Field Evaluation of ASTM E741-00 in Relation to Control Room Habitability Testing and Boundary Maintenance in Nuclear Power Plants.

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Control Room Habitability Testing

Reference Documents

- Originally directed by USNRC Generic Letter 2003-01 (GL2003-01)
- Periodic retest directed by TSTF 448 (Technical Specifications Task Force)
- And TSTF 508 (Clarification of items in TSTF 448)

Other Reference Documents

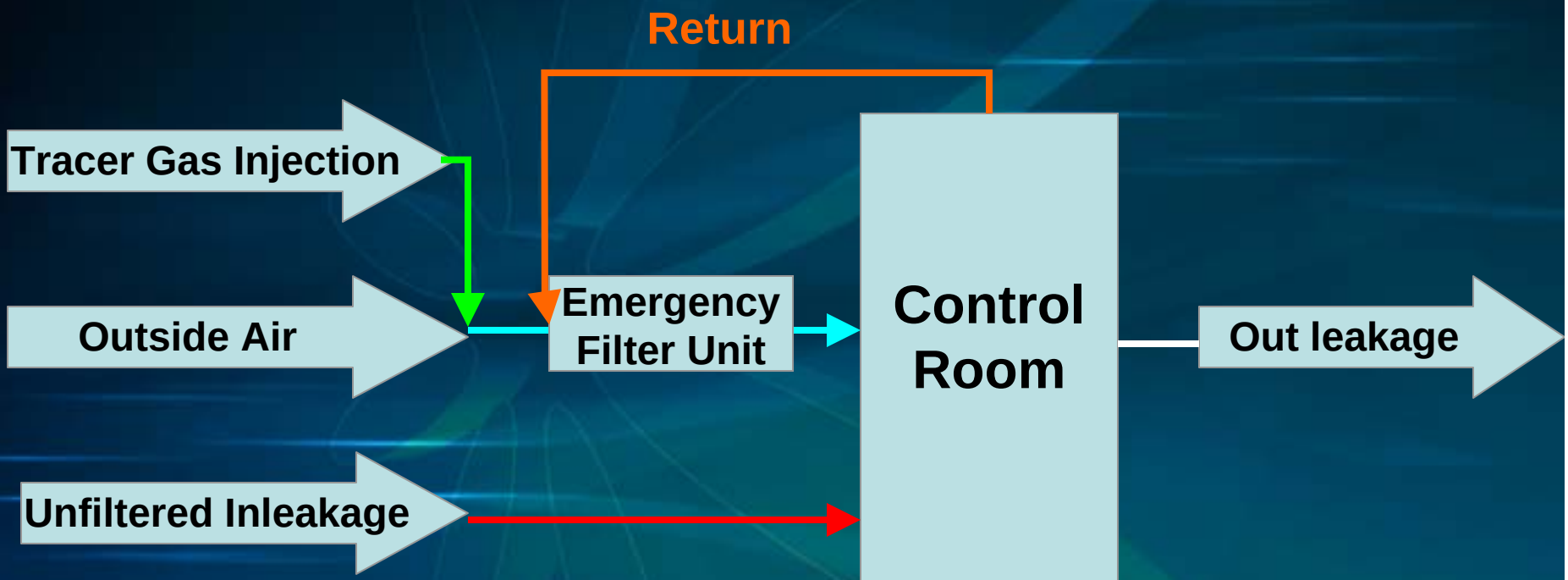
- Reg. Guide (RG) 1.196 “Control Room Habitability At Light-Water Nuclear Power Reactors”
- RG 1.197 “Demonstrating Control Room Envelope Integrity At Nuclear Power Reactors”

Other Reference Documents

- Nuclear Energy Institute (NEI) 99-03 “Control Room Habitability Assessment Guidance”
- American Society for Testing and Materials (ASTM) E-741 “Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution”
- American Society of Mechanical Engineers (ASME) PTC 19.1-1998, “Test Uncertainty” (Reaffirmed 2004).

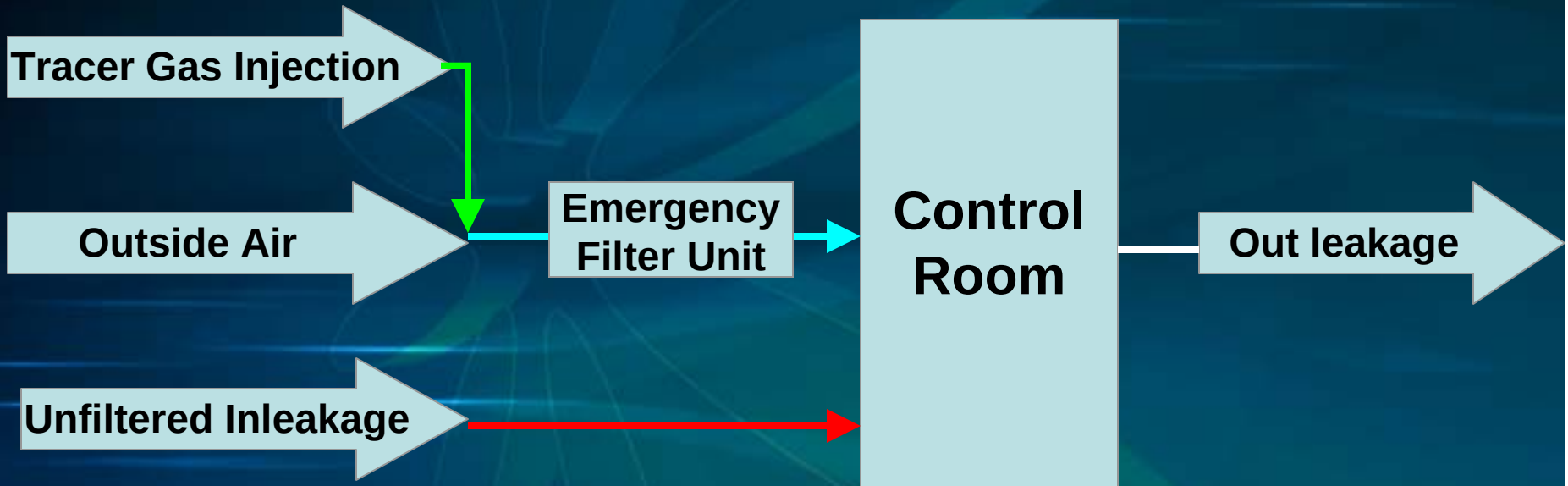
Simplified Test Setup #1

(Filtered Return)



Simplified Test Setup #2

(No Filtered Return)



Case 1

Performed at a European Power Plant

- Is a PWR
- Outside air and return air are supplied to the emergency filter trains.
- Ventilation equipment is located outside of the control room pressure boundary.
- Initial walkdown was performed and several vulnerabilities were identified.
- Repairs were made to these areas.

Case 1

Test Results

Train Configuration	Inleakage with Pitot Outside Air (SCFM)	Inleakage with Tracer Gas Outside Air (SCFM)
Train “A” Pressurization As Found	81 ± 7	78 ± 9
Train “B” Pressurization As Found	74 ± 3	70 ± 9

Case 1

Leak Identification

- **Bubble Solution Leak Detection**
- **Smoke Tubes**
- **Audible**

Case 1

Leak Locations

- Leaking conduit connections
- Improperly sealed inspection doors on ducting
- Leaks in flexible duct connections
- Leaking instrument penetrations

Case 1
Adventures In Duct Tape

Sealing the Cracks

Case 1
Adventures In Duct Tape

Sealing the Cracks

- **Temporary repairs were made using duct tape.**
- **Testing continued during the temporary fixing and a net decrease in overall inleakage was observed.**
- **Retesting of both Trains was performed and a reduction in overall unfiltered inleakage was observed to be about ½ of the original value.**

Case 1

Test Results

Train Configuration	Inleakage with Pitot Outside Air (SCFM)	Inleakage with Tracer Gas Outside Air (SCFM)
Train “A” Pressurization As Found	81 ± 7	78 ± 9
Train “A” Pressurization After Repairs to Unit	38 ± 4	37 ± 6
Train “B” Pressurization As Found	74 ± 3	70 ± 9
Train “B” Pressurization After Repairs to Unit	40 ± 6	40 ± 8

Case 2

- US Domestic Plant
- PWR
- Outside air and return air are supplied to the emergency filter trains.
- Ventilation equipment is located inside of the control room pressure boundary.
- Dual isolation dampers for normal outside air supply.

Case 2

Three Modes of Operation Were Tested

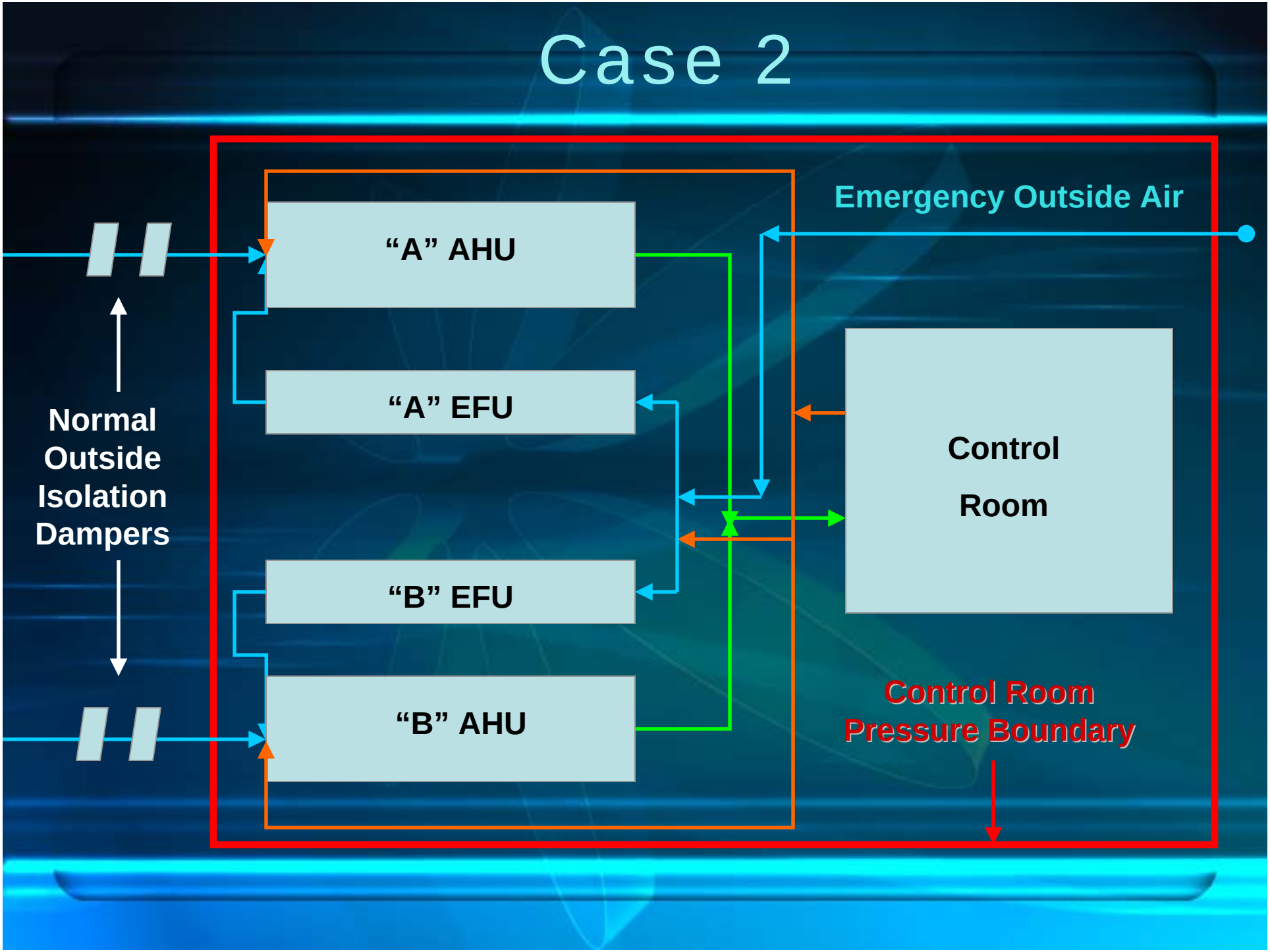
- Train “A” Air Handling Unit (AHU) and “A” Train Emergency Filter Unit (EFU) With One Of The Normal Outside Isolation Dampers Failed Open.
- Train “B” Air Handling Unit (AHU) and “B” Train Emergency Filter Unit (EFU) With One Of The Normal Outside Isolation Dampers Failed Open.

Case 2

Three Modes of Operation Were Tested

- Train “B” Air Handling Unit (AHU) with “A” And “B” Train Emergency Filter Units (EFU) Operating With One Of The Normal “B” Outside Isolation Dampers Failed Open.

Case 2


Emergency Outside Air
"A" AHU
"A" EFU
"B" EFU
"B" AHU
Control
Room
Normal
Outside
Isolation
Dampers
Control Room
Pressure Boundary

Case 2

Test Results (Initial)

Test Configuration	Inleakage with Pitot Outside Air (SCFM)
Train “A” Emergency Mode With Single Damper Active Failure	13 ± 10
Train “B” Emergency Mode With Single Damper Active Failure	49 ± 9
Train “B” Emergency Mode With Both Emergency Trains Operating And A Single Damper Active Failure	124 ± 23

Case 2

Repairs

- All Four Dampers For The Normal Outside Air Intakes Were Replaced With Bubble Tight Dampers.
- No Other System Modifications Were Performed.

Case 2

Test Results (Retest)

Test Configuration	Inleakage with Pitot Outside Air (SCFM)	Inleakage with Tracer Gas Outside Air (SCFM)
Train “A” Emergency Mode With Single Damper Active Failure	10 ± 18	10 ± 16
Train “B” Emergency Mode With Single Damper Active Failure	16 ± 13	15 ± 12
Train “B” Emergency Mode With Both Emergency Trains Operating And A Single Damper Active Failure	15 ± 8	15 ± 8

Case 2

Conclusion

- **The “A” emergency ventilation train demonstrated essentially the same inleakage for both tests.**
- **The “A” train’s original normal outside air dampers appeared to seal well and the addition of the new dampers did little to change this leakage.**

Case 2

Conclusion

- **The “B” emergency ventilation train demonstrated a vast improvement in the reduction of unfiltered inleakage after the dampers were replaced in either single or duel filtration mode.**
- **The unfiltered inleakage measured on the “A” and “B” trains after damper replacement is most likely a system characteristic and not associated with a single component.**

Case 3

- **Domestic Plant**
- **PWR**
- **HVAC system consists of three 50% capacity units (“A”, “B”, & “C” Trains).**
- **Each train consists of:**
  - **One Air Handing Unit**
  - **One Cleanup Unit (HEPA / Adsorber / HEPA)**
  - **One Outside Air Pressurization Unit (HEPA / Adsorber / HEPA)**
- **Only two of the three units operate at any given time.**

Case 3

- **Equipment Rooms Are Part Of the Control Room Pressure Boundary.**
- **Equipment Rooms Consist Of:**
  - **One Air Handing Unit**
  - **One Cleanup Unit (HEPA / Adsorber / HEPA)**
- **Outside Air Pressurization Unit (HEPA / Adsorber / HEPA) Are Outside The Control Room Pressure Boundary.**

Case 3

Test Results (Initial)

Train Configuration	Inleakage with Pitot Outside Air (SCFM)	Inleakage with Tracer Gas Outside Air (SCFM)
Train “A” and “B” Pressurization	115 ± 10	114 ± 20
Train “A” and “C” Pressurization	0 ± 9	0 ± 18
Train “B” and “C” Pressurization	76 ± 10	72 ± 18

Case 3

- **Train “A” / “C” shows minimal leakage**
- **Train “B” appeared to be the common factor in the higher leak rate.**
- **A Halide Generator and A NUCON Halide Detector were used to introduce tracer gas into the “B” equipment room and look for communication between zones.**

Case 3

Repairs In “B” Equipment Room

- Sealed penetrations
- Sealed floor joints
- Sealed wall joints
- Sealed ceiling joints

Case 3

Test Results (Retest)

Train Configuration	Inleakage with Pitot Outside Air (SCFM)	Inleakage with Tracer Gas Outside Air (SCFM)
Train “A” and “B” Pressurization	11 ± 6	11 ± 12
Train “B” and “C” Pressurization	64 ± 8	62 ± 15

Case 3

Conclusion

- Extending the sealing program should reduce the unfiltered inleakage in the “B” / “C” combination.

Case 4

- **Two unit PWR with a common control room**
- **Control room volume >300,000 Ft^3**
- **Ventilation equipment is located inside the control room pressure boundary**
- **Testing occurred because of the six year cycle and a modification to dampers**

Case 4

- **The system consists of an “A” and “B” train at 100% capacity each**
- **Each train has the following subsystems**
  - **One Air Handling Unit (AHU)**
  - **One emergency cleanup (recirculation) unit with installed HEPA/adsorber/HEPA**
  - **One emergency pressurization (outside air) unit with installed HEPA/adsorber/HEPA**

Case 4

- **“A” train test was well within the allowable unfiltered inleakage specification and was similar to the values determined in the initial test.**
- **“B” train tested outside of the allowable limits for unfiltered inleakage.**

Case 4

Test Results

Train Configuration	Inleakage with Pitot Outside Air (SCFM)	Inleakage with Tracer Gas Outside Air (SCFM)
Train “B” Pressurization Initial	36 ± 6	32 ± 4
Train “B” Pressurization retest	20 ± 3	18 ± 3

Case 4

- **The system had been well maintained and thoroughly inspected.**
- **Further inspection revealed several leaks on instrument air lines at the compression fitting.**
- **Plant personnel inspected these leaks and estimated the leakage at these fittings to be approximately 10 CFM based on the bubble method of leak estimation.**

Case 4

- **Repairs were made and a net reduction in total unfiltered inleakage was reduced by approximately 15 SCFM. This reduced the total unfiltered inleakage to an acceptable level.**
- **Due to the first “B” train failure, a retest will be required in three years.**

Case 4

Conclusion

- **Although the pressure boundary had been well maintained, some leaks can be introduced into the system.**
- **Routine maintenance, replacement of components, and aging of the system can all effect system inleakage.**

Case 5

- **A number of questions have been raised concerning the accuracy of ASTM E741 to measure low inleakage with a large outside air make-up.**
- **NEI 99-03 states that if the allowable inleakage is small (<100 CFM) and the outside air make-up is large (>1000 CFM) then the overall test uncertainty can approach 100% of the measured value (This assumes a 10% error in the outside airflow measurement).**

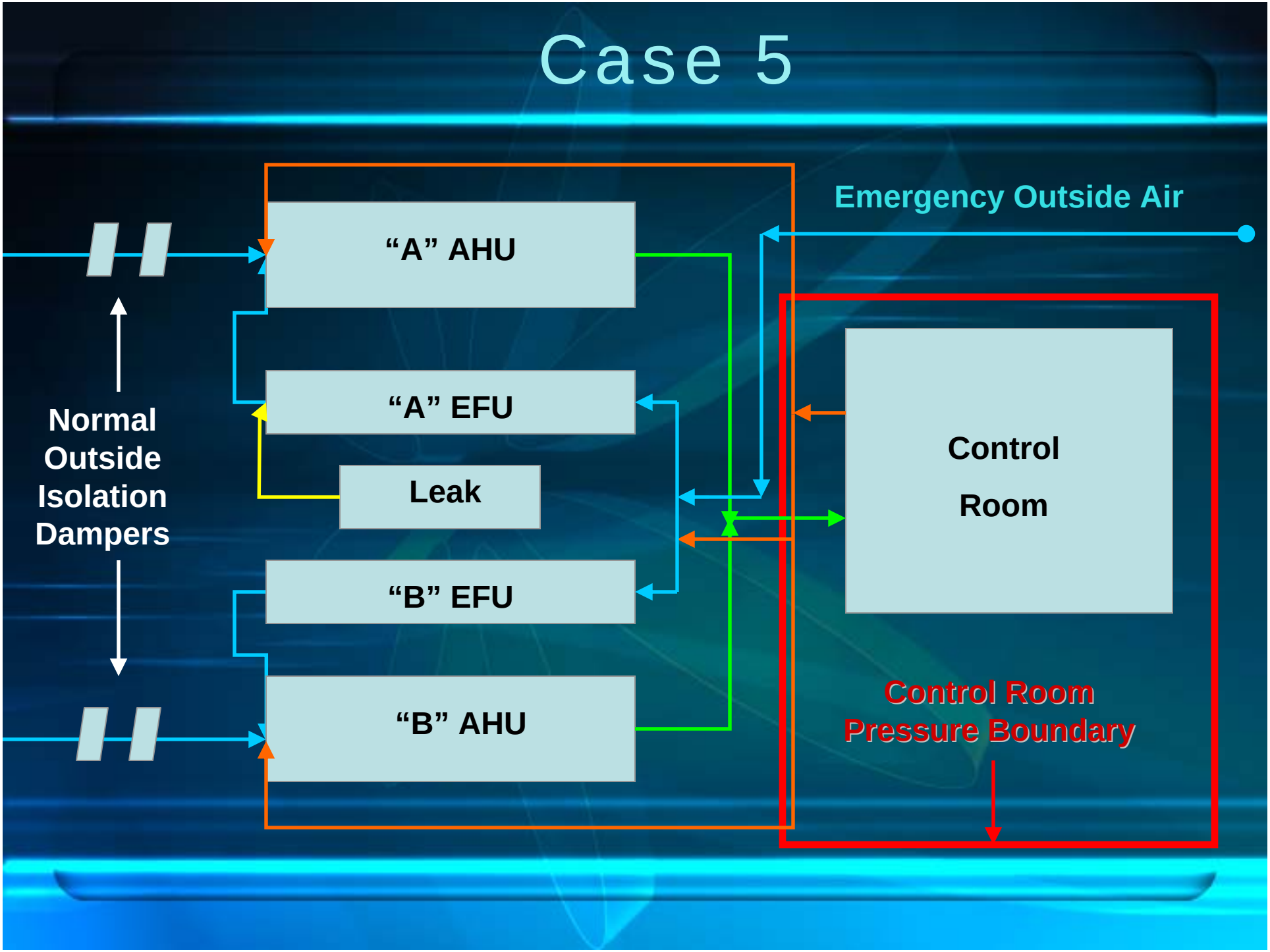
Case 5

- **While performing an inleakage test at a European nuclear plant the opportunity to demonstrate the accuracy of the constant injection method per ASTM E741 was provided.**
- **The plant is a single PWR design**
- **The control room is the only part of the pressure boundary with all of the ventilation and filtration units located outside of the boundary**

Case 5

- **The unfiltered inleakage was first established with no introduced leak.**
- **Two calibrated Brooks mass flow meters with a combined capacity of 38.2 SCFM were attached to the emergency outside air filtration unit.**
- **Outside makeup air (pressurization) was approximately 700 SCFM.**

Case 5


Emergency Outside Air
"A" AHU
"A" EFU
Leak
"B" EFU
"B" AHU
Normal Outside Isolation Dampers
Control Room
Control Room Pressure Boundary

Case 5

Test Results

Initial measured unfiltered inleakage	5 ± 5 SCFM
Simulated leak injection rate	38.2 SCFM
Estimated contribution to total inleakage from measured inleakage	0[A] to 15 SCFM
Projected inleakage	53.2 SCFM
Measured inleakage during injected leak experiment	56 ± 5 SCFM

Case 5

Footnote A

- **Zero inleakage was the least likely case, therefore the upper-range value was used for the inleakage prediction. The maximum estimated inleakage of 15 SCFM was derived by assuming that the uncertainties would remain essentially constant and were added to the worst-case inleakage based on the initial measurement.**

Case 5

Conclusion

- **This experiment demonstrates the accuracy of the ASTM E741 constant injection method to detect very low unfiltered inleakage.**
- **The NEI 99-03 assumption of 10% error while measuring the outside air prevents the accurate measurement of low inleakage is unrealistic.**

Case 5

Conclusion

- **By applying ASME PT-19.01 methodology for the determination of uncertainties, the relative contributions of all potential measurement errors can be accounted for.**

End Of Presentation

Thank you

Any Questions?