Inleakage into Critical Rooms Protected by CO_2 Fire Extinguishing Systems

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Critical Rooms

- Cable Spread Rooms
- Cable Penetration Rooms
- Switchgear Rooms
- Computer Rooms

Nuclear Power and Fire Protection

- Browns Ferry Fire -1975
  - Fire started when a candle was used to test fire barriers in the cable penetration room
  - 1600 cables affected, 600 important to plant safety
  - Almost 7 hours spent extinguishing the fire
  - NRC revises fire protection regulations to incorporate multiple layers of fire protection
    - Fire Barriers
    - Fire Detection
    - Fire Suppression

Nuclear Power and Fire Protection (continued)

- CO_2 Fire Extinguishing Systems are the fire suppression systems used in many nuclear power plant critical rooms
- NFPA 12 Standard "Carbon Dioxide Extinguishing Systems" provides guidance on the design, installation, and testing of these CO_2 systems

NFPA Standard 12 on Carbon Dioxide Extinguishing Systems

- In the nuclear power plant context we often deal with “Total Flooding Systems”
- Distinguish two types of fires
  - Surface fires---subject to rapid extinguishment
  - Deep-seated fires---maintain CO_2 concentration for period of time to extinguish smoldering and also allow cooling of material
- Assumes “fairly” tight room--if inleakage exists, the standard provides for extra CO_2 as a correction

NFPA Design Specifics

- NFPA specifies Minimum Design CO_2 Concentrations for "surface fires" as 20% more than the theoretical minimum concentration but <u>at least 34%</u>
  - i.e. Propane = 36%, Acetylene = 66%
  - Well-studied figures
- Per NFPA 12 Annex D, for "deep-seated" fires (as found in most nuclear power plant critical rooms) the "critical concentration required for extinguishment is less definite"

NFPA Design Specifics (continued)

- NFPA 12 design CO_2 requirements for deep seated dry electric fires in spaces > 2000 ft^3:
  - Design Concentration = 50%
  - 50% concentration w/in 7 minutes, 30% w/in 2 minutes
  - Holding time of *at least* 20 minutes
  - Volume Factor = 0.083 lb CO_2/ft^3 of free volume
  - Quantity based on “fairly tight” enclosures
- Per section 5.4.1.2, “Any possible leakage shall be given special consideration because <u>no allowance</u> is included in the basic flooding factors”
  - No guidance on “SPECIAL CONSIDERATION”

Actions in the event of a fire
(in a normally ventilated room)

- Isolate normal ventilation to room
- Start CO_2 mode room ventilation (isolate or exhaust only)
- Inject CO_2 into room in sufficient quantity to extinguish the fire
- Maintain CO_2 concentration for long enough time to allow cooling of combustible material

How determine room tightness?

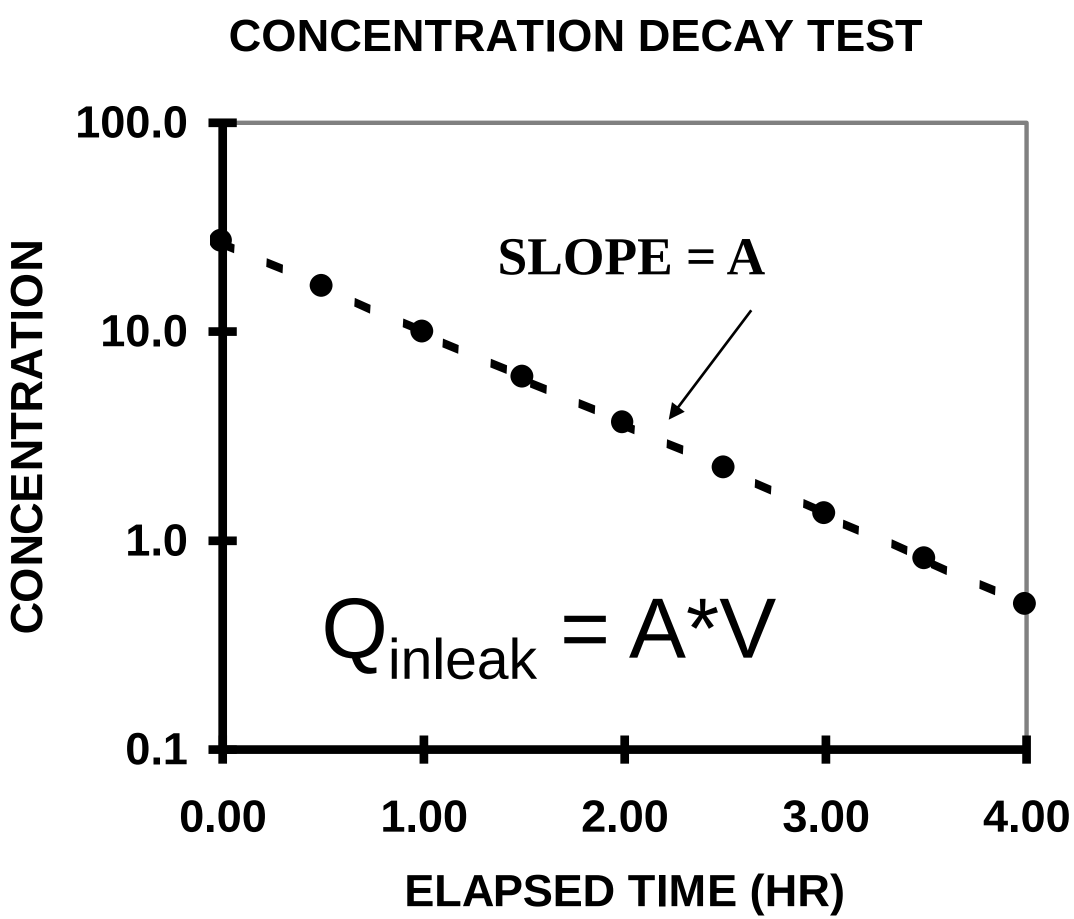
- Measure amount of air leaking into room
  - Inleaking air is ***dilution*** air!!
- Tracer gas test based on ASTM standard is used for Control Room Habitability studies
  - Measure total air inflow into room (air inleakage)
- Test directly *measures* total air inflow into a critical room under *actual* operating conditions
  - Can determine the effectiveness of adjustments or retrofits in the event that measured inleakage value is too large

Tracer Concentration Decay Test
ASTM Standard E741

- Inject a “Pulse” (initial volume) of tracer gas (SF_6) into Room and wait for mixing
- Measure concentration decay as a function of time
- Must know volume of Room
- Test provides Total Air Inflow rate into Room

Tracer Gas Decay Test

TIME	CONC
0.00	26.8
0.50	16.2
1.00	9.8
1.50	6.0
2.00	3.6
2.50	2.2
3.00	1.3
3.50	0.8
4.00	0.5



Ventilation Configuration during CO_2 Injection-Initial Tests

- A Electrical Penetration Room
  - Normal Supply & Return dampers closed, exhaust fans OFF
- A Switch Gear Room
  - Normal Supply & Return dampers closed
- B Electrical Penetration Room
  - Normal Supply & Return dampers closed, exhaust fans OFF
- B Switch Gear Room
  - Normal Supply & Return dampers closed

Measured Total Air Inflow Rates
(ACFM)

	Measured Value	Air Change Rate (ACH)
A Penetration Room	2262+/- 443	2.74
A Switchgear Room	2186 +/- 411	1.89
B Penetration Room	1155 +/- 190	1.40
B Switchgear Room	1711 +/- 149	1.52

Measured Air Change Rates

- None of these rooms qualify as "fairly tight"
- For comparison--published study results:
  - US residential air exchange, median ACH=0.5
  - US low income housing median ACH =0.9
  - Energy efficient homes in Pacific Northwest median ACH=0.25
  - Manufactured homes in Pacific Northwest

    median ACH=0.5
  - Swedish residences *require* <0.5 ACH

Potential Sources of Inleakage

- Isolation Damper by-pass leakage
- Inleakage through adjacent boundaries: walls, floor, ceiling
- Inleakage through penetrations in adjacent boundaries
- Leakage from positive pressure ductwork traversing the room

Ventilation Configuration Adjustments

- B Electrical Penetration Room
  - Normal Supply & Return dampers closed
  - Blank off dampers
- B Switch Gear Room
  - Normal Supply & Return dampers closed
  - Adjust dampers for better seal

Measured Inleakage Flow Rates
(ACFM)

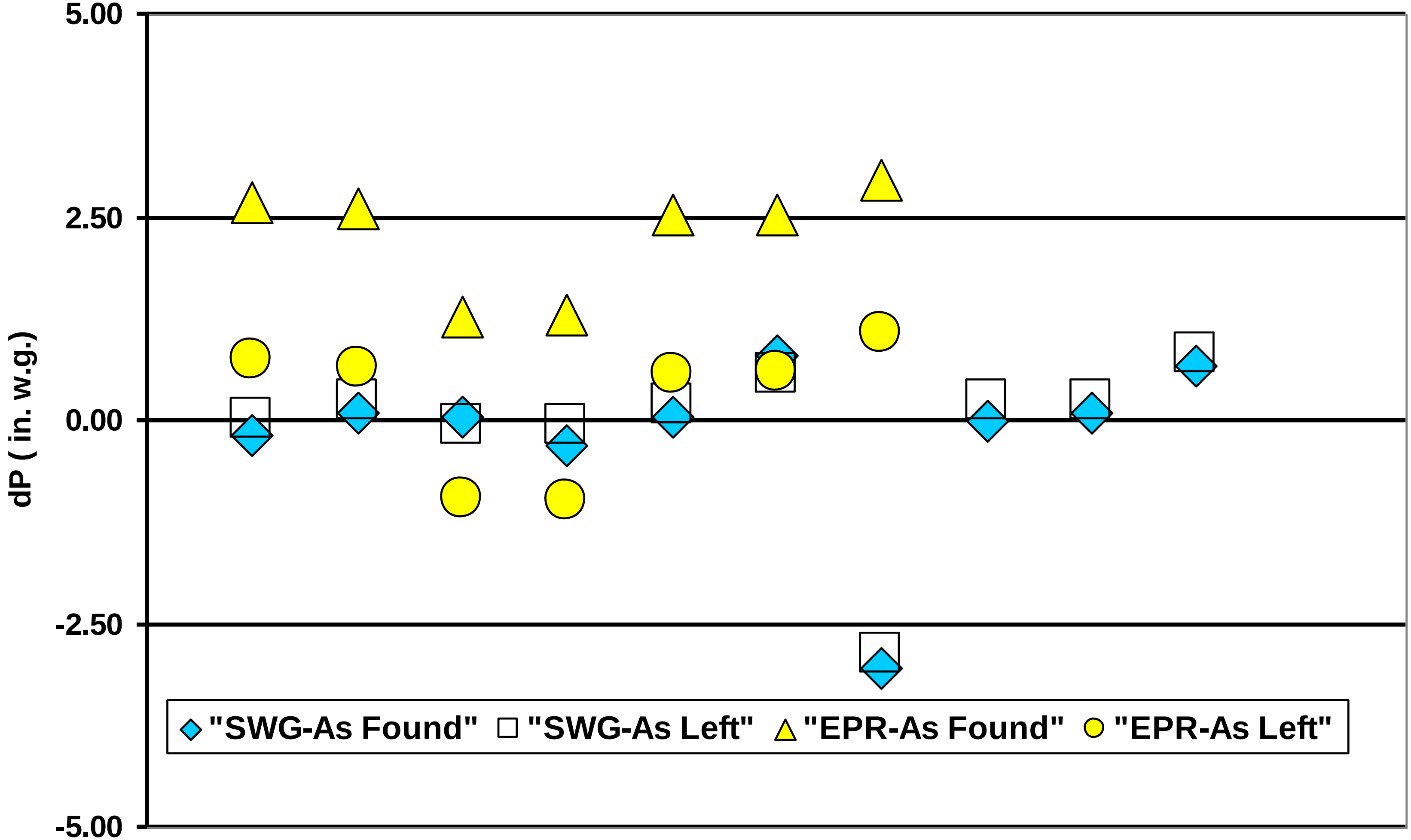
(after adjustments)

	As Found	As Left	Drop
B Penetration Room	1155 +/- 190	529 +/- 70	54%
B Switchgear Room	1711 +/- 149	1097 +/- 63	36%

Measure dP to All Surrounding Areas

- Assists in cost-effective room sealing by ranking possible leakage sites
- Higher values of dP imply potentially greater inleakage from dampers, ducts and walls

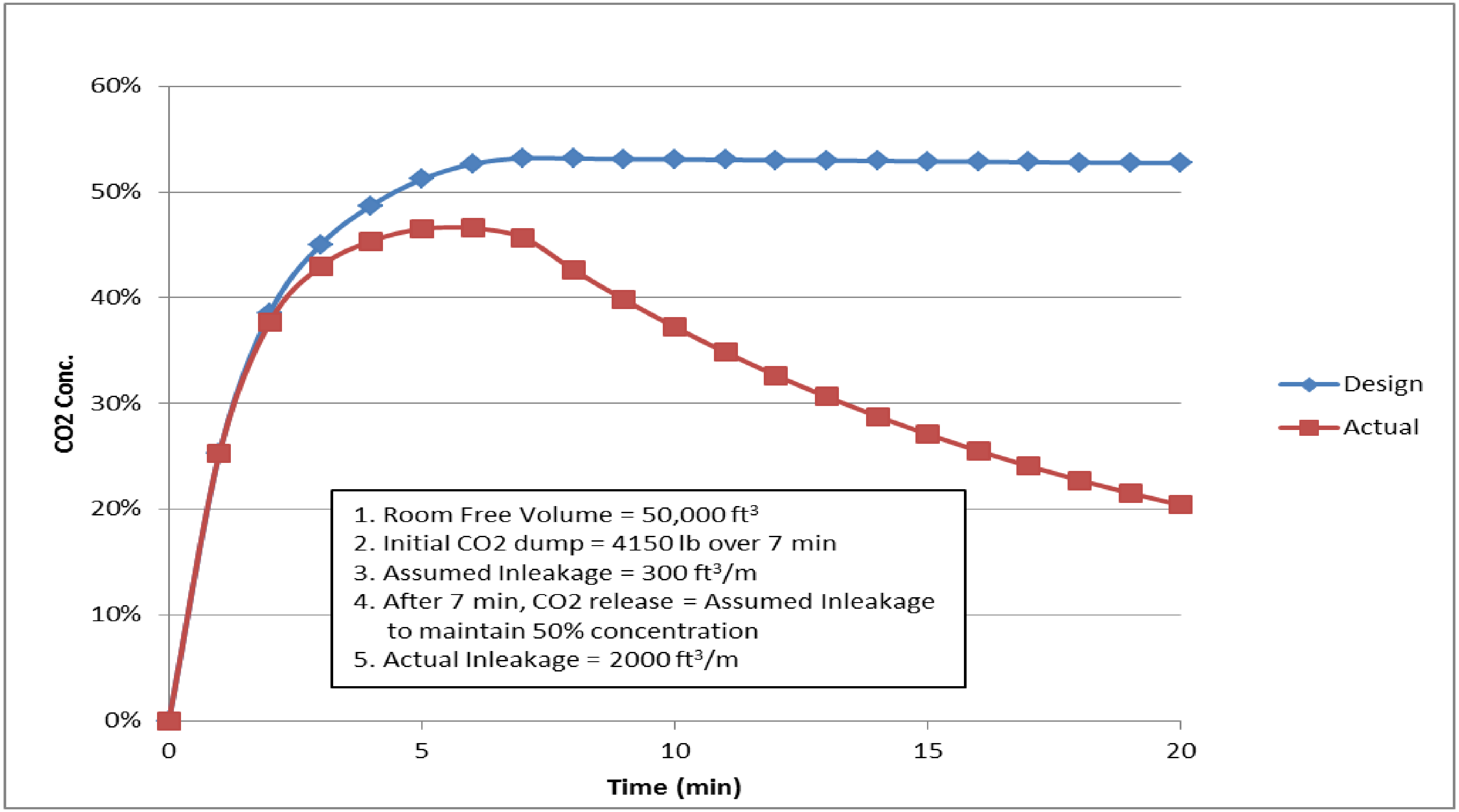
Differential Pressures for B Rooms



Consequences of a “non-tight” room

- Rate of CO_2 concentration increase is slower
  - Takes longer to attain a given concentration
- Ultimate CO_2 concentration will be less than design
- Unlikely to maintain the mandated 20 minute concentration-hold time at a required level
- CO_2 dump may NOT extinguish fire

High Inleakage Effect on a Simulated Design CO_2 Release



Test Conclusions

- Rooms tested do not qualify as “fairly tight”
  - CO_2 Extinguishing systems will not function as designed in leaky rooms
- Tracer gas test provides quantitative measure of air inleakage and room tightness
- Tracer gas test allows assessment of improvement in room tightness as part of sealing or retrofit program
- dP Measurement allows ranking of potential leakage sites/components in critical rooms