ASHRAE 110 Tracer Gas Containment Report - SDSU

Berkeley hood; Labconco Prototype, Alpha version – Rev. 2

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Table of Contents

ASHRAE 110 Tracer Gas Containment Test

Conducted at Lawrence Berkeley National Laboratory, Bldg. 63-103

Overview

The ASHRAE Standard, ANSI/ASHRAE 110- 1995, *Method of Testing Performance of Laboratory Fume Hoods*, is the foremost protocol used when testing laboratory-type fume hood performance. The ASHRAE-110 "Method" is an elaborate, three-part test that involves face velocity testing, flow visualization, and a tracer gas test. Refer to ANSI/ASHRAE 110-1995 for specific information regarding its Purpose (Section 1), Scope (Section 2), Definitions (Section 3), Instrumentation and Equipment (Section 4), and Test Conditions (Section 5). The tests, referenced below, used the ASHRAE 110 method's Section 6.1, Flow Visualization and Section 7 (7.1 through 7.10), Tracer Gas Testing Procedure to evaluate containment performance.

An Innovative Laboratory-type hood

Researchers at Lawrence Berkeley National Laboratory (LBNL) are developing an innovative containment technology that reduces required airflow through laboratory fume hoods. This technology provides containment at 50 to 70 percent lower airflow than a typical fume hood, based on total exhaust volume. It does not rely on face velocity, in the traditional sense, to maintain fume containment within a hood. Therefore, ASHRAE 110 face velocity tests were not performed (Section 6.2, Face Velocity Measurements).

The LBNL containment technology uses a "push-pull" displacement airflow approach to contain fumes and move air through a hood. Displacement air "push" is introduced with supply vents near the hood's sash opening. Displacement air "pull" is provided by simultaneously exhausting air from the hood. Thus, an "air divider" is created, between an operator and a hood's contents, that separates and distributes airflow at the sash opening. This air divider technology is simple, protects an operator, and delivers dramatic cost reductions in a facility's construction and operation.

Evolution of the Berkeley hood

Dr. Helmut Feustel, a LBNL staff researcher, developed basic concepts for a High-Performance Laboratory Fume Hood during 1995–1998. This High-Performance Laboratory Fume Hood is referred to, in this document, as the "Berkeley hood." In January 1999, LBNL's Environmental Energy Technologies Division (EETD) transferred the project to its Applications Team. At this time, the research project team developed a "prototype" Berkeley hood.

Prototype Berkeley hood

The first prototype hood was built with a superstructure provided by Labconco in early 1999. A standard Labconco superstructure was modified significantly to include the air divider technique. By August 1999, this hood had been evaluated extensively with a series of containment tests. The resulting design information was transferred to Labconco for them to build an "Alpha-Rev.1" version of the Berkeley hood.

UCSF Alpha-Rev.1 Berkeley hood by Labconco

Labconco highly customized their standard fume hood superstructure to accommodate the air divider technique supply air systems and baffle modifications. By November of 2000, the “Alpha-Rev.1” Berkeley hood was ready to be installed at the University of California, San Francisco Medical Center (UCSF) for a Pacific Gas and Electric (PG&E) field demonstration project. This demonstration project was completed in October of 2001. A full report on the UCSF project is available in LBNL report number LBID-2396. An ASHRAE 110 report is also available for testing performed at UCSF, LBNL-50070.

SDSU Alpha-Rev. 2 Berkeley hood by Labconco

Overview

This report provides ASHRAE 110-1995 protocol test results for a demonstration hood that is referred to as “Alpha-Rev.2.” This hood includes design refinements to the Alpha-Rev.1 hood installed at UCSF. The Alpha-Rev.2 is scheduled for installation at San Diego State University as a field demonstration of the LBNL air divider technique.

General

The nominal four-foot-wide version of the Berkeley hood by Labconco is 28 inches from the sash to the rear baffle. The fully open sash dimensions are 38-1/4 inches wide by 29-1/4 inches high, for a total open area of 7.76 square feet. Testing was conducted with total exhaust flow of 232 CFM and 386 CFM. This corresponds to 30 and 50 percent flow in a standard hood operating at a 100 FPM face velocity, respectively.

Push/Pull System

Like Alpha-Rev.1, this four-foot version of the Berkeley hood also uses three fans to push room air into the hood's cabinet. The "top" fan pushes air from behind the top of the sash towards the rear baffle. The "lower" fan pushes air from behind the lower airfoil towards the rear of the cabinet. The "front" fan blows air from the top of the face area down (and across the front of the sash when it is closed). All three fans have individual rheostats to manually adjust their speed. These three fans produce a vectored airflow (push) that provides containment at lower than normal exhaust airflow (pull). The push air is introduced at or inside the sash (face). Consequently, face velocity measurements are irrelevant.

Containment Tests and Setup

Description of Test Procedure

As noted above, LBNL researchers successfully applied two of ASHRAE’s 110-1995 test methods, flow visualization and tracer gas tests, Section 6.1 and Section 7, respectively. A general overview of these two tests is provided:

1) Flow visualization tests can be performed with various smoke-generating substances. Theatrical smoke, superheated glycol, smoke “sticks”, titanium tetrachloride, and dry ice, solid-phase CO_2, are examples of smoke sources. A qualitative understanding of containment is gained from conducting smoke tests. A rating system has been

devised for "poor- to-good" patterns of smoke containment by Tom Smith[1]. However, these tests are only used as indicators of containment. When satisfactory results are observed, they should be followed by tracer gas testing.

2) Tracer gas testing is the most reliable test for determining a fume hood's containment performance. A highly generalized overview of the test is provided. The gas typically used is sulfur hexafluoride, or SF_6. This gas flows into a fume hood being tested through a specially constructed "ejector." The ASHRAE 110 guideline includes engineering drawings to fabricate this ejector. SF_6 flow rate is set at four liters per minute (LPM). A mannequin is placed in front of the hood being tested to simulate an operator. An inlet port to a detector device is placed at the "breathing zone" (the nose) of the mannequin. This breathing zone is set a height of 26 inches above the hood's work surface. Tracer gas is allowed to flow for five minutes and spillage levels are recorded by the detector. Ratings can be provided for a hood at three levels of installation:

- "As manufactured" (AM) — initial test of performance in a highly controlled/idealized setting at the manufacturer's facility.
- "As installed" (AI) — testing is completed in the actual, fully operating facility, potentially more difficult conditions than the manufacturers' facility.
- "As used" (AU) — testing is performed by adding a hood operator's experimental equipment, a.k.a., "clutter", to the "as installed" hood, making the test conditions even more difficult.

Instrumentation

Test instrument used to detect SF_6 was a ITI-Qualitek Leakmeter 120. Inlet tube was located at nose of mannequin. Calibration was with known concentrations of SF_6 in "cal bags." Analog output readings (voltage) from the ITI-Qualitek Leakmeter were recorded with an A-to-D converter (a voltage-ohm-meter, VOM) and stored on a personal computer. Later these data were graphed with Microsoft Excel™ for presentation. (A conversion factor of 0.31 PPM was equal to 1.0 volts; therefore, the concentration was equal to 0.31 times voltage indicate by a VOM.)

A standard ASHRAE 110 ejector, manufactured by Air Flow Tech Products, Inc., was used during the test runs. A BIOS Dry-Cal DC-1 Flow calibrator was used to verify SF_6 volumetric flow at 4 LPM. A pressure gauge attached to the ejector was monitored during the flow calibration sequence at 21.8 psig and maintained throughout the test runs.

Total exhaust flow, out of the Berkeley hood, was verified by measuring pressure readings from two devices: a pitot tube and a "critical" orifice. The critical orifice is a device for maintaining a constant flow-rate through a sampling instrument. These devices were located in the exhaust stack outside the test lab. Correlation between these devices was better than 5 percent.

Supply plenum outlet velocities were tested with a TSI velocity meter, model 8360. Readings were averaged with a minimum of three points. Volumetric flow was determined by calculation, i.e., multiplying average velocity by the supply plenum's outlet surface area.

[1] Tom Smith, President of Exposure Control Technologies, Inc. 231-C East Johnson St. Cary, NC 27513
ph: 919.319.4290

Volumetric values were checked by measuring inlet velocity to each fan by attaching a long tube and performing a traverse of the flow induced in the tube.

Mannequin Setup

In the following, Figures 1 & 2 show the typical mannequin positioned in front of a Berkeley hood prior to mounting the ITI tracer gas detector.

Fig. 1 – Mannequin position for standard ASHRAE 110 SF6 test; 26 inches above, Center.

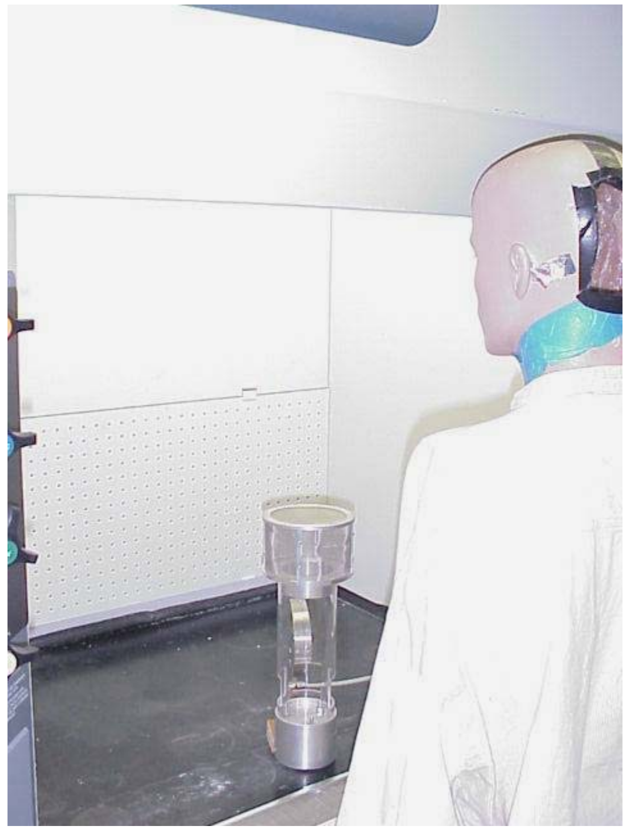


Fig. 2 – Ejector center position for standard ASHRAE 110 SF6 test.

Acceptability Level

Test criterion used for the "as manufactured" (AM) designation is from ANSI/AIHA Standard Z9.5 (1992). The acceptability level required for AM designation is 0.05 PPM, or less, averaged for five minutes. The LBNL test/fabrication laboratory is not a highly controlled/idealized setting as would be found in a manufacturer's facility, so the "as installed" (AI) criterion may be more appropriate. Therefore, both criterion are utilized and presented. The acceptability level required for AI designation is 0.1 PPM, or less, for five minute average.

Deviations from ASHRAE 110 Test Procedure

Face velocity tests were not performed. Velocity measurements were recorded for total exhaust airflow, and for supply plenum airflows. Tracer gas test runs were only performed with the ejector in the hood center position. Extensive testing at UCSF indicated that containment, in a four-foot wide hood, is not effected by ejector position; see ASHRAE 110 Tracer Gas Containment Report – UCSF; LBNL-50070.

Containment Test Airflows

Exhaust Airflow Rate

In a "conventional" hood, exhaust airflow rate is attained by flowing air at an average value of 100 FPM through the open sash area (a.k.a. face velocity) per CAL/OSHA 5154.1. The open sash area of the Labconco Alpha-Rev.2 Berkeley hood is equal to 7.76 square feet. Therefore, at a "conventional" face velocity of 100 FPM, this would require an exhaust airflow of 776 CFM through the hood. However, the Berkeley hood was operated and tested at an exhaust rate of 386 CFM, which is 50 percent of conventional hood. Initially, the hood's exhaust airflow was determined with a calibrated fan to generate a system pressure-drop curve. Subsequent airflow measurements were determined by using a pitot tube (in the hood's exhaust stack) and differential pressure meter with this system pressure-drop curve.

Supply Airflow Rate

Supply flows were set at the following values measured by an airflow velocity meter. Conversion from velocity to volumetric flows from the supply grills are approximations. Each supply grill/screen was measured with a hot wire anemometer with the following results:

Table 1: Configuration of Labconco Alpha-Rev.2 unit at LBNL.

Run #	Exhaust (CFM)	Exhaust %	Bottom 1.45 sq.ft. FPM/CFM	Front 0.86 sq.ft. FPM/CFM	Top (inside) 1.78 sq.ft. FPM/CFM	Sash Movement SME	Mann. height
1	386	50	34/49	51/44	30/54	X	26"
2	232	30	34/49	51/44	30/54		26"

Containment Test Results

Summary of Results

As noted in Table 2, the Labconco "Alpha-Rev.2" hood passed in all tests completed.

Table 2: ASHRAE 110 Test results for Labconco Alpha-Rev.2 unit at LBNL.

Run Number	*Test Type*	*Test Conditions*	*Air Flow % of "normal" (@ 100 fpm)*	*Non-Standard Tests*	*Berkeley Hood Containment AM (as mf'g)*	*Berkeley Hood Containment AI (as installed)*
	Smoke	Small volume Smoke tube	50%		Good	Good
1	Tracer gas	Sash full open; Center position	50%	Sash movement	Pass [a]	Pass [a]
2	Tracer gas	Sash full open; Center position	30%		Pass [a]	Pass [a]

a. Tracer gas Pass/Fail criterion per ANSI Z9.5 1992.

Test Run Narrative

Standard run

Test Run #1 presents results of ASHRAE's 110 protocol, Section 7 – Tracer Gas Test Procedures. Specifically, Sections 7.1 through 7.10 were performed with passing ratings, per ANSI Z9.5-1992, for both "as-manufactured" and "as-installed" conditions. The total exhaust airflow was 386 CFM. This exhaust flow equates to 50 percent of the volume when compared to the hood flowing with a face velocity of 100 FPM. As noted above, tracer gas test runs were only performed with the ejector in the hood center position. The SF_6 gas detector, an Ion Tracker Instruments (ITI) Leakmeter 120, was checked with calibrated bags of SF_6 tracer gas just prior to each test, thus ensuring accurate results.

Sash Movement Effect run

A Sash Movement Effect (SME) test per ASHRAE 110 Section 7.12 was performed. Per the protocol, this challenge involves opening the sash from 25 percent to fully open three times. During test Run # 1, this SME was performed only once and stabilizing time on closing was shortened slightly.

Safety Margin run

The Berkeley hood's operational safety margin relating to total exhaust airflow was evaluated. The total exhaust airflow was reduced to a value of 232 CFM in test Run #2. This volumetric flow equates to 30 percent of the hood flowing with a face velocity of 100 FPM. The Berkeley hood passed the AI and AM tests at this low exhaust rate.

Smoke Tests and Berkeley hood details

Figures 3 and 4 are photos of the Berkeley hood containing small, point-source smoke and large volume smoke, respectively. Figure 5 shows the unique floor sweeping effect of the Berkeley hood. In Figures 6 & 7, details of the rear baffle and bottom supply plenum are presented.

Fig. 3 – SDSU Berkeley hood containing point-source smoke at LBNL.

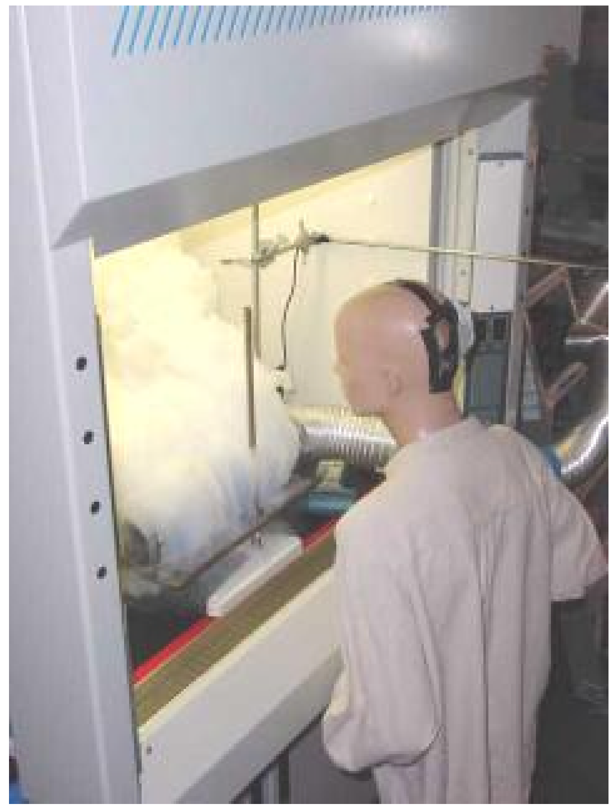


Fig. 4 – SDSU Berkeley hood containing large-volume-source smoke with mannequin.

Fig. 5 – SDSU Berkeley hood demonstrating floor sweep with point-source smoke.

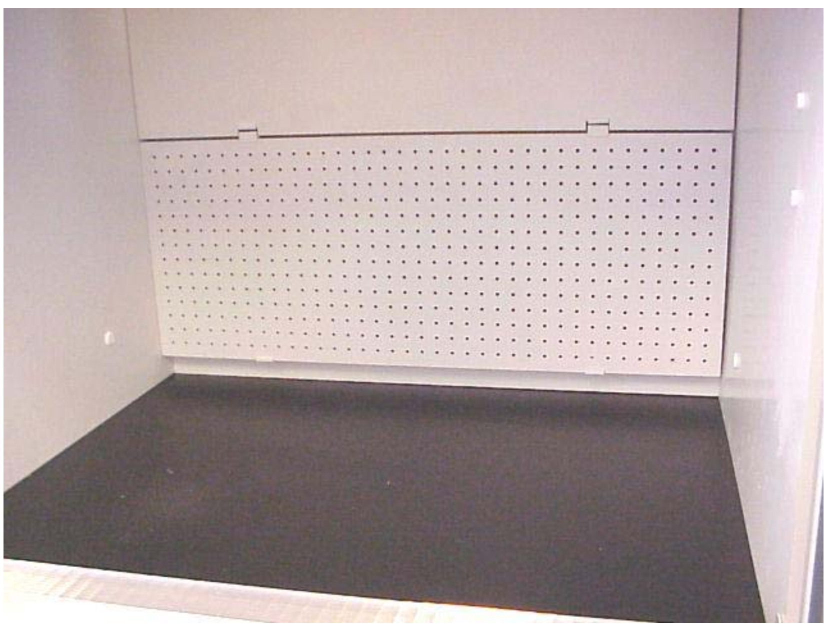


Fig. 6 – SDSU Berkeley hood, lower portion of rear-baffle with perforations and slot.

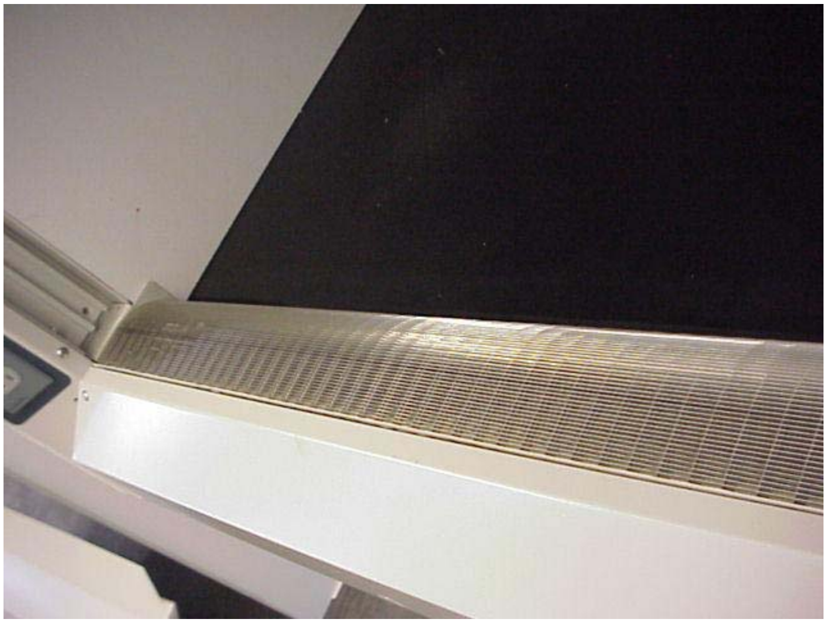


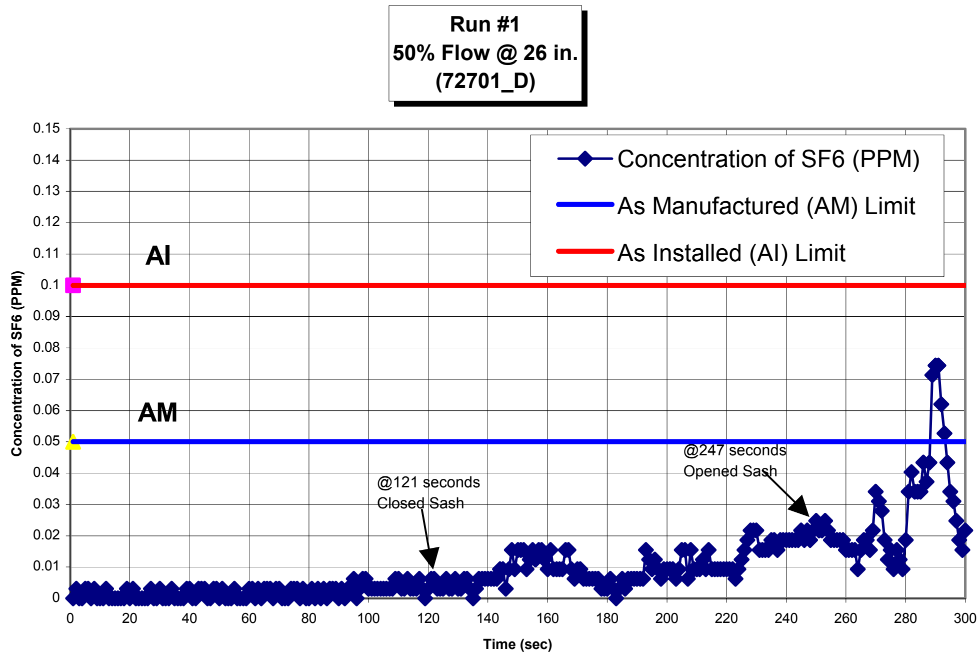
Fig. 7 – SDSU Berkeley hood bottom supply plenum with grill.

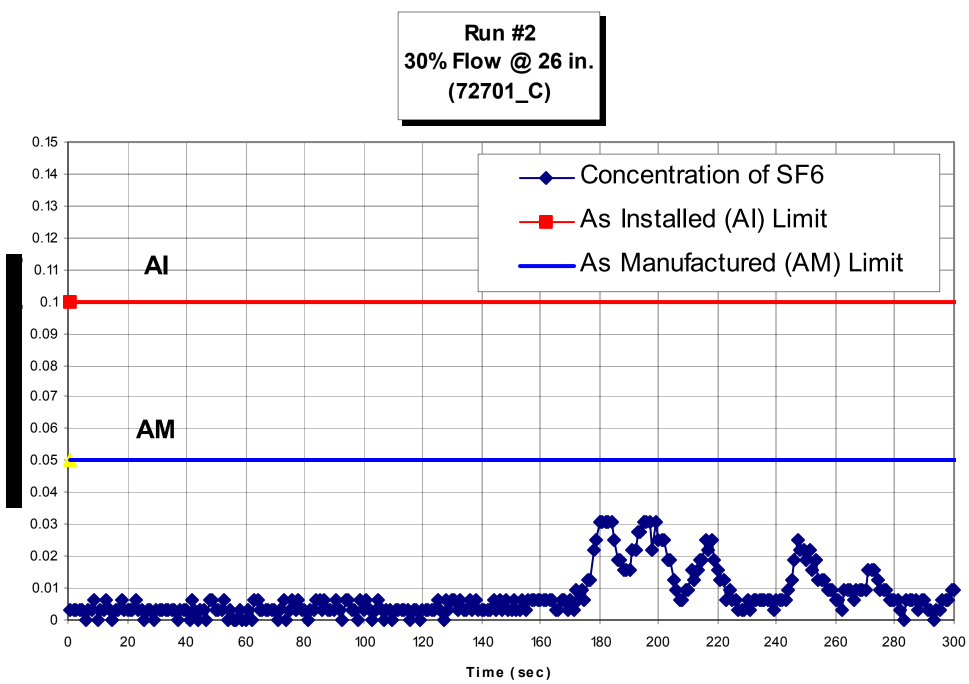
Air Divider Technique

Figure 8 of the Berkeley hood was taken to demonstrate the Berkeley air divider technique with theatrical smoke flowing from the front and bottom supply plenums.

Fig 8 – Run #1, 50 percent airflow, mannequin at 26 inches above work surface (note ejector).

Containment Test Run Plots





Note: Hood passes containment test if average concentration below limits shown for five minutes.