AmerenUE
Callaway Plant

PO Box 620
Fulton, MO 65251

July 16, 2007

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Mail Stop P1-137
Washington, DC 20555-0001

ULNRC-05427

Ladies and Gentlemen:

DOCKET NUMBER 50-483
CALLAWAY PLANT UNIT 1
UNION ELECTRIC CO.
FACILITY OPERATING LICENSE NPF-30
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
CONCERNING GENERIC LETTER 2003-01,
"CONTROL ROOM HABITABILITY"

References:
1. ULNRC-04885, dated August 11, 2003.
2. ULNRC-05104, dated December 15, 2004.
3. ULNRC-05298, dated June 6, 2006
4. NRC letter dated November 7, 2006, from Jack Donohew, NRC, to Charles Naslund, AmerenUE

By letter dated August 11, 2003 (Reference 1), Union Electric Company (AmerenUE) transmitted its preliminary response to NRC Generic Letter 2003-01, "Control Room Habitability." In the response AmerenUE identified that it would need to develop an alternate method of integrated inleakage testing because of the Callaway Plant Control Room/Control Building design. AmerenUE contracted with Brookhaven National Laboratory and performed this alternate integrated inleakage testing for Callaway Plant on September 17-19, 2004 using the Atmospheric Tracer Depletion (ATD) method. The results of the testing were transmitted by AmerenUE letters dated December 17, 2004 and June 6, 2006 (References 2 and 3, respectively).

During review of the responses, NRC developed a request for additional information (RAI) that was transmitted by its letter dated November 7, 2006 (Reference 4). In the

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RAI the NRC asked for two specific pieces of information. First, the NRC staff requested that the information required to evaluate the acceptability of the test method be submitted in accordance with bullets in the Regulatory Guide 1.197. Second, as it is AmerenUE's position that the ASTM E741 test method is not applicable for use with the Callaway Plant Control Room/Control Building configuration, the NRC staff requested an assessment of the capability of the alternative Atmospheric Tracer Depletion test method to provide an equivalent level of quality and safety in determining the unfiltered inleakage into the Callaway Plant Control Room envelope.

The response to the first request is hereby provided by the enclosure to this letter, which is a report from Brookhaven National Laboratory, titled "Information Required for Alternative Test Methods to determine in-leakage of air in the Control Room Envelope." The report is organized in the same way as the requirements of Regulatory Guide 1.197, "Demonstrating Control Room Envelope Integrity at Nuclear Power Reactors," with each section in the report addressing the corresponding bullet in the Regulatory Guide. It should be noted that Figures 2 and 3 in the report refer to Wolf Creek but they are also applicable to Callaway since both plants are of SNUPPS design.

The response to the second request is also contained in the enclosure. Specifically, Section 11 discusses the correlation of results obtained from using the two test methods (ASTM E741 and ATD) for a compatible test configuration at another facility. Although an ASTM E741 test was not performed at Callaway Plant (due to Callaway Plant's unique Control Room/Control Building configuration), the test case described in Section 11 does demonstrate that the ATD results are comparable to those obtained from the ASTM E741 test method.

In addition, Section 12 of the enclosed report provides a discussion of why the ATD test method is well suited to the conditions found at Callaway Plant. It also provides a comparison of the ATD test method and other tracer gas techniques to the ASTM E741 method. In that comparison it is shown that the ATD test meets 92% of the applicable ASTM E741 sub-elements while most standard approaches for measuring inleakage have met only 89% of the applicable ASTM E741 sub-elements.

The information provided in Sections 11 and 12 of the report confirms that the ATD method is consistent with the ASTM Standard and provides comparable results to ASTM E741. Alternate testing that is consistent with the ASTM E741 method and provides comparable results provides an equivalent level of quality and safety for quantifying the unfiltered inleakage into Callaway Plant Control Room envelope.

It should be noted that no regulatory commitments are made per this letter or its attachment. For any questions regarding this issue, please contact Scott Maglio at 573-676-8719.

I declare under penalty of perjury that the foregoing is true and correct.

Sincerely,

Executed on: July 16, 2007

Luke H. Graessle
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Enclosure

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Brookhaven National Laboratory
Energy, Environment, and National Security Directorate
Environmental Sciences Department

Information Required for Alternative Test Methods to determine in-leakage of air in the Control Room Envelope.

Revision 1

June 8, 2007

*Prepared by*______________________ *Date:* 6/8/07
Terry Sullivan

Technical Review by: ______________________ *Date:* 6/8/07
John Heiser

Information Required for Alternative Test Methods to determine in-leakage of air in the Control Room Envelope.

Regulatory guides describe methods acceptable to the NRC staff for demonstrating compliance with regulations. Regulatory Guide 1.197 (NRC, 2003) provides guidance on the type of information the staff needs to assess the capability of an alternative test method to demonstrate (Control Room Envelope) CRE integrity. Any alternative test method should incorporate characteristics for test attributes detailed in Section 4 of Appendix I of NEI 99-03 (NEI, 2001) with the clarification noted under regulatory Position 1, "Testing." Regulatory Guide 1.197 recommends the CRE integrity be tested using the approach specified in the American Society for Testing and Materials (ASTM) consensus standard E741, "Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution," (ASTM, 2000). ASTM E741 was not designed for pressurized systems such as those found in some control rooms and alternative testing techniques are often used in these cases. Regulatory Guide 1.197 requires a response to the following 12 questions in order to permit NRC to judge the acceptability of testing techniques that are alternatives to those specified.

1. Summary of the test method

During an emergency, air entering the control room envelope is filtered through a charcoal system using the Control Room Emergency Ventilation System (CREVS). The atmospheric tracer depletion (ATD) method uses perfluorocarbon tracers (PFTs) that are part of the normal background as surrogates for infiltration of unfiltered air into the Control Room Envelope (CRE). The four PFTs of 400 molecular weight are retained by the charcoal filters. Thus, if there were no unfiltered in-leakage (UI), at steady state, the concentration of these PFTs in the CRE would be the same low level as in the outflow of the charcoal filters; a slightly higher level in the CRE would mean a slight amount of UI. Figure 1 provides a simplified representation of the system. Through measuring of these PFTs in air outside the CRE (e.g. background concentration C_b) immediately after passing through the charcoal filters (filtered concentration C_f), and within the CRE (C_{CRE}), and using the known flow rate through the filter system, an accurate measure of in-leakage (Q_u) flow rate can be obtained.

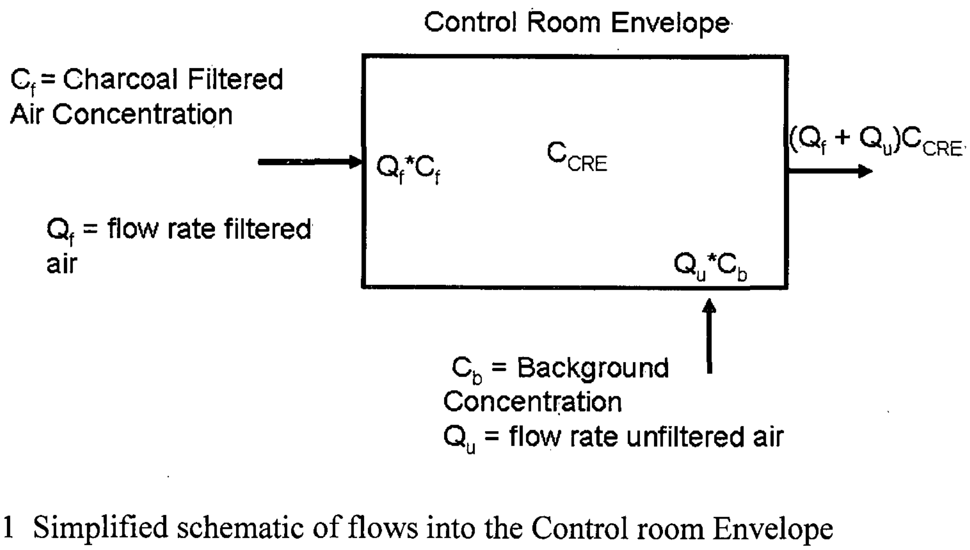

Figure 1 Simplified schematic of flows into the Control room Envelope

To perform appropriate ATD determinations, it is essential that measurements be made under steady state (SS) conditions – that is, the output depleted concentrations of the charcoal systems being used must be constant *and* the concentrations in the locations being sampled must no longer be changing. In principle, the stable performance of charcoal cells should be ascertained ahead of the actual in-leakage testing to be sure they are appropriately characterized and any portable charcoal systems used to accelerate the approach to steady state (SS) should also be evaluated; the systems should also be checked for potential interferences from other components already on the charcoals. In practice, these measurements are usually made at the time of actual in-leakage testing.

The schematic in Figure 1 is simplified and can be adjusted to address more complicated situations such as the potential for in-leakage into equipment rooms or other areas that are part of the CRE. In many cases, the CRE is not a single well-mixed zone – a requirement for successful implementation of any tracer testing. This was the case for SNUPPS (Standard Nuclear Unit Power Plant System) designed plants – the CRE in these systems consists of 3 distinct zones. The modeling of such situations is specified in the test design (TTC-TD-01, 2003) and developed specifically within the Wolf Creek and Callaway plants' testing procedures. For successful implementation, the mixing within such distinct zones must be demonstrated as well mixed.

It is important to note that the integrated ATD testing is a comprehensive approach to determining UI in a CRE – regardless of the pathway by which such UI arrives at the CRE. This is especially relevant to CREs which are contained within other zones or buildings of the plant such as at the Wolf Creek and Callaway plants.

2. Description of the test apparatus and tolerances;

The test apparatus brought to the Nuclear Power Plant consists of air sampling equipment to measure the PFT concentrations. These are described in detail below. In addition, calibrated ancillary measurement tools (flow meters, voltmeter, temperature recorders, and delta pressure meter) need to be performance-verified and miscellaneous materials (polyurethane tubing – 1/8″ OD by 1/16 in ID, shipping containers) as well as appropriate data sheets need to be prepared prior to testing. The flow meters are used to measure flow into the sampling equipment.

In order to improve mixing in certain zones and to reduce the time required to reach equilibrium, the utility may be asked to supply additional equipment – floor fans to enhance mixing and portable charcoal filter systems to accelerate the removal of background level of tracers down to the steady state level needed for accurate test results.

The test apparatus used back at Brookhaven consists of the sampler desorbers and the gas chromatograph (GC) system used to analyze the samples collected at the plant. The capability of the GC analysis system is matched to that of the field sampling equipment, to provide sufficient sample volume (i.e., sampling duration) to meet the measurement

needs with sufficient precision._ An example of this matching of capabilities is provided next, for the case of SNUPPS designed plants.

Depending on the ventilation systems' charcoal-filtered rates and volumes of the zones, the predicted ATD performance suggests sampled air will have fractional depletions running from 1.0 (outside air into the Control Building (CB) – thus, no depletion), to ~0.25 (CB steady state levels with charcoal filtration operating), to 0.001 to 0.01 (at steady state levels within the control room), and to <0.001 (Emergency Ventilation System—EVS charcoal filtered discharge air). Thus, collecting adequate sample volumes to quantify each of these levels and to automate that collection as much as possible are important goals.

Four types of sampling systems can be used – two automatic collection systems and two types that require manual change of sampling tubes. The Sequential Air Sampler (SAS) is a 20-tube automated sampler that collects air at high sampling rates (up to 550 mL/min) and is used where fractional depleted concentrations will be low – in the CR. The Air Pro (AP) is a 2-channel pump that is also capable of high flow-rate (up to 600 mL/min) sampling on two sampling tubes simultaneously and from ductwork where there is several inches of vacuum or pressure; the sampling tubes must be manually changed. The Brookhaven Atmospheric Tracer Sampler (BATS), an automated system with 23 tubes, is a low flow-rate (50 mL/min) sampler for where concentrations are higher and samples are needed from many different elevations. Lastly, many Personal Air Samplers (PASs) with moderate flow rates (150 mL/min) can be used at different locations on the CB elevations to verify good mixing.

The tolerances of the GC system and the flow rate determinations of the samplers are considered in the development of the testing plan and procedures. The GC system has a limit of detection (LOD) for the multiple PFTs of about 40 counts (GC peak area counts); thus, the minimum counts desired in a sample is about 4000 counts. Normal background air has an average surrogate ambient PFT (mcPDCH) concentration of ~7700 counts/L. With the SNUPPS design used at the Wolf Creek and Callaway plants, the following arrangement of samplers was used, Figure 2, to allow appropriate sample volume collection for the control room envelope (CRE) which includes the sample locations near RA (return air grill), CREVS (Control Room Emergency Ventilation System), Equipment Room A, ER_a and Equipment Room B, ER_b. The type of sampler and sample duration are specified in Table 1a. Samples were also collected from the Control Building, Figure 3, which includes sample locations either near the return air or supply air grills or the CBEVS, Control Building Emergency Ventilation System) inlets and outlets, Table 1b

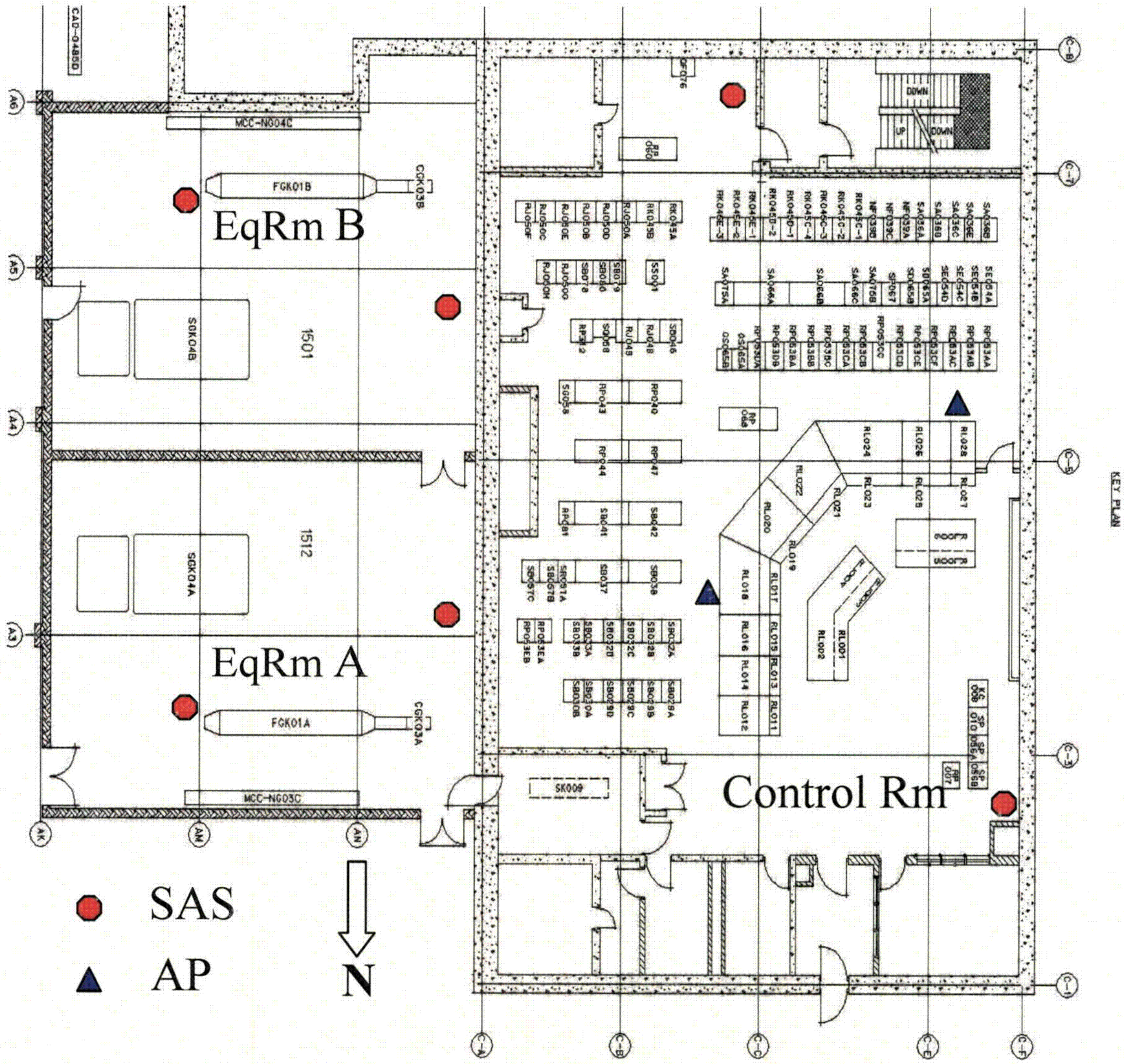

Figure 2 Control room Envelope Sample Locations used at the Wolf Creek plant.

Table 1a. Control Room Envelope Sampling Systems and Sample Quantity, Duration, Rates, and Locations

Envelope	Zone	Sampling Locations	Sampler(5)	Chan #/Qty	Tubes /Site	Comments
CRE	CR	RA grill #1	SAS(1) #1	1	20	1-h samples (16) from ~1600
	"	" #2	SAS #2	1	"	Friday to 2-h samples by 0900 Saturday (4) – 24 h total
	"	Near CR operator	AP(2) #1	1,2	3,3	~2-h samples on the Saturday only
	ER_a	Near CREVS	SAS #3	1	20	1-h samples (16) from ~1600
	"	@ 300 cfm RA	SAS #4	1	"	Friday to 2-h samples by 0900 Saturday (4) – 24 h total
	CREVS	CREVS inlet	AP #2	1	5	~1-h samples at ~300 mL/min; 2 on Friday (1500-1700) & 3 on Saturday
	"	CREVS outlet	"	2	3	~3-h samples at ~600 mL/min; 1 on Friday (1500-1800) & 2 on Saturday; 2 in series
	ER_i	Near CREVS	AP #3	1	4	~1-h samples at 600 mL/min on
	"	Near RA grill	"	2	4	Saturday only

(1)Each SAS (Sequential Air Sampler) automatically changes tubes (up to 20 times), sampling at ~550 mL/min (~33L/h)

(2)All Air Pro (AP) channels at 550 to 600 mL/min unless otherwise indicated; tubes are manually changed

(3)Brookhaven Atmospheric Tracer Sampler (BATS) automatically changes tubes (23), sampling at ~50 mL/min (~3L/h)

(4)All Personal Air Samplers (PASs) at 150 mL/min; tubes are manually changed; sampling only on 2nd day

(5)A total of 4 SASs, 4 APs, 6 BATS, and 14 PASs will be used

- the BATS 23 sampling tubes are permanently-installed stainless steel tubes containing adsorbent
- the other 3 samplers use glass sampling tubes with adsorbent; these are called CATS (capillary adsorption tube samplers)

Table 1b. Control Building Sampling Systems and Sample Quantity, Duration, Rates, & Locations

Envelope	Zone	Sampling Locations	Sampler	Chan #/Qty	Tubes /Site	Comments
CB	El 2000	Active RA grill	BATS[3]#1	1	11	2-h samples (1700 Friday to 1500 Saturday)
	"	4 areas	PASs[4]	4	4	~1-h samples; 2 each SWGR1/2 on Saturday
	El 2016	Active RA grill	BATS #2	1	11	2-h samples (1700 Friday to 1500 Saturday)
	"	4 areas	PASs	4	4	~1-h samples, 3 in Corr1/2, 1 in ER_a-Saturday
	"	CBEVS inlet	BATS #3	1	10	5 1-h samples @ 1700 Fri; 5 on Saturday
	"	CBEVS outlet	AP #4	1	3	~3-h sam; 1st tube; 1 1500-1800 Friday; 2 Sat.
	"	"	"	2	3	~3-h sam; 2nd tube; 1 1500-1800 Friday; 2 Sat.
	El 2032	Active RA grill	BATS #4	1	11	2-h samples (1700 Friday to 1500 Saturday)
	"	3 areas	PASs	3	4	~1-h samples from 3 locations on Saturday
	El2073½	Active RA grill	BATS #5	1	11	2-h samples (1700 Friday to 1500 Saturday)
	"	3 areas	PASs	3	4	~1-h samples from 3 locations on Saturday
	Any of 4	Active SA grill	BATS #6	1	11	2-h samples (1700 Friday to 1500 Saturday)
		Total primary sampling tubes:			**~230**	

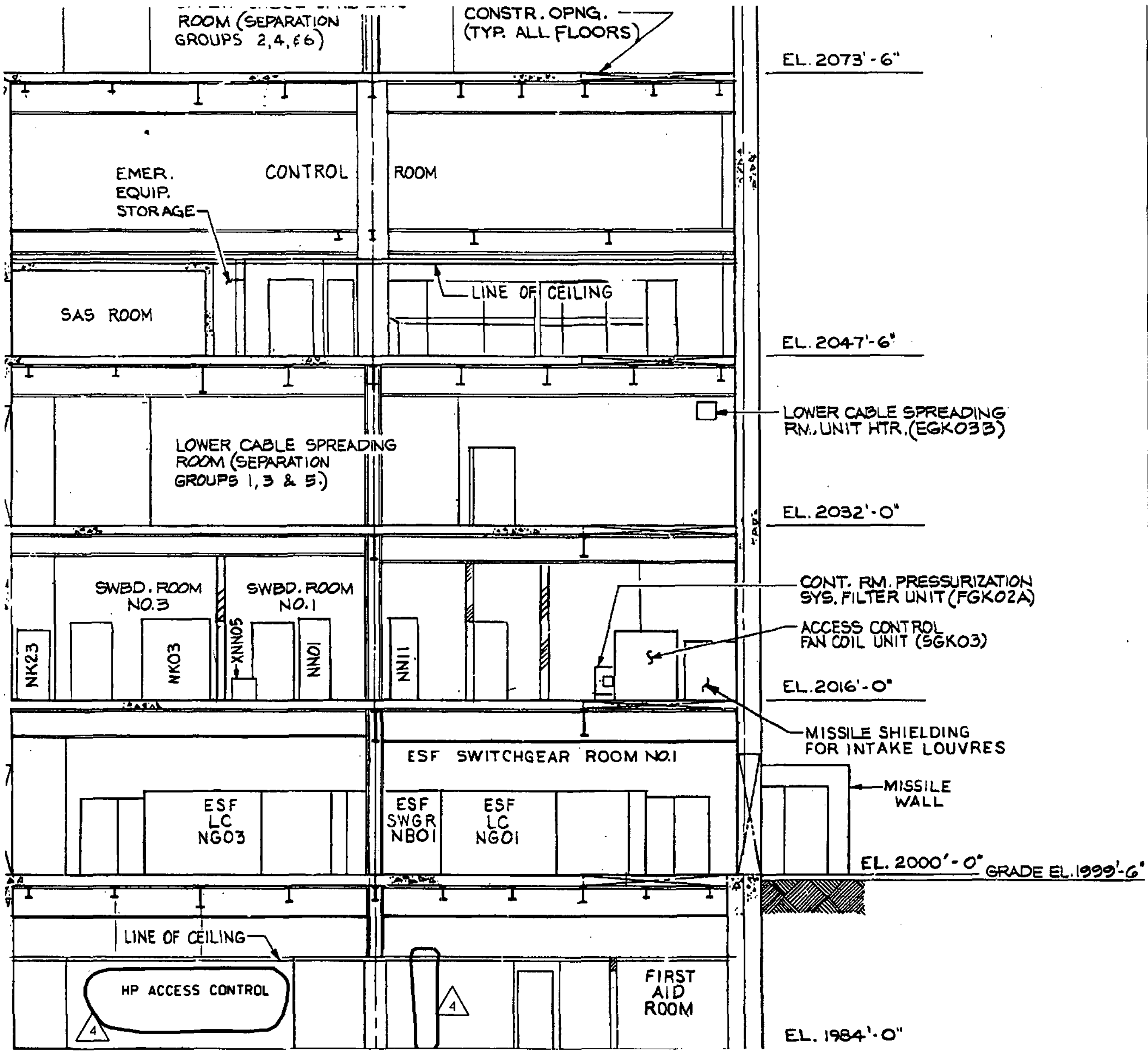

Figure 3 Wolf Creek Control Building Envelope with floor elevations.

3. Parameter specifications;

The major parameters that need to be measured to implement ATD are the flow rates through the charcoal-filtered EVS(s), the PFT concentration in the normal outside air (pre-charcoal filter), the PFT concentration in the air after passing through the charcoal filters in the EVS(s) (PFT depleted) and inside the CRE [and the CB in the case of SNUPPS plants] (PFT depleted plus PFTs from UI). If there were no UI, the air concentration in the CRE would equal the concentration after passing through the charcoal filters. The charcoal filters on the CREVS are typically effective at removing over 99% of the PFTs from the air; their performance is determined as part of the testing. Thus, any increase in the concentration in the CRE above that in the exhaust of the charcoal filters indicates UI. The magnitude of the UI is calculated using the flow rates of the filtered supply air; those rates and their uncertainties are either measured by the plant using their standard procedures or by a tracer determination using a separate PFT.

Using the simplified schematic in Figure 1, the ATD approach needs to use the measured filtered flow and PFT concentration (Q_f and C_f, respectively), the unfiltered PFT concentration (C_u), and the PFT concentration in the control room envelope (C_{CRE}). Performing a mass balance for steady-state conditions, the unfiltered flow rate can be determined from:

$$Q_u = Q_f * F_{dep}/(1 - F_{dep}) \qquad (1)$$

where F_{dep} is $(C_{CRE} - C_f)/C_u$.

Note that for the SNUPPS-designed plants, the actual equations for UIs into the control room and equipment rooms of the CRE and into the CB are somewhat more complex due to the possibility of leakage from the CRE into the CB, and the presence of equipment rooms in the CRE that receive some of the supply air from the CREVS.

SNUPPS Control Building Balance Equations.

At steady state (SS), the rate of UI into the CB is given by:

$$Q_{UI\text{-}CB} = Q_{f\text{-}CB} \bullet (C_{CB} - C_f)/(C_{amb} - C_{CB}) + \varepsilon Q_{CR} \bullet (C_{CB} - C_{CR})/(C_{amb} - C_{CB}) \qquad (2)$$

where the first term on the right accounts for the tracer depletion by the CB filtered supply-air (SA) rate and the second term accounts for the fraction, ε, of the exfiltrating CR pressurization air that enters the CB. That fraction, ε, could range from 0 to 1; thus, the calculated rate of UI will be a range rather than a discrete value. The "C" parameters are the measured concentrations in the Control Building (CB), filtered supply air (f), background (amb), and the Control Room (CR). The Q parameters are flow rates from the areas defined by the subscripts, e.g. Q_{fCB} is the filtered air from the control building, and Q_{CR} is the control room air flow

When the rate of exfiltration from the CR is not considered ($\varepsilon = 0$; the 2nd term disappears) and the depleted concentration from the CB charcoal filter (C_f) was close to zero, then Eq. 2 reduces to:

$$Q_{UI\text{-}CB} = Q_{f\text{-}CB} \bullet C_{CB}/(C_{amb} - C_{CB}) = Q_{f\text{-}CB} \bullet F_{CB}/(1 - F_{CB}) \qquad (3)$$

which is Eq 1, where F_{cb} is the depletion ratio C_{CB} / C_{amb}.

SNUPPS Control Building Balance Equations

At steady state, the rate of UI into the CR is given by:

$$Q_{UI\text{-}CR} = Q_{f\text{-}CR} \bullet (C_{CR} - C_f)/(C_{amb} - C_{CR}) - {}^1\!/_9 \bullet Q_{EqRm} \bullet C_{CR}/(C_{amb} - C_{CR}) \quad (4)$$

where the first term accounts for the filtered air entering the CRE and the second term accounts for exchange between the CRE and Equipment Room. The constant, ${}^1\!/_9$, is the nominal filtered SA rate (2000 cfm) divided by the AC fan rate (18000 cfm). The filtered SA concentration (C_f) is close to zero and given that the rate of the filtered SA is about 2,200 cfm and the flow rate into the active equipment room (Q_{EqRm}) is about 350 cfm (such that ${}^1\!/_9$ of the 350 cfm is about 2% of the $Q_{f\text{-}CR}$), then Eq. 4 reduces to:

$$Q_{UI\text{-}CR} = 0.98 \bullet Q_{f\text{-}CR} \bullet C_{CR}/(C_{amb} - C_{CR}) = 0.98 \bullet Q_{f\text{-}CR} \bullet F_{CR}/(1 - F_{CR}) \quad (5)$$

For both the CB and the CR, the explicit solution forms (Eq. 2 and 4, respectively) were used to calculate the final unfiltered inleakage (UI) results.

SNUPPS Equipment Room A Balance Equations

A material balance around this zone, which includes the CR Filtration System, was performed with the assumption that a portion (ε_1) of the total out-leakage (~350 cfm) from the CR enters Equipment Room A in addition to the 350 cfm directly from the CR AC System plus any UI directly into that zone. The assumption is that the higher pressure in the CR will allow some fraction of its total out-leakage to enter the Equipment Room. The resulting steady state solution for UI into the ER_a is given by:

$$Q_{UI\text{-}ERa} = \frac{[Q_{ERa} + \varepsilon_1 \bullet (Q_{UI\text{-}CR} + 350)]\, F_{depERa} - [{}^8\!/_9 \bullet Q_{ERa} + \varepsilon_1 \bullet (Q_{UI\text{-}CR} + 350)] \bullet F_{depCR}}{1 - F_{depERa}} \quad (6)$$

where Q_{ERa} is the 350 cfm flow rate from the CR AC system directly into equipment room A (equivalent to the 300 cfm return from this zone back to the filtration system plus the 50 cfm of pressurization air in this zone), the 350 cfm is the CR pressurization rate, the F_{dep} are for the respective depleted concentration ratios, and ε_1 is defined above (ε_1 might range from 0.1 to certainly no more than 0.6 of the total CR out-leakage entering the ER_a). The factor ${}^8\!/_9$ of Q_{ERa} is because the 18,000 cfm of the CR AC system only contains 16,000 cfm of CR recycle air.

SNUPPS Equipment Room B Material Balance

A material balance around this zone was done making the assumption that a fraction (ε_2) of the CR out-leakage and a fraction (ε_3) of that from Equipment room A enter Equipment Room B, along with its UI. The steady state solution is:

$$Q_{UI\text{-}ERb} = \frac{[\varepsilon_3\{50 + Q_{UI\text{-}ERa}) + \varepsilon_1(Q_{UI\text{-}CR} + 350)\} + \varepsilon_2(Q_{UI\text{-}CR} + 350)]F_{depERb} - \varepsilon_3\{\ \}F_{depERa} - \varepsilon_2(50 + Q_{UI\text{-}Era})]F_{depCR}}{1 - F_{depERb}} \quad (7)$$

where the terms have been previously defined. The solution depends on the previously determined UI rates into the CR (precisely determined) and the ER_a (reasonably bounded) *and* on estimates for ε_2 and ε_3; note that ε_1 would be chosen earlier to bound the ER_a UI rate.

4. Material requirements;

The ATD method requires sampling equipment to collect the PFTs from the air and portable fans and portable charcoal filter systems as discussed in response to item 2. There are no tracer gases released and no analyses performed at the plant and thus, no GC instruments or operating gases at the plant.

5. Safety implications of the test (e.g., personnel safety, impact on plant operations and on plant equipment);

Safety and operational concerns with this testing are minimal. Sampling equipment is battery operated and low voltage. The tracer is already present in the atmosphere and additional injection of new material is not required; thus, the safety of the PFTs is not an issue. However, the tracers are all perfluorocarbons and their Material Safety Data Sheets (MSDSs) show them to be chemically inert and biologically inactive. PFTs have been used extensively in atmospheric dispersion testing and in ventilation testing in homes and buildings.

The ATD method has minimal impact on plant operations. In the usual nuclear plant, to use this method, the Control Room Emergency Ventilations System (CREVS) must be operated long enough to reach a steady state depleted concentration in the CRE; This time is a function of the filtered flow rate through the CREVS and the volume of the CRE. In addition to the sampling equipment, the only other change to plant operations is the use of additional fans to improve mixing (only in those few zones where good mixing is inherently not present) and the short-term use (a few hours) of portable charcoal filtration systems to more quickly reach the steady state conditions necessary to quantify unfiltered in-leakage. After the portable charcoal systems are turned off, the CRE depleted concentrations are sampled over a remaining time sufficient for steady state to be achieved with just the CREVS charcoal filters running. Plant operations are not changed.

The ATD method does not influence the performance or safety of plant equipment. All systems are operated in accordance with standard operating procedures. The only intrusion into plant equipment involves the use of probes placed in some ductwork to collect air samples for determination of depleted PFT levels. Full details of needs are given in the specific testing plans and procedures.

6. Preparations before initiation of the test;

Building plans are reviewed to determine air flow pathways and the magnitudes of re-circulating (mixing) and filtered flow rates. Prior to testing, data collection is performed of all room volumes and nominal flow rates within the CRE (and CB for SNUPPS plants). This information is needed to determine the time to reach steady state conditions, assure that mixing is sufficient, and to perform a preliminary sampling design; other than an accurate knowledge of the filtered supply-air rates, zonal volumes and other flow rates are not relevant to quantification of UI. If the time to reach steady state is unacceptably

long or mixing is not sufficient, provisions are made to bring in charcoal filter systems and fans. Complete details on the generic approach are specified in Test Design Procedure, (TTC-TD-01, 2007).

Using the provided flow rates and room volumes, a detailed sampling plan is developed. The plan defines sample locations, sample volumes, total number of samples, and test duration. Based on the sample plan, sampling equipment is emplaced or installed at ductwork as required. Plant-specific details are provided in a testing plan and procedures document, provided to each plant prior to testing.

7. Calibration of the test equipment;

The Tracer Technology Center Quality Assurance Plan addresses calibration of test equipment. The overarching standard for calibration is the Brookhaven National Laboratory Calibration Subject Area which addresses the identification of equipment to be calibrated and the related calibration requirements. The frequency and rigor of calibration of the equipment items is tailored according to the potential impact on the environment, safety, health, and quality of the analysis. Measuring or test equipment used to monitor processes or generate data, important to the project or activity, is calibrated and maintained. Automatic sampling equipment is tested to confirm it is operating within specifications immediately prior to shipping to the plant for the tests. The gas chromatographs undergo a standard checkout procedure prior to sample analysis. Pressure flow meters used in this test are primary standards calibrated at the factory and do not require further calibration for one year. All pressure flow meters were used within one year of purchase. Voltmeters and micrometers are calibrated annually.

The implementing procedures within the Tracer Technology Center (TTC) are the following:

TTC-TP-03, Calibration of Active CATS Pumps (Flow rate, Battery Voltage and inlet pressure)
TTC-SA-01, QA for Calibration Standard
TTC-SA-02, Carrier Gas QA Procedure
TTC-SA-03, Chromatograph Maintenance and Performance Checks
TTC-SA-04A, Chromatograph GC-1 Pre-Sample Analysis Checkout Procedure
TTC-SA-04B, Chromatograph GC-2 Pre-Sample Analysis Checkout Procedure
TTC-SA-07, CATS/BATS Calibration Standard Loading Procedure

8. Description of the test procedure;

The objective of the ATD testing is to demonstrate that unfiltered in-leakage into the Control Room Envelope (CRE) are below the design basis used in the dose assessment calculations. The ATD tests are to be performed in the least intrusive fashion possible while meeting this objective. For SNUPPS-designed plants, this means allowing for normal Control Building (CB) and CRE ingress/egress. The test is done with a secondary objective to obtain a worst-case CB and CRE configuration and adjacent-zone HVAC operation to provide an upper bound on unfiltered in-leakage. This latter objective,

however, is controlled by the plant operators – such that test conditions are consistent with the limiting conditions in their licensing basis. The multi-tracer ATD method meets these objectives.
The first step in the test procedure is to review the dimensional plans of the facility and the CB/CR ventilation diagrams to determine important inputs needed to meet the measurement objectives. For SNUPPS-designed plants, with the Control Building and Control Room Emergency Ventilation Systems (CB/CREVS) operating, the CB unfiltered in-leakage (UI) should be less than 300 cfm and the Control Room (CR) UI should be less than 10 cfm. The 10 cfm for the CR was an assumed UI due to ingress and egress – the CR boundary UI is assumed to be zero.

The presence of the CR inside a mostly-filtered CB environment is what adds complexity to the determination of CR- and CB-UI and confounds the typical single tracer gas techniques. Using the atmospheric tracer depletion (ATD) of the normal background concentration of four (4) perfluorocarbon tracers (PFTs) of 400 molecular weight by the charcoal filters, in-leakage can be measured. The PFTs act as a direct surrogate for contamination in the outside air during an incident – once the original levels in the CR and CB have been displaced, that is, reached steady state with the EVS running. The CB-determined flow rate of UI represents the flow rate of unfiltered outside air leaking directly into the CB. The CR determination represents the equivalent rate; a value of 10 cfm could be 100% from the outside air *or* could be the equivalent of 40 cfm of CB air that is leaking in but contains only ¼ of the normal outside air concentration of contamination. The ATD testing will not provide the pathway – only the equivalent magnitude.

To perform appropriate ATD determinations, it is essential that measurements be made under steady state conditions – that is, the output depleted concentrations of the charcoal systems being used must be constant *and* the concentrations in the locations being sampled must no longer be changing. The stable performance of the CR and CB EVS charcoal cells should be ascertained ahead of the actual in-leakage testing to be sure they are appropriately characterized. Any portable charcoal systems to accelerate the approach to steady state should also be evaluated. Their times to steady state are strictly a function of the condition of the charcoal. The systems should also be checked for potential interferences from other components already on the charcoals.

The attainment of steady state concentrations in the CB and CR are dependent on the volumes and flow rates through these regions. Detailed calculations were performed for the SNUPPS plants to determine the time to reach steady state. The calculations indicated that it would take several days in some rooms of the plant and suggestions were made to add fans and charcoal filtration systems to improve mixing and accelerate the depletion process.

Based on the calculated time to reach steady state, a sampling sequence is defined. The sequence is selected to collect a few air samples as the PFT levels approach steady state and several samples after steady state is predicted to occur. The PFT levels are measured using a gas chromatograph at Brookhaven National Laboratory. The values are reviewed to demonstrate that steady state has been reached and the steady state values are used to calculate in-leakage.

9. Manner of calculating in-leakage and associated error from test results;

Using the measured flow rates and steady state PFT concentrations, a mass balance is performed to determine the unfiltered in-leakage. The basic equation for the CB, CR, and Equipment Rooms A and B are provided in Section 3.

The Design Basis Accident assumes unfiltered in-leakage into the CB at a rate of 300 cfm, Measuring the steady state value of PFT depletion, F_{dep}, the value of unfiltered in-leakage, Q_{UI}, can be determined. The Control Room Envelope is within the Control Building. Therefore, the depletion will be even greater within the CRE.
The results of the tests are provide in Table 2 (Wolf Creek) and Table 3 (Callaway). These plants have two independent air treatment systems (Train A and Train B) and both were tested. Using the equations in section 3, the following UI rates and uncertainties were computed concentration results:

Table 2 . Unfiltered In-Leakage (UI) Rates, cfm at the Wolf Creek Plant

	Train A Test	*Train B Test*
CR	6.9 ± 0.4	10.5 ± 2.6
CB	<63	14.2 ± 3.0
Equipment Room B (ER1501)	5.6 ± 2.2	2.1 ± 0.7
Equipment Room A (ER1512)	23.0 ± 4.9	32.3 ± 13.5

The CR UI rates are just about at the values assumed in the DBA originally submitted, although that during the Train-A testing is statistically lower than 10 cfm. The tightness of the CR is essentially independent of which train was operating.
Details of the calculation are found in (Dietz, 2004a, 2004b, 2004c).

Table 3 Unfiltered In-Leakage (UI) Rates, cfm at the Callaway Plant

	Train A Test	*Train B Test*
CR	10.1 ± 0.9	4.7 ± 1.1
CB	69 to 97	109 to 166
Equipment Room B (ER1501)	0.9 ± 1.0	3.4 ± 0.3
Equipment Room A (ER1512)	21.2 ± 2.4	1.5 ± 0.7

During the Train-A testing, the CR UI rate was just about at the value assumed in the design basis accident originally submitted (10 cfm); for Train-B testing, the rate was half that value. The two rates are statistically different; one would expect the tightness of the CR to be independent of which train was operating – unless there were differences in the pressurization air rates (nominally 400 cfm) from the CB. Those rates had not been measured.

The CB was reasonably tight – at about ⅓ to ½ of the DBA value of 300 cfm. The UI was less during the Train-A testing when the outside air (OA) rate was 833 cfm versus during the Train-B testing – consistent with the lower OA rate of 674 cfm. Thus, pressurization air rates have a strong inverse impact on UI rates.

The UI rates in Table 3 above into the Equipment Rooms are different from those into the CR and CB. The latter are the total UI rates into those locations whereas for the Equipment Rooms, they are *additional* UI rates – calculated using assumptions for flow communications between the CR and the Equipment Rooms. . For 3 of the 4 cases, other than CR air (with its proportionate amount of UI) at 350 cfm that is deliberately discharged into the active Equipment Room, there is little additional UI. However, Equipment Room A in the "A" train testing did have 21 cfm of additional UI.

As originally assumed, the CRE is not a single zone – there are statistically different UI rates into the CR, and the two equipment rooms. Multizone systems are known to be a problem for the standard ASTM E 741 methods.

10. Uncertainty (e.g., precision, accuracy) of results obtained with the test method;

A procedure for calculating the accuracy of the results using the test method is described in TTC-DP-02, Data Processing for ATD Testing. A major advantage of the ATD testing procedure is that the error is primarily a function of the error in the measured concentration of PFT. This error can be minimized through designing the test to collect larger volumes of air for sample analysis when concentrations are expected to be low. In contrast, for pressurized CREs, traditional tracer tests are limited by the absolute error in the measured filtered supply air rate into the CRE. For typical systems this can be 5 to 10% of the total air flow. Thus, for a 1000 CFM system, the accuracy of traditional tracer tests is limited to ± 50 to 100 CFM. For systems with expected low unfiltered in-leakage rates, this is not accurate enough to quantify that rate.

The general equation for calculating uncertainty is:

$$\Delta Q_{UI}\text{, fraction} = [(\Delta F_{dep}\,(1+F_{dep}/(1-F_{dep}))^2 + (\Delta Q_f\,)^2]^{1/2} \qquad (3)$$

Where, ΔQ_{UI} is the fractional uncertainty of the unfiltered in-leakage rate, ΔF_{dep} is the fractional uncertainty in the fractional depletion F_{dep}, the ratio of the PFT concentration inside the CRE versus that outside the CRE, and ΔQ_f is the fractional uncertainty in measured flow rate into the CRE through the CREVS. For low values of F_{dep} (< 5%) the second term, $F_{dep}/(1-F_{dep})$, is small compared to 1 and Eqn 3 is approximated as

$$\Delta Q_{UI}\text{, fraction} = [(\Delta F_{dep})^2 + (\Delta Q_f\,)^2]^{1/2} \qquad (4)$$

The uncertainty estimate depends on the number of samples collected at steady state. For a single sample the error in ΔF_{dep} has been determined to be bounded by the relationship (TTC-DP-02, 2003):

$$(\Delta F_{dep})^2 = 0.01 + (50/A_{dep})^2 \qquad (5)$$

where, .01 is the squared value for the analytical uncertainty in the measured PFT due to uncertainties in sample volume and area under the peak, $50/A_{dep}$ is the counting statistics error where A_{dep} is the number of counts for the PFT surrogates. Using Eqns 4 and 5, the fractional uncertainty is estimated from the following equation.

$$\Delta Q_{UI}\text{, fraction} = [0.01 + (50/A_{dep})^2 + (\Delta Q_f)^2]^{1/2} \qquad (6)$$

Table 4 provides examples of total and percentage error under different conditions and shows the total error of this method is between for a 12 and 15% of the estimated value for a wide range of conditions including unfiltered infiltration rates as low as 30 CFM. In contrast, the error estimate of the standard tracer techniques is directly proportional to the error in measured flow rate. For example, in case 2 with a 7% uncertainty in flow into the system, ΔQ_f, using the standard tracer techniques would provide an error estimate of ±140 CFM. The uncertainty in this estimate is almost a factor of 5 greater than the estimate of the unfiltered infiltration rate obtained using the ATD method with the same conditions.

Table 4 Calculated error under different in-leakage conditions

	1	**2**	**3**
Q_f, cfm	1200	2000	4700
ΔQ_f, fraction	0.06	0.07	0.07
$F_{dep}(PFT)_{SS}$	0.140	0.0150	0.0101
A_{dep}, cts	7000	750	530
Q_{UI}, cfm	195	30	48
ΔQ_{UI}, cfm (%)	23 (12%)	4.2 (14%)	7.4 (15%)

Table 3 shows that the fractional error in the estimate of unfiltered in leakage is 12 – 15% for a wide range of conditions. This level of accuracy is adequate for demonstrating compliance with design basis in-leakage rates of a few cfm.

In the case where 3 or more measurements are taken at steady state, there are enough separate determinations for F_{dep} (PFT at steady state) to use their average in Eqn. 3 to get the average Q_{UI} and the standard deviation of that average, SD_F, to get the uncertainty in Q_{UI} as:

$$\Delta Q_{UI}\text{, fraction} = [(SD_F)^2 + (\Delta Q_f)^2]^{1/2} \qquad (7)$$

Where SD_F is the standard deviation in F_{dep}, which is the ratio of CRE and unfiltered PFT concentrations.

11. Correlation of the results of the alternative test method with a test performed in accordance with regulatory Position 1.1; and

The ATD method was compared to a traditional injection method using a tent testing procedure at the Dominion Nuclear Power Plant. The tent testing (a tracer component injection test) of three of the four emergency charcoal filter fan systems was done just before the CRE boundary testing and the 4th, afterwards – following the standard ASTM E 741 approach. "Tent Testing" of the negative pressure portion of the 4 systems was performed by installing a tent around the filter housing just downstream of the charcoal filter housing and up to the fan housing, including the fan shaft seal. The plastic tenting was pressurized with a known concentration of PFTs; their presence and magnitude in the fan discharge air confirmed unfiltered in-leakage was occurring and quantified the extent. Not counting tent and sampling setup, each test took 2.5 to 3.5 hours.

The tent tests comprised 3 periods of ~30-min samples collected at each of 2 discharge-air locations while periodically confirming the tent-air concentration by extracting ~50-mL aliquots onto Capillary Absorption Tube Samplers (CATS) from each of 4 locations in the tent. Permeation sources of two different PFT types were placed in the in-take of a 25-cfm fan used to pressurize the tent and provide the expected known concentration. The actual fan flow rate was measured using a rotary-vane anemometer and found to be 23 cfm. The ratio of the PFT concentration in the discharge air to that in the tent air times the 1000 cfm charcoal-bed fan rate gave the unfiltered in-leakage rate in that portion of each system.
The PFTs used to tag the tent were PDCB and PTCH. The tent samples corroborated the expected concentrations in the first three tests; the 4th tent was 70% of the expected level because the in-leakage was larger than the effective 23 cfm source-fan rate. Simultaneously, the Atmospheric Tracer Depletion method was implemented using 2 PFTs (mcPDCH and PECH) that were not released in the tent testing and not released in the CRE testing. The 2 ATD PFTs were measured in the Turbine Bldg air (entering the EVS inlet) and at the fan discharge; the ratio of the discharge to the inlet concentration times the nominal fan rating (1000 cfm), gave the reported ATD results. Because the concentrations of the two tracers used for ATD were not measured in the charcoal exhaust, the ATD result is presented as an upper bound. Regardless, the agreement, shown in table 5, demonstrates that the ATD test results are comparable to the ASTM E741 method ("tent testing") results.

Table 5 CREVS Unfiltered In-Leakage, cfm

CRE Region	Tent Testing	ATD
Main Control Room Unit 1	15.6 ± 3.2	<17.8 ± 0.3
Main Control Room Unit 2	13.3 ± 0.5	<15.8 ± 1.2
Switch Gear Room Unit 1	8.5 ± 0.4	<11.5 ± 1.1
Switch Gear Room Unit 2	26.8 ± 2.0	<38

12. Assessment that determines the acceptability of the alternative test in lieu of a test performed in accordance with regulatory Position 1.1.

The ASTM E 741 standard was not devised with consideration of multizones within buildings; in particular, that standard declares that "single zones [CRE] within multizone buildings are difficult to isolate such that they exchange air only with the outside and not to other zones…"(section 3.1.7.1) (ASTM, 2000). Further, most CREs are, themselves, not single zones as was shown to be the case at the SNUPPS designed plants. The Atmospheric Tracer Depletion (ATD) was developed as a new industry standard consistent with ASTM E 741 specifically for pressurized CREs with low design-basis unfiltered in-leakages (UIs). A unique feature is the comprehensive nature of the test; it directly determines total UI, regardless of the in-leakage pathway and the zones contiguous to the CRE.

ATD avoids the multizone issues Mentioned in ASTM E 741 The normal outside air has a known concentration of ambient PFTs and, at steady state with the control room emergency ventilation system (CREVS) running, the CRE has a measurable depleted concentration. That ratio is a direct determination of unfiltered in-leakage – regardless of the pathway and the connection to surrounding zones. Although its strength is in the stated application, it can be used in neutral-balanced envelopes as well.

The ATD tests rely on using charcoal filters present in the Control Room Emergency Ventilation System to remove background concentrations of PFTs in the air. The PFT levels can be measured accurately down to 1% or less of background using readily achievable sample volumes. Therefore, the method is capable of accurately measuring in-leakage to less than a few cfm. For pressurized CREs, other approaches that tag the filtered supply air and measure the difference between the concentration inside the CRE versus that in the supply air, are not accurate for small in-leakage rates such as those that exist at Wolf Creek or Callaway. For example, the NEI report (1) states that traditional "tracer gas testing uses flow measurements for positive pressure control rooms, which increases the overall uncertainty of the test result. If the actual unfiltered in-leakage is small (< 100 cfm) and the pressurizing air flow is relatively large (>1000 cfm), the uncertainty in the air flow measurement causes the accuracy of the tracer gas test to become very poor." For example, if the pressurizing flow is 2000 cfm and the uncertainty in this measure is 5%, this leads to an error band of at least +/- 100 cfm. When this error is compared to the measured in-leakage, the overall test uncertainty can exceed 100 percent of the measured value. In contrast, the ATD method was shown to determine unfiltered in-leakage of less than 10 cfm (±25%) in systems with total flow rates of 2000 cfm.

A detailed comparison of the ATD method and the ASTM Standard E-741 was performed as part of a larger review of infiltration detection techniques (Dietz, 2003). The review included analysis of each of the 18 major elements or sections of the standard

with respect to the four tracer techniques used to measure unfiltered in-leakage. The techniques are SF6 (sulfur hexafluoride) decay, SF6 injection, AIMS (Air Infiltration Measurement System) based on injection of PFTS and the focus of this report, the ATD method. Of these 18 major elements, 14 were specifically applicable. Within the 14 applicable elements there were 108 sub-elements. Table 5 summarizes the comparison between four tracer techniques used to examine unfiltered in-leakage and the ASTM Standard.

Table 6 Comparison of Tracer Test Methods with ASTM Standard E741 sub-elements.

	SF_6 Decay	**SF_6 Inject**	**AIMS**	**ATD**
Test Meets Sub-element	80	83	84	69
(percentage of subtotal)	(89%)	(89%)	(91%)	(92%)
Test does not meet Sub-element	9	9	8	5
Uncertain	1	1	-	1
Subtotal	90	93	92	75
Not applicable	18	15	16	33
TOTAL	108	108	108	108

When this review was conducted in the end of May 2003, the reviewer was not aware of the exceptions to the standard as noted in the Control Room Habitability Guidance Report (NEI, 2003 Appendix EE, p. EE-1). It will be seen that many of the exceptions noted in the NEI document were also noted in the Dietz, 2003 review as "not applicable" (na).

The comparison of the ATD technique and the elements in the ASTM Standard E-741 showed that there was agreement on 92% of the applicable elements (Dietz, 2003). In comparison, the standard approaches for measuring in-leakage met only 89% of the ASTM Standard elements. Thus, the ATD technique is consistent with the ASTM Standard E-741.

In addition to improved accuracy compared to other in-leakage tests, the ATD offers less disruption of plant operations, minimal NPP staff support, and minimal impact on plant operations.

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