Berkeley High Performance Fume Hood Test Plan for Cal/OSHA

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Dale Sartor

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1 Background

LBNL and Cal/OSHA Division and Board staff are working to develop a set of tests that if successfully performed will result in staff's recommendation to the Standards Board that a variance for the Berkeley Hood be granted. It is understood that the Board acts independently and that staff recommendations do not assure the Board's approval.

Cal/OSHA requires fume hoods to operate at 100 fpm average face velocity as an indicator (not a measure) of containment and safety. We propose in lieu of meeting the face velocity requirement to use a standardized tracer gas test as an equivalent/superior indicator of performance.

The variance application form requires the employer to describe their plan to provide equal or superior safety. A plan was submitted for an innovative push-pull type fume hood that uses ASHRAE 110-1995 test methods to document containment per ANSI/AIHA Z9.5 recommended thresholds. This innovative fume hood, a.k.a., a Berkeley Hood, shall be operated in a push-pull mode after passing the ASHRAE 110-1995 tracer gas (SF_6) test method with a control level of less than 0.10 parts per million (ppm) at a SF_6 release rate of 4 liters per minute (lpm) per the ANSI/AIHA Z9.5-2003 standard. This is consistent with a formal interpretation requested by the Cal/OSHA Standards Board from ANSI/AIHA which states, "…the tracer gas portion of ASHRAE 110 with an as installed performance of 4 liters per minute at 0.10 ppm is a superior test of fume hood safety and containment than simply verifying the hood as having 100 feet per minute of average face velocity."

It is the applicant's premise that face velocity is not a good indicator of containment or safety. In fact, many hoods meeting the Cal/OSHA face velocity standard fail more robust tracer gas tests. Accordingly, tracer gas testing (per ASHRAE 110) is a better indicator of containment than face velocity. Therefore, when a hood passes the tracer gas test, it is more likely to contain contaminants, and is thus providing worker safety equal or superior to the Cal/OSHA standard.

With input from Cal/OSHA staff, the applicant's commissioning test procedure was expanded to include tests to determine a safe operating range of the push-pull hood. Such testing is not required of conventional hoods that most likely operate out of their specified range (with no knowledge of the impact).

The following test plan includes Static Tests as specified in the application, plus additional, Non-Standard Tests (not part of the variance application).

2 Static Tests

2.1 Berkeley Hood Startup

1. The design exhaust airflow volume is 50 cfm per square foot of the maximum face area. For example, for an 8 square foot open face area, the design exhaust rate will be 400 cfm. Total directed air-stream plenum flow will be adjusted to approximately 40 percent of the exhaust airflow volume. The remaining 60 percent airflow volume is induced through the hood's face by the exhaust airflow. Overall exhaust airflow will be determined by measuring the average face velocity with the directed air stream (push) fans off, or by flow measurement in the hood's exhaust outlet. Air flows from three directed air stream plenums will be measured in at least three locations (e.g. 6 inches from each side and at the center of each plenum grill). A velocity sensor will be placed one inch(1") from the plenum to measure flow. The locations (9 total) will be documented to assure repeatability.
2. The directed air supply systems and exhaust ventilation system will be measured and adjusted, as necessary, to provide the directed air stream, total exhaust, and inward airflows as specified. Fine-tuning of these airflows may be made to optimize performance. Final set points will be documented for the as-installed operating conditions.

2.2 Tracer Gas Testing

2.2.1 Containment Tests

Tracer gas containment tests per the ASHRAE 110-1995 protocol will be performed in the "as installed" condition with sashes fully open. The basis for acceptance will be 4-AI-0.10 (per ANSI/AIHA Z9.5-2003).

2.2.2 Special Commissioning Tests

Special "Commissioning Tests" shall be performed to determine a safe operating range (deviation from as-installed set points) in the hood's as-installed condition. Tests shall be performed at gradually reduced exhaust rates until the hood fails to contain (per ANSI/AIHA Z9.5-2002 AI threshold of 0.10 ppm in the center ejector and mannequin position). The exhaust flow rate shall be set at least 50 percent above the demonstrated failure point (actually above a demonstrated containment point above the failure point). The as-installed set point(s) shall be adjusted if required.

1. The operating range minimum shall be set at least 25 percent above the "failure" point to ensure a margin of safety. For example, if the hood is proven to contain at 260 cfm exhaust (but not below), the as-installed exhaust airflow rate will be set at 390 cfm (260 x 1.5) or more, and the acceptable operating minimum would be 325 cfm or greater (260 x 1.25).
2. The flow rates through each directed air stream plenum shall also be reduced and the hood tested to determine an acceptable operating minimum. The operating minimum will be at least 25 percent higher than

any failure point to provide a margin of safety. The flow rates through each directed air stream plenum will also be increased to determine an acceptable operating maximum (for each). If a failure occurs within the capacity of the as-installed system, the operating maximum will be set 20% below the failure point to provide a margin of safety.

3. A minimum of seven tracer gas tests will be performed documenting containment at low exhaust and high (maximum) and low flows (off) for each of the three internal supply fans.

All hoods have the potential to deviate from design or as-installed conditions. Since our objective is to demonstrate equivalent or superior performance to a hood meeting the Cal/OSHA face velocity standard, then these special commissioning tests fall into the "superior" category, as standard hoods do not demonstrate their range of operation or robustness.

3 Non-Standard Tests

3.1 Human-as-Mannequin Dynamic Tests

A push-pull hood will be subjected to non-standard, dynamic challenges of a type that are intended to represent normal safe operation that can cause spillage. These challenges, or tests, will account for the combined ability of the hood to contain, capture internally, and re-capture as required. These so-called "Human-as-Mannequin Dynamic Tests" are intended to be practical, dynamic challenges to simulate actual hand, and arm movement and manipulation of objects within a fume hood that may cause loss of containment.

These tests are not presented in the ASHRAE 110-1995 Method or the ANSI Z9.5 Ventilation Standard. There are no US industry standards for Human-as-Mannequin dynamic challenge tests, and no recommended threshold values for pass and fail. Therefore, we shall establish thresholds by testing a conventional, "state-of-the-shelf" hood and comparing it with a push-pull hood. The conventional hood shall be a Jamestown "Isolator" complete with bottom air-foil, tapered/angled inlets, adjustable baffles, and vertical rising sash. The conventional hood and the Berkeley hood will be manufactured by the same manufacturer to minimize the number of different design variables. Tracer gas concentrations shall be measured at a technician's breathing zone and averaged over the test period. The threshold value will be the higher of 0.10 ppm (with 4 lpm as used in the Static Tests, above) or the average concentration over the test period for the conventional hood with 100 fpm average face velocity.

Since many factors affect hood performance, it is important that the conventional hood and the push-pull hood be measured under equivalent environmental conditions. Consequently, side-by-side tests shall be performed at LBNL on six-foot hoods.

This draft test protocol draws on information and points-of-view from numerous sources including: Tom Smith at Exposure Control Technologies, Inc.; Dale Hitchings at SafeLab Corporation; Mike Ratcliff at RWDI, Debbie Decker, et al, at University of California Industrial Hygienists; Geoffrey Bell at the LBNL Applications Team.

3.1.1 Hood Setup and Operational Overview

Testing shall be conducted in a side-by-side comparative manner. Two hoods of the same manufacturer shall be tested; one hood shall be conventionally configured and operated and the other hood shall be configured to include Berkeley Hood containment features and operated accordingly. Both hoods shall have passed the Static Containment Test specified in 2.2.1 with sashes fully opened (with the traditional hood operated at 100 fpm face velocity). The conventional hood shall be operated at 100 feet per minute face velocity per CAL/OSHA 5154.1 with its sash in a full open position for the entire **Choreographed Sequence,** (see below). The Berkeley hood shall be operated, as specified elsewhere, with the sash in a full open position) for the entire **Choreographed Sequence,** (see below).

3.1.2 Tracer Gas Test Procedure

Set up each Ejector Position per ASHRAE 110-1995 Tracer Gas Test Procedure (see Section 7). Initiate tracer gas flow at the beginning of each Dynamic Test and shut off at the end of each Dynamic Test. Each **Choreographed Sequence** shall be time-data logged, noting start and finish times and record tracer gas control level as a function of time. The **Choreographed Sequences** shall be performed and documented by an independent testing firm or conducted with a CAL/OSHA staff member in attendance.

3.1.3 Technician

The tracer gas detector probe inlet shall be located on the front of the technician near the technician's breathing zone at approximately 26 inches above the work surface. The maximum length of tubing from the probe's inlet to the detector shall be six (6) feet long. At the beginning of each phase, the technician shall stand directly in front of the ejector and position their breathing zone at approximately three (3) inches away from the plane of the sash. The technician shall:

- Be familiar with performing the ASHRAE 110-1995 Tracer Gas Test Procedure, Section 7, inclusive.
- Be familiar with **Test Plan Glossary** (below) before performing **Sequence**. **GLOSSARY** terms are shown in ***bold italic*** font throughout the text of this document.
- Be practiced in performing each movement listed in the **Glossary** at least two times
- Be practiced in performing the entire **Choreographed Sequence** (without tracer gas flowing) at least two times.

- Be prompted or use other devices such as a metronome to assure a consistent pace.
- Be the same person performing the **Choreographed Sequence** on each hood.
- Be wearing a lab coat.

3.1.4 Duration

The duration of each **Dynamic Test**; **Center**, **Left**, **Right**, (three for each hood, total of six Tests per complete side-by-side Sequence) shall be equivalent in duration by plus or minus (±) 20 seconds of the averaged duration.

3.2 Choreographed Sequence

This **Choreographed Sequence** includes three **Dynamic Tests**: **Center**, **Left**, and **Right**. Each **Dynamic Test** includes six (6) phases: **Center Dynamic Test**, **Phase One** through **Six**; **Left Dynamic Test**, **Phase Seven** through **Twelve**; **Right Dynamic Test**, **Phase Thirteen** through **Eighteen**. Therefore, the **Choreographed Sequence** for each hood has eighteen phases.

3.2.1 Phase One: Center Dynamic Test

1. Locate ***Ejector - Center*** in hood and Place ***Objects – Center*** according to **Table Phase One**, below.

Table Phase One

12 inches behind sash					
6 inches behind sash	1	2	**E**	3	4

2. Begin **Test** by starting tracer gas flow and waiting for 15 seconds.

3.2.2 Phase Two

3. ***Insert Hands and Arms*** for 15 seconds.
4. ***Remove Hands and Arms***; lower to side for a minimum of five seconds.

3.2.3 Phase Three

5. ***Insert Hands and Arms*** into the hood.
6. Starting from the left and working to the right, Grasp each object, ***Move Objects*** individually to a position that is twelve (12) inches from the plane of the sash (rearward), using each hand as appropriate.

Table Phase Three

12 inches behind sash	1	2		3	4
6 inches behind sash			**E**		

7. ***Remove Hands and Arms***; lower to side for a minimum of five seconds

3.2.4 Phase Four

8. ***Insert Hands and Arms*** into the hood.
9. Starting from the left and working to the right, Grasp each object, ***Exchange Objects*** and ***Move Objects*** individually to a position that is six (6) inches from the plane of the sash (forward) .

Table Phase Four

12 inches behind sash					
6 inches behind sash	4	3	**E**	2	1

10. ***Remove Hands and Arms***; lower to side for a minimum of five seconds.

3.2.5 Phase Five

11. ***Insert Hands and Arms*** into the hood.
12. Grasp object #1 on the right side of the ejector and ***Transfer Liquids*** from object #1 to object #2 (refer to **Table Phase Four**).
13. ***Remove Hands and Arms*** ; lower to side for a minimum of five seconds.

3.2.6 Phase Six

14. ***Insert Hands and Arms*** into the hood.
15. Grasp object number three (3) on the left side of the ejector and ***Remove Hands and Arms***. Note: left hand is holding object number three (3).
16. Lower right hand to side and ***Rotate Body*** to left.
17. ***Insert Hands and Arms*** into the hood.
18. Replace object number three (3).
19. ***Remove Hands and Arms***; lower to side for a minimum of five seconds.
20. End **Test** by waiting for 15 seconds and ending tracer gas flow.

3.2.7 Phase Seven: Left Dynamic Test

21. Locate ***Ejector - Left*** in hood and Place ***Objects – Left*** according to **Table Phase Seven**, below.

Table Phase Seven

12 inches behind sash					
6 inches behind sash	2	**E**	3	4	1

22. Begin **Test** by starting tracer gas flow and waiting for 15 seconds.

3.2.8 Phase Eight

23. ***Insert Hands and Arms*** for 15 seconds.
24. ***Remove Hands and Arms***; lower to side for a minimum of five seconds.

3.2.9 Phase Nine

25. ***Insert Hands and Arms*** into the hood.

26. Starting from the right and working to the left, Grasp each object, ***Move Objects*** individually to a position that is twelve (12) inches from the plane of the sash (rearward), using each hand as appropriate.

Table Phase Nine

12 inches behind sash	2		3	4	1
6 inches behind sash		**E**			

27. ***Remove Hands and Arms***; lower to side for a minimum of five seconds.

3.2.10 Phase Ten

28. ***Insert Hands and Arms*** into the hood.
29. Starting from the right and working to the left, Grasp each object, ***Exchange Objects*** and ***Move Objects*** individually to a position that is six (6) inches from the plane of the sash (forward) .

Table Phase Ten

12 inches behind sash					
6 inches behind sash	3	**E**	2	1	4

30. ***Remove Hands and Arms***; lower to side for a minimum of five seconds.

3.2.11 Phase Eleven

31. ***Insert Hands and Arms*** into the hood.
32. Grasp object #1 on the right side of the ejector and ***Transfer Liquids*** from object #1 to object #2 (refer to **Table Phase Ten**).
33. ***Remove Hands and Arms***; lower to side for a minimum of five seconds.

3.2.12 Phase Twelve

34. ***Insert Hands and Arms*** into the hood.
35. Grasp object number Three (3) on the left side of the ejector with left hand and ***Remove Hands and Arms***. Note: left hand is holding object number Three (3).
36. Lower right hand to side and ***Rotate Body*** to left.
37. ***Insert Hands and Arms*** into the hood.
38. Replace object number Three (3).
39. ***Remove Hands and Arms***; lower to side for a minimum of five seconds.
40. End **Test** by waiting for 15 seconds and ending tracer gas flow.

3.2.13 Phase Thirteen: Right Dynamic Test

41. Locate ***Ejector - Right*** in hood and Place ***Objects – Right*** according to **Table Phase Thirteen**, below:

Table Phase Thirteen

12 inches behind sash					

6 inches behind sash	1	4	3	**E**	2

42. Begin **Test** by starting tracer gas flow and waiting for 15 seconds.

3.2.14 Phase Fourteen

43. ***Insert Hands and Arms*** for 15 seconds.
44. ***Remove Hands and Arms***; lower to side for a minimum of five seconds.

3.2.15 Phase Fifteen

45. ***Insert Hands and Arms*** into the hood.
46. Starting from the left and working to the right, Grasp each object, ***Move Objects*** individually to a position that is twelve (12) inches from the plane of the sash (rearward), using each hand as appropriate.

Table Phase Fifteen

12 inches behind sash	1	4	3		2
6 inches behind sash				**E**	

47. ***Remove Hands and Arms***; lower to side for a minimum of five seconds.

3.2.16 Phase Sixteen

48. ***Insert Hands and Arms*** into the hood.
49. Starting from the left and working to the right, Grasp each object, ***Exchange Objects*** and ***Move Objects*** individually to a position that is six (6) inches from the plane of the sash (forward) .

Table Phase Sixteen

12 inches behind sash					
6 inches behind sash	4	1	2	**E**	3

50. ***Remove Hands and Arms***; lower to side for a minimum of five seconds.

3.2.17 Phase Seventeen

51. ***Insert Hands and Arms*** into the hood.
52. Grasp object #1 on the left side of the ejector and ***Transfer Liquids*** from object #1 to object #2 (refer to **Table Phase Sixteen**).
53. ***Remove Hands and Arms***; lower to side for a minimum of five seconds.

3.2.18 Phase Eighteen

54. ***Insert Hands and Arms*** into the hood.
55. Grasp object number Three (3) on the right side of the ejector with right hand and ***Remove Hands and Arms***. Note: right hand is holding object number Three (3).
56. Lower left hand to side and ***Rotate Body*** to right.
57. ***Insert Hands and Arms*** into the hood.

58. Replace object number Three (3).
59. ***Remove Hands and Arms***; lower to side for a minimum of five seconds.
60. End **Test** by waiting for 15 seconds and ending tracer gas flow.

3.3 Results

The time-averaged tracer gas control level in the Human-as-Mannequin breathing zone shall be calculated for the entire **Sequence** (three Dynamic Tests totaling Eighteen Phases) for each hood (excluding the time between the three Tests) and reported.

For each hood, the Human-as-Mannequin **Sequence**, as described above, will be repeated three times developing a **Series**. For each hood, the time-averaged tracer gas control level from each **Sequence** in the **Series** will be totaled. This **Series Total Value** will provide an overall performance indicator for comparison purposes between the two hoods.

The **Series Total Value** for the Berkeley hood will be compared to the **Series Total Value** for the conventional hood. If the Berkeley hood's **Series Total Value** is lower, then its containment will be considered superior.

If the Berkeley hood proves to have superior containment performance at low-flow rates under the dynamic tests described, then similar Berkeley Hoods, tested in the field (as-installed) in accordance with ASHRAE 110-1995 and meeting the ANSI/AIHA Z9.5 recommended containment thresholds, will be considered to have equivalent or superior performance to hoods meeting the Cal/OSHA face velocity requirements (subject to Cal/OSHA Standards Board variance approval).

3.4 Test Plan Glossary

3.4.1 Ejector – Center

Use the ASHRAE 110-1995 requirements for center placement of the ejector (Section 7.3) and SF_6 flow rate (Section 4.1). Accordingly, the SF_6 ejector shall be placed in the center of each fume hood, and six (6) inches into the hood's interior as measured from the plane of the sash for the **Choreographed Sequence; Center Dynamic Test, Phase One** through **Phase Six,** (see above).

3.4.2 Ejector – Left

Use the ASHRAE 110-1995 requirements for left placement of the ejector (Section 7.3) and SF_6 flow rate (Section 4.1). Accordingly, the SF_6 ejector shall be placed twelve inches (12 in.) from the left sidewall of each fume hood, and six (6) inches into the hood's interior as measured from the plane of the sash for the **Choreographed Sequence; Left Dynamic Test, Phase Seven** through **Phase Twelve,** (see above).

3.4.3 Ejector – Right

Use the ASHRAE 110-1995 requirements for right placement of the ejector (Section 7.3) and SF_6 flow rate (Section 4.1). Accordingly, the SF_6 ejector shall be placed twelve inches (12 in.) from the right sidewall of each fume hood, and six (6) inches into the hood's interior as measured from the plane of the sash for the **Choreographed Sequence; Right Dynamic Test, Phase Thirteen** through **Phase Eighteen,** (see above).

3.4.4 Objects – Center

Provide four objects for the **Center Dynamic Test** in the following order starting from left to the right:

1. a 500 ml beaker, filled halfway with water.
2. a 250 ml graduated cylinder filled halfway with water.
3. a capped, 500 ml (or one pint) bottle.
4. a box, 4 inch cube.

Place these object in the following manner by referring to **Table Phase One**, included below:

- Provide a reference line (#1) on each hood's work surface that is six (6) inches into the hood's interior, as measured from the plane of the sash (with tape or a temporary marker on the hood's work surface).
- Mark a point twelve (12) inches to the left of the ejector's base (see **E** in **Table Phase One**, below) on reference line #1.
- Place the center of object number One (1) on this point behind reference line #1, which is six (6) inches into the hood's interior.
- Mark a point six (6) inches to the left of the ejector's base (see **E** in **Table Phase One**, below) on reference line #1.
- Place the center of object number Two (2) on this point behind reference line #1, which is six (6) inches into the hood's interior.
- Place the remaining two objects; Three (3) and Four (4), in the same geometric arrangement, to the right of the ejector (**E**), i.e., six (6) inches and twelve (12) inches to the right of the ejector's base, respectively and behind reference line #1, which is six (6) inches into the hood's interior, as measured from the plane of the sash.

Table Phase One

12 inches behind sash					
6 inches behind sash	1	2	**E**	3	4

- Provide another reference line (#2) on each hood's work surface that is twelve (12) inches into the hood's interior, as measured from the plane of the sash (with tape or a temporary marker on the hood's work surface). Mark points for intervening positions of each object behind reference line #2 with a line that is perpendicular to each object's point marked behind reference line #1.

3.4.5 Objects – Left

Provide four objects for the **Left Dynamic Test**:

1. a 500 ml beaker, filled halfway with water.
2. a 250 ml graduated cylinder filled halfway with water.
3. a capped, 500 ml (or one pint) bottle.
4. a box, 4 inch cube.

Place these object in the following manner by referring to **Table Phase Seven**, included below:

- Provide a reference line (#1) on each hood's work surface that is six (6) inches into the hood's interior, as measured from the plane of the sash (with tape or a temporary marker on the hood's work surface).
- Mark a point six (6) inches to the left of the ejector's base (see **E** in **Table Phase One**, below) on reference line #1.
- Place the center of object number Two (2) on this point behind reference line #1, which is six (6) inches into the hood's interior.
- Mark a point six (6) inches to the right of the ejector's base (see **E** in **Table Phase One**, below) on reference line #1.
- Place the center of object number Three (3) on this point behind reference line #1, which is six (6) inches into the hood's interior.
- Place the remaining two objects; Four (4) and One (1), in the same geometric arrangement, to the right of the ejector's base (**E**), i.e., twelve (12) inches and eighteen (18) inches to the right, respectively and behind reference line #1, which is six (6) inches into the hood's interior, as measured from the plane of the sash.

Table Phase Seven

12 inches behind sash					
6 inches behind sash	2	**E**	3	4	1

- Provide another reference line (#2) on each hood's work surface that is twelve (12) inches into the hood's interior, as measured from the plane of the sash (with tape or a temporary marker on the hood's work surface). Mark points for intervening positions of each object behind reference line #2 with a line that is perpendicular to each object's point marked behind reference line #1.

3.4.6 Objects – Right

Provide four objects for the **Right Dynamic Test**:

1. a 500 ml beaker, filled halfway with water.
2. a 250 ml graduated cylinder filled halfway with water.
3. a capped, 500 ml (or one pint) bottle.
4. a box, 4 inch cube.

Place these objects in the following manner by referring to **Table Phase Thirteen**, included below:

- Provide a reference line (#1) on each hood's work surface that is six (6) inches into the hood's interior, as measured from the plane of the sash (with tape or a temporary marker on the hood's work surface).
- Mark a point six (6) inches to the right of the ejector's base (see **E** in **Table Phase One**, below) on reference line #1.
- Place the center of object number Two (2) on this point behind reference line #1, which is six (6) inches into the hood's interior.
- Mark a point six (6) inches to the left of the ejector's base (see **E** in **Table Phase One**, below) on reference line #1.
- Place the center of object number Three (3) on this point behind reference line #1, which is six (6) inches into the hood's interior.
- Place the remaining two objects; Four (4) and One (1), in the same geometric arrangement, to the left of the ejector's base (**E**), i.e., twelve (12) inches and eighteen (18) inches to the left, respectively and behind reference line #1, which is six (6) inches into the hood's interior, as measured from the plane of the sash.

Table Phase Thirteen

12 inches behind sash					
6 inches behind sash	1	4	3	**E**	2

- Provide another reference line (#2) on each hood's work surface that is twelve (12) inches into the hood's interior, as measured from the plane of the sash (with tape or a temporary marker on the hood's work surface). Mark points for intervening positions of each object behind reference line #2 with a line that is perpendicular to each object's point marked behind reference line #1.

3.4.7 Inserting Hands and Arms

Begin with hands three (3) inches away from the sash plane. Both hands and (fore) arms shall be inserted into the hood's interior simultaneously (even in phases requiring one hand in use) with palms of hands oriented vertically and fingers relaxed (slightly open, not cupped) and forearms oriented "normal" (perpendicular in all directions) to the plane of the sash. The rate of hand/arm insertion shall be approximately one (1) foot per second (1.0 fps).

3.4.8 Removing Hands and Arms

Hands and (fore) arms shall be removed from the hood's interior together with palms of hands oriented vertically and fingers relaxed (slightly open, not cupped) and forearms oriented "normal" (perpendicular in all directions) to the plane of the sash. As appropriate, end with hands three (3) inches away from the sash plane. As appropriate, hands and arms shall then be lowered to the technician's side for a minimum of five seconds. The rate of hand/arm removal and lowering shall be approximately one (1) foot per second (1.0 fps).

3.4.9 Moving Objects

When required, the objects shall be moved from their resting position to their new position in a line perpendicular to the plane of the hood's sash. The rate of movement shall be approximately one (1) foot per second (1.0 fps).

3.4.10 Exchanging Objects

As appropriate, objects shall be exchanged behind the ejector maintaining a minimum distance parallel to the plane of the sash of twelve (12) inches until they can be ***Moved***, see above ***Moving Objects*** for additional information. They shall be exchanged (handed-off) individually, in turn, starting from their resting position (rearward) to their new position (forward); see appropriate Tables (e.g., **Table Phase Four**). The rate of movement shall be approximately one foot per second (1.0 fps). The necessary handoff shall be one to two seconds.

3.4.11 Transferring Liquids

When required, water in the 500 ml beaker shall be transferred to the 250 ml graduated cylinder until the cylinder is filled to the 250 ml mark. Return 500 ml beaker to starting position.

3.4.12 Rotating Body

When required after ***Removing Hands and Arms***, the technician shall rotate their body's torso 90 degrees, as noted in **Sequence**, pause for five seconds; return torso to position at start of ***Rotating Body***; pause for five seconds before continuing the test **Sequence**.

4 Appendix 1: Overview of ASHRAE 110-1995

4.1 Tracer Gas
The tracer gas shall be sulfur hexafluoride, or a gas of similar molecular weight and stability, supplied from a cylinder capable of maintaining 30 psig (200 kPa [gage]) at the test release rate for at least one hour. **The tracer gas release rate shall be 4.0 Lpm.** One pound of sulfur hexafluoride will provide 4 liters per minute for approximately 19 minutes at sea level. (One kilogram of sulfur hexafluoride will provide 4 liters per minute for approximately 42 minutes [70 mL/s for 40 min].)

4.1.1 The tracer gas shall be commercial grade or reagent grade. Since the detection instrument is calibrated by the actual tracer gas, 100% pure gas is not required. Low grade mixtures are inappropriate since they significantly reduce the limit of detection for the test.

4.1.2 Substitution of another tracer gas. may be made if the standard tracer gas is deleterious

5.2 Hood Condition

5.2.1 Sash Position The **sash** or sashes **shall be located in the design position** or positions.

5.2.2 NA

5.3 NA

5.4 Background Level
If air contaminants are present that are sensed by the detector as tracer gas at more than 10% of the presumed control level, use of such materials shall cease until background readings fall below 10% of the presumed control level or until substitution of tracer gas (4.1.2) shall be implemented.

5.5 Preliminary Data

5.5.1 A sketch of the room shall be prepared indicating the location of significant equipment. Minimum data shall include a general layout of the room and location(s) of the test hood and other hoods.

5.5.2 A sketch of the air supply system indicating the type of supply fixture (grilles, registers, ceiling diffusers, perforated ceiling, other) shall be made. Other activities in the room shall be indicated. Information on the number of other fume hoods and their condition of operation is required.

5.5.3 The hood type and size, sash configurations, presence of an airfoil, beveled entries, sash stops, and position of baffles shall be noted.

5.5.4 The location of material storage and the amount of work surface space occupied by materials within the hood shall be noted.

5.5.5 The tracer gas detector and the sample rate shall be identified.

6. FLOW VISUALIZATION AND VELOCITY PROCEDURE

6.1 Flow Visualization

This test is a visualization of a hood's ability to contain vapors. **The test consists of both a small local challenge and a gross challenge to the hood.** The intent of this test is to render an observation of the hood performance as it is typically used. Visible smoke is provided by means of a plastic bottle that contains an ampule of liquid titanium tetrachloride. Once the ampule is broken and the bottle squeezed, the plastic bottle will release a visible, persistent plume if titanium dioxide can be used to visualize airflow. Other sources of persistent, neutral buoyancy aerosols could provide the same visualization of the airflow.

6.1.1 Local Visualization Challenge

6.1.1.1 The operation of the bottom air bypass air foil **shall be tested by running the smoke bottle under the air foil**. Smoke shall be exhausted smoothly and not be entrained in the vortex at the top of the hood.

6.1.1.2 A stream of **smoke shall be discharged from the bottle along both walls and the floor of the hood in a line parallel to the hood face and 6 in. (150 mm) behind the face of the hood and along the top of the face opening.**

6.1.1.3 A stream of **smoke shall be discharged from the bottle in an 8 in. (200 mm) diameter circle on the back of the hood.** Air movement toward the face of the hood shall be defined as reverse airflow, and lack of air movement shall be defined as dead air space. Smoke shall be generated at the work top of the hood and along all equipment in the hood. All the smoke shall be carried to the back of the hood and exhausted. Airflow patterns and time for hood clearance shall be observed and noted.

6.1.1.4 **If there is visible smoke flow out of the front of the hood, the hood fails the test and will receive no rating.**

6.1.2 Large-Volume Visualization Challenge

A suitable source of **smoke** or other visual challenge **shall be used to release a large volume in the center of the sash opening on the work surface 6 in.**

(150 mm) inside the rear edge of the sash. Some smoke sources generate a jet of smoke that produces an unacceptably high directional component to the challenge to the hood (see A-6.1.2 for acceptable methods). Care is required to ensure that the generator does not disrupt the hood performance, leading to erroneous conclusions. It must be noted that containment is best observed from the side of the hood face. A release of smoke from the hood that is steady and visible is an indication of failure. Equipment in the hood, such as heating devices and agitators, shall operate during a test to determine if it contributes to leakage. Airflow patterns and time for hood clearance shall be observed and noted.

6.2 Face Velocity Measurements
NA

6.3 Test Method for Variable-Air-Volume (VAV) Fume Hoods

NA

6.4 VAV Response Test
NA

7. TRACER GAS TEST PROCEDURE

7.1 The detector shall be turned on and **allowed time to equilibrate**, and room background shall be determined. If the background is excessive (see 5.4), corrective procedures shall be implemented.

7.2 Immediately before each test, the detector function shall be checked by subjecting the detector to a low concentration of tracer gas. If the detector does not respond properly, the hood test shall not be performed until the defect has been corrected. The detector shall at all times be operated in accordance with the manufacturer's instructions.

7.3 The ejector shall be installed at a test position. For typical bench-type hoods, **three positions are required: left, center, and right** as seen looking into the hood. **The left position is with the ejector centerline 12 in. (300 mm) from the left inside wall of the hood, center position is equidistant from the inside side walls, and right is 12 in. (300 mm) from the right inside wall. All positions are with the front of the ejector body 6 in. (150 mm) from the hood face.** (See Figure 7.)

7.4 **The probe shall be positioned in the breathing zone of the manikin, with the breathing zone of the manikin 3 in. (75 mm) from the plane of the sash.** (See Figure 7.)

7.5 **The detector probe shall be fixed** in a position touching the face of the manikin in the region of the breathing zone, **with the center of the probe 26 in. (660 mm) above the work surface and 3 in. (75 mm) in front of the sash** (see Figures 8 and 9). The detector probe shall be attached to the manikin or fixed on a typical laboratory ring stand and clamp. Care shall be taken to ensure that any method of attaching the detector probe in the breathing zone of the manikin does not interfere with the flow patterns around the manikin or probe.

7.6 The tracer gas block valve shall be opened.

7.7 Manually or by recorder, **the detector readings shall be observed and recorded for 5 minutes with a reading taken at least every 10 seconds. The positional control level is the average of the tracer gas concentrations during the five minute test.**

7.8 The ejector and manikin shall be relocated to another test position and the **measurements shall be repeated for each test position**.

7.9 The control-level rating of the hood shall be the maximum of the positional control levels for the three test positions (see 7.3).

7.10 The performance rating of the hood shall be recorded as either AU yyy, **AI yyy**, or AM yyy, where yyy equals control level, ppm.

7.11 **With the manikin removed from the face of the hood and the block valve open to the ejector, the periphery of the hood openings shall be traversed with the probe. While standing away from the face of the hood, the probe shall be held 1 in. (25 mm) away from the edge of the hood opening and moved slowly around each opening at a rate of 3 in. (75 mm) per second.** The maximum concentration and location observed during the traverse shall be recorded. Care shall be taken to stand to the side during measurement to affect flow as little as possible.

7.12 Sash Movement Effect

7.12.1 **The manikin shall be located at the appropriate test position with the sash at the design opening. The block valve shall be opened and the sash closed. After two minutes**, a background level with the sash closed shall be determined. If tracer gas is detected with the sash closed, the test shall be terminated until the source of leakage is determined and eliminated. **The sash shall be opened to the design opening in a smooth motion at a velocity between 1.0 ft/s (0.3 m/ s) and 1.5 ft/s (0.5 m/s) while tracer gas is released and the tracer gas concentration shall be recorded. The peak levels shall be noted.** After the system has stabilized (i.e., the face velocity has reached and maintained the design face velocity within 10%), but **for a minimum of two minutes after opening the sash, the sash shall be closed at a rate between 1.0 ft/ s (0.3 m/s) and 1.5 ft/s (0.5 m/s) while continuing to record the tracer gas concentration. The cycle shall be repeated three times.**

7.12.2 The ***sash movement effect* (SME) is the maximum peak tracer gas concentration** determined in 7.12.1. The ***sash movement performance rating* of the hood shall be recorded as** SME-AU yyy, **SME-AI yyy,** or SME-AM yyy, where yyy equals sash movement effect, ppm.