INLEAKAGE RE-TESTING IN LIGHT OF TSTF 448

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Purpose of CRE and CREVS

- Provide a suitable environment during normal operation for both the control room operators and equipment
- Provide a habitable environment 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 safely operate the plant during an on-site or off-site toxic chemical incident

What is Inleakage and Why should we Care?

- Inleakage is non-design air that enters the CRE by any means during operation of the CREVS
  - **Can be filtered or unfiltered**
  - **Assumed, not measured, values were provided in safety analyses submitted during initial licensing process in the US**
- Inleakage air must be accounted for in any radiological dose analysis
  - **Prior to Generic Letter 2003-01 inleakage was usually assumed to be equal to zero (plus 10 CFM for doors) in Pressurization CREs**
  - **Starting in the 1990s tracer gas testing demonstrated that, in some plants, inleakage values were much greater than assumed**

CRE Inleakage History

- GDC 19
  - **"Control Room shall be provided ………. 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"**
- TMI Action Item III.D.3.4
  - **Requested in 1980s in response to TMI**
  - **Required submittal of CRE/CREVS Conditions**
- Generic Letter 2003-01
  - **Published in 2003**
  - **Required all licensees to submit measured inleakage value(s) or provide detailed justification of assumed inleakage value**
- TSTF 448
  - **Published in 2007**
  - **Requires Inleakage testing on six year basis for plants that adopt TSTF 448**
  - **Regulatory Guide 1.197 provides test guidance**

CRE Inleakage Testing to support TSTF 448

- ASTM E741 “Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution”
  - Suggested in Generic Letter 2003-01
  - Suggested in Regulatory Guide 1.197
  - Essentially Required in TSTF 448
- Uncertainty Analysis using ANSI Standard PTC 19.1
  - Provides 95% Confidence Intervals
  - Accepted in other parts of the nuclear industry as a valid statistical technique

ASTM Standard E741

- Concentration Decay Test
  - Most useful for Recirculation CREVS
- Constant Injection Test
  - Most useful for Pressurization CREVS
- Constant Concentration Test
  - Primarily a research method since equipment required is complex and data interpretation is questionable

Inleakage Testing using ASTM Standard E741

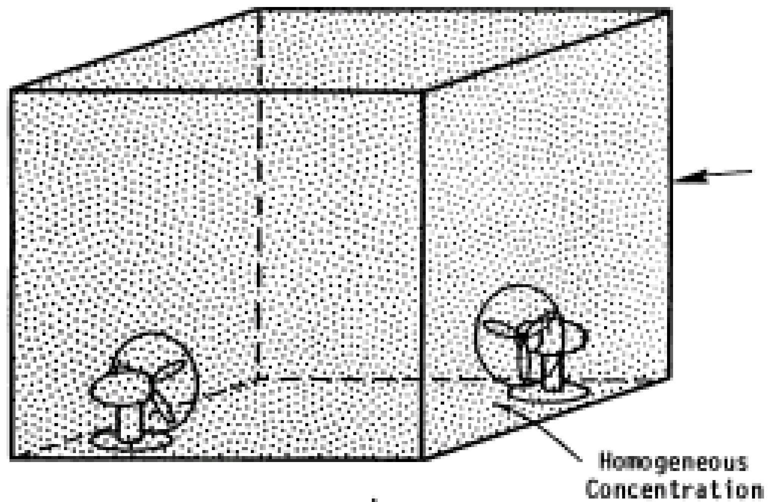
- Inject Tracer gas
  - Pulse for Concentration Decay Test (CDT)
  - Continuously for Buildup/Steady State Test (BSST)
- Mix tracer gas
  - Homogenize and then measure versus time for CDT
  - Homogenize and attain equilibrium concentration for BSST
    - » **Must measure makeup flow rate to obtain inleakage**
    - » **Non-attainment of equilibrium can result in *substantial* uncertainty**
- Use conservation of mass equations to calculate inleakage

Necessary Conditions for a Valid E741 Test

- CRE Volume acts as a *single* zone
- Tracer gas is well mixed in the zone
  – Well stirred reactor theory applies
- Tracer gas concentration is in equilibrium
  – Only necessary for buildup/steady state test
  – Non-equilibrium usually results in *overestimate* of total air inflow into CRE

AIR LEAKAGE BY CONCENTRATION DECAY

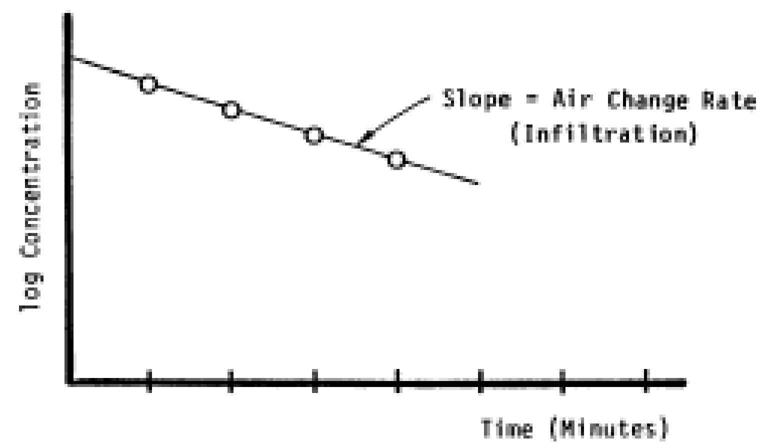
ASTM E-741



1. Inject Tracer
2. Homogenize
3. Measure Decay

$$C = C_o \exp\left(-\frac{L}{V}t\right)$$

Concentration	Time
C_0	0
C_1	10
C_2	20
C_3	30
•	•
•	•
•	•



Concentration Decay Test Equations

$$C = C_0 \bullet \exp(-A \bullet t)$$

$$A = \left(\frac{1}{t}\right) \bullet \ln\left(\frac{C}{C_0}\right)$$

$$A = \frac{L}{V}$$

A=Air Exchange Rate

L=Total Air Inflow Rate

V=CRE Volume

Concentration Decay Test Calculations

$$L_{TOT} = A \bullet V$$

$$L_{TOT} = L_{INLEAK} + L_{M/U}$$

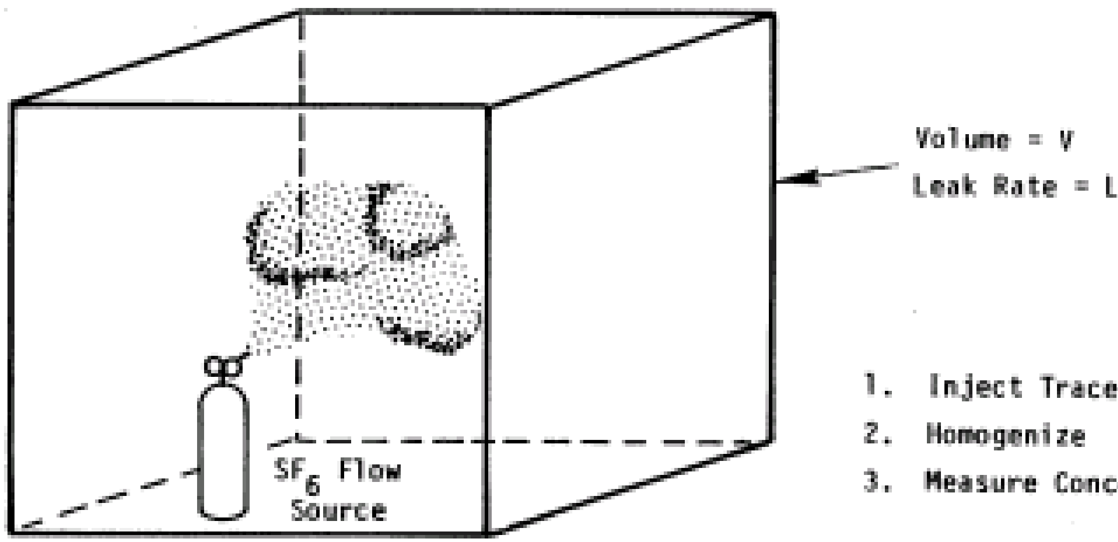
$$L_{INLEAK} = A \bullet V - L_{M/U}$$

No M/U flow in Recirculation CREVS

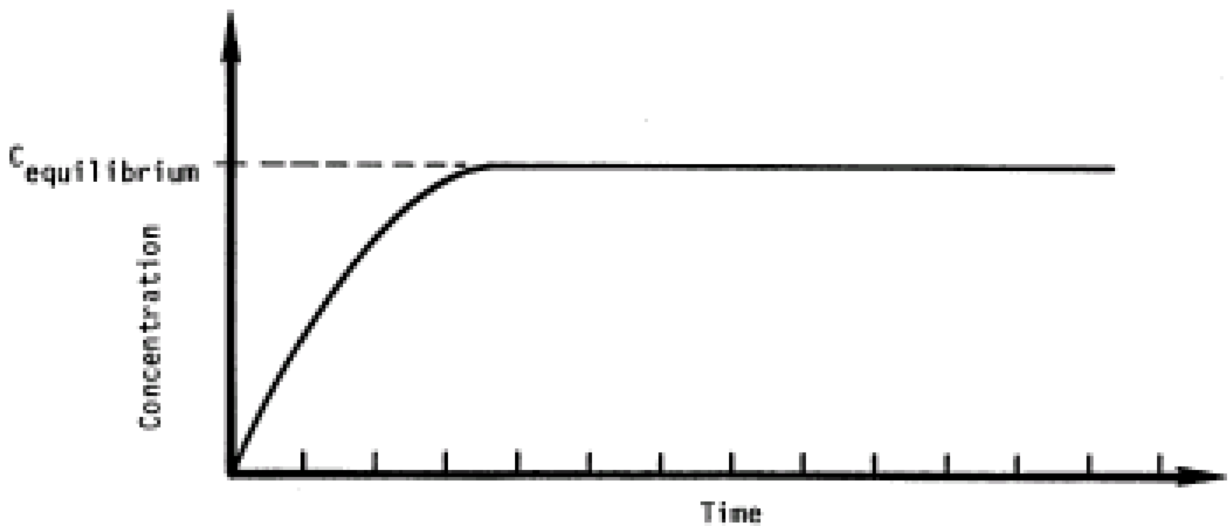
Recirculation CREVS Results

PLANT	CRE Volume (Cu Ft)	Recirculation Mode Inleakage Train A (ACFM)	Recirculation Mode Inleakage Train B (ACFM)	Year of Test
A	184,000	--	NM**	1997
A	184,000	--	469 +/- 26	2006
D	141,800	--	142 +/- 12	1994
D	141,800	--	222 +/- 30	2004
E	364,922	439 +/- 21	442 +/- 23	1997
E	364,992	450 +/- 19	501 +/- 26	1999
E	364,992	583 +/- 32	550 +/- 35	2007

CONSTANT FLOW TEST



1. Inject Tracer at Constant Flowrate
2. Homogenize
3. Measure Concentration in Room



Buildup/Steady State Equation

$$C(t) = \left(\frac{S}{L}\right) \bullet \left[1 - \exp(-A \bullet t)\right]$$

at equilibrium, the exponential term goes to zero

$$C_{EQUIL} = \left(\frac{S}{L}\right)$$

Buildup/Steady State Calculations

$$L_{TOT} = \frac{S}{C_{eq}}$$

$$L_{TOT} = L_{M/U} + L_{INLEAK}$$

$$L_{INLEAK} = L_{TOT} - L_{M/U}$$

Pressurization CREVS Test Results

PLANT	CRE Volume (Cu Ft)	Pressurization Mode Inleakage* Train A (SCFM)	Pressurization Mode Inleakage* Train B (SCFM)	Year of Test
A	184,000	222 +/- 55	88	1997
A	184,000	71	56	2006
B	108,000	80	128 Estimated	1998
B	108,000	0	0	2001
B	108,000	0	0	2007
C	54,000	73	236 Estimated	1998
C	54,000	0	0	2001
C	54,000	0	34	2007
D	141,800	45	-----	1994
D	141,800	64	-----	2004

Conclusions

- No large increases in measured inleakage values over a time interval of years
  - Appears to be more "creep" in Recirculation Inleakage Values
    - » **Suggests that Boundary Condition is more of an Issue**
  - All measured inleakage values result in operator doses well below dose limits in Control Room Habitability analyses
- All plants tested so far have *active* CRH Boundary Control Programs
- In 2009-2010 the majority of plants will undertake their first re-test
  - A summary paper at the 2010 ACC may provide useful insights into the state of Control Room Habitability