AmerenUE
Callaway Plant

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Fulton, MO 65251

December 15, 2004

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

ULNRC-05104

Ladies and Gentlemen:

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

Ref: 1. Generic Letter 2003-01, "Control Room Habitability," June 12, 2003.
2. ULNRC-04885, dated August 11, 2003.

Reference 1 transmitted Union Electric Company (AmerenUE) preliminary response to NRC Generic Letter 2003-01, "Control Room Habitability". In this response it was identified that AmerenUE 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 on September 17 – 19, 2004. A comparison of the Brookhaven National Laboratory alternate test method used to the ASTM E741 test standard is provided in the enclosure to this letter.

Attachment I to this letter provides the results of this testing and the status of Callaway Plant chemical and smoke evaluations. Attachment II contains commitments for submittal of a Technical Specification change.

A102

If you have any questions or require additional information, please contact me at (573) 676-8659, or Mr. Dave Shafer at (314) 554-3104.

Sincerely,

Keith D. Young

Keith D. Young
Manager – Regulatory Affairs

Attachments: I Follow-up Response
II Commitments

Enclosure: Brookhaven National Laboratory alternate test method comparison to ASTM E741

STATE OF MISSOURI )
) SS
CALLAWAY COUNTY )

Keith D. Young of lawful age, being first duly sworn upon oath says that he is Manager - Regulatory Affairs, for Union Electric Company; that he has read the foregoing document and knows the content thereof; that he has executed the same for and on behalf of said company with full power and authority to do so; and that the facts therein stated are true and correct to the best of his knowledge, information and belief.

By Keith D. Young
Keith D. Young
Manager, Regulatory Affairs

SUBSCRIBED and sworn to before me this 15 day of DECEMBER, 2004

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Notary Public - Notary Seal
STATE OF MISSOURI
Callaway County
My Commission Expires: Aug. 3, 2007

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**Follow-Up Response to the Requested Information of NRC Generic Letter 2003-01**

Below is AmerenUE's follow-up response to NRC Generic Letter 2003-01, "Control Room Habitability," dated June 12, 2003. The information requested by the Generic Letter is shown in bold followed by Callaway Plant response.

**Requested Information**

1. **Confirm that your facility's Control Room meets its applicable habitability regulatory requirements (e.g., GDC 1, 3, 4, 5, and 19) and that the CRHSs are designed, constructed, configured, operated, and maintained in accordance with the facility's design and licensing basis.**

Callaway Plant Response:

Callaway Plant is committed to the General Design Criteria of Appendix A of 10CFR50 as documented in our Final Safety Analysis Report.

The results of confirmatory testing performed at Callaway Plant in September 2004, showed that the Callaway Plant's Control Room is capable of meeting the regulatory habitability requirements. The testing demonstrated that the Control Room Habitability systems (CRHS) limited control room inleakage to acceptable values when configured, operated, and maintained as designed and constructed. The programs described in the reference submittal remain in place and the systems were operated in accordance with these procedures for this test.

Inleakage test results for one train of Callaway's Control Room Emergency Ventilation System (CREVS) did exceed the value reported in Callaway's FSAR (10.1 cfm measured vs. 10 cfm FSAR reported value). This was entered into Callaway's corrective action program, and an Operability Determination demonstrated that pending resolution of the issue and revision of Callaway's FSAR, that the measured inleakage value does not render that CREVS train inoperable.

Post-accident doses to Callaway Plant Control Room personnel continue to be bounded by the values reported in Table 15.6-8 of the Callaway Plant FSAR. These FSAR-reported values are below the regulatory limits. Therefore, the Callaway Plant Control Room meets the regulatory requirements for habitability.

The Callaway Plant / SNUPPS (Standardized Nuclear Unit Power Plant System) Control Room Envelope (CRE) design is unique. The control building by and large surrounds the CRE. The CRE is required by Technical Specifications to be at a positive pressure with respect to its surrounding environment. The Control Building is also designed to be at a positive pressure with respect to its surrounding environment although not positive with respect to the CRE. In the emergency pressurization and filtration mode, the Control Room air volume receives air through a filtration system that takes suction on the Control Building. The Control Building in turn receives filtered air from the outside environment.

The Generic Letter proposed ASTM E741 test methodology is designed for testing a single zone and basically implicitly assumes that all air can be categorized as either unfiltered outside air or filtered inside air. As described above, the SNUPPS plant design has two separate control zones, the Control Building and the CRE. It is invalid to treat them as merely different volumes within a common zone. Based on the SNUPPS plant design the CRE dose model has three categories of air; unfiltered outside air, single filtered control building air, and double filtered Control Room air.

The Control Building has multiple common boundaries with the CRE. With the CRE pressurized, a substantial fraction of the out leakage from the CRE will go into the Control Building. This air could then be drawn back into the filtered pressurization system and put back into the Control Room. The current ASTM E741 tracer gas test does not account for re-introduction of tracer gas back into the test volume, potentially leading to erroneous and non-conservative inleakage test results. In order to provide valid test results for this configuration Callaway Plant and WCNOC chose to perform an alternate tracer gas test using the Atmospheric Tracer Depletion Method described below.

Tracer Gas Test Using the Brookhaven National Laboratory Atmospheric Tracer Depletion (ATD) Method

It has been shown that Control room inleakage can be determined by using a tracer gas test methodology. Tracer gases can be injected into a controlled volume or the tracer gases that are already present in the atmosphere can be used for tracer gas testing. Performing a tracer gas test utilizing the tracer gases (perfluorocarbons) that are present in the air is described as an Atmospheric Tracer Depletion (ATD) inleakage method. Both the ATD and injection tracer gas tests methods are very similar in that they both have the ability to accurately measure air leaking into a controlled environment (control room). In both tracer gas test methods air that is leaking into the controlled area (control room) causes a dilution of the tracer gas that is being measured.

1) In the tracer gas injection method a measured quantity of test gas is injected into the controlled area. The volume of the controlled area is a known quantity and the amount of filtered air entering and leaving the controlled volume is also known. After it has been determined a steady state condition is reached the concentration of injected tracer gas can be determined. The amount of tracer that should exist in the controlled area can be determined for zero or a given inleakage. If the amount of tracer dilution is greater than the value calculated then an inleakage value can be determined by comparing calculated difference dilution values to the measured dilution values.

2) For the ATD method the air leaking into the controlled area (control room) affects the measured tracer gas very similar to the injection method. For the ATD method the concentration of perfluorocarbons that exist in the air before the test begins are measured and used as a reference value. The Callaway Plant control room

Filter/Adsorber units (F/A) are located inside the controlled area and are capable of removing the perfluorocarbons to a percent equivalent to their removal efficiency, which is typically greater than 99.9 percent. One of the steps of the ATD test is to measure the concentration of tracer gas at both the inlet and outlet of the F/A units. This measurement is taken throughout the duration of the test. With this measurement verification the removal efficiency of the emergency F/A units is achieved. Since the volume of the controlled area is a known quantity and the amount of filtered air entering and leaving the controlled volume is also known a dilution of the tracer gas in the controlled area can be calculated. Similar to the injection tracer gas method, the ATD method equates the deviation from a determined dilution as inleakage into the controller area. The ATD method measures the increase of the tracer gas caused by the inleakage where as the injection method is measuring the decrease to the tracer caused by inleakage. The F/A units remove the tracer gases from the atmosphere and any inleakage will be indicated by the increase of the concentration of tracer gas inside the controlled volume. When steady state conditions are reached, with zero inleakage into the controlled area the quantity of tracer gas present would be equivalent to the removal efficiency of the F/A units.

<u>Example:</u>

If the quantity of perfluorocarbon tracer that is naturally existing in the air is 10 ppb and the F/A unit provides 99.9% removal efficiency, then after steady state is reached the amount of tracer gas remaining in the controlled area would be 0.1%, with zero inleakage. Air leaking into the controlled area would cause the concentration to increase above the 0.1%. The increase above the 0.1% is equated to CFM inleakage value. The method of determining inleakage relative to the dilution of a tracer gas is a similar process in both the Tracer Gas Injection and ATD testing methods and both methods comply with the intent of the E741 requirements.

A detailed comparison of this test to the ASTM E741 method is provided in the enclosure to this letter from Brookhaven National Laboratory, the vendor who performed the test. Based on this comparison, it was determined that performing on alternate tracer gas test using the Atmospheric Tracer Depletion Method was appropriate for inleakage testing of the Callaway's Control Room/Control Building configuration.

These results are in agreement with the May 2000 Strategic Teaming and Resource Sharing (STARS) self-assessment that concluded the Control Room design and operation were adequate. This along with the following administrative controls ensures continued compliance with the Control Room Habitability design and licensing bases.

These controls include:

<u>Breach Control Program</u>

HVAC boundary breaches at the Callaway Plant are controlled by procedure EDP-ZZ-04107 "HVAC Pressure Boundary and Watertight Door Control." The Callaway Plant HVAC system engineer oversees this procedure. Work activities at Callaway Plant are administered via a computerized planner that the planning and construction departments use. The review process for the planned activities includes an electronic sign off by the HVAC System Engineer for his systems needs and requirements. The breach control program address limits, precautions, and allowed mitigation that encompass the needs associated with protecting the control room pressure boundary, as required by the Technical Specifications.

Procedure Control

APA-ZZ-00101, "Procedure Preparation, Review, and Approval," controls the generation and revision of procedures at the Callaway Plant. Interdisciplinary reviews are required, as appropriate, which should prompt the control room HVAC systems engineer to review related procedure changes.

Hazardous Chemical Control

Hazardous chemicals used at Callaway Plant are controlled by procedure APA-ZZ-00831 "Hazardous Chemical Control Program." This procedure requires an evaluation of all chemicals brought onsite to determine their impact on Control Room habitability. In addition, the Callaway Plant License Impact Review (LIR) form includes questions to initiate an evaluation of Control Room Habitability impact for all new chemicals brought onsite.

Design Change Control

The Plant Modification program is controlled at Callaway Plant by procedure APA-ZZ-00600 "Design Change Control." The program provides the processes and requirements for managing and controlling changes to the plant. At Callaway Plant a Request For Resolution (RFR) is prepared under procedure EDP-ZZ-04015 "Evaluating and Processing Requests For Resolution (RFRS)." The modification procedures require the screening of the change using a screening checklist per procedure APA-ZZ-00140 "Safety, Environmental and Other Licensing Evaluations." The checklists include questions involving the evaluation of the effect of the changes upon safety related equipment. The screening form will cause the Design Engineer to obtain additional programmatic or interdisciplinary reviews or evaluations as required. Independent verification is performed by another qualified engineer for all plant modifications in accordance with procedure EDP-ZZ-04033 "Design Verification" at Callaway Plant. One of the expectations is the verification that the appropriate reviews have occurred and that consideration has been taken for all important design attributes such as control room integrity.

Temporary Modifications to the plant are control led by procedure APA-ZZ-00605, "Temporary System Modifications" at Callaway Plant. A screening process and review is also performed on Temporary Modifications.

Maintenance Control

Work activities performed on the Callaway Plant systems, structures, or components are controlled by the work control process addressed in procedure APA-ZZ-00320 "Processing Job Requests." Work activities are administered via a computerized planner that the planning and construction departments use. The review process for the planned activities includes an electronic sign off by the HVAC System Engineer for systems needs and requirements. The Preventive Maintenance program at the Callaway plant is controlled by procedure APA-ZZ-00330 "Preventive Maintenance Program." During the May 2000 assessment, representative PMs were reviewed and found to be adequate for maintain the control room boundary integrity.

AmerenUE plans continue to work in alliance with STARS to build upon the synergy of the combined effort thus far to ensure that control room habitability is maintained in the long-term.

Based on the above, Callaway's Control Room continues to meet its regulatory requirements and licensing and design bases.

**1(a) That the most limiting unfiltered inleakage into your CRE (and the filtered inleakage if applicable) is no more than the value assumed in your design basis radiological analyses for Control Room habitability. Describe how and when you performed the analyses, tests, and measurements for this confirmation.**

Callaway Plant Response:

Callaway Plant design basis radiological analysis for control room habitability is described in FSAR Appendix 15A for a postulated large break loss of coolant accident. This analysis was last performed in 2000 using the methods described in Regulatory Guide 1.4 and Standard Review Plan Section 6.4. The most limiting unfiltered inleakage from the outside environment into the control room envelope was assumed to be zero standard cubic feet per minute (scfm). However, an unfiltered inleakage rate of 300 scfm was assumed to account for some unfiltered air that may leak into the control building wherein the control room envelope is located. In addition, an infiltration rate of 10 scfm was assumed for opening and closing of doors associated with activities required by the plant emergency plans and procedures. The results of this analysis are presented in FSAR Table 15.6-8, "Radiological Consequences of a Loss-of-Coolant-Accident."

Callaway Plant and WCNOC evaluated conducting an integrated test and component test for control room inleakage to be responsive to the intent of Generic Letter 2003-01 and NRC Regulatory Guide 1.197. This evaluation determined that ASTM E741 testing methods would not provide valid results for the SNUPPS CRE design.

Because of these design conditions Callaway Plant performed an integrated inleakage test using an alternate test technique. A test method developed by Dr. Russell Dietz of Brookhaven National Laboratory (BNL) entitled Atmospheric Tracer Depletion (ATD) testing was selected. (See enclosure to this response for a comparison of the ATD test method to the standard ASTM E741 test methods.)

In conjunction with Dr. Dietz and BNL, Callaway Plant developed a test plan that measured the inleakage to the Control Room Envelope, the Control Building, and the associated Equipment Rooms. The test was performed over a three-day period in September 2004, and the results support the conclusion of a previous assessment, that the design, construction, and operation of the Control Room Habitability Systems were sufficient to limit inleakage to acceptable limits. The test results are shown in Table 1 below, for each train of control room equipment.

The values reported below have been evaluated for impact on the Callaway Plant Control Room dose model. These values will not result in post-accident dose to exceed the values reported in Table 15.6-8 of the Callaway Plant FSAR.

Table 1

| Train | Inleakage CR (CFM) | Inleakage CB (CFM) | Inleakage ER (B/A) (CFM) |
|---|---|---|---|
| A | 10.1 | 69 | 1.5/21.2 |
| B | 4.7 | 109 | 3.4/0.9 |

**1(b) That the most limiting unfiltered inleakage into your CRE is incorporated into your hazardous chemical assessment. This inleakage may differ from the value assumed in your design basis radiological analyses. Also confirm that the reactor control capability is maintained from either the control room or the alternate shutdown panel in the event of smoke.**

Callaway Plant Response:

During the May 2000 assessment, Callaway Plant determined there was no offsite storage or transportation of chemicals that presented a hazard to control room habitability. In addition, there were no onsite chemicals that posed a credible hazard to control room habitability. Engineered controls for the control room are not required to ensure habitability against a hazardous chemical threat. Therefore, the amount of unfiltered inleakage is not incorporated into Callaway Plant's hazardous chemical assessment.

The offsite and onsite hazardous chemical analyses have been updated to confirm the conclusion of the 2000 assessments.

An evaluation to confirm reactor control capability from either the Control Room or the alternate shutdown panel was performed in accordance with the current revision of NEI 99-03, Appendix A, which is now the smoke evaluation section. In the event that smoke or other combustion products enter the Control Room such that occupation of the Control Room cannot be sustained, control of the plant can be maintained outside of the Control Room at the Auxiliary Shutdown Panel and through local control of equipment. The Auxiliary Shutdown Panel is located in the Auxiliary Building. The HVAC system for the Auxiliary Shutdown Panel is independent of the HVAC system for the Control Room. A single postulated event could not render both the Control Room and the Auxiliary Shutdown Panel inaccessible.

**1(c) That your technical specifications verify the integrity of your CRE and the assumed inleakage rates of potentially contaminated air. If you currently have a ΔP surveillance requirement to demonstrate CRE integrity, provide the basis for your conclusion that it remains adequate to demonstrate CRE integrity in light of the ASTM E741 testing results. If you conclude that your ΔP surveillance requirement is no longer adequate, provide a schedule for: 1) revising the surveillance requirement in your technical specification to reference an acceptable surveillance methodology (e.g., ASTM E-741), and 2) making any necessary modifications to your CRE so that compliance with your new surveillance requirement can be demonstrated.**

**If your facility does not currently have a technical specification surveillance requirement for your CRE, explain how and on what frequency you confirm your CRE integrity and why this is adequate to demonstrate CRE integrity.**

Callaway Plant Response:

Callaway Plant's Technical Specifications require that surveillance be performed on an 18 month staggered basis to verify that one Control Room Emergency Ventilation System (CREVS) train can maintain a positive pressure of $\geq$ 0.125 inches water gauge, relative to the outside during the pressurization mode of operation. The Callaway Plant Technical Specification Bases state that this surveillance requirement verifies the integrity of the Control Room enclosure and the assumed inleakage rates of potentially contaminated air.

Positive pressure surveillance testing does verify the operability of the CREVS train and provides an indication of Control Room boundary integrity. However, this testing does not confirm Control Room integrity using inleakage values. Callaway Plant acknowledges that some form of inleakage testing appears to be the optimal method for confirming boundary integrity. Callaway Plant believes that it is inappropriate to submit changes to the current Technical Specifications until resolution has been achieved between the NRC and the industry on the programmatic guidance and technical specifications for verifying and maintaining Control Room Habitability to satisfy General Design Criterion (GDC) 19. Callaway Plant will submit a license amendment request to revise the Technical Specifications within one year after NRC resolution of TSTF-448, "Control Room Habitability." This license amendment request will utilize the guidance of TSTF-448, as appropriate.

Callaway Plant does not anticipate that any plant modifications will be required to incorporate a Control Room Integrity Program into the Technical Specifications as described above.

**2. If you currently use compensatory measures to demonstrate CRE habitability, describe the compensatory measures at your facility and the corrective actions needed to retire these compensatory measures.**

Callaway Plant Response:

Callaway Plant does not use compensatory measures to demonstrate Control Room envelope habitability.

**3. If you believe that your facility is not required to meet either the GDC, the draft GDC, or the "Principle Design Criteria" regarding control room habitability, in addition to responding to items 1 and 2 above, provide the documentation (e.g., Preliminary Safety Analysis Report, Final Safety Analysis Report sections, or correspondence, etc.) of the basis for this conclusion and identify your actual requirements.**

Callaway Plant Response:

Callaway Plant is committed to the General Design Criteria of Appendix A of 10CFR50 as documented in the FSAR.

## LIST OF COMMITMENTS

The following table identifies those actions committed to by AmerenUE in this document. Any other statements in this document are provided for information purposes and are not considered commitments. Please direct questions regarding these commitments to Mr. David E. Shafer at (314) 554-3104.

| COMMITMENT | Due Date/Event |
| --- | --- |
| AmerenUE will submit a license amendment request to revise the Technical Specifications within one year after NRC resolution of TSTF-448, "Control Room Habitability." This license amendment request will utilize the guidance of TSTF-448, as appropriate. | Within 1 year of resolution of TSTF-448. |

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August 8, 2003

# APPLICABILITY OF ASTM E741 TO FOUR TECHNIQUES FOR MEASURING UNFILTERED IN-LEAKAGE

## 1. Overview

A review was made of each of the 18 major elements or sections of the standard with respect to the four techniques for measuring unfiltered in-leakage. The techniques – concentration decay and constant injection – have traditionally been performed with sulfur hexafluoride ($SF_6$) but the standard indicates that any acceptable tracer and corresponding samplers and analyzers are acceptable. Perfluorocarbon tracers (PFTs) can also be used in both these techniques. The subcommittee E 06.41 on Air Leakage and Ventilation has prepared a ballot to include PFTs in the standard's Table X1.1 and X1.2 that list tracer gases used to determine air change; PFTs have been used for more than 20 years for this purpose[1].

The other two techniques in this review are the Brookhaven National Laboratory (BNL) Air Infiltration Measurement System (AIMS) and Atmospheric Tracer Depletion (ATD). In practice, a one-zone AIMS test is a constant injection technique as defined by the standard. A further advantage of AIMS is the availability of multiple PFTs for tagging multiple zones simultaneously[2,3]. The multi-zone capability is invaluable for quantifying in-leakage from other zones contiguous to a control room envelope (CRE) or for testing CREs that are comprised of normally multiple well-mixed zones. Although this capability goes beyond the intended scope of the standard, AIMS will be shown to conform to the elements within the standard.

The last technique, ATD, was newly conceived in November 2002, and, therefore, was not in existence for consideration by the standard's subcommittee. Further, ATD can only be used in buildings or envelopes that are equipped with a charcoal filtration air handling system such as a nuclear power plant's control room emergency ventilation system (CREVS). The standard was not devised with consideration of such envelopes; in these cases, however, ATD is a perfect candidate for the direct determination of unfiltered in-leakage. This fourth and last technique is also evaluated with respect to its conformance to the standard.

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 NEI 99-03 (Rev. 1, 3/03)[4] report (Appendix EE, p. EE-1). It will be seen that many of the exceptions noted in the NEI document were also noted in this review as "not applicable" (na).

This description of that review comments on the answers given in the Appendix: Comparison Table on Conformance to the Standard. The summary of that review, given in Section 3, was presented at ANS and NHUG meetings. The Conclusion (Section 4) is that all four (4) techniques conform to about the same 90% or so.

## 2. Comments on Comparison Table

This section is numbered according to the 18 elements and steps in the standard. As mentioned earlier, with one tracer, AIMS is essentially identical to $SF_6$ constant injection, so the answers to conformance should be similar; differences will be discussed. During ATD testing, when the CREVS is first turned on, the ambient background concentration of PFTs is being depleted (decaying) in a fashion that mimics the concentration decay techniques. Thus, unfiltered in-leakage can be obtained from this initial ATD decay with time in a manner similar to total in-leakage from $SF_6$ concentration decay. The usual approach, however, is to perform measurements after steady state has been attained.

*1. Scope*

1.1 All the techniques involved dilution of tracer gas. Concentration decay pertains to "decay" and ATD and constant injection to "inject" and AIMS.

1.2 The standard is restricted to a single tracer gas which all four (4) techniques can use. Additionally, the review asked the questions: Are multiple tracers used in a single zone (only ATD was Yes), and Are multiple tracers used in multiple zones (only AIMS was Yes).

1.3 All four techniques use gas analyses, instruments, etc.

1.4 This step asks the question: Are individual components testable. There are really three qualifiers:

- easily: only ATD is "Yes" (this is the answer used in the analysis)
- with special tagging: $SF_6$ inject and AIMS are "Yes",
- defined in E 741 (all "No").

1.5 Results pertinent to tested conditions: all "Yes".

1.6 And 1.7 General info; therefore <u>na</u> for all.

*2. Reference Documents*

2.1 The first and last two references were not applicable. Packed column chromatography is practiced by all but ATD which uses capillary column GC.

*3. Terminology*

3.1 The definitions are about the same for all four (4) techniques. Step 3.17.1 is an uncertain element. When there are two (2) or more distinct zones within the CRE or even multiple zones contiguous to the boundary, both $SF_6$ techniques as well as ATD may be uncertain in their applicability. AIMS is applicable.

3.2 Each of the techniques use a number of the symbols listed. This step was not considered.

*4. Summary of Test Method*

4.1 All techniques perform tracer gas measurements in a single zone. Concentration is only needed for "inject" and AIMS, whereas, relative response is used by the other two (2). Measurement of a tracer injection rate is only by "inject" and AIMS and injection techniques are needed for all but ATD. All have to consider sampling strategies.

4.2 All techniques are available for choosing.

4.2.1 The air change quantity determined is different for the four techniques. "Decay" measures total air change rate, whereas, "inject" and AIMS measure a total air in-leakage flow rate; thus, "decay" only provides an indirect measure of total air in-leakage. Further, only ATD provides a direct measure of unfiltered in-leakage.

5. *Significance and Use*

General relevance; not used in ranking.

6. *Apparatus*

6.1 Distributing tracer is na for ATD (no tracer release required). Obtaining air samples and using a gas analyzer is "Yes" for all four (4).

6.2 Tracer gases are "used" in all four (4) techniques (Yes).

6.2.1 All four use a tracer gas standard (Yes). However, "decay" and ATD do not need the tracer standard for intended in-leakage results.

6.3 Tracer gas injection and distribution. ATD does not require tracer release.

6.3.1 And 6.3.2 All but ATD are "Yes"; ATD is na.

6.4 Tracer gas sampling (and all the sub-elements – 6.4.1 to 6.4.3) are "Yes" to all four (4) techniques.

6.5 All techniques use relevant tracer gas analysis capabilities.

6.6 Ancillary measurements.

6.6.1 Meteorological equipment was excluded here as well as in the NEI exceptions.[4]

6.6.2 And 6.6.3 The reviewer gave a "Yes" to all four (4) techniques. Temperature is important to AIMS for correcting source emission rates and is a good indicator of the stability of HVAC equipment. Timing is important to all techniques.

6.7 Data acquisition was na for all four (4) techniques. This was recognized by NEI as well.

7. *Hazards*

All four (4) techniques consider 7.1 (Safety) and 7.2 (Health).

7.3 Explosive limits is na to all four (4) techniques.

7.4 Only "decay" and "inject" must consider compressed gases at the site.

8/9. *Concentration Decay/Constant Injection Test Methods*

In the E 741 standard, both of these methods follow the same sub-elements. Therefore, only a single set of sub-elements was considered for conformance by all four (4) techniques.

8/9.1 The general summary was considered na for all four (4) techniques.

8/9.2 Preparation is important to all techniques.

8/9.2.1 Ancillary measurements were important to all four (4) during preparation with respect to how zones will be operated and volume of zones (for calculating time constants). This applies to 8/9.2.2 as well.

8/9.2.3 The requirements for estimating tracer gas injection rates and initial volumes is important to all three (3) techniques but ATD (no tracer injected). Accelerating time to steady state for "inject" and AIMS can also be considered here.

8/9.2.4 Where to sample is relevant to all four (4) techniques.

8/9.3 Only ATD does not have to implement tracer injection.

8/9.4 All four (4) techniques need to consider spatial and time-dependent sampling.

8/9.5 Analyses is different for the four (4) techniques.

8/9.5.1 The first two (2) techniques analyze on site and the last two (2), off site.

8/9.5.2 Uniformity of concentrations or adequately determined volume-weighted average concentrations must be determined.

8/9.5.3 The first three (3) techniques calculated total air change rate or flow rate; ATD does not. However, the first three (3) techniques do not directly determine unfiltered in-leakage; ATD does ("Yes").

*10. Constant Concentration Method*

This review and NEI considered this step to be na.

*11. Preparation of Zones*

11.1 Ancillary measurements (such as temperature), zone volumes, and estimated total zonal flow rates are important for all four (4) techniques. Temperatures indicate stability of HVAC systems. Zone volumes and flow rates are needed for times to steady state.

11.2 Status of zone being tested as well as contiguous zones is important to all techniques.

*12. Procedure for Distributing Tracer Gas*

For most steps in this section, ATD response is na since no tracer is intentionally released.

12.1 Avoiding contamination is always important.

12.1.1 Handling bottles and regulators ("decay" and "inject") as well as permeation sources (AIMS) is important for these techniques.

12.1.2 Anything that might adversely affect the conservation of the tracer, even that being depleted in ATD, must be considered.

12.1.3 A measure of potential interferences before testing is important to all.

12.2 Manual injection is used for "decay" and to accelerate approach to steady state for "inject" and AIMS.

12.3 Metered injection is only used for "inject" and AIMS

12.4 Uniformity of concentrations

12.4.1 Uniformity of released-tracer concentrations within a zone is to be within 10% of the average. Sampling done at several return air locations or averaged over many volume-weighted locations can assure appropriate values for the three techniques using tracer release. However, ATD is like a negative tracer release – i.e., depletion. Thus, the "source" location of that depleted air must also be uniformly determined. Therefore, "Yes" to all four (4) techniques.

12.4.2 Aids to mixing are important to all but ATD. With the latter, a volume-weighted determination is generally preferred in order to observe locations where unfiltered in-leakage might actually be occurring. Mixing would eliminate that observation without a real significant gain in reducing uncertainty in determining unfiltered in-leakage. That is not the case for "decay" or "inject". Because unfiltered in-leakage is obtained by difference, accuracy and precision needs to be much better; concentration variability needs to be much tighter than for ATD. Thus, only ATD is na.

*13. Sampling Tracer Gas*

Sampling tracer gas is important and "Yes" for all sub-elements in this section. No exceptions.

*14. Procedures for Gas Analysis*

Procedures for gas analysis are also all "Yes" with the exception of using standards for the GC during ATD analyses.

14.1 Calibration of the gas analyses for ATD is na. However, prior studies were made of gas analyzer accuracy (14.1.1.), gas analyzer precision (14.1.2), and other factors that affect estimated measurement precision (14.1.3) to assure that this step is not needed for each field test.

*15. Procedure for Ancillary Measurements*

This procedure is not used in the NEI recommendations. Outdoor temperature and wind (15.1) and correlation with in-leakge is na for all four (4) techniques.

15.2 Indoor temperature is important for AIMS sources, but, also to verify air handling system performance; all "Yes".

15.3 Zone volumes are needed for all techniques to estimate times to steady state.

*16. Report*

NEI recommendations were to not use the standard guidelines. The original review considered Sections 16.1 and 16.2 to be all "Yes" for all four (4) techniques.

16.3 Data analysis

16.3.1 Record of tracer injection is na for ATD.

16.3.2 All four (4) techniques consider a record of concentration or tracer response.

16.3.3 The first three (3) techniques calculate total air change rate or flow; ATD is na. However, only ATD directly calculates unfiltered in-leakage (ATD "Yes" and all others "No").

16.3.4 All techniques consider an error analysis.

*17. Precision and Bias*

Again, the NEI recommendations were to not follow the standard but use the vendor's procedures. This original review considered how the four (4) techniques would conform to the standard.

17.1 This overview statement was not ranked.

17.2 Precision is considered by all techniques ("Yes"). All look at variability in concentration or response as a function of time and sampling location.

17.2.1 All techniques use a tracer gas standard to verify performance of the analyzer prior to use – including precision across multiple samples.

17.2.2 Again, all techniques use zone volume to determine time constants to steady state and for mixing.

17.2.3 Scatter about a tracer decay result relates to magnitude of precision for that technique only.

17.2.4 Scatter in concentration versus time and location relates to precision in the other three techniques.

17.2.5 None of the four (4) techniques relate to the constant concentration technique.

17.3 All four (4) techniques consider bias. ATD is the likely technique least influenced by bias.

## 3. Summary

| | |
|---|---|
| Major element in E 741 standard: | 18 |
| - specifically applicable | 14 |
| Total specific sub-elements | 108 |

| | $SF_6$ Decay | $SF_6$ Inject | AIMS | ATD |
|---|---|---|---|---|
| Sum of "Yes" | 80 | 83 | 84 | 69 |
| (percentage of subtotal) | (89%) | (89%) | (91%) | (92%) |
| Sum of "No" | 9 | 9 | 8 | 5 |
| Uncertain | 1 | 1 | - | 1 |
| Subtotal | 90 | 93 | 92 | 75 |
| Not applicable | 18 | 15 | 16 | 33 |
| TOTAL | 108 | 108 | 108 | 108 |

## 4. Conclusion

All four (4) techniques equally conform to the ASTM E 741 standard – that is, each to about 90% of all sub-elements.

## 5. References


1. Dietz, R.N. and Cote, E.A., *Air Infiltration Measurements in a Home Using a Convenient Perfluorocarbon Tracer Technique,* Environ. Int. 8, pp. 419-433, 1982.

2. Dietz, R.N., Goodrich, R.W., Cote, E.A., and Wieser, R.F., Detailed Description and Performance of a Passive Perfluorocarbon Tracer System for Building Ventilation and Air Exchange Measurements, In *Measured Air Leakage of Buildings, ASTM STP 904,* H.R. Trechsel and P.L. Lagus, Ed., American Society for Testing and Materials, Philadelphia, 1986, pp. 203-264.

3. D'Ottavio, T.W., Senum, G.I., and Dietz, R.N., *Error Analysis Techniques for Perfluorocarbon Tracer Derived Multizone Flow Rates,* Building and Environment, 23 (3), pp. 187-194, 1988.

4. *Control Room Habitability Guidance,* NEI 99-03 (Rev. 1), Nuclear Energy Institute, March 2003.

## Applicability of ASTM E 741 to Four Techniques for Measuring Unfiltered In-Leakage

**Appendix:**
**Comparison Table on Conformance to the Standard – yes, no, or na (not applicable)**

| No. | Item | $SF_6$ Decay | $SF_6$ Inject | AIMS | ATD |
|---|---|---|---|---|---|
| **1.** | **Scope** | | | | |
| 1.1 | Tracer gas dilution | Yes | Yes | Yes | Yes |
| | (1) Concentration decay | Yes | No | No | No |
| | (2) Constant injection | No | Yes | Yes | na |
| 1.2 | Single tracer gas for single zone | Yes | Yes | Yes | Yes |
| | Multiple tracer gas for single zone | No | No | No | Yes |
| | Multiple tracer gas for multiple zones | No | No | Yes | No |
| 1.3 | Gas analysis, instruments, units | Yes | Yes | Yes | Yes |
| 1.4 | Individual components testable | No | No | No | Yes |
| 1.5 | Results pertain to tested conditions only | Yes | Yes | Yes | Yes |
| 1.6 | Notes & footnotes | na | na | na | na |
| 1.7 | Safety & health | na | na | na | na |
| **2.** | **Referenced Documents** | | | | |
| 2.1 | ASTM standards | | | | |
| | D 4480 meas. surface winds | na | na | na | na |
| | E 260 Practice for packed column GC | na | na | na | na |
| | E 779 Fan pressurization testing | Yes | Yes | Yes | na |
| | E 1186 Air leakage site detection | na | na | na | na |
| **3.** | **Terminology** | | | | |
| 3.1 | Definitions | | | | |
| 3.1.1 | Air change flow | na | Q, $m^3/h$ | R, $m^3/h$ | R, $m^3/h$ |
| 3.1.2 | Air change rate | A, $h^{-1}$ | na | na | na |
| 3.1.3 | Envelope | Yes | Yes | Yes | Yes |
| 3.1.3.1 | discussion | Yes | Yes | Yes | Yes |
| 3.1.4 | Tracer gas | Yes | Yes | Yes | Yes |
| 3.1.5 | Tracer gas analyzer | Yes | Yes | Yes | Yes |
| 3.1.6 | Tracer gas concentration | $m^3/m^3$ | $m^3/m^3$ | $nL/m^3$ | $cts/m^3$ |
| 3.1.7 | Single zone | Yes | Yes | Yes | Yes |
| 3.1.7.1 | multiple zones | uncertain | uncertain | Yes | uncertain |
| 3.2 | Symbols | --- | --- | --- | --- |
| **4.** | **Summary of Test Method** | | | | |
| 4.1 | Tracer gas measurement in single zones | Yes | Yes | Yes | Yes |
| | – measurement of concentration | na | Yes | Yes | na |
| | – measurement of relative response | Yes | na | na | Yes |

| No. | Item | $SF_6$ Decay | $SF_6$ Inject | AIMS | ATD |
|---|---|---|---|---|---|
| | Measurement of tracer injection rate | na | Yes | Yes | na |
| | Injection techniques | Yes | Yes | Yes | na |
| | Sampling strategies | Yes | Yes | Yes | Yes |
| 4.2 | Choice of techniques | Yes | Yes | Yes | Yes |
| 4.2.1 | Air change quantity | | | | |
| | – total air change rate | Yes | No | No | No |
| | – total air change flow | No | Yes | Yes | No |
| | – direct unfiltered flow | No | No | No | Yes |
| **5.** | **Significance and Use (general relevance)** | | | | |
| **6.** | **Apparatus** | | | | |
| 6.1 | Distributing tracer | Yes | Yes | Yes | na |
| | – obtaining air samples | Yes | Yes | Yes | Yes |
| | – gas analyzer | Yes | Yes | Yes | Yes |
| 6.2 | Tracer gases | Yes | Yes | Yes | Yes |
| 6.2.1 | Tracer gas standard | na | Yes | Yes | na |
| 6.3 | Tracer gas injection/distribution | | | | |
| 6.3.1 | Tracer gas metering | Yes | Yes | Yes | na |
| 6.3.2 | Tracer gas distribution | Yes | Yes | Yes | na |
| 6.4 | Tracer gas sampling | Yes | Yes | Yes | Yes |
| 6.4.1 | Materials for sampling | Yes | Yes | Yes | Yes |
| 6.4.2 | Manual samplers | Yes | Yes | Yes | Yes |
| 6.4.3 | Automatic samplers | Yes | Yes | Yes | Yes |
| 6.4.3.1 | Sampling network | Yes | Yes | Yes | Yes |
| 6.4.3.2 | Automated samplers | Yes | Yes | Yes | Yes |
| 6.5 | Gas analyzers | Yes | Yes | Yes | Yes |
| 6.6 | Ancillary measurement devices | | | | |
| 6.6.2&3 | Temperature and timing | Yes | Yes | Yes | Yes |
| 6.7 | Data acquisition and control | na | na | na | na |
| **7.** | **Hazards** | | | | |
| 7.1 | Safety | Yes | Yes | Yes | Yes |
| 7.2 | Health | Yes | Yes | Yes | Yes |
| 7.3 | Explosive limits | na | na | na | na |
| 7.4 | Compressed gases | Yes | Yes | na | na |
| **8/9.** | **Concentration decay/Constant injection** | | | | |
| 8/9.1 | Summary | na | na | na | na |
| 8/9.2 | Preparation | | | | |
| 8/9.2.1 | Ancillary measurements | Yes | Yes | Yes | Yes |
| 8/9.2.2 | Zonal operation | Yes | Yes | Yes | Yes |
| 8/9.2.3 | Tracer gas injection volume | Yes | Yes | Yes | na |
| 8/9.2.4 | Sampling | Yes | Yes | Yes | Yes |

| No. | Item | $SF_6$ Decay | $SF_6$ Inject | AIMS | ATD |
|---|---|---|---|---|---|
| 8/9.3 | Tracer injection | Yes | Yes | Yes | na |
| 8/9.4 | Sampling | Yes | Yes | Yes | Yes |
| 8/9.5 | Analysis | | | | |
| 8/9.5.1 | – analyze on site | Yes | Yes | No | No |
| | – analyze off site | No | No | Yes | Yes |
| 8/9.5.2 | Uniformity of concentration | Yes | Yes | Yes | Yes |
| 8/9.5.3 | – calc air change rate or flow | Yes | Yes | Yes | No |
| | – calc direct unfiltered in-leakage | No | No | No | Yes |
| **10.** | **Constant Concentration Method** | na | na | na | na |
| **11.** | **Preparation of Zone** | | | | |
| 11.1 | Auxillary measurements | Yes | Yes | Yes | Yes |
| 11.2 | Preparation of zone | Yes | Yes | Yes | Yes |
| **12.** | **Procedures for Distributing Tracer Gas** | | | | |
| 12.1 | Avoid contamination | | | | |
| 12.1.1 | Handling tracer gases | Yes | Yes | Yes | na |
| 12.1.2 | Conservation of tracer gas | Yes | Yes | Yes | Yes |
| 12.1.3 | Pre-existing tracer gas | Yes | Yes | Yes | Yes |
| 12.2 | Manual injection | Yes | Yes | Yes | na |
| 12.3 | Metered injection | na | Yes | Yes | na |
| 12.4 | Uniformity of concentration | | | | |
| 12.4.1 | Uniformity determined | Yes | Yes | Yes | Yes |
| 12.4.2 | Aids to mixing | Yes | Yes | Yes | na |
| **13.** | **Sampling Tracer Gas** | | | | |
| 13.1 | Manual sampling | Yes | Yes | Yes | Yes |
| 13.2 | Automated sampling | Yes | Yes | Yes | Yes |
| 13.3 | Spatial sampling | | | | |
| 13.3.1 | When to sample | Yes | Yes | Yes | Yes |
| 13.3.2 | Where to sample | Yes | Yes | Yes | Yes |
| 13.4 | Avoid contamination/dilution | Yes | Yes | Yes | Yes |
| **14.** | **Procedures for Gas Analysis** | | | | |
| 14.1 | Calibration of analyzer | Yes | Yes | Yes | Yes |
| 14.2 | Tracer gas sampling records | Yes | Yes | Yes | Yes |
| 14.3 | Tracer gas measurements | Yes | Yes | Yes | Yes |
| **15.** | **Procedure for Ancillary Measurements** | | | | |
| 15.1 | Outdoor temperature & wind | na | na | na | na |
| 15.2 | Indoor temperature | Yes | Yes | Yes | Yes |
| 15.3 | Zone volume | Yes | Yes | Yes | Yes |
| 15.4 | Correlation with air change | na | na | na | na |

| No. | Item | $SF_6$ Decay | $SF_6$ Inject | AIMS | ATD |
|---|---|---|---|---|---|
| **16.** | **Report** | | | | |
| 16.1.1 | Background information | | | | |
| 16.1.1.1 | Description of enclosure | Yes | Yes | Yes | Yes |
| 16.1.1.2 | Zone description(s) | Yes | Yes | Yes | Yes |
| 16.1.2 | Design of test | | | | |
| 16.1.2.1 | Test method | Yes | Yes | Yes | Yes |
| 16.1.2.2 | Zone operation | Yes | Yes | Yes | Yes |
| 16.1.2.3 | Tracer gas distribution | Yes | Yes | Yes | na |
| 16.1.2.4 | Tracer gas sampling | Yes | Yes | Yes | Yes |
| 16.1.2.5 | Gas analyzer | Yes | Yes | Yes | Yes |
| 16.1.2.6 | Data gathering | Yes | Yes | Yes | Yes |
| 16.1.2.7 | Ancillary measurements | Yes | Yes | Yes | Yes |
| 16.1.3 | Data analysis | | | | |
| 16.1.3.1 | Record of tracer injection | Yes | Yes | Yes | na |
| 16.1.3.2 | Record of tracer concentration | Yes | Yes | Yes | Yes |
| 16.1.3.3 | – Calculation of total air change | Yes | Yes | Yes | na |
| | – Calc. of direct unfiltered in-leakage | No | No | No | Yes |
| 16.1.3.4 | Error analysis | Yes | Yes | Yes | Yes |
| **17.** | **Precision and Bias** | | | | |
| 17.1 | Overview | --- | --- | --- | --- |
| 17.2 | Precision | Yes | Yes | Yes | Yes |
| 17.2.1 | Gas analyzer (stds, repetitive samples, etc) | Yes | Yes | Yes | Yes |
| 17.2.2 | Zone volumes | Yes | Yes | Yes | Yes |
| 17.2.3 | Tracer decay scatter | Yes | na | na | na |
| 17.2.4 | Constant tracer injection | na | Yes | Yes | Yes |
| 17.2.5 | Constant concentration | na | na | na | na |
| 17.3 | Bias | | | | |
| 17.3.1-3 | Identified biases | Yes | Yes | Yes | Yes |
| **18.** | **Key Words** | --- | --- | --- | --- |
| **Summary** | | | | | |
| | Sum of "Yes" | 80 | 83 | 84 | 69 |
| | **(percentage of subtotal)** | (89%) | (89%) | (91%) | (92%) |
| | Sum of "No" | 9 | 9 | 8 | 5 |
| | Uncertain | 1 | 1 | --- | 1 |
| | Subtotal | 90 | 93 | 92 | 75 |
| | Not applicable | 18 | 15 | 16 | 33 |
| | TOTAL | 108 | 108 | 108 | 108 |