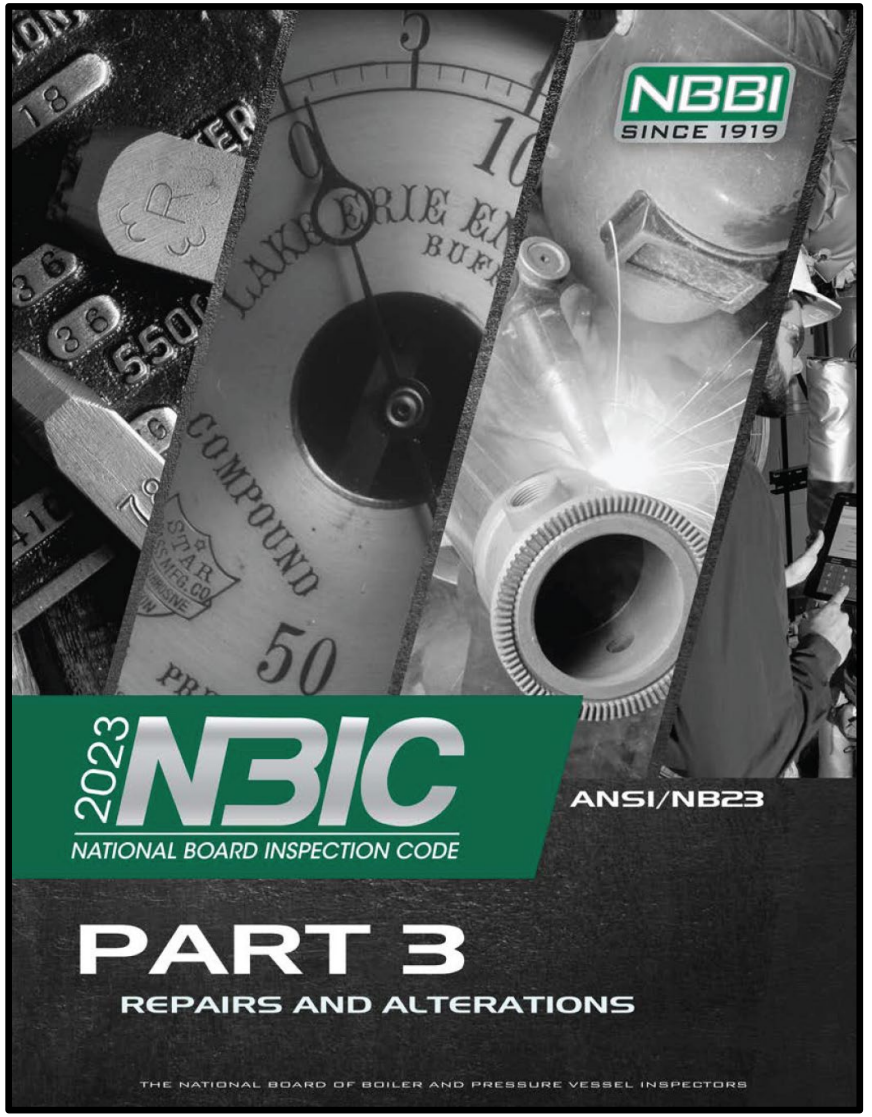
USA combined cycle units



- ~22 years
- >100,000 hours
- Sizeable population approaching or exceeding 150,000 hours

More alternative repairs will be needed

- Part 3 is unique in its guidance and application to power industry needs with respect to alternative weld repairs
  - **Welding Method 4** – temper bead for P-No. 4 and 5A materials
  - **Welding Method 6 –** repair of P15E tubing internal to boiler
  - **Welding Method 7 –** dissimilar metal weld repair to P15E
  - **Supplement 8 –** repair P15E and dissimilar metal welds in balance-of-plant components
  - **Repair of pressure-retaining items without complete removal of defects**
- **>$7M industry investment since 2011 in EPRI research**
  - Service experience continues to show that repairs can be made safely and has helped industry immensely

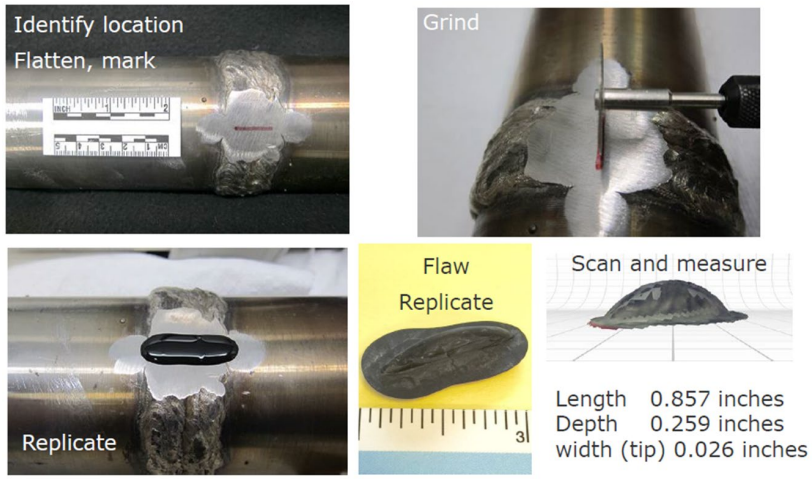


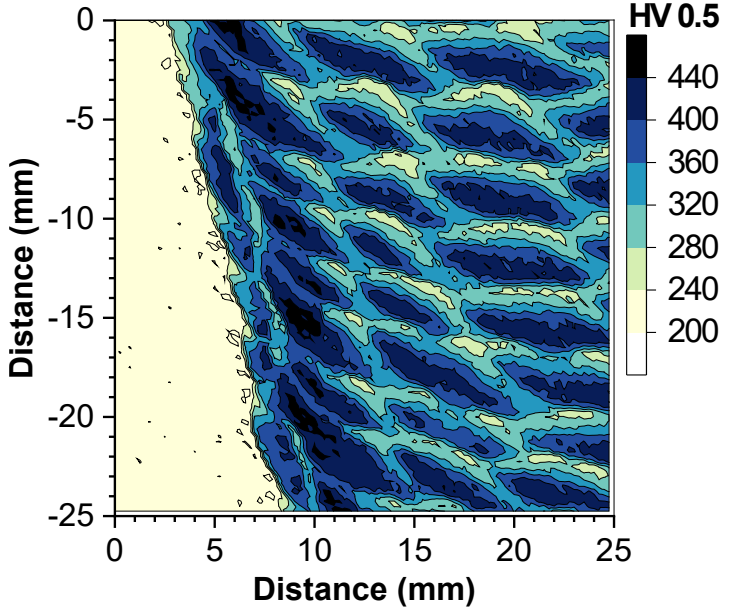
Considerable and on-going efforts to push EPRI research outcomes and technology into the NBIC

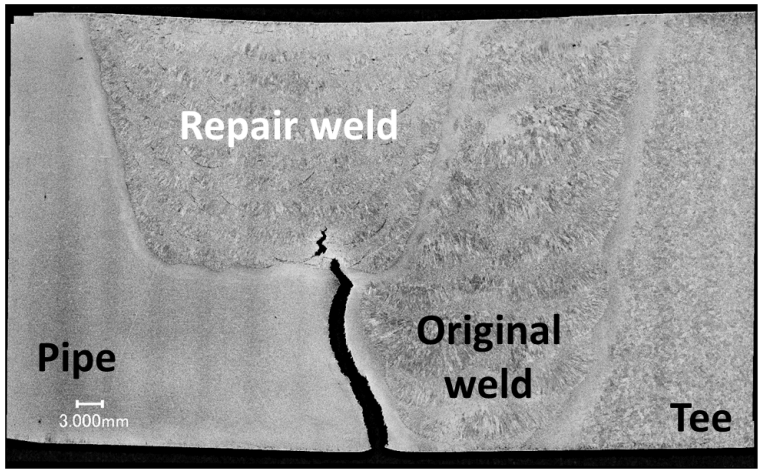
Supporting research for alternative weld repairs is extensive

- >200 high-temp. feature tests including assessment of ex-service repairs
- >800,000 hours creep testing
  - Uniaxial tests in simple or feature test geometries
  - Small and large vessel tests
- Time independent testing including burst tests
- >250,000 hardness indents
- Qualified welding procedures

>10,000 alternative weld repairs in Grade 91 steel now operating for ≥70,000 hours







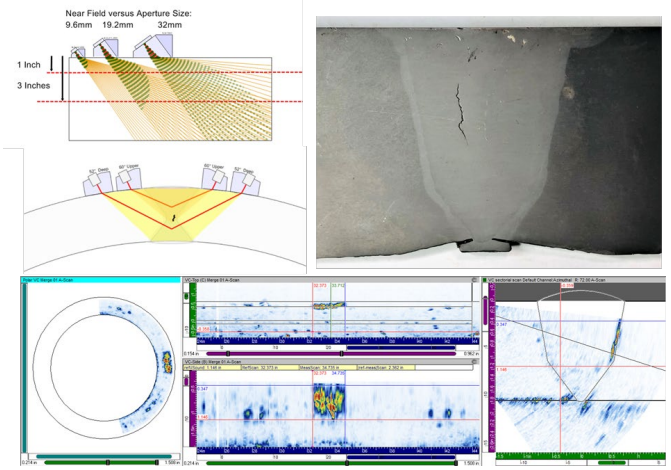
Plants *will have to run* with cracks

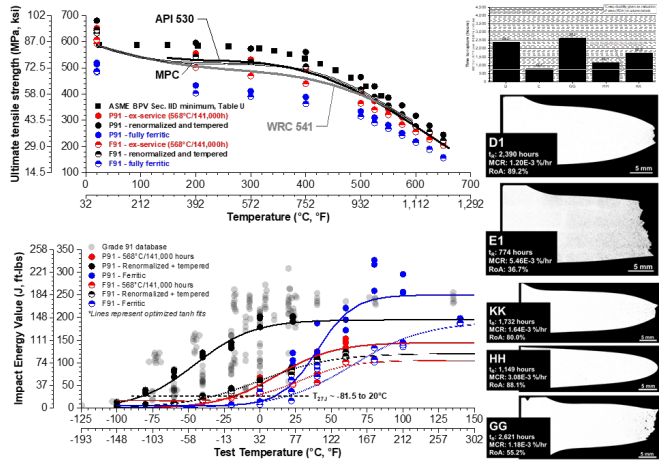
- Fitness for service methodologies like ASME FFS-1 or BS 7910 are recognized by the NBIC Parts 2 and 3
  - Approaches need to be optimized or improved for power generation applications
    - Components frequently subjected to repeated (severe) thermal transients
    - Creep is active in materials or conditions not addressed by these documents
- **$3.5M industry investment since 2020 in EPRI research**
  - Phase 2 effort starting in 2026 to develop, track, and verify plant case studies supporting improved assessment procedures

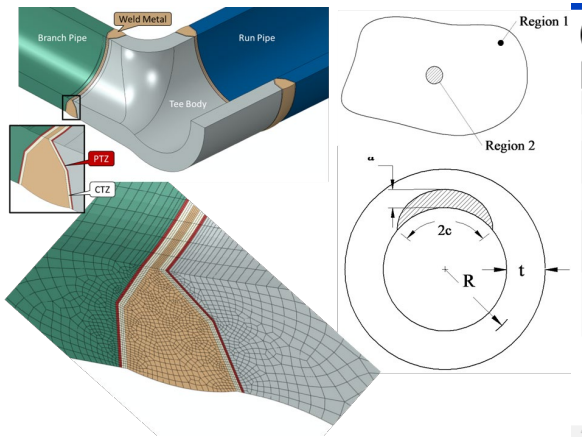
Considerable and on-going efforts to push EPRI research outcomes and technology into the NBIC

Supporting research for *safely* running with cracks is extensive

- Addressed gaps and developed a library of complimentary information critical to executing a well-engineered assessment (see 3002020435)
  - NDE
  - Evaluation of operating data
  - Dimensional measurements
  - Materials data for damage initiation and propagation in the new, ex-service or fully degraded condition
  - Identification of damage mechanism(s)
  - Reporting/documentation
  - Case studies

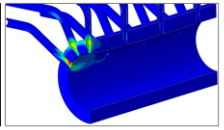






Run Swollen superheat outlet header

Details, facts and figures	
Type	Gas-fired boiler
Location	Texas, USA
Operational	1958, header replaced in 1986 (1986-2022, ~25% capacity)
Component	Superheater outlet header
Findings	November 2022 inspection finds gross swelling (~10%) to a local section of header
Constraint(s)	❖ Replacement material unavailable ❖ Need component available for winter season



Recommendations and conclusions:
- EPRI onsite to assist the outage inspection
- Personnel barriers to avoid area of concern
- Install thermocouples to confirm assumed temperatures and refine FFS assessment
- (Re)inspect after 2,000 operating hours

Unit was able to run for ~1-year to outage for local section replacement (section now at EPRI for post-mortem evaluation)

Efforts underway to determine how best to transition this extensive library into the open domain to support post construction activities linked to fitness for service

Summary

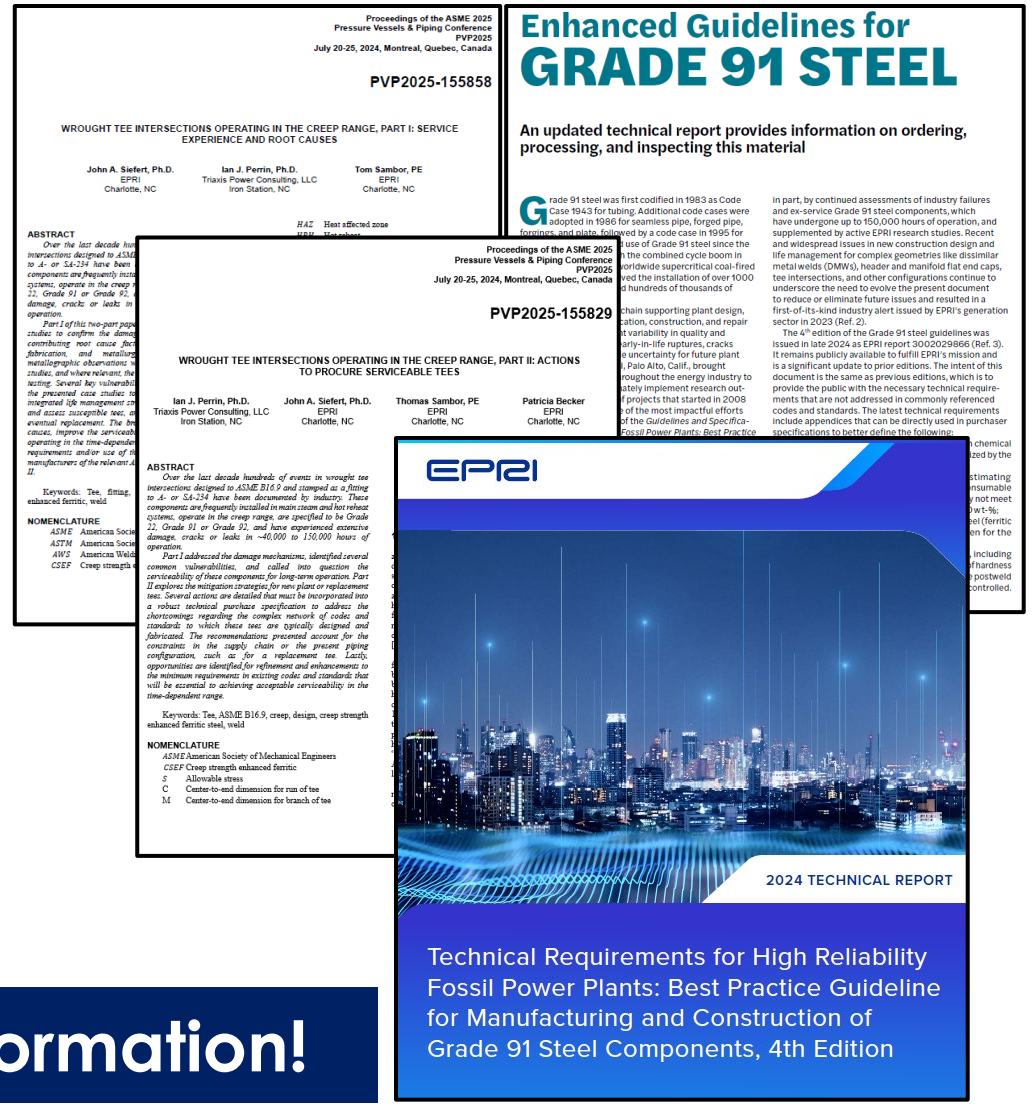
The challenges are real and are beyond what EPRI can do unilaterally

- Emerging issues, like tee fittings, lay bare the deficiencies in simple design rules for handling creep-dominated damage development
  - A single rule or update to a table will not address fundamental gaps that have existed for decades
- Load growth a reality and already happening
  - More challenges and issues requiring *more repairs and replacements*
  - Cost and schedule dictating ‘build it now’ and ‘fix it later’
- Who should be responsible for industry alerts?
  - OEM perspective lost, infrequent or no longer relevant
- Increasing needs and requests for consideration regarding
  - Temporary repairs to allow for time to plan for a permanent solution
    - Supply chain (cannot get what is needed quickly enough)
    - Significant safety concerns for the public in times of high demand (winter cold or summer heat)
  - Safe operation with documented and monitored cracks (fitness for service)

Is industry prepared to mobilize resources to meet challenges in new and post construction?

Continued efforts to educate and raise awareness in 2025

- NBIC Bulletin Spring 2025 “Emerging Issues in the Power Generation Industry”
- *Welding Journal* May 2025 “Enhanced Guidelines for Grade 91 Steel”
  - Additional information (publicly available!) *Technical Requirements for High Reliability Fossil Power Plants: Best Practice Guideline for Manufacturing and Construction of Grade 91 Steel Components, 4th Edition*, 3002029866 LINK
- PVP2025-155858 “Wrought Tee Intersections Operating in the Creep Range, Part I: Service Experience and Root Causes” (*to be made publicly available)*
- PVP2025-155829 “Wrought Tee Intersections Operating in the Creep Range, Part II: Actions to Procure Serviceable Tees” (*to be made publicly available)*



Be on the lookout for complimentary information!

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