TEN YEAR RETROSPECTIVE LOOK AT HRSG FAC ASSESSMENT AND INCIDENCE

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FAC EXPERIENCE AND CONTROL

- FAC became a front burner issue in 1980's in Nuclear and conventional boiler systems.
- Development and diffusion of FAC guidance was concentrated on nuclear and only secondarily on conventional boilers.
- Combined Cycle steam systems were not widespread or of large size in this period. CC units were often not owned or operated by organizations that also owned or operated nuclear and conventional boilers.
- Diffusion of FAC knowledge to CC HRSG's was not a high priority.
- Experience in Nuclear and Conventional Boilers were primarily in piping systems. Heat exchanger manifolds were not viewed as a large risk (even though erosive wear in shell and tube HX was well known).
- Small HRSG's regarded as industrial boilers for O&M purposes.

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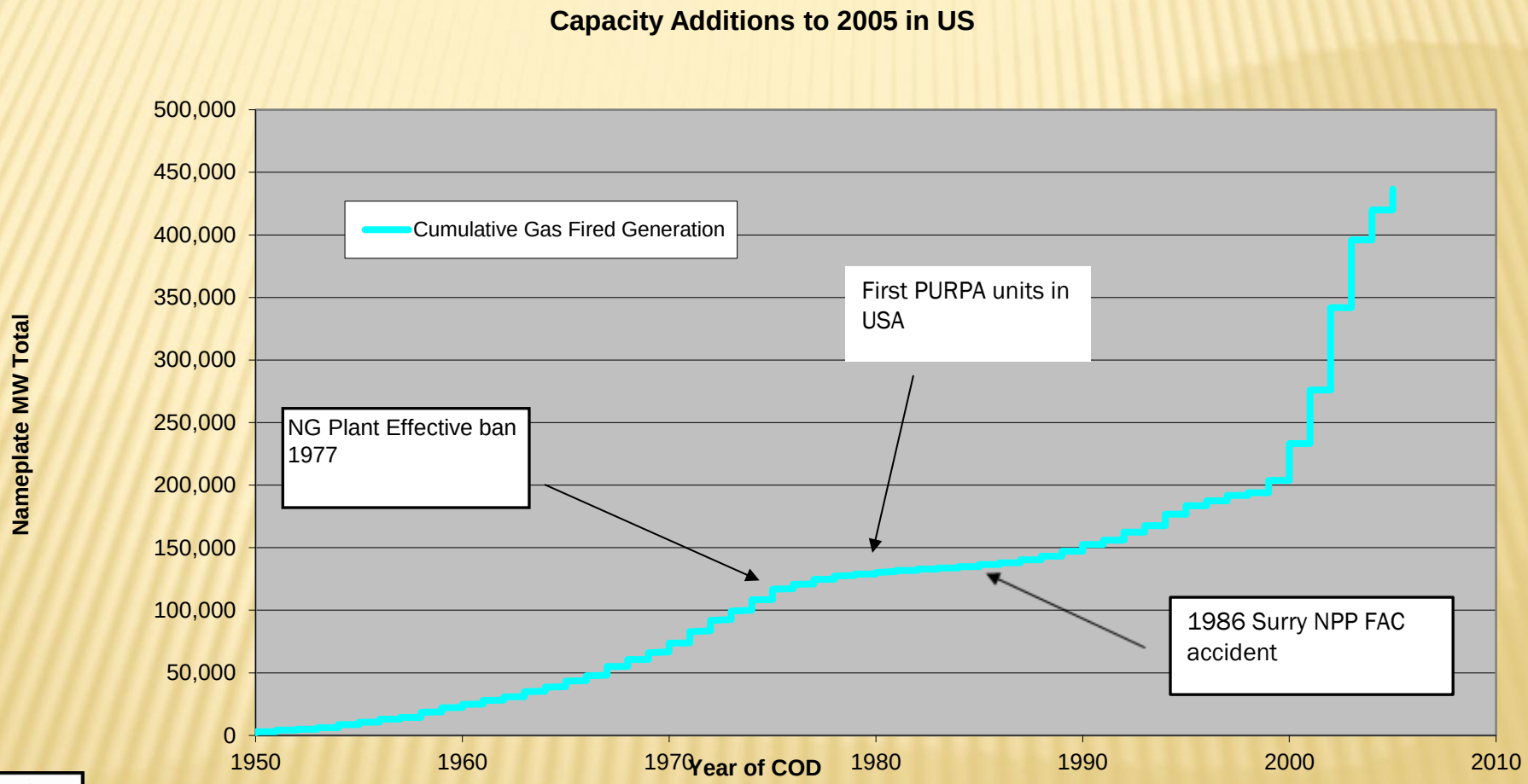
GROWTH IN COMBINED CYCLE PLANTS



SIZE OF CC STEAM UNITS

- Median CC ST rating in US
  - 1977 - 1990 16.3 MW
  - 1991-1999 42.3 MW
  - 2000-2008 196 MW
- Size of HRSG's (as well as steam conditions) was relatively small in initial FAC interest period (1986-1990)
- First larger plants built in early 1990's
- Very large plants with modern steam conditions built in large numbers after 2000.

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COGENERATION UNITS

- Many of the first CC units in USA built under PURPA QF (Qualifying Facility Rules) after 1978.
- Favorable Power tariffs available along with preferred dispatch if facility met qualifications for a cogeneration facility (thermal energy sent to user).
- Plant Size was small, operating pressures were often low, water chemistry programs geared to standard industrial guidance along with needs of steam users.

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FAC DAMAGE IN EARLY COGEN HRSGS

- Rapid FAC wear in evaporators and boiler piping resulted in extensive damage within 30-60,000 hours. Wear in the range of 1.5 mills/khr (0.03 to 0.14 mm/khr) were frequently seen.
- Major component and piping replacement was a consequential action to repair HRSG's.

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EXPERIENCE FROM EARLY FAC

- Improved Water Chemistry halted or greatly slowed FAC.
- Initiatives to upgrade materials were limited to known problem areas
- Other areas of concern not easily visible as older units ran less than before due to higher heat rates (lower efficiency)

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EARLY LARGE UNITS

- The first large HRSG's were built in the early to mid 1990's in the US (dual or triple pressure HRSG's.
- Many were still QF facilities
- FAC is part of overall plant operational concern
- Failures from FAC are more localized or reflect un-anticipated higher two-phase wear

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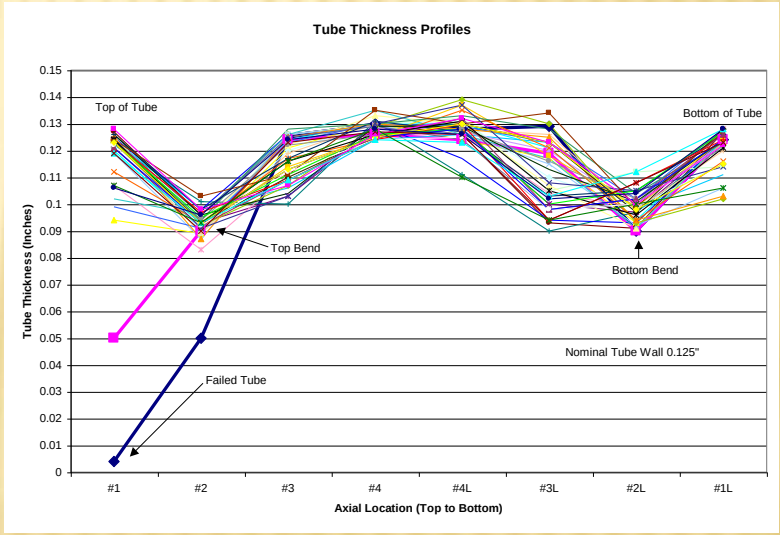
LOCALIZED WEAR

- Single tubes on LP Evaporator with hot gas bypass at side wall causing high local circulation. Other tubes show no damage



CURRENT LARGE UNITS

- Current large HRSGs (3PRH, main steam 400 kpph (50 kg/s) unfired) were built in large numbers from 2000 to 2005.
- Service now ~ 25,000 to 60,000 hrs many in cycling service
- FAC is addressed by control of WC and Inspection
- FAC issues are localized but reflect more high turbulence/flow effects than earlier problems.

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FAC CONCERNS OF RECENT LARGE HRSG

- Two-Phase Conditions
  - Localized medium rate wear due to two phase conditions in LP evaporator tubes
  - Impact of part load seen in wear rates
- High Local Single Phase Wear Rates
  - Confined to specific geometries with high local turbulence
  - Other areas (bends, etc) see little or no wear
  - Often associated with high plant flows (for example high duct firing conditions)

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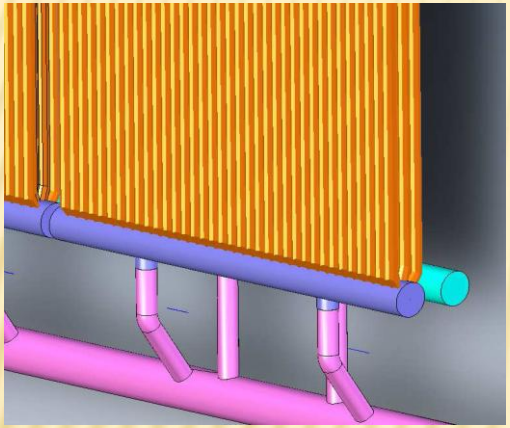
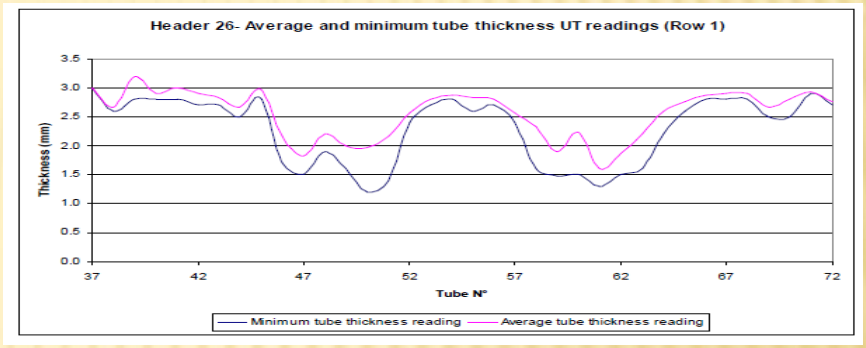
HIGH LOCAL WEAR RATES





SUMMARY

- Early HRSG FAC Damage often major reflecting lack of updated chemistry control Wear rates 2-6 mills/khr (0,05 to 0.15 mm/khr) were common. Major Damage 30-50,000 hours.
- Better FAC understanding and implementation of control methods reduced average wear rates substantially. (<0.15 mills/khr, 0.004 mm/khr) Damage is now often very localized in high flow/turbulence areas. (0.7-1.0 mills/khr, 0.01-0.03 mm/khr)
- FAC is shifting form a rapid wear over major areas of pressure parts to a slower wear process with some higher risk areas.
- Areas of improvement for FAC Control include better understanding of risks from operational changes (part load, peak load) and design issues promoting local high wear.
- Better inspection access and technology are required to aid in slower, more localized FAC control in HRSGs

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