Tracer Gas Inleakage Testing. What have we learned in Twenty Years?

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What is Inleakage?

- Inleakage is the entrance of untreated air into the CRE ***by any means*** when the CREEVS is operating
  - Means #1: Penetrations/Openings in CRE
    - dP must be greater outside CRE than inside
  - Means #2: Unsealed openings in the negative dP sections of the CREEVS
  - Means #3: Non-CREEVS ducts or plant support tubing passing through the CRE
    - To represent potential inleakage these must exhibit a higher pressure than that in the CRE during operation of the CREEVs

Why does inleakage occur?

- Differential pressure exerted on CREEVS components, on non-CREEVS components passing through the CRE, or on the CRE itself can create inleakage flow through unsealed openings *of any kind*.
  - If this inleakage is from a potentially contaminated area it must be accounted for in any habitability analysis.
  - Depending on the exact location of the leak site, the inleakage may be *filtered* or *unfiltered*.

History of Interest in Inleakage by NRC

- GDC 19
- SRP 6.4 (1980)
- NUREG 0737 (1981)
  - Action Item III.D.3.4
- ACRS recommends NRC develop inleak test (1983)
- NRC 3 Plant Study (1985)
- NRC 12 Plant Study (1988)
- NRC Conference (1998)
- NEI 99-01, 99-03
- NEI/NHUG Conference (2001)
- Generic Letter 2003-01
  - Reg Guide 1.196
  - Reg Guide 1.197
- TSTF 448 Rev 3 (2007)
  - NHUG-G-001 (2008)

In the beginning

- GDC 19

  Criterion 19—Control room. A control room shall be provided ....

  “Adequate radiation protection *shall* be provided to permit access and occupancy of the control room under accident conditions without personnel receiving radiation exposures in excess of 5 rem whole body, or its equivalent to any part of the body, for the duration of the accident.”

Control Room Envelope

The plant area, defined in the facility licensing basis, that, in the event of an emergency, can be isolated from the plant areas and the environment external to the CRE.

This area is served by an emergency ventilation system (Now called CREEVS by NRC) with the intent of maintaining the habitability of the control room.

This area encompasses the control room and may encompass other non-critical areas to which frequent personnel access or continuous occupancy is not necessary in the event of an accident.

Purpose of the CREEVS

- Provide a <u>suitable environment</u> during normal operation for both the control room operators and equipment
- Provide a <u>habitable environment</u> in which the operators can safely shut down and maintain the plant after a design basis accident for the duration of the accident.
- Provide an environment from which the operators can <u>safely operate</u> the plant during an off-site toxic chemical accident

Implication of GDC 19

- Requires a habitability analysis to demonstrate compliance
  - Complex calculational format specific to each plant
  - One input to the analysis is the ***unfiltered inleakage***
    - » Tech Specs or FSAR commit to a max value
  - Prior to the adoption of tracer gas technology by the NRC and the nuclear power industry there was no way to measure the unfiltered inleakage
  - Sometimes the habitability analysis involved “back calculating” an inleakage value
    - » Some plants pressurized the CRE using a blower door and called that one half that number “inleakage”

Inleakage Testing

is based on

ASTM Standard E-741 “Standard Test Methods for Determining Air Change in a Single Zone by means of Tracer Gas Dilution”

Usefulness of Tracer Gas Test

- Directly *measures* Air Inleakage into CRE under *actual* operating conditions.
- Requires no assumptions about leak site distribution or CREEVS performance.
- Can directly measure *component leakage*, i.e. dampers, ducts, shaft seals.
- Often can locate actual in (or out) leakage sites as an aid in sealing CRE.

Sulfur Hexafluoride, (SF6) Is The Most Commonly Used Tracer Gas

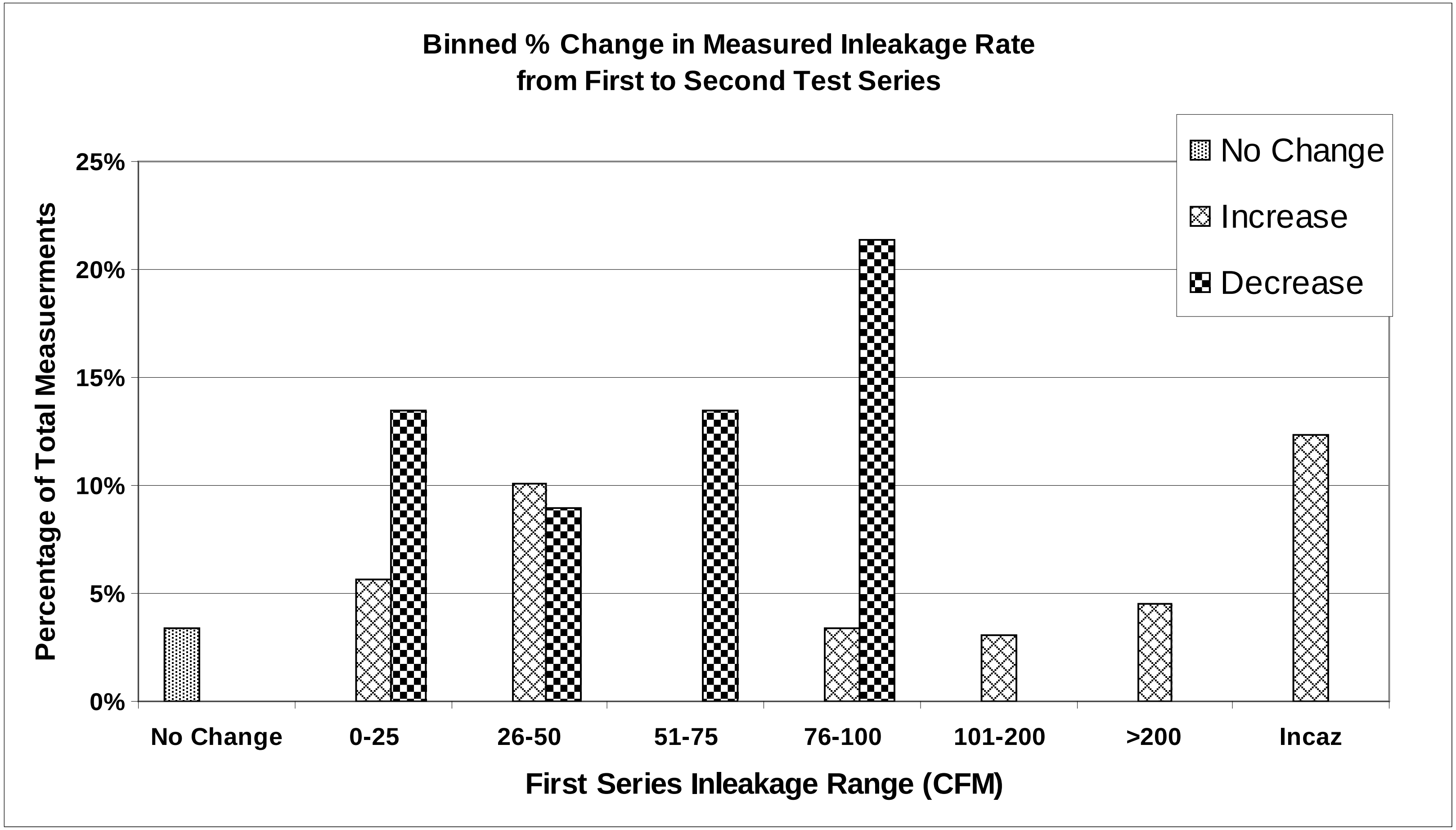
- Non toxic, inert, colorless, odorless
- Not a normal constituent of plant atmosphere
- Not adsorbed by nuclear charcoal filters
- Detectable at very low concentrations (parts per billion to parts per trillion)
- Is a greenhouse gas
  - Use very small amounts and use sensitive gas analyzers to minimize environmental impact

Where does inleakage occur?

- Duct seams
- Duct access doors and hatches
- Fan shaft seals
- AHU housings
- Fan vibration boots
- Isolation dampers
  - Normal Mode
  - Smoke Exhaust
- Actuator shaft penetrations
- Openings in CRE
- Personnel access doors to CRE
- Duct misalignment
- Duct Penetrations
- Non Safety Ducts passing thru CRE

Comparison of Inleakage Results

- Two Test Series
  - First Series: 2002-2005
    - » A few plants tested earlier are included
      - These plants did not test in the 2002-2005 period
  - Second Series: 2008-2011
    - » Early plants all tested in this period
- 90 Inleakage tests
- Paired data sets by *same* testing contractor
  - Pairing minimizes differences due to differing test techniques



Binned % Change in Measured Inleakage Rate
from First to Second Test Series
No Change
Increase
Decrease
25%
20%
15%
10%
5%
0%
Percentage of Total Measuerments
No Change
0-25
26-50
51-75
76-100
101-200
>200
Incaz
First Series Inleakage Range (CFM)

First & Second Test Series Comparisons

- All plants tested were within allowable inleakage
- 3 % Evidenced unchanged Inleakage
- 40 % Evidenced increased Inleakage
  - All increased values did not exceed allowable limits
  - Enhanced vigilance is needed to moderate future increases
- 57 % Evidenced decreased Inleakage

Lessons Learned #1

- OPS support is critical to a successful test program
- Maintenance of CREEVS components is important
- Operate CREEVS ***prior to*** inleakage test
  - Look at dP values and damper positions
- Non-CREEVS ductwork running through the CRE can be a problem
- Don't ignore smoke exhaust systems

Lessons Learned #2

- Pittsburgh seam ductwork leaks—BIG TIME
- Penetrations in Boundary may not be as important as previously thought (for pressurization CREEVS)
- Insulated ducts and housings can be a problem
- Adjacent (non-CREEVS) systems are important
  - Test with realistic "worst case" conditions
  - Reg Guide 1.197 requires this
- + dP does NOT guarantee an absence of inleakage
  - SRP 6.4 seems to imply that it does
    - » NRC didn't seem to understand how ventilation systems work!!!
  - *Any* – dP section of CREEVS has potential for inleaks

Lessons Learned #3

- Smoke testing provides info on inleakage locations
- Periodic visual inspection of CREEVS components is recommended
- Leaking ducts and housings can be sealed
  - NEI 99-03 provides guidance
- Door seals may be important
  - Poor door seals in a pressurization system costs dP
  - Poor door seals in a neutral pressure system can result in higher inleakage

Lesson Learned #4

- Watch for sources of SF6 within the plant
  - Insulated electrical feed through fittings
  - Insulated coaxial signal cables
  - Heat exchanger tube leak testing
- Watch for tracer re-entrainment
  - Tracer gas can re-enter CRE through outside air intakes
    - » Monitor intake and account for it in equations
- Watch for tracer gas sources external to test
  - Breakers in switch yards use SF6 as insulating medium
    - » Pressure relief valves release small amounts of SF6

Conclusions

- Tracer gas testing for inleakage is explicitly accepted by the NRC
- All plants tested were within allowable inleakage values
- Inleakage increased in approx 40% of the plants tested over a nominal six year period
  - These plants need to enhance vigilance
  - Continuing increase implies failure of the boundary control program
- By and large, industry has done a good job of maintaining integrity of CRE Boundary and CREEVS
- No time for complacency: Inleakage has SAFETY significance
  - TMI, Chernobyl, and Fukushima are burned into the public memory