APPENDIX J

COLLECTION VEHICLE ODOR SAMPLING REPORT

MARCH 2005

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EXECUTIVE SUMMARY

Sampling of odors from Manhattan District 8 collection vehicles, which would be serviced by the East 91st Street Converted MTS, was performed on July 20, 2004. Odor generation from waste decomposition is expected to be at its peak during the months of July and August when daily temperatures are at their highest annual level. A total of six vent samples and two quality assurance/quality control (QA/QC) samples were collected. Of the eight samples, three vent samples were used to calculate the odor emission factor used to establish odor emission rates for DSNY collection vehicles queuing at the Proposed Plan Facilities and Alternative Facilities, as applicable.

In accordance with guidance documents published by USEPA and AWMA, whole air odor samples were collected from the exhaust vent intake located on the east wall of the maintenance alley at the Manhattan District 8 garage facility using a vacuum chamber sampling system that consisted of a rigid, airtight container with an inlet port connected to an internal Tedlar® bag and an outlet port connected to a portable pump (see Section 2.1.2.3 for a more detailed description of the sampling methodology).

The analytical technique used on the odor samples is referred to as an odor panel evaluation in which a group of people, the "odor panel," quantifies the following:

- Detection and recognition thresholds ("odor concentration");
- Odor intensity; and
- Odor persistence ("dose response").

The odor panel members were selected and odor analysis conducted by the laboratory in accordance with the following established protocols and standards set by the American Society of Testing Materials (ASTM):

- Selection and Training of Sensory Panel Members (Standard Practice 758);
- Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series Method of Limits (Standard Practice E679-91); and
- Referencing Suprathreshold Odor Intensity (Standard Practice E544-99).

Based on the results of the sampling study, emission factors were conservatively estimated for the DSNY collection vehicles by: (1) using the detection threshold (DT) value provided by the laboratory (the DT value is that recorded when the odor is first detected); and (2) using only the maximum emission rate for the three vent samples (3.2 odor units [OU/s]/collection vehicle); and (3) applying a 2.5 peak-to-mean factor to the maximum emission rate and associated effects.

1.0 BACKGROUND AND OBJECTIVES

This Collection Vehicle odor sampling report outlines the procedures, results and conclusions that were used to develop representative odor emission factors for use in estimating the potential odor effects associated with queuing of DSNY collection vehicles on facility access ramps in the DEIS and this FEIS.

The purpose of odor sampling was to develop DSNY collection vehicle odor emission estimates for a standard DSNY 25 cubic yard compactor collection vehicle. A description of how the collection vehicle odor emissions rates were modeled and impacts analyzed is described further in Section 3.18.6 of this FEIS.

2.0 SAMPLING, ODOR PANEL AND DATA REDUCTION METHODOLOGIES

2.1 Sampling Methodology

2.1.1 Sampling Site and Location Selection

2.1.1.1 Sampling Site Selection

The total enclosure approach to sampling full DSNY collection vehicles was applied to measure refuse-related odor emissions and develop a representative odor emission factor for estimating odor impacts from collection vehicles queuing on an MTS access ramp. This approach involved placing several full collection vehicles inside a ventilated room, allowing inside air to "sweep over" the collection vehicles and exit through an active ventilation system at an assumed 100% capture rate (in accordance with USEPA Method 204 total enclosure criteria).

DSNY identified the Manhattan District 8 waste garage facility located at 423 West 215th Street, as the most favorable location to sample odors from collection vehicles. This facility does not have vehicle refueling operations (and associated odors or the type of on-site maintenance activities that can significantly interfere with odor sampling.), and has a complete building enclosure within which the collection vehicles can be staged and sampled.

The maintenance alley (former ash transfer alley) section of the garage facility was chosen to stage 12 full collection vehicles for sampling. The maintenance alley interior measures 218 feet long, 33 feet wide and 19 feet high. It has a vehicle access door at both its east and west ends and a single wall exhaust vent adjacent to the western vehicle access door. A small access door in the east vehicle-access door was left open during odor sampling to supply "sweep air" across the staged collection vehicles, which was sampled and exhausted at the west end wall vent. Facial velocities through the small access door were maintained in excess of 200 feet per minute, in accordance with USEPA Method 204 total enclosure criteria. The facial velocity is the velocity of air through a building opening (i.e., measured within the frame of an open door).

2.1.1.2 Sampling Location Selection

To capture odors from the collection vehicles at the Manhattan 8 waste district garage, vent samples were collected from the single wall exhaust adjacent to the western garage door. Three samples were collected at various residence times after the maintenance alley was filled with 12 collection vehicles and USEPA Method 204 capture criteria (> 200 FPM facial velocity through building openings) was established.

A field duplicate was collected at the wall vent intake a background sample was collected at a location outside/upwind of the garage facility, not influenced by DSNY operations. A media blank Tedlar® bag sample was set aside for laboratory preparation and evaluation. Any measurable odor in the media blank sample would indicate possible odorant contribution by the Tedlar® bag material.

2.1.2 Sampling Program Procedures

2.1.2.1 Capture Assessment and Improvement

To most accurately determine the refuse-filled collection vehicle odor generation rate, fugitive emissions must be reasonably minimized. Minimization of fugitive emissions was accomplished by operating the building ventilation system, closing various building openings (e.g., doors), and collecting various flow and recording physical observations before and during the odor sampling program. Flow through some openings must be maintained in order for the ventilation system to operate properly and to produce a flow of "sweep air" across the collection vehicles. Therefore, the small access door built into the eastern vehicle access door to the maintenance alley was left open. All other access doors were closed during sampling.

To effectively comply with USEPA Method 204 Total Enclosure Capture criteria, the following measurements/observations were made:

- The direction and facial velocity of the air through the various building openings. All facial velocities were measured with a hot-wire anemometer. The direction of the airflow must be and was into the building. The average facial velocity of air through all building openings was approximately 200 feet per minute or higher.

- Distance of the vehicles' waste loading apparatus (expected location of odor generation) from building openings. Under ideal circumstances these sources of odors should be at least four equivalent diameters (actual equivalent diameter of each building opening) from each exposed vehicle waste loading area opening. This was achieved by keeping all access doors closed with the exception of the small access door through the eastern vehicle access door during each sample collection period. By closing various building openings, the equivalent diameter of the opening is reduced to zero, thereby reducing the required separation distance (four equivalent diameters) between the waste operations and the building opening, making it easier to comply with this USEPA Method 204 criteria. In addition, no vehicle's waste loading apparatus was staged closer than 1.5 vehicle lengths from the east and west vehicle access doors.

- The total area of all openings should not exceed 5% of the surface area of the building's four walls, floor and ceiling. This was achieved by keeping all but the one small access door closed during each sample collection period.

By following these criteria, greater than 99% odor capture and odor emission discharge through the building ventilation system was assumed. In addition to evaluating the maintenance alley area for the above criteria, odor sampling staff made qualitative observations just prior to any sampling at locations immediately outside of building openings to assess whether significant fugitive odor was escaping. Because no odor was detected at such openings, fugitive odor emissions were assumed to be negligible.

2.1.2.2 Building Ventilation Measurements

Design fan exhaust rates for the ventilation system were measured during both the collection of indoor background odor samples and collection vehicle odor samples and applied in all odor emission calculations and factors.

2.1.2.3 Odor Sampling

In accordance with guidance documents published by the USEPA and the AWMA, whole air odor samples were collected from the single wall exhaust intake in the maintenance alley using a vacuum chamber sampling system. The vacuum chamber sampling system consists of a rigid, airtight container with an inlet port connected to an internal Tedlar® bag, and an outlet port connected to a portable pump (see Figure 2.1.2.3-1). The sampling location was connected to the inlet port of the vacuum chamber with a short length of Teflon® tubing. The Teflon® tubing was inserted well into the exhaust stream to avoid interference from outside ambient air. The air inside the vacuum chamber, but outside the Tedlar® bag, was withdrawn over an approximate five-minute sample duration at 1 to 5 liters per minute (l/min). This air was drawn through the outlet port with the portable pump to effectuate the flow of vent air (and odors) through the Teflon® line and inlet port and into the Tedlar® bag. This design ensures that the vent air never comes into contact with the sampling pump. The Teflon® tubing was replaced between samples, or flushed with ambient air at a rate of 5 l/min for several minutes between samples. As recommended by the AWMA Subcommittee on the Standardization of Odor Measurement (AWMA Odor Subcommittee), Tedlar® bags were used because they have a low permeability that results in minimal sample loss or outside infiltration (thus maintaining sample integrity) and have the lowest background (material-related) odor.

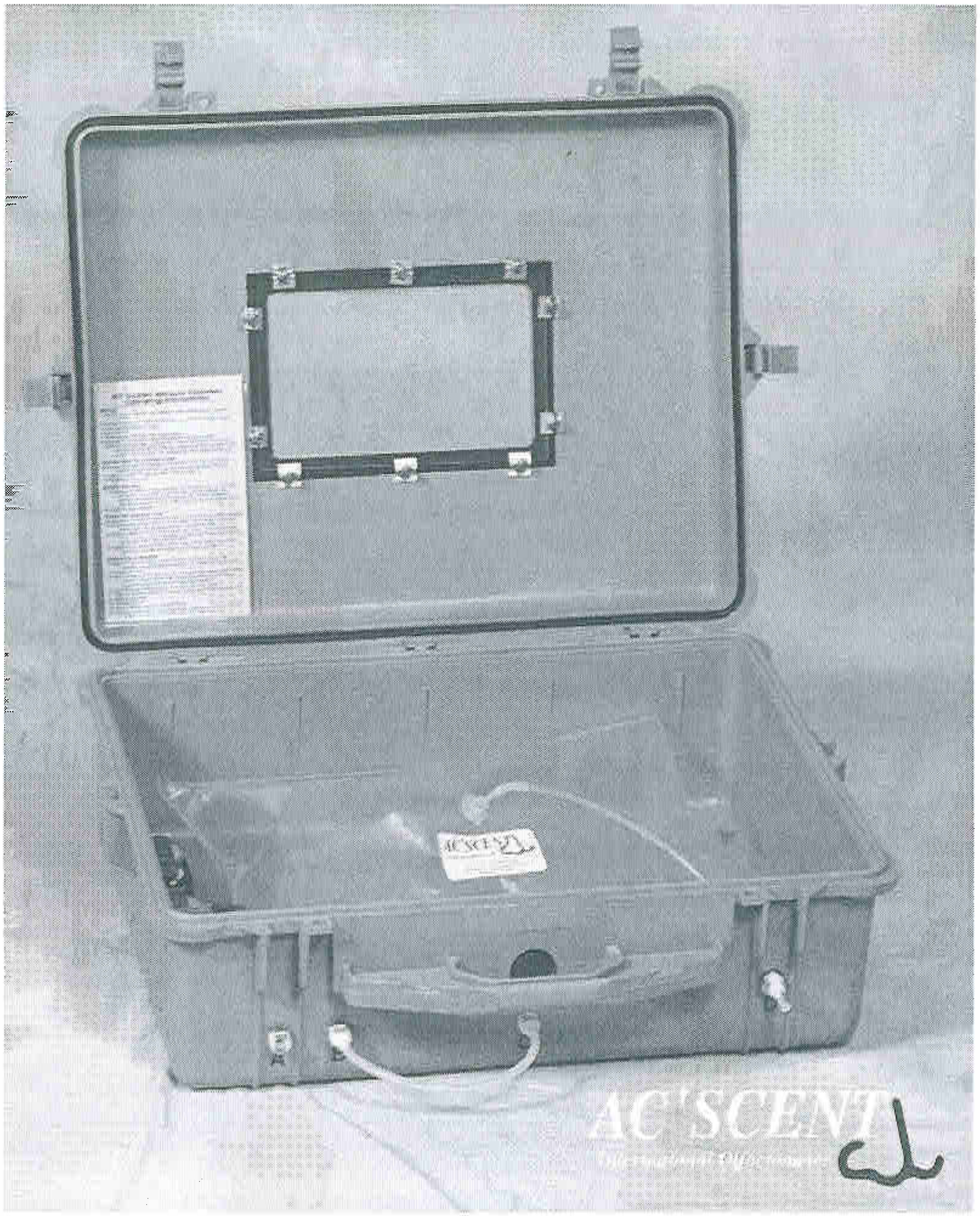
In keeping with practices recommended by the AWMA Odor Subcommittee, the sampling line and each sample bag were pre-conditioned (filled) with a sample of the odorous air being evaluated, and then the air was evacuated from the bag prior to collecting the actual sample. The Tedlar® bags were filled/reduced to approximately 75% of capacity to prevent decompression during shipping. All samples were delivered to the odor panel for evaluation within 24 hours following sample collection.

The firm performing the odor panel evaluations, St. Croix Sensory, was limited to approximately 75 samples per day. Sample delivery totals were identified with the odor laboratory at least 24 hours in advance and were scheduled one to three days in advance.

Photographs of sampling activities are included in Attachment A (Photographic Log) to this report.

Figure 2.1.2.3-1

Vacuum Chamber Sampling System



2.1.3 Process Operations

The following data were collected during odor sampling:

- Collection Vehicle Identification Numbers (waste amount contained in each vehicle was received by DSNY personnel the day after the sampling effort);
- The physical dimensions of the maintenance alley;
- The volumetric flow rate of the wall exhaust; and
- Facial velocities through building opening(s).

2.1.4 Documentation

Field notes (including capture assessment), vent drawings, odor sampling (location, date, time duration, sample identification number) and processing operation observations were completed and obtained for each sample. Copies of field documentation and supporting information are included in Attachment B to this report.

2.1.5 Sample Handling

Each sample was assigned a unique sample identification number to allow for proper data management. These sample numbers were included on the sample label, the sampling notes and the Chain of Custody (COC) records. Samples were labeled immediately upon collection. Other information included on the sample label is sample location, date and time of collection, initials of sampler(s) and requested analyses. The information on the labels was printed with indelible ink.

The following steps were followed for packing and shipping samples to the analytical laboratory:

- Air samples were placed in a sturdy container (corrugated box) to protect the integrity of the sample.
- The Primary Sampler signed the COC record relinquishing custody of the samples.
- The Primary Sampler retained a copy of the COC record.

- The Primary Sampler placed the remaining copies of the COC record in the shipping container.
- The shipping container was closed and sealed with shipping tape.
- When more than one shipping container was required, the containers were numbered (e.g., 1 of 5, 2 of 5, 3 of 5, etc.).
- The appropriate shipping label was affixed to the shipping container(s) and the label was covered with clear, waterproof shipping tape.
- The Primary Sampler contacted the analytical laboratory at the end of each day prior to sending the shipping container(s) to the laboratory.
- The Primary Sampler transported the shipping container to the shipper.
- The Primary Sampler retained an original copy of all shipping manifests.

2.1.6 Quality Assurance/Quality Control

As part of the Quality Assurance/Quality Control (QA/QC) program, Quality Assurance (QA) samples and analyses were prepared/performed. A Tedlar® bag media blank sample was sent to the laboratory for preparation with odorless "zero air" and analyzed. One set of duplicate field samples were collected and analyzed.

2.2 Odor Panel Methodology

An Illinois Institute of Technology Research Institute (IITRI) dynamic dilution triangle olfactometer with a sample presentation flow rate of 0.5 l/min, a method detection limit for detection threshold (DT), and recognition threshold (RT) of 4, was used to determine the thresholds for each odor evaluation. The method detection limit of 4 means that an odor with a full strength dilution to threshold "concentration" of 4 cannot be, within standard method accuracy, distinguished from diluted aliquots of the same odor. In other words, although an odor concentration of 1 DT can be detected under laboratory condition (using filtered clean air), low odor concentrations less than 4 DT cannot be distinguished within the method's standard level of confidence.

The analytical technique used on the odor samples is referred to as an odor panel evaluation in which a group of people, the "odor panel," quantifies the following:

- Detection and recognition thresholds ("odor concentration")

- Odor intensity
- Odor persistence (dose response)

The odor panel members were selected and odor analysis conducted by the laboratory in accordance with the following established protocols and standards set by the American Society of Testing Materials (ASTM):

- Selection and Training of Sensory Panel Members (Standard Practice 758);
- Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series Method of Limits (Standard Practice E679-91); and
- Referencing Suprathreshold Odor Intensity (Standard Practice E544-99).

Copies of the above ASTM methods are provided in Attachment C to this report.

The odor panel evaluation used 6 to 12 trained and experienced assessors who together possess odor sensitivity representative of the general population.

2.2.1 Detection and Recognition Thresholds

Odor thresholds are determined using a presentation method called the "three-alternative forced-choice" method or the "triangular forced-choice" method. Each odor panel assessor performs the odor evaluation task by sniffing the diluted odor from an olfactometer. The assessor sniffs three sample presentations; one contains the odor while the other two are "blanks" (odor free). He/she must then select the one of the three that is "different" from the other two. The assessor is required to choose one of the three and acknowledges his/her response as a "guess," "detection," or "recognition," as defined by ASTM Standard Practice E679-91.

After the first set of three presentations, the assessor is then presented with the next dilution level. The assessor is again presented with three sample choices, one of which is the diluted odor sample. However, this next dilution level presents the odor at a higher concentration (e.g., two times higher). This is one-half the dilution ratio (fewer number of dilutions = higher concentration). The first dilution level presented to the assessor is below the odor thresholds (subthreshold). The assessor proceeds to higher levels of sample presentation following these methods. This statistical approach is called "ascending concentration series."

Results are computed for each assessor based on the dilution levels where correct "detection" or "recognition" responses are recorded. The responses of all assessors are averaged to determine the sample's detection and recognition thresholds.

The dynamic dilution of an odorous emission is the physical process that occurs in the atmosphere downwind of the odor source. The dilution ratio is an estimate of the number of dilutions needed to make the actual odor sample just detectable to an average nose. Under laboratory conditions, the concentration of an odor that is just detectable (i.e., at the detection threshold) is described as having a DT concentration of 1. The recognition threshold (RT) is the concentration at which the assessor first detects, or recognizes, the odor's character (smells like ..."), and is typically several times higher in concentration than the DT value.

For comparison purposes, an average person in a laboratory setting could just barely detect that there was something different about a sample that contained a concentration of 1 odor unit (OU) (1 DT), in comparison to clean, filtered background air. However, an odor concentration impact at 1 OU would not likely be detected in outdoor air within the City which, based on background measurements taken during this Study, had on the order of a 5 DT, or 5 OU concentration even without local source impacts. Adding a concentration of 1 OU to such air would probably not make a detectable difference to an average observer. It is expected that an added impact of 5 OU from a Proposed Plan Facility or Alternative Facility, as applicable, would be a more likely level of odor impact that would begin to be detected by an average observer. Also, it is expected that an added impact of 10 OU from a Proposed Plan Facility or Alternative Facility, as applicable, would be a more likely odor impact that would be recognized and found objectionable by an average observer.

Odor impact analyses frequently use the RT value because it represents the concentration of the odor in the air that would be first recognized by an individual downwind of the odor source. For the purpose of this Study, the more conservative DT value has been used as the basic measure of odor concentration because it is expected that the DT value can be determined more consistently and accurately by an odor panel.

The DT value is dimensionless; however, it is "assigned" dimensions of odor units per cubic meter (OU/m^3) for the purpose of calculating effective odor emission rates. One odor unit is defined for the purposes of this Study as the amount of odor in a cubic meter of air that will provide an odor concentration of DT = 1, or in other words, an odor that is just detectable in the laboratory.

2.2.2 Odor Intensity

The odor intensity is the relative strength of the odor above the recognition threshold (suprathreshold). The intensity of an odor is referenced on the ASTM Odor Referencing Scale described in ASTM Standard Practice E544-99, Referencing Suprathreshold Odor Intensity. The IITRI dynamic dilution binary olfactometer (butanol wheel) is the method St. Croix Sensory uses for the procedure of odor intensity referencing.

The odor referencing was accomplished by a comparison of the odor intensity of the odor sample to the odor intensity of a series of concentrations of the reference odorant (butanol). The olfactometer delivered the butanol in air to glass sniffing ports. The olfactometer had eight sniffing ports with a series of increasing concentrations of butanol (12, 24, 48, 96, 192, 384, 768 and 1,536 ppm butanol).

A larger value of butanol means a stronger odor, but not in the same numerical proportion as the increase in concentration. The average value (of all assessors' observations) of the odor evaluation was the reported intensity for the odor sample.

2.2.3 Odor Persistence (Dose Response)

"Odor persistence" is a term used in conjunction with odor intensity. The perceived intensity of an odor will change in relation to its concentration. However, the rate of change in intensity versus concentration is not the same for all odors. This rate of change of intensity is termed the persistence of the odor. The persistence of an odor is represented as a dose-response function. The dose-response function is determined from intensity measurements of an odor at full strength and at several dilution levels above the threshold level, and from a dose-response curve prepared by St. Croix Sensory that is a logarithmic plot of the equivalent butanol intensity dilutions (x-axis) versus the equivalent butanol intensity concentrations (y-axis). The slope of this line defines the odor's persistence. A steeper slope (approaching -1) means that the odor intensity decreases rapidly as dilutions occur. A flatter slope (closer to 0) means that the odor intensity tends to persist even as dilutions occur.

2.3 Data Reduction Methodology

The same odor panel protocol used for the February 2001 Final Comprehensive Solid Waste Management Plan Modification and Final Environmental Impact Statement (2001 Plan) was applied for this Study to provide a comparable measure of results from the 2001 Plan and this Study. However, since the 2001 Plan analysis, which used "butanol-equivalent" emissions rates for the modeling analysis, the odor evaluation industry has changed its direction in projecting odor. Rather than estimating and modeling dispersion of butanol-equivalent emissions, the currently preferred method involves applying a dispersion model to the odor emissions from individual sources to calculate the degree of odor dilution in the ambient air, in comparison to the DT level. Therefore, for the purpose of calculating odor emissions from the Proposed Plan Facilities and Alternative Facilities, as applicable, odor emission factors, and odor control equipment efficiency, only the DT values determined from the laboratory data were applied in the following calculations.

2.3.1 Pretest Room Air Exchanges

After the maintenance alley doors are closed, odors within the room must come to equilibrium before they are sampled. Using USEPA Isolation Chamber sampling guidance, concentration equilibrium should be established after 4 to 5 room air exchanges. All indoor odor samples were collected after approximately 4 to 9 room air exchanges were accomplished. Room air exchanges are calculated from the time all the doors are closed (except the small access door which was left open during the entire sampling effort in order to provide "sweep air") by multiplying the time (minutes) since the doors were closed by the room ventilation rate (cfm) and dividing this product by the volume of the room. This calculation is expressed as follows:

Pretest Room Air Exchanges = (minutes since last door closed (minutes) x vent rate (cfm)/)Maintenance area room volume (ft^3)

2.3.2 Total Emission Rate (OU/sec)

An odor emission rate in odor units per second (OU/sec) for the single wall vent was calculated by multiplying the vent's design air flow rate in cubic meters per second (m^3/sec) by the vent's odor concentration measured and reported by the odor panel as a multiple of the detection threshold (DT), applied as "odor units per cubic meter" (OU/m^3). This product is the total emission rate (OU/sec) for all 12 collection vehicles staged in the maintenance alley during odor sampling. For the indoor background odor sample, this value is the total emission rate for the maintenance alley without the collection vehicles staged inside. This calculation is expressed as follows:

Total Emission Rate (OU/sec) = measured flow rate (m^3/sec) x DT (OU/m^3)

2.3.2 Emission Factor ([OU/sec]/collection vehicle)

Average collection vehicle emission factors were calculated for each sample by dividing the total emission rate by the number of collection vehicles in the maintenance alley at the time of sampling. This provided emission factors in odor units per second per collection vehicle

([OU/sec]/collection vehicle) for each sample. Separate samples were obtained for different room air exchanges. Thus, a Proposed Plan Facility or Alternative Facility, as applicable, sample set emission factor was calculated as follows:

$$\text{Emission Factor (OU/sec/collection vehicle)} = \frac{\text{Total Emission Rate (OU/sec)}}{\text{Number of collection. vehicles sampled}}$$

3.0 SUMMARY OF ODOR SAMPLING, RESULTS AND STUDY EMISSION FACTORS

3.1 Summary of Results

Table 3.1-1 provides a summary of results from the one-day sampling event. DT values ranged from 5 to 7. Collection vehicle emission factors ([OU/sec]/col. veh.) ranged from 2.7 to 3.2.

The program's QA samples suggest no significant contamination in the sample media blank, with a 5 DT result that is slightly higher than the method detection limit of 4. The 6 DT outside/upwind sample value is typical and suggests little or no significant background source interference with the sampling program. Finally, the deviation about the average of the field duplicate sample was 0%, as compared to the typical range of +25%/-20%.

Attachment D of this report contains a summary of general field observations and laboratory and sampling results for the sampling effort performed at the Manhattan District 8 garage.

Table 3.1-1
DSNY Collection Vehicle Odor Study at the Manhattan 8 Garage Facility
Sampling Summary and Results
July 20, 2004

Sample #	Start Time	Stop Time	Sample Description	Pretest Room Air Exchanges (~ #)	Collection Vehicles (# of Veh.)	Average Facial Velocity (FPM)	Measured Flow Rate (m3/s)	DT (o.u./m3)	Total Emission Rate (o.u./s)	Average Emission Factor ([o.u./s]/Col. Veh.)
TRUCK ODORS INCLUDING INDOOR BACKGROUND										
072004-M8-03	13:44	13:47	Test #1	4	12	220	5.5	7	38	3.2
072004-M8-04	14:10	14:13	Test #2	6	12	220	5.5	6	33	2.7
072004-M8-05	14:40	14:46	Test #3	9	12	220	5.5	6	33	2.7
doors closed @	13:00									
BACKROUND, DUPLICATE AND BLANK SAMPLES										
072004-M8-01	12:12	12:15	indoor background	5	0	250	5.5	5	27	----
072004-M8-02	12:12	12:15	outdoor background	----	----	----	----	6	---	----
072004-M8-06	14:40	14:46	Test #3 duplicate	9	12	220	5.5	6	33	---
072004-M8-07	12:15	12:18	indoor background	5	0	250	5.5	6	33	----
Tedlar bag blank	----	----	sample media blank	----	----	----	----	5	----	----
doors closed @	11:15	(for indoor background samples only)								

Notes:
Maintenace Area Room Volume (ft^3) = 136,686
Average Room Ventilation Rate (cfm) = 11,610

3.2 Emission Factors

Table 3.1-1 provides a summary of the estimated odor emission factors based on all odor samples analyzed for this Study. These data show that the emission factors ranged from 2.7 ([OU/sec]/collection vehicle) to 3.2 ([OU/sec]/collection vehicle), with a mean value of 2.9 ([OU/sec]/collection vehicle).

To be conservative, the 3.2 ([OU/sec]/collection vehicle) maximum emission factor was applied to establish a maximum odor emission rate (OU/sec) for each queuing collection vehicle to estimate the potential off-site impacts from on-site operations.

3.3 Comparison to the 2001 Final Comprehensive Solid Waste Management Plan

In cases where individual sources at a facility have the same odor characteristics, the modeled odor impacts from individual sources can be assumed to be additive. Therefore, for the purpose of calculating odor impacts in this study, a single model run was made for each facility evaluated, with appropriate emission factors for each of the individual odor sources (e.g., MTS exhaust vent, trucks queuing on entrance ramp).

3.4 Conclusions

Sampling was performed during the high heat of the summer months (July and August), when waste decomposition and odor generation is expected to be at its peak. Therefore, sampling results should conservatively represent odor emissions for the year. Of the 6 vent samples, the data seemed to correlate well. Field duplicate sample differences were well within acceptable tolerances. Vent sample odor levels were found to be low and within range of indoor and outdoor background levels as well as the method detection limit of 4 DT.

These results are supported by sampling staff observations that most of the 12 collection vehicles sampled had very little or no perceivable odors when walking by the vehicles. The odors from the one truck that smelled the worst could only be detected within 4 to 5 feet of the vehicle's waste loading area (where waste had accumulated, and was visible and exposed to ambient air). Many of the other vehicles sampled also had exposed waste inside the waste loading area.

Emission factors were conservatively estimated. Odor impact analyses frequently use the RT value because it represents the concentration of the odor in the air that would be first recognized by an individual downwind of the odor source. For the purpose of this Study, the more conservative DT value (when the odor is first detected) has been used as the basic measure of odor concentration and because it is expected that the DT value can be determined more consistently and accurately by an odor panel.

Emission factors were also conservatively applied by using only the maximum emission rate from the three vent tests.

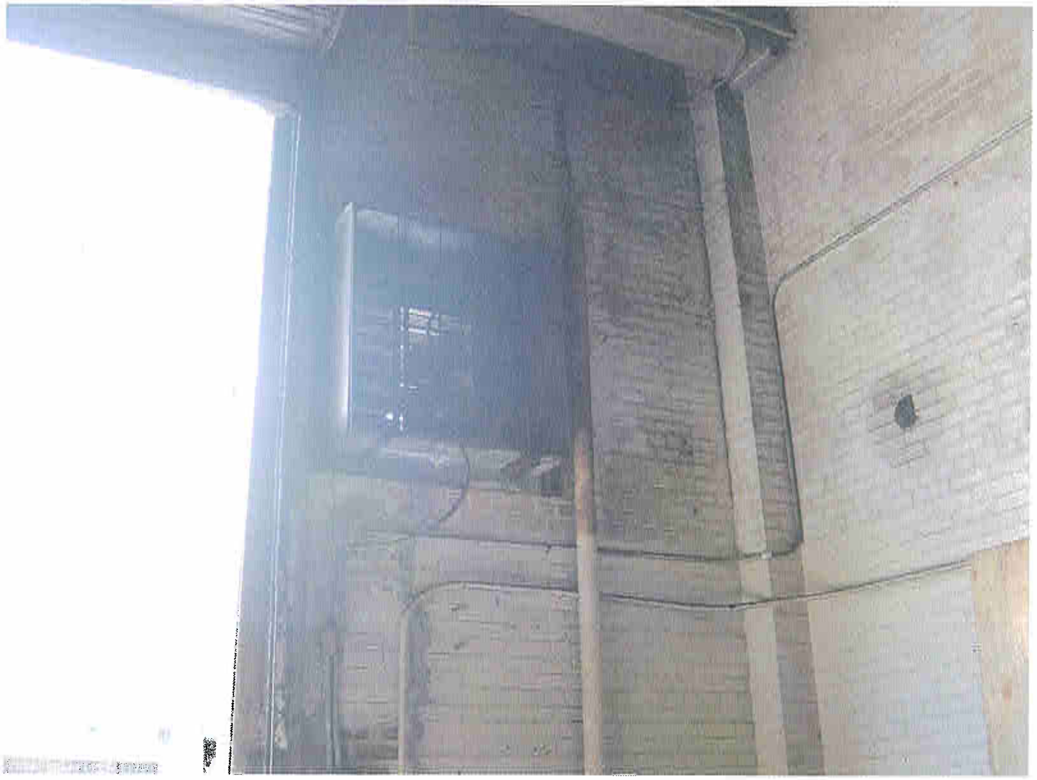
A total of 6 vent samples and 2 field QA samples were collected for the Study odor sampling effort. Of the 6 vent samples, 3 vent samples were used to conservatively calculate the collection vehicle odor emission factors that were then applied in establishing odor emission rates for modeling impacts

City of New York
Department of Sanitation

FEIS
COLLECTION VEHICLE ODOR SAMPLING REPORT

ATTACHMENT A

Photographic Log



Exhaust fan and vent.

Outside view of exhaust vent

Manhattan 8 Garage where odor samples were collected

Collection Vehilcle lined up for odor sampling

Manhattan 8 Garage where odor samples were collected

Collection Vehilcle lined up for odor sampling

Collection Vehilcle lined up for odor sampling

Collection Vehilcle lined up for odor sampling

Collection Vehilcle lined up for odor sampling

Collection Vehilcle lined up for odor sampling

The back of one of the collection vehicles

Collection Vehicles outside Manhattan 8 Garage

Collection Vehicles outside Manhattan 8 Garage

City of New York
Department of Sanitation

FEIS
COLLECTION VEHICLE ODOR SAMPLING REPORT

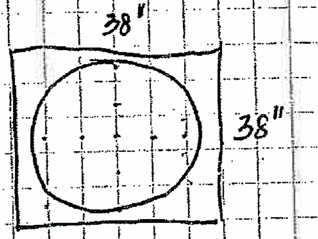
ATTACHMENT B

Field Data Sheets, Sampling Notes and Collection Vehicle Waste Load Data Summaries

~~1. [illegible]~~
~~2. camera~~
~~3.~~

7/20/04 Odor Sampling M8 Garage

Fan



10 ft²

Room
33' x 218' x 19' H = 136686 ft³

1 Air change

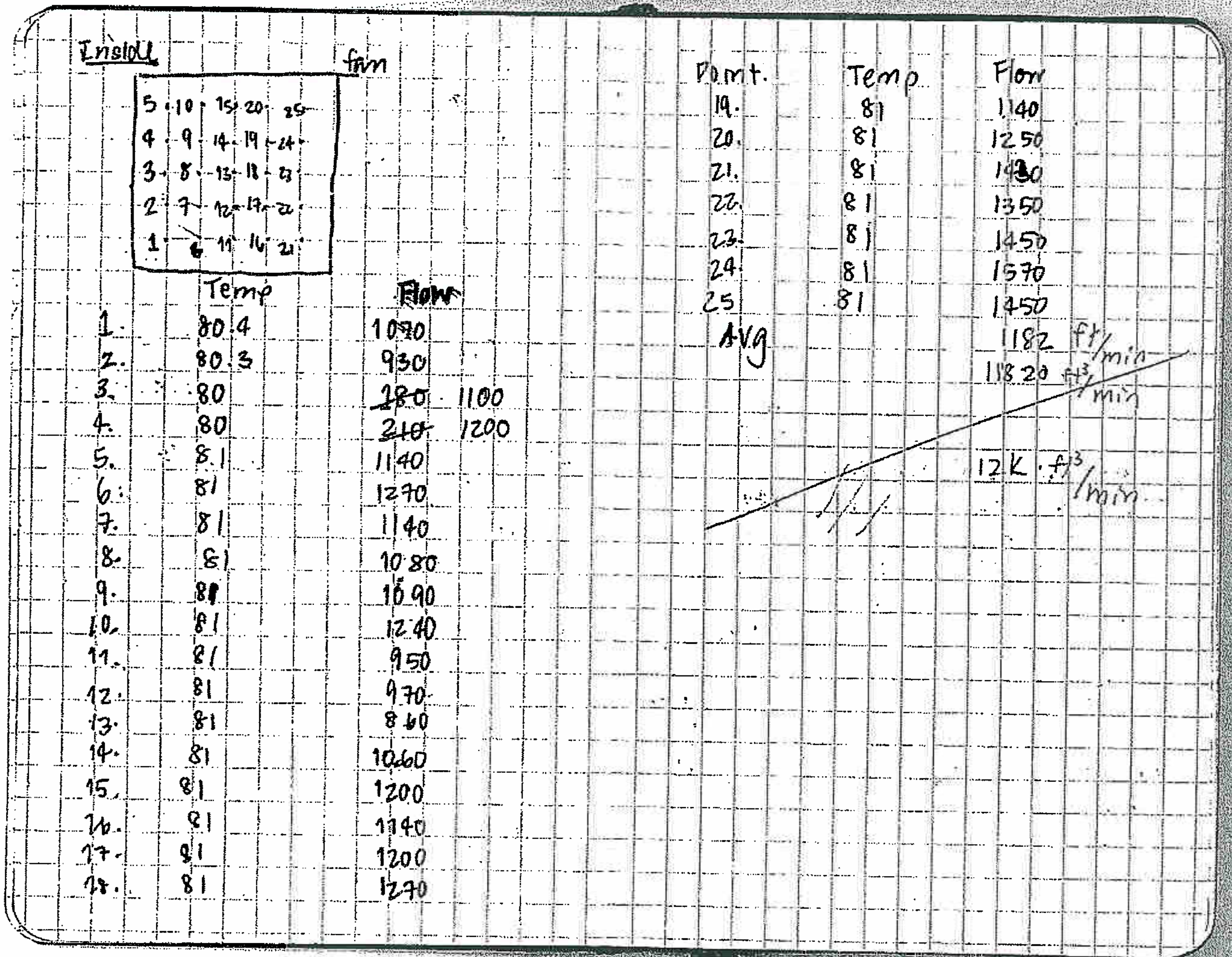
$$\frac{136686 \text{ ft}^3}{10 \text{ ft}^2 \text{ fan } 1150 \text{ ft/min}} = 11.9 \approx 12m$$

Facial velocity ~ 210 ft/min
@ 9" open

facial velocity ~ 330 ft/min
@ 6" open

1' 10" x 4' 9" door ~ 250 ft/min
22" x 57"

door closed @ ~ 11:15 a.m.



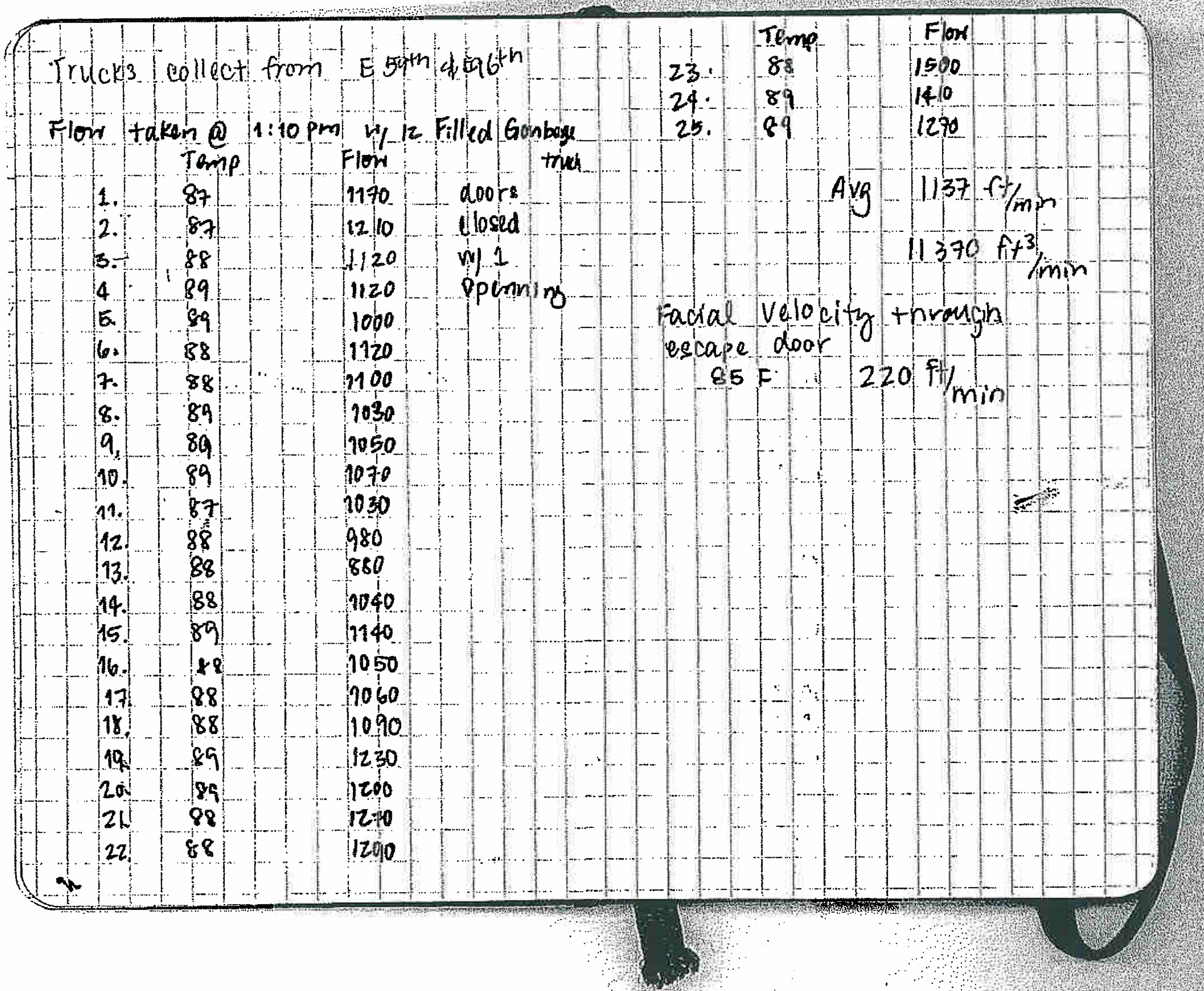
Inside fan

5	10	15	20	25
4	9	14	19	24
3	8	13	18	23
2	7	12	17	22
1	6	11	16	21

	Temp	Flow	
1.	80.4	1070	
2.	80.3	930	
3.	80	~~180~~	1100
4.	80	~~210~~	1200
5.	81	1140	
6.	81	1270	
7.	81	1140	
8.	81	1080	
9.	81	1090	
10.	81	1240	
11.	81	950	
12.	81	970	
13.	81	860	
14.	81	1060	
15.	81	1200	
16.	81	1140	
17.	81	1200	
18.	81	1270	

Point.	Temp	Flow
19.	81	1140
20.	81	1250
21.	81	1430
22.	81	1350
23.	81	1450
24.	81	1570
25	81	1450
Avg		1182 ft/min
		11820 ft³/min

12K ft³/min



Trucks collect from E 59th & 96th

Flow taken @ 1:10 pm w/ 12 Filled Garbage truck

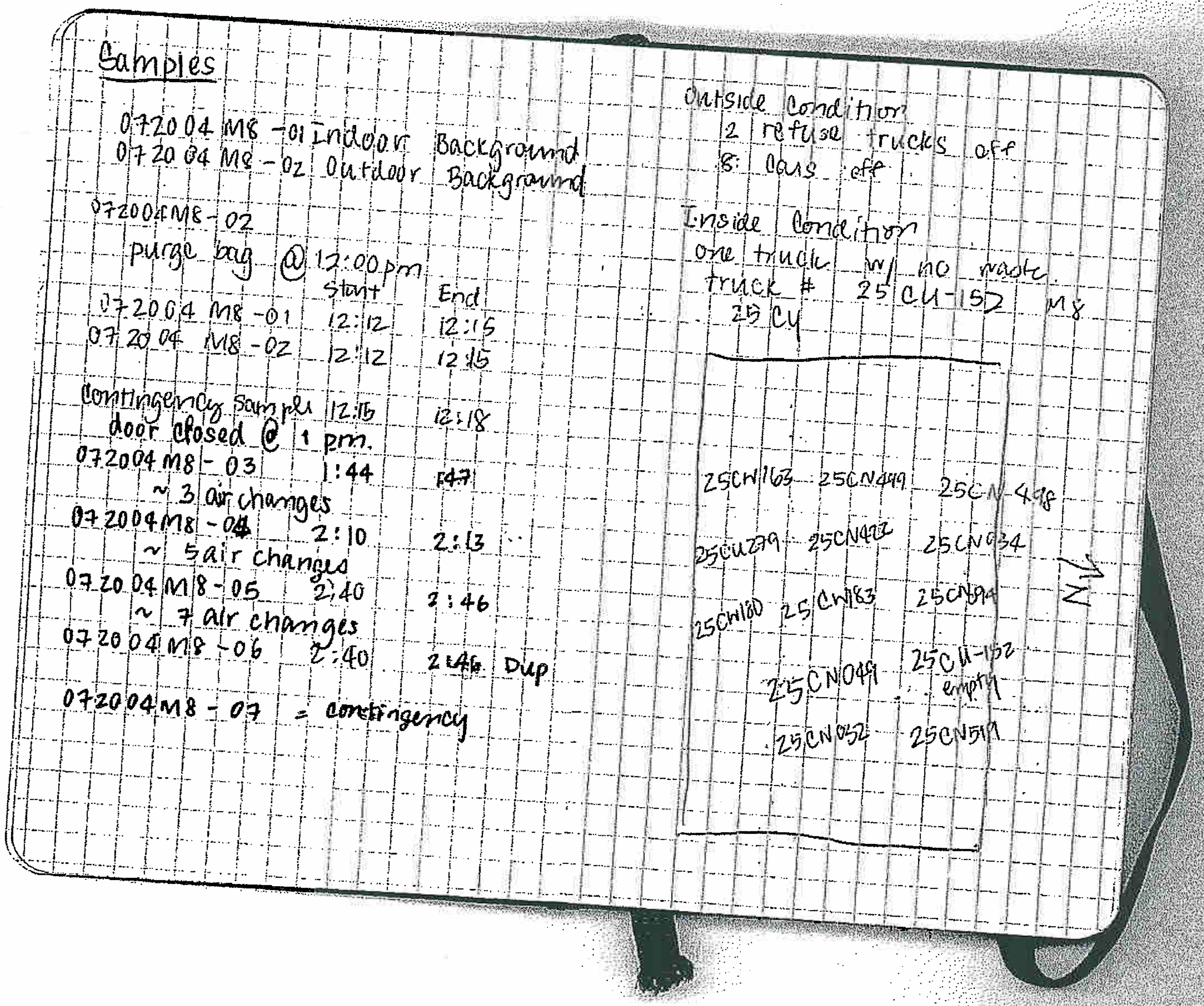
	Temp	Flow	
1.	87	1170	doors
2.	87	1210	closed
3.	88	1120	w/ 1
4	89	1120	opening
5.	89	1000	
6.	88	1120	
7.	88	1100	
8.	89	1030	
9.	89	1050	
10.	89	1070	
11.	87	1030	
12.	88	980	
13.	88	860	
14.	88	1040	
15.	89	1140	
16.	88	1050	
17.	88	1060	
18.	88	1090	
19.	89	1230	
20.	89	1200	
21.	88	1270	
22.	88	1200	
23.	88	1500	
24.	89	1410	
25.	89	1270	

Avg 1137 ft/min

11370 ft³/min

Facial Velocity through escape door

85 F 220 ft/min



Samples

072004 M8 -01 Indoor Background
072004 M8 -02 Outdoor Background

072004 M8-02
purge bag @ 12:00pm

	Start	End
072004 M8 -01	12:12	12:15
072004 M8 -02	12:12	12:15
Contingency sample	12:15	12:18

door closed @ 1 pm.

072004 M8 - 03	1:44	1:47
~ 3 air changes		
072004 M8 - 04	2:10	2:13
~ 5 air changes		
072004 M8 - 05	2:40	2:46
~ 7 air changes		
072004 M8 - 06	2:40	2:46 Dup

072004 M8 - 07 = contingency

Outside Condition
2 refuse trucks off
8 cars off

Inside Condition
one truck w/ no waste
truck # 25 CU-152 M8
25 CY

25CW163 25CN499 25CN-498
25CU279 25CN422 25CN034
25CW180 25CW183 25CN94
25CN049 25CU-152 empty
25CN052 25CN519

N

St. Croix Sensory, Inc.

CHAIN OF CUSTODY RECORD FOR ODOR SAMPLES

Page 1 of 2

Client: HDR - M8 DOS Garage	Sampled By: D. Mills / [illegible]
Project Name: Truck Odor	Sampling Date: 7/20/04

Comments: [illegible] (7/21) [illegible]

Odor Evaluations Requested: (X)

For Laboratory use Only

Odor Evaluation Report No.

Line No.	Field No.	Sample Description	Sample Time	Field H_2S (ppm)	Odor Concentration (DT, RT)	Odor Intensity (PPM)	Odor Characterization (Hedonic Tone & Descriptors)	Odor Persistency ("Dose-Response")	Laboratory Sample No. LN	Laboratory Sample No. FN
1	072004M8-01	[illegible]	[illegible] pm	NA	✓	✓	✓	✓		
2	072004 M8-02	[illegible]	[illegible]		✓	✓	✓	✓		
3	072004 M8-03		[illegible]		✓	✓	✓	✓		
4	072004 M8-04		[illegible]		✓	✓	✓	✓		
5	072004 M8-[illegible]		[illegible]		✓	✓	✓	✓		
6	072004 [illegible]		[illegible]		✓	✓	✓	✓		
7	[illegible]07		[illegible]		✓	✓	✓	✓		
8	Field Blank 1	Blank	NA		✓	✓	✓	✓		
9	Field Blank 2	Blank ([illegible])	NA	↓	✓	✓	✓	✓		
10										

Transfer & Shipping Information

Number of "Air-Pacs"/ Shipping Boxes 2

Relinquished By	Date	Time	Accepted By	Date	Time	Comments & Exceptions Noted
[illegible]	[illegible]	[illegible]				
Received at St. Croix Sensory Laboratory						

LAB COPIES WHITE & YELLOW

CLIENT COPY PINK

TABLE 1

DSNY Collection Vehicle Odor Study
at the Manhattan 8 Garage Facility

Collection Vehicle Waste Load Data
July 20, 2004

Collection Vehicle Number	Waste (ton)
25CW- 163	13.00
25CN- 499	13.58
25CN- 498	13.00
15CU- 279	12.60
25CN- 422	13.97
25CN- 34	15.44
25CW- 180	13.14
25CW- 183	13.77
25CN- 94	14.71
25CN- 49	13.50
25CN- 32	14.67
25CN- 519	13.63
Average Load =	13.75
Maximum Load =	15.44

Notes:
- 7/20/04 waste load data received from Supervisor Hudgins by phone on 7/21/04.

City of New York
Department of Sanitation

FEIS
COLLECTION VEHICLE ODOR SAMPLING REPORT

ATTACHMENT C

American Society of Testing Materials (ASTM) Methods

Appendix 1:	Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series Method of Limits (Standard Practice E679-91)
Appendix 2:	Referencing Suprathreshold Odor Intensity (Standard Practice E544-99)

ATTACHMENT C

American Society of Testing Materials (ASTM) Methods

Appendix 1: Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series Method of Limits (Standard Practice E679-91)

Designation: E 679 – 91 (Reapproved 1997)

An American National Standard

Standard Practice for
Determination of Odor and Taste Thresholds By a Forced-Choice Ascending Concentration Series Method of Limits[1]

This standard is issued under the fixed designation E 679; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

The obtaining of odor and taste thresholds requires the sensory responses of a selected group of individuals called panelists. These thresholds may be determined in order to note the effect of various added substances on the odor and taste of a medium. They may also be determined in order to characterize and compare the odor or taste sensitivity of individuals or groups.

It is recognized that precise threshold values for a given substance do not exist in the same sense that values of vapor pressure exist. The ability to detect a substance by odor or taste is influenced by physiological factors and criteria used in producing a response by the panelist. The parameters of sample presentation introduce further variations. Thus, the flowrate of a gaseous, odorous sample has an influence on the detectability of an odor. However, a concentration range exists below which the odor or taste of a substance will not be detectable under any practical circumstances, and above which individuals with a normal sense of smell or taste would readily detect the presence of the substance.

The threshold determined by this practice is not the conventional group threshold (the stimulus level detectable with a probabililty of 0.5 by 50 % of the population) as obtained by Practice E 1432, but rather a best estimate not far therefrom. The bias of the estimate depends on the concentration scale steps chosen and on the degree to which each panelist's threshold is centered within the range of concentrations he or she receives. The user also needs to keep in mind the very large degree of random error associated with estimating the probability of detection from only 50 to 100 3-AFC presentations.

1. Scope

1.1 This practice describes a rapid test for determining sensory thresholds of any substance in any medium.

1.2 It prescribes an overall design of sample preparation and a procedure for calculating the results.

1.3 The threshold may be characterized as being either (*a*) only *detection* (awareness) that a very small amount of added substance is present but not necessarily recognizable, or (*b*) *recognition* of the nature of the added substance.

1.4 The medium may be a gas, such as air, a liquid, such as water or some beverage, or a solid form of matter. The medium may be odorless or tasteless, or may exhibit a characteristic odor or taste per se.

1.5 This practice describes the use of a multiple forced-choice sample presentation method in an ascending concentration series, similar to the method of limits.

1.6 Physical methods of sample presentation for threshold determination are not a part of this practice, and will depend on the physical state, size, shape, availability, and other properties of the samples.

1.7 It is recognized that the degree of training received by a panel with a particular substance may have a profound influence on the threshold obtained with that substance **(1)**.[2]

1.8 Thresholds determined by using one physical method of presentation are not necessarily equivalent to values obtained by another method.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1292 Test Method for Odor in Water[3]

E 544 Practice for Referencing Suprathreshold Odor Intensity[4]

E 1432 Practice for Defining and Calculating Individual and Group Sensory Thresholds from Forced-Choice Data Sets of Intermediate Size[4]

3. Terminology

3.1 *Definitions:*

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[1] This practice is under the jurisdiction of ASTM Committee E-18 on Sensory Evaluation of Materials and Products and is the direct responsibility of Subcommittee E18.04 on Fundamentals of Sensory.

Current edition approved Aug. 15, 1991. Published October 1991. Originally published as E 679 – 79. Last previous edition E 679 – 79.

[2] The boldface numbers in parentheses refer to the list of references at the end of this practice.

[3] *Annual Book of ASTM Standards*, Vol 11.01.

[4] *Annual Book of ASTM Standards*, Vol 15.07.

3.1.1 *sample*—a material in any form that may or may not exhibit an odor or taste, depending on the amount of odorous or sapid components that it may contain.

3.1.2 *medium*—any material used to dissolve, disperse, or sorb odorous or sapid material whose threshold is to be measured.

3.1.3 *blank sample*—a quantity of the medium containing no added odorous or sapid material.

3.1.4 *test sample*—the medium to which an odorous or sapid material has been added at a known concentration.

3.1.5 *detection threshold*—the lowest concentration of a substance in a medium relating to the lowest physical intensity at which a stimulus is *detected* as determined by the best-estimate criterion.

3.1.6 *recognition threshold*—the lowest concentration of a substance in a medium relating to the lowest physical intensity at which a stimulus is *recognized* as determined by the best-estimate criterion.

3.1.7 *best-estimate criterion*—an interpolated concentration value, but not necessarily the concentration value that was actually presented. In this practice it is the geometric mean of the last missed concentration and the next (adjacent) higher concentration.

3.1.8 *panelists*—individuals whose odor or taste thresholds are being evaluated, or who are utilized to determine the odor or taste threshold of the substance of interest.

3.1.9 *ascending scale of concentrations*—a series of increasing concentrations of an odorous or sapid substance in a chosen medium.

3.1.10 *scale steps*—discrete concentration levels of a substance in a medium, with concentrations increased by the same factor per step throughout the scale.

3.1.11 *3-alternative forced choice (3-AFC) presentation*—a set consisting of one test sample and two blank samples (as applied to this practice).

3.1.12 *geometric mean*—the *n*th root of the product of terms. In this method, the terms are concentration values.

4. Summary of Practice

4.1 A series of test samples is prepared by dispersing the substance whose threshold is to be determined in the medium of interest. This concentration scale should increase in geometric increments so that any two adjacent concentration steps are separated by a constant factor. At each concentration step, two blank samples consisting of the medium only are made available to the panelist. The blank and test samples are encoded so that there is no visual, audible, tactile, or thermal difference between the samples other than code designators **(2)**.

4.2 The panelist starts at the lowest concentration step, which should be two or three concentration steps below the estimated threshold. Each sample within the set of three is compared with the other two.

4.3 The panelist indicates which of the three samples is different from the other two. A choice must be made, even if no difference is noted, so that all data can be utilized.

4.4 Individual best-estimate values of threshold are derived from the pattern of correct/incorrect responses produced separately by each panelist. Group thresholds are derived by geometrical averaging of the individual best-estimate thresholds.

5. Significance and Use

5.1 Sensory thresholds are used to determine the potential of substances at low concentrations to impart odor, taste, skinfeel, etc. to some form of matter.

5.2 Thresholds are used, for example, in setting limits for air pollution, in noise abatement, in water treatment, and in food science and technology.

5.3 Thresholds are used to characterize and compare the sensitivity of individual or groups to given stimuli, for example, in medicine, in ethnic studies, and in the study of animal species.

6. Preparation of Concentration Scale

6.1 The concentration levels of the test substance in a medium should begin well below the level at which the most sensitive panelist is able to detect or recognize the added substance, and end at (or above) the concentration at which all panelists give a correct response.

6.2 The increase in concentration of the test substance per scale step should be by a constant factor. It is desirable to obtain a scale step factor that will allow the correct responses of a group of nine panelists to distribute over three to four concentration steps (see Appendix X1). This will allow more accuracy in determining the threshold value based on the geometric mean of the individual panelists.

6.3 Good judgment is required by the person in charge in order to determine the appropriate scale step range for a particular substance. This might involve the preparation of an approximate threshold concentration of the odorous or sapid substance in the medium of choice. The concentration of the substance may be increased two to three times for odorants or 1.5 to 2.5 times for sapid substances depending on how the perceived intensity of odor or taste varies with the concentration of the substance providing the sensory response. Thus, if x represents an approximate odor threshold concentration, then a series of concentration steps would appear as follows if a step factor of "3" were used:

$$\ldots x/27, x/9, x/3, x, 3x, 9x, 27x \ldots$$

6.4 In actual practice, the various concentrations are obtained by starting at the highest concentration and diluting three times per step, thus providing a series of dilution factors, "V_i" being the initial volume:

$$\ldots 729V_i, 243V_i, 81V_i, 27V_i, 9V_i, 3V_i, V_i, \ldots$$

6.5 At each selected concentration or dilution, a 3-AFC sample set consisting of one test and two blank samples is presented to panelists in indistinguishable fashion **(3)**. It is desirable to have all samples prepared and ready for judging before the evaluation session begins. (Reference **(2)** contains sound practices for coding the samples, rotating the positions of these test and blank samples as the test proceeds, etc.)

6.6 If the samples are arranged in a left-center-right, or an above-center-below order, care must be taken that the test sample is presented in one third of the presentations in the left (top) position, one third in the center position, and one third in the right (bottom) position to eliminate positional bias.

6.7 If only one sample at a time is available, the test and blank samples may be presented one after another in units of three presentations, with the test sample being randomized to be the first, the second, and the third, and requesting the response after all three samples in the set have been presented. Better results, however, are obtained if the test and the two blank samples are available for a direct comparison, so that the panelist may sniff or taste back and forth at ease until a decision is reached.

7. Judgment Procedure

7.1 The panelist begins judging with that set which contains the test sample with the lowest concentration (highest dilution) of the odorous or sapid substance, takes the time needed to make a selection, and proceeds systematically toward the higher concentrations.

7.2 Within each set, the panelist indicates that sample which is different from the two others (detection threshold) or which exhibits a recognizable odor or taste of the substance (recognition threshold). If the panelist cannot readily discriminate, a guess must be made so that all data may be utilized.

7.3 The judgments are completed when the panelist either (*1*) completes the evaluation of all sets of the scale, or (*2*) reaches a set wherein the test sample is correctly identified, then continues to choose correctly in higher concentration test sample sets.

8. Data Evaluation

8.1 The series of each panelist's judgments may be expressed by writing a sequence containing (0) for an incorrect choice or (+) for a correct choice arranged in the order of judgments of ascending concentrations of the added substance.

8.2 If the concentration range has been correctly selected, all panelists should judge correctly within the range of concentration steps provided. Thus, the representation of the panelists' judgments as in 8.1 should terminate with two or more consecutive plusses (+).

8.3 Because there is a finite probability that a correct answer will occur by chance alone, it is important that a panelist continues to take the test until there is no doubt by that person of the correctness of the choice.

8.4 The best-estimate threshold concentration for the panelist is then the geometric mean of that concentration at which the last miss (0) occurred and the next higher concentration designated by a (+).

8.5 The panel threshold is the geometric mean of the best-estimate thresholds of the individual panelists. If a more accurate threshold value of an individual panelist is desired, it may be obtained by calculating the geometric mean of the best-estimate threshold of all series administered to that person.

9. Report

9.1 Successful completion of the foregoing procedure provides either the detection or recognition threshold of the substance in the medium of interest in accordance with this practice.

9.2 The threshold value is in concentration or dilution units appropriate for the substance tested **(4)**.

9.3 For enhanced understanding of the threshold results, the following information is recommended:

Threshold of:
Procedure: ASTM Practice E 679 (Rapid Method)
Presentation:
Number of scale steps:
Dilution factor per step:
Temperature of samples:
Panelist selection:
Number of times test given:
Type of threshold (detection or recognition):
Best-estimate threshold:
  Individual:
  Panel:

9.4 Refer to Appendix X1 for an example of the calculation required and reporting.

10. Precision and Bias

10.1 Because sensory threshold values are functions of sample presentation variables and of individual sensitivities, interlaboratory tests cannot be interpreted statistically in the usual way, and a general statement regarding precision and bias of thresholds obtained by this practice cannot be made. However, certain comparisons made under particular circumstances are of interest and are detailed below.

10.2 When 4 panels of 23 to 35 members evaluated butanol in air **(5)**, the ratio of the highest to the lowest panel threshold was 2.7 to 1; when the same panel repeated the determination on 4 days, the ratio was 2.4 to 1. For 10 panels of 9 members evaluating hexylamine in air, the ratio was 2.1 to 1.

10.3 When 26 purified compounds were tested for threshold by addition to similar beers by 20 brewery laboratories (each compound was tested by 2 to 8 laboratories), the ratios of the highest to the lowest panel threshold varied from less than 2.0 to 1, to 7.0 to 1 or more **(6)**. The lowest variability was found with simple compounds of high threshold (sugar, salt, ethanol), and the highest with complex compounds of low threshold (eugenol, hop oil, geosmin).

10.4 When 14 laboratories determined the threshold of purified hydrogen sulfide in odorless air **(7)**, the ratio of the highest to the lowest laboratory threshold was 20 to 1. Interlaboratory tests with dibutylamine, isoamyl alcohol, methyl acrylate and a spray thinner for automobile paint gave somewhat lower ratios. Although the methods used vary somewhat from this practice, the results are comparable.

10.5 A discussion of the likely bias of results by this practice compared to a true threshold can be found in references **(5)**, **(8)** and **(9)**.

11. Keywords

11.1 air pollution; ascending method of limits; odor; panel; sensory evaluation; taste; threshold; water pollution

APPENDIX

(Nonmandatory Information)

X1. EXAMPLE

X1.1 The odor threshold of an odorous air sample was to be determined.

X1.2 Six different concentrations of the odorous sample in air were prepared. Each of these was presented in conjunction with two samples of nonodorous air. The concentrations were increased by a factor of three per concentration step. Nine randomly selected panelists participated. Each proceeded from the lower to higher concentrations. At each concentration level, panelists compared the three samples—two blanks and one diluted odorous sample—and indicated which sample was different from the other two.

X1.3 The following results were obtained (see Table X1.1):

X1.4 Details of calculation are as follows:

X1.4.1 For Panelist 1, the best-estimate threshold is $\sqrt{135 \times 45} = 78$, or at a dilution by a factor of 78 (one volume of the odorous air sample diluted with nonodorous air to occupy 78 volumes in total). For Panelist 2, the threshold is at $\sqrt{1215 \times 405} = 701$.

X1.4.2 Panelist 4 missed at the highest concentration, where the dilution is only by a factor of 15. It is assumed that he would have been correct at a higher concentration level, where the dilution would have been a factor 15/3 = 5.

X1.4.3 Consequently, an estimate of his threshold is $\sqrt{15 \times 5} = 9$. The underlying assumption is that since the thresholds of the other panelists were within the presented scale range, his threshold should not be far away from the range if he belongs to the same statistical population. If the test were to establish the sensitivity of the panelists, this panelist would have been retested, with a scale range extended to the right of the results in Table X1.1.

X1.4.4 Panelist 6 represents the opposite extreme. The estimate is based on the assumption that a miss would have occurred at a dilution of $3 \times 3645 = 10\ 935$; the best-estimate threshold is then $\sqrt{10\ 935 \times 3645} = 6313$.

X1.4.5 In Table X1.1, dilutions change exactly by a factor of three per scale step. Experimentally, small deviations from such equal spacing occur, and the actual dilutions or concentrations should be used in calculating the best-estimate thresholds from two adjacent values in the table.

TABLE X1.1 Example of Odor Threshold

NOTE 1—This example has been selected to represent both extremes. Panelist 4 missed even at the highest concentration. Panelist 6 was correct even at the lowest concentration and continued to be correct at all subsequent higher concentrations.

Panelists	Judgments^A							
	Dilution Factors						Best-Estimate Threshold (BET)	
	(concentrations increase →)						Value	$\log_{10}$ of Value
	3645	1215	405	135	45	15		
1	0	+	+	0	+	+	78	1.89
2	+	0	+	+	+	+	701	2.85
3	0	+	0	0	+	+	78	1.89
4	0	0	0	0	+	0	9	0.94
5	+	0	0	+	+	+	234	2.37
6	+	+	+	+	+	+	6313	3.80
7	0	+	+	0	+	+	78	1.89
8	+	0	0	+	+	+	234	2.37
9	+	0	+	+	+	+	701	2.85
Group BET geometric mean							$\Sigma\log_{10}$ →	20.85
							209 ←	2.32
Standard deviation								0.81

^{A} "0" indicates that the panelist selected the wrong sample of the set of three. "+" indicates that the panelist selected the correct sample.

X1.5 *Report*—The report shall include the following information:

Odor threshold: Odorous Air Sample XX
Procedure: ASTM Practice E 679
Presentation: at 500 ml/min (dynamic dilution olfactometer)
Number of scale steps: 6
Dilution factor per step: 3
Temperature: 25°C (room and samples)
Panelist selection: random
Number of panelists: 9
Type of threshold: detection
Best-estimate threshold:

$$Z_{OL} = 209$$

$$\log_{10} Z_{OL} = 2.32$$

$$\text{Standard log deviation} = 0.81$$

NOTE X1.1— The symbol Z represents a dilution factor proposed to designate a dimensionless measure of sample dilution needed to reach some target effect **(10)**.[5] For threshold work, the subscript "OL" represents the dilution at which the odor reaches a limit that corresponds to the best-estimate threshold.

X1.6 *Additional examples*—References **(11-20)** contain examples of thresholds determined according to this practice or by equivalent methods.

---

[5] The dilution factor, Z, is used in modest honor of H. Zwaardemaker, a Dutch scientist and early investigator in olfactometry. Alternate terminology in use: Dilution-to-Threshold Ratio (D/T or D-T); Odor Unit (OU); Effective Dose (ED).

REFERENCES

(1) Brown, D. G. W., et al., *Journal of the American Society of Brewing Chemicals*, Vol 36, No. 73, 1978.

(2) *Manual on Sensory Testing Methods, ASTM STP 434*, Am. Soc. Testing Mats., p. 11, section (e) for coding procedures.

(3) Baker, R. A., *Annals of New York Academy of Sciences*, Vol 116, p. 495, 1964.

(4) *Compilation of Odor and Taste Threshold Values Data, ASTM DS 48A*, Am. Soc. Testing Mats., 1978.

(5) Dravnieks, A., Schmidtsdorff, W., and Meilgaard, M., *Journal of the Air Pollution Control Association*, Vol 36, p. 900, 1986.

(6) Meilgaard, M. C., Reid, D. S., and Wyborski, K. A., *Journal of the American Society of Brewing Chemists*, Vol 40, p. 119, 1982.

(7) German Standard VDI 3881, Part 1. *Olfactometry. Odour Threshold Determination Fundamentals*. Verein Deutscher Ingenieure, VDI-Verlag GmbH, Düsseldorf, 1986, pp. 25–27.

(8) Morrison, G. R., *Journal of the Institute of Brewing*, Vol 88, pp. 167 and 170, 1982.

(9) Polta, R. C., and Jacobson, R. L., (Metropolitan Waste Control Commission, Minneapolis/St. Paul). Letter to A. Dravnieks, May 19, 1986, on file with Subcommittee E18.04.25.

(10) Turk, A., "Expressions of Gaseous Concentration and Dilution Ratios," *Atmospheric Environment*, Vol 7, p. 967, 1973.

(11) Amoore, J. E., Venstrom, D., and Davis, A. R., *Perceptual and Motor Skills*, Vol 26, p. 143, 1968. (thresholds in solutions)

(12) Guadagni, D. G., Buttery, R. G., and Okano, S., *Journal of the Science of Food and Agriculture*, Vol 14, p. 761, 1963. (thresholds in solutions)

(13) Hertz, J., Cain, W. S., Bartoshuk, L. M., and Dolan, T. F., *Physiology and Behavior*, Vol 14, p. 89, 1975. (thresholds in water solution)

(14) Dravnieks, A., *Annals of New York Academy of Sciences*, Vol 237, p. 144, 1974. (thresholds in air)

(15) Dravnieks, A., and Prokop, *Journal of the Air Pollution Control Association*, Vol 25, p. 28, 1975.

(16) Engen, T., *Perceptual and Motor Skills*, Vol 10, p. 195, 1960.

(17) Jones, F. N., *American Journal of Psychology*, Vol 69, p. 672, 1956. (general)

(18) Cederlöf, R., Edfors, M. L., Friberg, L., and Lindvall, T., *Journal of the Technical Association of the Pulp and Paper Industry*, Vol 48, p. 405, 1965. (thresholds in air)

(19) Meilgaard, M. C., *Technical Quarterly, Master Brewer's Association of the Americas*, Vol 12, p. 151, 1975. (thresholds in beer)

(20) Salo, P., Nykänen, L., and Suomalainen, H., *Journal of Food Science*, Vol 37, p. 394, 1972. (thresholds in alcohol-water mixture)

ATTACHMENT C

American Society of Testing Materials (ASTM) Methods

Appendix 2: Referencing Suprathreshold Odor Intensity
(Standard Practice E544-99)

Designation: E 544 – 99

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
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Standard Practices for Referencing Suprathreshold Odor Intensity[1]

1. Scope

1.1 These practices are designed to outline a preferred means for referencing the odor intensities of a material in the suprathreshold region.

1.2 The general objective is to reference the odor intensity rather than other odor properties of a sample.

1.3 These practices are designed to reference the odor intensity on the ASTM Odor Intensity Referencing Scale of any odorous material. This is done by a comparison of the odor intensity of the sample to the odor intensities of a series of concentrations of the reference odorant, which is 1-butanol (*n*-butanol).

1.4 The method by which the reference odorant vapors are to be presented for evaluation by the panelists is specified. The manner by which the test sample is presented will depend on the nature of the sample, and is not defined herein.

1.5 Test sample presentation should be consistent with good standard practice **(1)**[2] and should be explicitly documented in the test report.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See Annex A1 for specific safety data.

2. Referenced Documents

2.1 *ASTM Standards:*
D 1292 Test Method for Odor in Water[3]

3. Terminology

3.1 *ASTM odor intensity referencing scale*—a series of 1-butanol dilutions used to establish which concentration exhibits an odor intensity matching that of the sample.

3.2 *concentration*—a series of concentrations of 1-butanol in odorless air, nitrogen, or the water diluent, made to specific reference dilutions which serve as the reference scale, volume basis, of 1-butanol diluted air or in water. In the latter case, the temperature of the solution during the test should be reported.

3.3 *dynamic scale*—the reference scale in which vapor dilutions are prepared by continuous mixing of vapors of 1-butanol with an odorless gas, such as air, to yield constant dilutions of vapor in the gas.

3.4 *panelists*—the individuals who compare the odor intensity of the sample to the reference scale. These individuals should be able to do this with a consistency described in 5.5.

3.5 *perceived (sensory) odor intensity*—the intensity of an odor sensation which is independent of the knowledge of the odorant concentration.

3.6 *sample*—a material in any form exhibiting an odor that needs to be measured.

3.7 *static scale*—the reference scale in which dilutions of 1-butanol in water are prepared in flasks and presented for odor intensity comparison from the flasks.

3.8 *suprathreshold odor intensity*—perceived (sensory) intensity of the odor in that intensity region in which the odor is clearly experienced.

4. Summary of Practice

4.1 The reference odorant used to generate an odor intensity scale is 1-butanol (*n*-butanol). The reasons for its selection are summarized in Appendix X1. A geometric progression scale with a ratio of 2 is recommended, that is, a scale in which each reference dilution differs in its 1-butanol concentration from the preceding dilution by a factor of 2.

4.2 Two procedures, A and B, are described in these recommended practices. They differ in the method by which the diluted 1-butanol vapors are prepared.

NOTE 1—The relationships between the odor intensity of 1-butanol concentrations in air and in water have not been evaluated. Translation of Procedure B data to the numerical values of Procedure A is not possible at this time.

4.2.1 In Procedure A, hereafter referred to as the dynamic scale method, a dynamic-dilution apparatus is used. This is equipped with a series of sniffing ports from which constant concentrations of 1-butanol emerge at constant volumetric flow rates in air.

4.2.2 In Procedure B, hereafter referred to as the static-scale method, a series of Erlenmeyer flasks containing known concentrations of 1-butanol in water is used.

4.3 The odor of the sample is matched, ignoring differences in odor quality, against the odor intensity reference scale of 1-butanol by a panel yielding at least eight independent

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[1] These practices are under the jurisdiction of ASTM Committee E-18 on Sensory Evaluation of Materials and Products and are the direct responsibility of Subcommittee E18.04 on Fundamentals of Sensory.

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[2] The boldface numbers in parentheses refer to the list of references at the end of these recommended practices.

[3] *Annual Book of ASTM Standards*, Vol 11.01.

judgments. Panelists report that point in the reference scale which, in their opinion, matches the odor intensity of the unknown.

4.4 The independent judgments of the panelists are averaged geometrically (see 7.4) with respect to the 1-butanol concentrations of the indicated matching points. Results are reported as an odor intensity, in parts per million, of 1-butanol in air (Procedure A) or water (Procedure B) on the ASTM Odor Intensity Referencing Scale. When water is used as a diluent, the temperature of the reference scale solutions during the test must be reported.

4.5 The odor intensity equivalent values which are obtained may then be used to compare the relative intensities of sample groups. These values are reference values and are not related to the odor intensities by a simple proportionality coefficient (see 8.2).

5. Procedure A—Dynamic-Scale Method

5.1 *Reagents*:

5.1.1 *1-butanol (n-butanol),*[4] the reference odorant, with required purity 99+ mol % by gas chromatography. Also shall be free of strong odorous impurities.

5.1.2 *Diluent*—Nonodorous room or cylinder air.

5.2 *Preparation of Dynamic Scale*:

5.2.1 Prepare the 1-butanol airflow mixtures in an olfactometer apparatus as follows: Pass air over an expanded surface of 1-butanol in order to produce a saturated vapor at a known ambient temperature. Temperatures should be ambient in order to avoid condensation in the airflow lines. Air becomes saturated (98+ %) at flow rates up to 60 mL/min when passed over a surface of 1-butanol that is 120 mm long by 10 mm wide in a 13-mm inside diameter glass tube which is held in a horizontal position. Saturated vapor prepared by bubbling air through 1-butanol is less desirable since the bubbles burst at the surface and produce droplets. In such methods of vapor generation, glass wool filter, operating at the same temperature as the 1-butanol liquid sample, must be used to remove the droplets. Obtain concentrations of vapor below saturation by diluting the saturated vapor with additional volumes of air.

5.2.2 If air, such as pumped ambient air which contains water vapor is used, replace the 1-butanol in the saturation tube every 2 to 3 h; otherwise it will become diluted by the absorption of water which will lower the vapor pressure of 1-butanol, and will result in a lower odorant concentration at the sniffing ports.

5.2.3 An adequate concentration range for most applications is between 5 and 2000 ppm of 1-butanol in air. Above 2000 ppm, the odor intensity is too strong for accurate judgment. Below 5 ppm, the odor is too close to the threshold limit for panelists to make accurate judgments.

5.2.4 The temperature of 1-butanol in the saturation tube should be noted at the start and kept constant during the test. It should be within the range of comfortable room temperatures.

5.2.5 The rate of dynamic delivery of air carrying diluted 1-butanol vapor from sniffing ports should be 160 ± 20 mL/min from a port with a cross-section of 400 to 500 mm^2, resulting in a nominal linear flow rate of 300 mm/min. A rate that is too slow allows the stimulus to be diluted with increasing amounts of room air. A rate that is too fast creates a mechanical sensation in the nose which complicates the odor intensity judgment.

5.2.6 An example of a dynamic dilution apparatus, called a dynamic olfactometer, is diagrammed in Fig. X1.1 and its operation is explained, in Appendix X4.

5.3 *Reference Concentrations*:

5.3.1 This practice is intended to establish, on a continuous ppm 1-butanol scale, that ppm value which best corresponds in its odor intensity to the odor intensity of the sample. Since such a scale is technically difficult, the one designed consists of a series of discrete concentration points at sniffing ports continuously delivering known concentrations of 1-butanol vapor in air.

5.3.2 A geometric progression scale of concentrations is used, in which each reference port differs in its 1-butanol concentration from the preceding port by a factor of 2. It would have been desirable to select and always use the same ppm values for the same ports, however, this would require very complex flow adjustment systems. Although the ppm values delivered by the scale ports change with temperature, they remain in the same ratio to each other, and thus still permit the intensity equivalence point to be easily found.

5.3.3 The scale points are arranged systematically, in the order of increasing concentrations, and are numbered in ascending integers, from 1 for the lowest concentration of 1-butanol.

5.3.4 The matching points normally used are the scale points, or positions between the scale points, but can also be those points beyond either end of the scale.

5.4 *Test Room*—The test room must be well-ventilated, essentially odor-free, and comfortable. In order to avoid bias, waiting panelists should not observe or learn the judgments of the panelist currently matching the odor intensity of the sample to the scale **(1,2)**.

5.5 *Odor Panel*:

5.5.1 *Number*—The number of panelists should be eight or more, to permit elementary statistical tests on their judgments. A smaller number of panelists may be used with replicate judgments to increase the total to eight or more. It is important when obtaining replicate data that all bias is removed. Precautions such as separate sessions and recoding are recommended **(1)**.

5.5.2 *Selection*—Special training is not needed but precautions must be taken in the selection of the panelists **(3)**. An individual with insufficient sensitivity to detect the odor of 10 ppm of 1-butanol in air should not be a panelist. Also, some individuals have been observed to experience difficulty in matching odor intensities. Prospective panelists can be screened by having them repeatedly match the odor intensity of a known concentration of 1-butanol vapor to the 1-butanol reference scale. Those whose standard deviation in repeated testing exceeds 1.5 scale steps should not be used in the panel. Periodic retesting of panelists may be advisable.

5.6 *Judgment Procedure*:

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[4] 1-Butanol (*n*-butanol), available from Allied Fisher Scientific Co., 2775 Pacific Drive, P.O. Box 4829, Noreross, GA 30091. Catalog 74 (1974), No. A-384 (p. 976), or equivalent.

5.6.1 Panelists are instructed on the nature of the 1-butanol odor intensity reference scale. They are told that the ports are numbered beginning with No. 1, which represents the weakest odor and that the odors increase systematically in intensity with increasing port identification numbers.

5.6.2 Panelists are instructed to smell the unknown sample and then to smell the scale, beginning with its weakest end, and match the unknown to the scale, ignoring differences in the odor quality. They are permitted to check and recheck the unknown against the scale any number of times and should not be hurried or biased by others in any manner.

5.6.3 Panelists are advised that they may report one of the scale points as the best match, or else may report that the best match occurs between two adjacent points, for example, the unknown is stronger than scale point No. 7, but weaker than scale point No. 8.

5.6.4 Panelists should be advised that the odor may also be weaker than the weakest point of the scale, or stronger than the strongest point of the scale.

5.6.5 When his judgment is within scale limits, the panelist should make sure that the selected position is a good match, that is, that the next lower concentration of 1-butanol indeed smells weaker than the unknown, and that the next higher concentration indeed smells stronger.

5.6.6 Panelists report the matching point in terms of the port identification number. When the best match is a position between the scale points, such as between port Nos. 7 and 8, the half-number, 7.5, is used.

5.6.7 During repeated smelling of one or more samples or scale points, olfactory adaptation (fatigue) occurs, rendering the sense of smell less sensitive. However, the relative position of the unknown with respect to the scale is not unduly influenced unless the rates of adaptation to 1-butanol and to the sample are very different. The adaptation rate to 1-butanol has been reported to be average when compared to other odorants **(4)**. Therefore, the complication that may result from differences in the adaptation rate to the unknown and to 1-butanol is minimized by selecting 1-butanol as the reference odorant.

5.6.8 Because of the olfactory adaptation discussed in 5.6.7, a panelist may find that after judging at higher odor intensity points on the scale, he may have difficulty in detecting odor at the lowest points of the scale. A rest of 2 to 5 min will usually correct this effect.

5.6.9 Panelists may differ in the amount of time required to render a judgment. The panelist should be allowed to proceed at a rate comfortable to him. As many as six test stimuli can be handled by a panel of nine in a 1-h session.

6. Procedure B—Static-Scale Method

6.1 The reference odorant is 1-butanol, (see 5.1.1). The diluent is distilled water that is odor-free.

NOTE 2—If diluent other than water is used, equivalent ppm (vol/vol) values will not exhibit matching odor intensities because of differences in molecular weights, densities, and the activity coefficients of 1-butanol in different solvents. Use of other solvents is therefore not recommended.

6.2 Follow the procedures outlined in Section 5, except for 5.2.

6.3 *Preparation of Static Scale*:

6.3.1 Prepare solutions of 1-butanol in water, using pipets and volumetric flasks, following the usual laboratory procedures for solution preparation.

6.3.2 *Procedure*—Place the reference sniffing solutions into standard 500-mL wide-mouth, conical Erlenmeyer flasks (see Test Method D 1292). The volume of solution should be 200 mL and should be replaced by new solutions after a maximum period of 2 h. Between sniffings, cover the top of each flask with aluminum foil in order to assure equilibration between the solution and the air head-space above it. The flasks should be gently shaken by each panelist prior to each sniffing in order to assure equilibrium.

6.3.3 The temperature of the reference solutions during the test should be ambient, and should be noted and kept constant during the test.

6.3.4 The odor threshold of 1-butanol in water is 2.5 ppm at 21°C **(5)**. The useful concentration range for the static scale is above this value but does not extend to the solubility limit of 7.08 % of 30°C (70 800 ppm) **(6)**. At concentrations close to the solubility limit, excess 1-butanol may separate from the solution with temperature change. If this occurs the odor becomes equivalent to that of pure 1-butanol.

6.3.5 Considerable latitude as to the selection of concentrations is allowed. To go from the saturation point to the threshold requires 16 flasks, assuming that each succeeding mix is one half of the preceding concentration (70 800, 35 400, 17 000, 8 850 ppm, etc.). Solutions stronger than 20 000 ppm of 1-butanol exhibit an odor that is too intense for most comparisons.

6.3.6 The most useful concentration range is approximately between 10 and 20 000 ppm, and may be covered by twelve flasks containing 10 ppm in flask No. 1, 20 ppm in flask No. 2, etc. These flasks constitute the static scale. The unknown sample is matched to the static scale in the same manner as in the dynamic method (see 5.6).

7. Calculation

7.1 *Procedure A*—Table 1 lists 1-butanol concentrations, in parts per million, by volume, in vapor at equilibrium with pure, liquid 1-butanol at different temperatures. Use this table to calculate the concentrations of 1-butanol in air (Procedure A).

7.1.1 *Example 1*—Assume that the temperature of 1-butanol was 20.3°C and the following linear interpolation of ppm values is used:

$$6513 + [(7000-6513)(0.3/1)] = 6659 \text{ ppm} \quad (1)$$

If air saturated with 1-butanol vapor at 20.3°C is further diluted with additional air to obtain a lower concentration, the value of 6659 ppm is divided by the corresponding dilution factors to obtain the values for 1-butanol vapor concentrations at the respective scale points.

7.1.2 For instance, if a 74-mL/min flow of air saturated with 1-butanol vapor is mixed with a 310-mL/min flow of nonodorous air, the resulting 1-butanol vapor concentration would be the following:

$$(6659)[74/(74 + 310)] = 1283 \text{ ppm by volume} \quad (2)$$

7.2 *Procedure B*—For the static-scale method, the values of parts-per-million concentrations of 1-butanol in water solutions are known from the method of preparation (see 6.3.1).

7.3 When a panelist indicates that a position between two

TABLE 1 Vapor Pressure and Concentration Data for the 1-Butanol Odor Intensity Scale[A]

Temperature, °C	Vapor Pressure, mm Hg[B]	Concentration[C]	$\log_{10}$, ppm
12	2.78	3 660	3.56
13	2.99	3 930	3.59
14	3.23	4 250	3.63
15	3.48	4 580	3.66
16	3.74	4 920	3.69
17	4.01	5 280	3.72
18	4.31	5 670	3.75
19	4.61	6 070	3.78
20	4.95	6 510	3.81
21	5.32	7 000	3.85
22	5.69	7 490	3.87
23	6.11	8 040	3.91
24	6.53	8 590	3.93
25	6.97	9 170	3.96
26	7.50	9 870	3.99
27	8.01	10 500	4.02
28	8.55	11 300	4.05
29	9.14	12 000	4.08
30	9.76	12 800	4.11
31	10.42	13 700	4.14
32	11.07	14 600	4.16
33	11.83	15 600	4.19
34	12.63	16 600	4.22
35	13.42	17 700	4.25
36	14.33	18 900	4.28
37	15.78	20 800	4.32

[A] *Handbook of Chemistry and Physics,* 50th Ed., Chem. Rubber Publ. Co., Cleveland, OH, 1969–70, p. D-152. See Table on Vapor Pressure Organic Compounds (pressures less than 1 atm). Values given for 1-butanol are: 1 mm Hg, −1.2°C; 10 mm Hg, +30.2°C; and 40 mm Hg, 53.4°C. These three points were used to interpolate for other temperatures. Later editions have deleted this table.

The values of vapor pressures for 12 to 37°C for the table were calculated as follows: the Handbook values of °C were converted to K, the vapor pressures to log(mm Hg), and the least squares fit straight line was calculated for a plot of log(mm) versus reciprocal of the K temperatures. This equation was used to interpolate vapor pressures in mm Hg for the integral ° C values in the table.

The conversion of vapor pressures to ppm by volume was conducted as follows: As an example, the vapor pressure of 1-butanol at 25°C is 6.97 mm Hg. Air saturated with 1-butanol vapor at this temperature and 760-mm Hg total pressure contains (6.97 × 1 000 000)/760 = 9171 ppm of 1-butanol.

[B] 1 mm Hg = 133 Pa.

[C] Concentration of 1-butanol in air saturated with 1-butanol vapor.

scale points is the best match, the concentration value for this position is calculated as the geometrical mean of the concentrations at the two adjoining scale points. This applies to both procedures. For example, if the 1-butanol concentrations at points No. 7 and No. 8 are 685 and 1280 ppm, then the concentration that would correspond to the intermediate position of 7.5 is found by the following logarithmic computation:

$$\log\,(\text{ppm for position } 7.5) = \frac{\log\,(658) + \log\,(1280)}{2} = 2.96 \qquad (3)$$

Tables of antilogarithms give 918 ppm as the estimate for the 1-butanol concentration at the scale position 7.5.

7.4 *Averaging Panelists' Data*—A geometric average of a group of panelists' judgments is computed and converted into an ASTM Odor Intensity Referencing Scale value, in parts per million of 1-butanol, in a manner illustrated by the following example:

7.4.1 The odor of 3 % vol/vol of anethole dissolved in propylene glycol and prepared in 125-mL Erlenmeyer flasks was evaluated for its odor intensity in comparison to that of a dynamically prepared scale at sniffing ports such as those described in Appendix X4. Nine panelists participated.

Panelist	Matching Sniffing Port No.	1-Butanol Concentration Data	
		ppm (vol/vol)	log (ppm)
1	5	165	2.22
2	6.5	452	2.66
3	7	658	2.88
4	6.5	452	2.66
5	7.5	919	2.96
6	7.5	919	2.96
7	7.5	919	2.96
8	6.5	452	2.66
9	5.5	226	2.35

7.4.2 The mean $\log_{10}$ in parts per million was equal to 2.701. The antilogarithm of 2.701 is 502 ppm of 1-butanol. This would be the best mean for the odor intensity match for the anethole solution. This result should be reported in accordance with Section 8.

7.5 *Standard Deviation*—It is desirable to quote, the standard deviation of the mean $\log_{10}$ (ppm) value **(2)**, for the method of calculation used when reporting the results. For the example given in 7.4.2, the standard deviation of the mean log (ppm) of 2.701 is ±0.27.

8. Report

8.1 *Procedure A*—Report the result as follows:

8.1.1 The odor intensity of the sample is equivalent to;lm ppm of 1-butanol (air) on the ASTM Odor Intensity Referencing Scale for Procedure A.

8.2 *Procedure B*—When the diluent is water and the static-scale method is used, report the result as follows:

8.2.1 The odor intensity of the sample is equivalent to __ ppm of 1-butanol in water, __ °C, in the ASTM Odor Intensity Referencing Scale for Procedure B.

8.3 Report the standard deviation of the result (see 7.5), if it is calculated. Also report the number of panelists that participated.

8.4 Values that are reported in this manner permit the comparison of odor intensity measurements for the same material to be conducted in different locations by different panels, the comparison of odor intensities for samples which are not available at the same time, and the reconstruction of a reported odor intensity for an unknown material in other laboratories.

9. Keywords

9.1 *n*-butanol; supra threshold odor intensity

ANNEX

(Mandatory Information)

A1. SAFETY DATA FOR 1-BUTANOL

A1.1 *General*—1-butanol is a common chemical used as a solvent for fats, waxes, resins, gums, and varnishes. It is also used in the manufacture of lacquers, detergents, and rayon; in special cleaning applications; and as a fuel. It is not a listed carcinogen and it does not cause lasting damage in case of accidental moderate overexposure. If ingested it is metabolized in a manner analogous to that of ethanol. It is however an irritant for eyes, skin, and the respiratory tract. Prolonged inhalation or ingestion causes dizziness and narcosis. Accordingly, contact times and concentrations of exposure should under no circumstances exceed those required for the application of the method. Exposure to concentrations in excess of the ACGIH Ceiling Value should be avoided or, if deemed necessary, should be kept to a few seconds per exposure. Assessors who experience symptoms of uneasiness during the test should be allowed the choice of not completing it.

A1.2 *OSHA Requirement*—The Occupational Safety and Health Authority enforces a workplace TLV (Threshold Limit Value) of 100 ppm (300 mg/m^3). This refers to an 8-h time-rated average. To determine compliance in a workroom situation, air sampling should be conducted around the user at intervals during the work period, and the average exposure should be calculated.

A1.3 *ACGIH Recommendation*—The American Conference of Governmental Industrial Hygienists, Inc., 6500 Glenway Ave., Bldg. D-7, Cincinnati, OH 45211-4438, recommends a TLV-C (TLV-Ceiling) of 50 ppm (152 mg/m^3). The user should obtain the relevant documentation in full. A TLV-C is a momentary value; in a workroom situation, it signals the need to begin air sampling in order to monitor any exposure above this level.

A1.4 *Realistic Assessment*—Determine the number of seconds an assessor is exposed to each concentration, then calculate the 8-h time-rated average. Example: 1 min at 1000 ppm, 2 min at 500 ppm, 4 min at 250 ppm, total $1 \times 1000 + 2 \times 500 + 4 \times 250 = 3000$ ppm × min. or $3000/60 \times 8 = 6.25$ ppm over 8 h. An assessor performing 4 such assessments within the same 8-h period is exposed to an 8-h time-rated average of $4 \times 6.25 = 25$ ppm.

APPENDIXES

(Nonmandatory Information)

X1. SELECTION OF 1-BUTANOL AS THE REFERENCE ODORANT

X1.1 1-Butanol was selected as the reference odorant because:

X1.1.1 It is a common chemical and is readily available in 99+ mol % purity.

X1.1.2 It is non-toxic, except in multigram doses.

X1.1.3 It has good stability in the presence of air and water.

X1.1.4 Its odor is somewhat unrelated, so that its odor quality can be more easily ignored when comparing with other odors which may have different qualities.

X1.1.5 The majority of people do not object to sniffing it frequently when doing odor-intensity referencing.

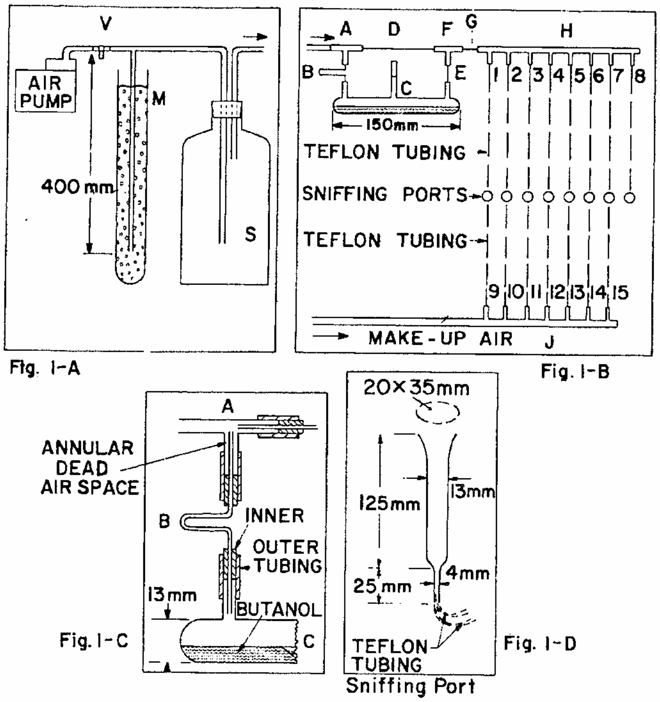

Fig. 1-A

Fig. 1-B

Fig. 1-C

Fig. 1-D

FIG. X1.1 Butanol Scale Olfactometer

TABLE X1.1 Capillary Tubing Calibration Data Used in the Design of the Flow Splitters and the Stimulus Generator[A]

Tubing Composition	Diameter[B]		Standard Flow, Rate, V (ml/min)[C,D]	Equivalent Lengths[D,E]
	OD,[F] mm (in.)	ID,[G] mm (in.)		
Stainless steel	1.6 (1⁄16)	0.76 (0.030)	220	1
Stainless steel	1.6 (1⁄16)	0.48 (0.019)	43	0.20
Stainless steel	1.6 (1⁄16)	0.25 (0.010)	2.3	0.010
PTFE	AWG 15[H]		4110	18.7

[A] The following types of tubing have been found satisfactory: *(1)* Stainless steel capillaries (all 1⁄16-in. OD)—0.030-in. ID, Supelco Co., Catalog No. 02-0529, Bellefonte, PA; 0.010-in. ID, Supelco Co., Catalog No. 02-0535, Bellefonte, PA; 0.019-in. ID, Chromatronix, Catalog No. SO63019, Berkeley, CA; and *(2)* PTFE AWG 15—standard wall thickness tubing, natural color, available from Pennwalt Plastics Co., Clifton Heights, PA.

[B] Nominal values, in practice the inside diameters vary from lot to lot.

[C] Airflow rate, mL/min, through a 100-mm length of tubing at a manostat pressure (immersion of the manostat leg in water) of 100 mm Hg of water, as measured with a soap film flowmeter with no other restrictions in the flow path.

[D] These values must be determined for each lot of tubing.

[E] The length of tubing of the indicated size (ID) which has a flow resistance equivalent to that of one unit length of 0.76-mm (0.030-in.) ID tubing.

[F] Outside diameter.

[G] Inside diameter.

[H] PTFE spaghetti tubing of standard wall thickness.

X1.1.6 Its perceived-odor intensity changes rapidly with concentration, for example, the slope of the logarithmic odor intensity versus the concentration plot is steep (see X3.2). Therefore, such a scale will cover a broad range of sensory intensities with a reasonable number of scale points. Also, a well-noticeable odor-intensity difference occurs between two adjoining concentration-scale points that differ in 1-butanol vapor content in air by a factor of 2.

X1.1.7 Since its odor threshold is relatively high (2 to 6 ppm (vol/vol) in air flowing at 100 to 200 mL/min), a continuous discharge of its vapors into the test room air does not result in a noticeable odor level in a normally ventilated room.

X1.1.8 Its concentration in air, down to the odor threshold concentration level, can be monitored with hydrogen-flame ionization detectors without the need for preconcentration.

TABLE X1.2 Design Requirements for the Stimulus and Make-Up Air Flow Splitters (Flow Rates and Capillary Tubing Dimensions)[A]

Port No.	Required Flow Rates, mL/min		Lengths of Stainless Steel Capillaries, mm					
			Stimulus Splitter				Make-Up Air Splitter	
			Inside Diameters of Capillaries, mm					
	Stimulus	Make-Up Air	0.76		0.48	0.25	0.76	
			Design[B]	Actual[C]			Design[B]	Actual[C]
8	160	none	120	99	...	...	none	none
7	80	80	240	219	...	...	240	219
6	40	120	480	459[D]	92		160	139
5	20	140	960	939[E]	188	...	137	116
4	10	150	1 920	1 890[E]	378	...	128	107
3	5	155	3 840	3 820[E]	...	38	124	103
2	2.5	157.5	7 680	7 660[E]	...	77	122	101
1	1.25	158.8	15 360	15 340[E]	...	153	121	100

[A] The calculated values are based on the assumption that each stainless steel capillary is connected in series with a 400-mL length of AWG 15 standard wall thickness PTFE spaghetti tubing.

[B] The design length is that length, in millimetres, of the indicated stainless steel capillary tubing which, by itself, would provide the required airflow resistance in the absence of the PTFE tubing.

[C] The actual length, in millimetres, of the indicated size of stainless capillary tubing which, if connected in series with 400 mm of PTFE tubing,[a] provides a combined flow resistance equivalent to that of the "design" length. In terms of 0.76-mm ID stainless steel capillary tubing, the actual length is equal to the design length minus 21 mm.

[D] Either the 0.76-mm ID or 0.48-mm ID tubing is practical.

[E] These lengths are impractical; use the indicated length of the smaller size tubing.

X2. PSYCHOPHYSICAL (SENSORY) INTERPRETATIONS

X2.1 It has been established **(7, 8, 9, 10)** that the expression of odor intensity in terms of multiples of odor-threshold concentration of an odorous material does not by itself properly reflect the actual sensory intensity of the odor presented. Odor intensities increase with concentration at different rates for different odorants.

X2.2 Although category scales of words or numbers are valid for the evaluation of odor intensities, the absence of standards for defining categories such as "slight,"" moderate," etc., generate difficulties when comparing odor intensity values obtained by category scaling by different groups of panelists.

X2.3 It should be emphasized that the values obtained in parts per million of 1-butanol in accordance with this recommended practice are not direct measures of odor intensities, because the perceived odor intensities of 1-butanol vapors are not linearly proportional to 1-butanol concentrations. For example, an increase in 1-butanol concentration by a factor of 2 results in an odor that is less than twice as intense. Therefore, the odor intensities expressed in parts per million of 1-butanol are simply numbers for recording and communicating in a reproducible form. A larger ppm value of 1-butanol means a stronger odor, but not in a simple numerical proportion. These numbers can be translated into perceived odor intensity values, however, this translation is not applicable to these recommended practices.

X3. COMPARISON OF TWO UNKNOWN SAMPLES

X3.1 The 1-butanol scale refers to the odor intensity of samples in terms of that concentration of 1-butanol which exhibits a matching odor intensity. When many samples are compared by separate matching to the 1-butanol scale, yielding different matching points, two typical questions may be asked:

X3.1.1 *Are two samples, X and Y, significantly different in their odor intensity?*—This can be estimated either by a generalized *t*-Test **(1)** if the judgment is by different panels; or by the *t*-Test-by-Difference, if the same panel judged *X* and *Y*. The latter test gives better discriminations.

X3.1.2 *How much stronger is X in comparison to Y?*—This can be estimated in terms of the perceived intensity ratios if the perceived odor intensity ratios for various concentrations of 1-butanol are known (see X3.2).

X3.2 Three laboratories **(9, 11, 12, 13)** have given estimates of the perceived odor intensity ratios for 1-butanol odors of different concentrations delivered in air with forced flow from dynamic preparation apparatus. Based on their findings, it appears that on the average, the odor intensity of 1-butanol vapor in air changes proportionally to 0.66 power of its concentration. For example, if the odor intensities of *X* and *Y* were equivalent to 1000 ppm and 200 ppm of 1-butanol, respectively, the perceived odor intensity ratio is

$$\frac{X}{Y} = \left(\frac{1000}{200}\right)^{0.66} = 2.9 \tag{X3.1}$$

Thus, the odor intensity of sample *X* was approximately three times stronger in comparison to sample *Y*.

X4. 1-BUTANOL SCALE OLFACTOMETER

X4.1 The following description of a 1-butanol scale olfactometer is offered as a practicable example of a dynamic method for stimulus preparation and presentation. However, use of this apparatus is *not* a requirement of the standard.

X4.2 The olfactometer shown in Fig. X1.1, comprises two parts, an air supply system and an odorant vaporization-dilution system.

X4.3 *Air Supply*—The air (see 5.1.2) functions both as a carrier gas and as a diluent for 1-butanol vapor. Continuous streams of appropriately diluted 1-butanol vapor are thereby made available for sniffing. Any convenient source of nonodorous air may be used, such as air from a compressed gas cylinder (Note X4.1) or from an arrangement (see Fig. X1.1-A) comprised of an air pump, manostat, and surge bottle, as follows (Note X4.2):

NOTE X4.1—It is not known to what extent the odor intensity is affected by the existence of humidity differences between the odor stimuli and the test environment. To minimize possible problems in this regard, it may be desirable to humidify dry air from a compressed gas cylinder to approximate the room air humidity.

NOTE X4.2—The air supply shown in Fig. X1.1-A is both convenient and inexpensive to build. Two such units are needed (see X4.4.1 and X4.4.3).

X4.3.1 *Pump*—The pump for the air supply is an aquarium pump[5] (Note X4.3) which delivers ambient room air (Note X4.4) into the manostat.

NOTE X4.3—Some aquarium pumps contain components such as diaphragms, that odorize the pumped air.[6]

NOTE X4.4—The use of ambient room air as the air source may eliminate complications which could conceivably arise from preconditioning the nose at one set of conditions (relative humidity, temperature) and then testing under a different set of conditions **(10)**.

X4.3.2 *Manostat*—The manostat, *M*, an air-pressure regulator, is of the simple T-tube type. Most of the excess air from the pump is permitted to escape by means of a three-way brass bleeder valve, *V*.[5] The remaining excess air escapes through the leg of the tee which is immersed in a column of water. The depth of immersion determines the air pressure in the tee. The pressure remains constant as long as air bubbles continue to slowly emerge from the immersed leg of the tee. This pressure provides the driving force required for maintaining a continuous air flow through the odorant vaporization-dilution section of the olfactometer (see X4.4).

X4.3.3 *Surge Bottle*— The surge bottle, *S* (Fig. X1.1-A), of approximately 2-L capacity, is inserted between the manostat and the odorant vaporization-dilution system. It effectively dampens the pressure pulses caused by the pump and, to a slight extent, by the bubbling of the manostat (Note X4.5). The rubber stopper at the mouth of the surge bottle is lined with aluminum foil to minimize leakage of odorants from rubber into the air flow system.

NOTE X4.5—Unless the pressure pulses are eliminated, the air flow through the flow splitters such as used in the stimulus generator will result in a time-flow distribution unlike that for steady flow. This can drastically change the odorant vaporization rate in the stimulus generator and thus give invalid data.

X4.3.4 Air connections between the pump, manostat, surge bottle, and odorant vaporization-dilution system should be made with odorless tubing.[7]

X4.4 *Odorant Vaporization-Dilution System*—In this section of the olfactometer shown in Fig. X1.1-B, the headspace atmosphere over an enclosed pool of 1-butanol becomes saturated with 1-butanol vapor. This saturated vapor is converted to a series of eight concentrations of 1-butanol in air, with each concentration differing from the preceding one by a factor of two, by means of a two-stage air dilution sequence. These eight concentrations of 1-butanol flow continuously from eight sniffing ports.

X4.4.1 *Stimulus Generator*—The stimulus generator, in which odorant vaporization and first-stage air dilution occur, is shown in Fig. X1.1-B (parts *A* through *G*). It is connected to an air supply such as described in X4.3. The horizontal, 150-mm long vaporization chamber, *C*, is made from glass tubing of 13-mm outside diameter (OD). The three side spouts are 4-mm OD glass tubing and are 12 mm in length. The middle spout on vessel, usually stoppered by a glass rod fitted with a flexible plastic sleeve, is used to introduce 1-butanol into the vessel. One millilitre of 1-butanol, added to vessel *C* by means of a syringe, provides 2 to 3 h of use (5.2.2).

NOTE X4.6—In practice, the pump is permitted to run day and night since, with continuous pump operation, the system is easily purged of the 1-butanol remaining from a previous session. This procedure avoids a possible complication wherein 1-butanol evaporates from vessel *C*, condenses elsewhere in the system, and then evaporates during the next sniffing session to produce faulty 1-butanol concentrations. It also prevents the accumulation in the system of odor from flexible plastic and rubber parts.

X4.4.1.1 The tees at junction *A* and *F* are brass.[5] In the first tee, *A*, air splits into two portions. One part, 20 % of the flow, passes through stainless steel capillary tubing *B* into the headspace of vessel *C*, which contains 1-butanol. The other portion, which is 80 % of the air flow, goes through a bypass capillary, *D*. As the 20 % portion of air passes over the 1-butanol surface, it becomes saturated with 1-butanol vapor at the temperature of the vessel (Note X4.7). This saturated vapor exits from vessel *C* through a stainless steel capillary, *E*, and in a brass tee *F* mixes with the bypass air from *D*. This mixture, after passing through another stainless steel capillary, *G*, enters the stimulus-flow splitter bulkhead, *H* (Note X4.8).

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[5] Available from aquarium supply dealers.

[6] A small piston pump, such as Supreme Special Model B2F, available from Eugene G. Danner Mfg., Inc., Brooklyn, NY, or equivalent has been found satisfactory.

[7] Food-grade vinyl tubing, Formulation B-44-4X exhibits odor insufficient to create olfactometric problems. The size 5⁄32 in. ID and 7⁄32 in. OD has been found convenient.

NOTE X4.7—Tests with a hydrogen-flame ionization detector have indicated that 98 % saturation is achieved at airflows of up to 60 mL/min in such vessels. Over-the-surface air flow eliminates the possibility of droplet entrainment and the need for filtration.

NOTE X4.8—Capillaries *E* and *G* serve to assure high linear flow rates of air and vapor mixtures and thus to prevent vapor back-diffusion effects.

X4.4.2 *Stimulus-Flow Splitter Bulkhead*—The stimulus flow splitter bulkhead, *H* (Fig. X1.1-B), is made of glass and has eight side spouts of 4-mm OD glass tubing. Stainless steel capillaries (1 through 8) are attached to the spouts. These capillaries supply the 1-butanol air mixture from the bulkhead to eight pieces of PTFE spaghetti tubing which, in turn, terminate in eight sniffing ports (see X4.5.3 for port design details). The dimensions of the capillaries, that is, the inside diameter (ID) and length, are such that the highest-numbered port receives 160 mL/min; the next highest, 80 mL/min; the next, 40 mL/min, etc. (see X4.7.5).

X4.4.3 *Glass Splitter Bulkhead*—A second air supply system is connected to a seven-way glass splitter bulkhead, *J*. This bulkhead has seven attached stainless steel capillaries of appropriate sizes (see X4.7.6). These supply make-up air through PTFE spaghetti tubing to seven of the eight sniffing ports to assure that the total flow from each of the ports is 160 mL/min, just as from the port of highest 1-butanol concentration (No. 8). (Note that stage two of the 1-butanol vapor-air dilution sequence takes place in the sniffing ports.)

X4.4.4 Since the stimulus splitter bulkhead, *H*, is supplied from the stimulus generator (X4.4.1) which, by itself, exhibits a flow resistance, the actual driving pressure required for the vapor-carrying branch will be considerably greater than that for the make-up air branch. Typical manostat pressures for the stimulus and the make-up air systems correspond to 300 and 100 mm of water, respectively. Some adjustments in pressures may be necessary. These are made by changing the depth of immersion of the manostat tubes.

X4.4.5 The odor intensities in the olfactometer stabilize within 15 to 30 min after glass vessel *C* has been supplied with 1-butanol and stoppered, and after the pumps have been turned on.

X4.5 *Design Details:*

X4.5.1 Details of the stimulus generator connections are shown in Fig. X1.1-C. Similar connections are used for the splitter bulkheads. Each stainless steel capillary always protrudes well into the brass tee or glass spout to which it is connected and is held firmly in place by a sleeve made from two overlapping sizes of flexible plastic tubing.[8] The annular space between the stainless steel capillary wall and the surrounding brass or glass tubing wall forms a dead air pocket, across which odorant vapors can only slowly diffuse. This effectively isolates the flexible plastic connector from the mainstream of flow. As a consequence, any loss of 1-butanol from the gas stream by diffusion and solution in the plastic connector produces a negligible effect on the mainstream concentration of 1-butanol. By the same token, noticeable contamination of the mainstream vapors by extraneous odorants released from the plastic connector is avoided.

X4.5.2 All stainless steel capillaries are 1.6 mm (1⁄16 in.) in outer diameter. The selection of inner diameters and lengths is discussed in X4.7.

X4.5.3 Sniffing port dimensions are indicated in Fig. X1.1-D. Each port is made of glass and has a flared, elliptical upper end. The PTFE spaghetti tubing delivering stimuli and make-up air are held in the lower, narrower tubing of the port by means of a short piece of flexible plastic tubing used as a wedge. It is unnecessary to completely seal the narrow end (partially occupied by tubing), since the flow resistance here is much larger than at the mouth of the port.

X4.6 *Calibration*—The various flow rates are calibrated by means of a soap bubble flowmeter.[9]

NOTE X4.9—The flow resistance from other types of flowmeters is excessive. Therefore, they will not yield sufficiently accurate flow rates.

X4.6.1 Connections to the flowmeter must have large openings in order to avoid distortions in the flow rates. The eight flows from the 1-butanol flow splitter, *H*, and the seven flows from the make-up air splitter, *J*, are measured at the ends of the PTFE spaghetti tubing which terminate in the sniffing ports. The flow rates used to determine the stimulus generator dilution ratio are obtained by disconnecting tee *F* and measuring the flow rates from capillaries *D* and *E*. These 17 flow measurements, which can be completed in 10 to 20 min, are sufficient to check all calibrations. Since actual flow rates are used for the calculation of data, it is not necessary that they correspond precisely to the flow rates specified by the design (see X4.7). Flow rates within ±10 % of design are quite satisfactory, and additional refinements may be unnecessarily time-consuming.

NOTE X4.10—Virtually the same odor intensity is expected for any concentration within this ±10 % range because intensity is not sensitive to concentration changes of as little as 10 %. In general, the differential odor intensity threshold (odorant concentration change required to produce a just noticeable odor intensity change) is on the order of 15 to 30 %.

X4.7 *Selection of Capillaries*—Capillary tubing is used to control flow rates throughout the olfactometer system. At a constant pressure drop the flow rate of a capillary is determined by its dimensions (internal diameter and length).

NOTE X4.11—At a given pressure drop, the flow rate of a piece of capillary tubing is inversely proportional to its length and approximately directly proportional to the fourth power of its internal diameter. Thus, a small change in internal diameter is considerably more influential in changing the flow rate than is a change in length.

X4.7.1 Stainless steel tubing and PTFE spaghetti tubing of the nominal sizes indicated in Table X1.1 can be used. In practice, the inside diameter for capillary tubing of the same nominal size will vary from one lot to the next. Therefore, it is necessary to calibrate each lot of tubing before use.

X4.7.2 Calibration of each size of capillary tubing with respect to flow rate at a standard set of conditions yields

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[8] The following tubing has been found satisfactory: larger tubing—1⁄8-in. ID, 1⁄16-in. wall thickness neoprene tubing; and smaller tubing—0.0315-in. ID, 0.1625 in. OD food-grade vinyl tubing, Catalog No. 6419-41, available from Cole Parmer Co., Chicago, IL.

[9] A similar flowmeter available from Varian Associates, Instrument Div., Downey, CA. Catalog No. 96-000015-00, has been found satisfactory.

information which serves as an aid for cutting the tubing to the required lengths. A convenient standard measure is the volumetric air flow rate, V, calibrated in millilitres per minute, obtainable from a 100-mm length of tubing (with no other flow restrictions of consequence) at a manostat pressure of 100 mm Hg of water. Examples of some standard flow rates, obtained from actual samples of capillary tubing, are shown in Table X1.1.

X4.7.3 It is possible to compute equivalent lengths of capillary tubing from the standard flow rates. (The utility of these values will become evident later.) An equivalent length of capillary tubing is that length of tubing of a particular size (ID) which is equivalent in flow resistance to one unit length of tubing of a different size. To compute the length of tubing of size N that would be equivalent in its flow resistance to a length, L_M, of tubing of size M, the following equation is used:

$$L_N = L_M(V_N/V_M) \tag{X4.1}$$

where:

L_M = length of tubing of Size M,

L_N = length of tubing of Size N,

V_M = standard volumetric airflow rate for tubing of Size M, and

V_N = standard volumetric airflow rate for tubing of Size N.

If a 0.76-mm (0.030-in.) ID capillary with a standard flow rate of 220 mL/min is chosen to be the reference capillary ($L_{0.76} = 1$, $V_{0.76} = 220$), then the length of 0.48-mm (0.019-in.) ID tubing which is equivalent in its flow resistance to one unit length of the 0.76-mm tubing would be:

$$L_{0.48} = 1 \times (43/220) = 0.20 \tag{X4.2}$$

where the standard flow rate for the 0.48-mm tubing is 43 mL/min ($V_{0.48} = 43$). In the above manner the equivalent lengths listed in the right hand column of Table X1.1 were calculated, using the standard flow rate data from the same table. This set of equivalent lengths served as an aid for the construction of Table X1.2 in which the required capillary lengths for the stimulus and make-up airflow splitters are listed. The equivalent length data were also employed for the computation of the lengths of the capillaries used in the stimulus generator (see X4.7.7).

X4.7.4 Since PTFE spaghetti tubing is used to connect the splitter ends to the sniffing ports, its flow resistance must be taken into account when designing the splitter capillaries. A convenient length for the PTFE tubing is 400 mm. Its flow resistance can be calculated with the use of the appropriate equivalent length value from Table X1.1. This flow resistance is equivalent to (400/18.7) = 21 mm of 0.76-mm ID stainless tubing.

X4.7.5 The size requirements for the stimulus splitter capillaries are determined in the following manner. At the starting point, the flow path from the stimulus splitter, H (Fig. X1.1-B), to the port of highest 1-butanol concentration (No. 8) is designed to provide a flow resistance equal to that of 120 mm of 0.76-mm (0.030-in.) ID stainless steel tubing. Since 400 mm of the PTFE tubing is equivalent to 21 mm of 0.76-mm ID stainless tubing, the actual length of 0.76-mm ID stainless tubing required is 120 − 21 = 99 mm. The next port (No. 7) must receive a 1-butanol concentration which is, by a factor of two, smaller than for port No. 8. This flow path, therefore, requires a design length with twice the flow resistance, for example, 120 × 2 = 240 mm of 0.76-mm ID tubing. Since the connecting PTFE tubing is again equivalent to 21 mm of 0.76-mm ID tubing, the required length is actually 240 − 21 = 219 mm of 0.76-mm ID tubing. The next port (No. 6), similarly calculated, would require 459 mm of 0.76-mm ID tubing. If desired, this may be replaced by a shorter, more convenient, length of 0.48-mm ID stainless steel tubing of equal flow resistance. The calculation, using the appropriate equivalent length from Table X1.1, is 459 × 0.20 = 92 mm of 0.48-mm ID tubing. Typical lengths of other stimulus splitter capillaries, all to be used in series with 400 mm of PTFE tubing, are listed in Table X1.2.

X4.7.6 Capillary sizes for the make-up air splitter, J, are calculated as follows. Port No. 7 must receive make-up air at the same rate (80 mL/min) at which the stimulus-carrying air is supplied. Hence, it uses the same size capillary, a 219-mm length of 0.76-mm ID tubing, connected in series with 400 mm of PTFE tubing. This is a total equivalent design value of 240 mm of 0.76 mm ID tubing. The next port, No. 6, must receive 120 mL/min of make-up air. The design length for the line from the make-up air splitter to this port would be 240 × (80/120) = 160 mm of 0.76-mm ID tubing. (Note that the faster flow requires a shorter tubing length.) Since, once again, the 400 mm of PTFE tubing is equivalent to 21 mm of 0.76-mm ID tubing, the actual length of 0.76-mm ID tubing needed is 160 − 21 = 139 mm. The lengths for the remaining make-up air splitter capillaries, listed in Table X1.2, are calculated similarly.

X4.7.7 Stimulus generator capillaries D, E, and G (Fig. X1.1-B) are made of 0.76-mm ID stainless steel tubing with lengths of 210, 50, and 120 mm, respectively. The size of capillary B is determined by the stimulus generator design requirements and also by the sizes of capillaries D and E. The stimulus generator design calls for a flow-rate ratio of (air saturated with 1-butanol vapor):(bypass air) = 1:4. Thus, capillary B requires 158 mm of 0.48-mm, ID stainless steel tubing, calculated as follows. Capillaries B and E are connected in series, and this combination is connected in parallel with capillary D. In order to achieve the desired flow rate ratio of 1:4, the combined flow resistance for capillaries B and E must be, by a factor of four, greater than that for D. That is, the flow resistance for the combination B plus E must be equivalent to 4 × 210 = 840 mm of 0.76-mm ID capillary tubing. Since capillary E comprises 50 mm of this length, the remainder, 840 − 50 = 790 mm of 0.76-mm ID tubing, must be supplied by capillary B. Instead, a shorter and more convenient length of 0.48-mm ID tubing is selected for capillary B. The calculation, using the appropriate equivalent length from Table X1.1, is 790 × 0.20 = 158 mm of 0.48-mm capillary tubing.

X4.7.8 After the stimulus generator and the flow splitters are assembled, the actual flow rates can be checked and adjusted if necessary. To increase an individual flow rate, the corresponding capillary tubing may be shortened. To decrease an individual flow rate, a longer piece of capillary tubing may be used, or an additional piece may be attached with the aid of

PTFE tubing, or sharp bends may be made in the existing tubing (Note X4.11 and Note X4.12). To increase or decrease all of the flow rates simultaneously, the pressures in the manostats are changed (see X4.4.4).

NOTE X4.12—Stainless steel capillaries are easily cut to length by use of the following procedure. Hold the tubing in a pair of stub-nosed pliers and, close to the jaws, file a sharp (but not through-the-wall) notch in one side. Grasp the portion of tubing beyond the notch with the free hand, and while maintaining the pliers, grip with the other hand. Sharply bend the tubing at the notch while simultaneously pulling the two segments apart. The use of this procedure prevents restriction or closure of the opening from occurring, such as happens when using tubing cutters.

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City of New York
Department of Sanitation

FEIS
COLLECTION VEHICLE ODOR SAMPLING REPORT

ATTACHMENT D

Summary of Odor Sampling and Results

ATTACHMENT D

Summary of Odor Sampling and Results

1.0 GENERAL FIELD OBSERVATIONS, AND LABORATORY AND SAMPLING RESULTS

This Attachment contains a summary of general field observation, and laboratory and sampling results for the sampling efforts performed at the Manhattan District 8 garage facility. A table summarizing pertinent sampling information, parameters, laboratory detection threshold (DT) values and sampling results is referenced below. Data provided in the summary table include:

- **Sample #** - The odor sample identification number assigned during sampling and referenced in the field data notes and Odor Evaluation Report.
- **Start Time** – Local start time during which the associated sample was collected.
- **Stop Time** – Local stop time during which the associated sample was collected.
- **Sample Description** – Brief description of the odor sample collected.
- **Pretest Room Air Exchanges** – The approximate number of room air exchanges that occurred from when the room enclosure was "closed" (to meet total enclosure capture criteria [USEPA Method 204]) to when the associated sampling ended. Sampling should only be performed after the odor concentration within the room has reached equilibrium, typically 4 to 5 room air changes.
- **Collection Vehicles** – The number of collection vehicles staged in the room enclosure (maintenance alley) at the time the sample was collected.
- **Average Facial Velocity (ft/min)** – The average facial velocity in feet per minute (ft/min) measured through an opening in the building, in part supporting an assumed 100% capture efficiency of all odors exhausted through the active wall vent exhaust.
- **Measured Flowrate (m^3/s)** – Volumetric flow rate in cubic meters per second of the wall fan exhaust measured during the indoor background or collection vehicle odor sampling effort.
- **DT Value (OU/m^3)** – The odor concentration of a sample, expressed as a multiple of the detection threshold. A unitless value but for calculation purposes, expressed as odor units per volume of air (i.e., odor units per cubic meter [OU/m^3]).
- **Total Emission Rate (OU/sec)** – A total maintenance alley (room enclosure) odor emission rate for a defined sample set/operating mode (operations with or without collection vehicles staged inside the maintenance alley).

- **Average Emission Factor ([OU/sec]/collection vehicle)** – The average odor emission rate from each collection vehicle calculated by dividing the total emission for all 12 collection vehicles by 12.

1.1 July 20, 2004 Collection Vehicle Odor Sampling Field Effort

As noted in Table D.1.1-1, three sets of collection vehicle odor samples were collected from a lone, active wall exhaust vent. The first, second and third collection vehicle odor samples were collected after 4, 6 and 9 room air exchanges occurred, ensuring odor level equilibrium. Average facial velocities greater than 200 ft/min, supporting an assumed 100% ventilation system odor capture efficiency, were observed for all collection vehicle odor sampling. A duplicate sample (072004-06) was collected at the lone vent concurrent with Sample 072004-05). A media blank sample was set aside for submission to the odor laboratory. An outdoor background sample was collected approximately 10 feet east of the eastern vehicle access door to the maintenance alley.

Also noted in Table D.1.1-1 are the results of the odor panel analysis (DT – detection threshold multiple) for each sample. For collection vehicle odor samples, DT multiples ranged from 6 to 7, with a total emission rate (OU/sec) ranging from 33 to 38. The collection vehicle-based emission factors ([OU/sec]/collection vehicle) ranged from 2.7 to 3.2.

The program's QA samples suggest no significant sampling media contamination in the Tedlar Bag media blank with a 5 DT result that is slightly higher than the method detection limit of 4. The outdoor/background sample 6 DT and indoor sample 5 to 6 DT values suggests little or no significant background source interference with the on-site sampling program. Finally, the deviation about the average of the field duplicate samples (results of 6 and 6 OU) was 0 OU (0%), which is within the typical range of +25%/-20%.