Minnesota Pollution Control Agency

December 8, 1995

Ms. Maryanne Hruby, Executive Director
Legislative Commission to Review Administrative Rules
State Office Building, Room 55
100 Constitution Avenue
St. Paul, Minnesota 55155

Dear Ms. Hruby:

Re: Proposed Statement of Need and Reasonableness of Proposed Repeal of Minn. R. Ch. 7011, Concerning Odorous Emissions and the Adoption of New Rules to be Codified at Minn. R. Ch. 7029 Governing Odorous Emissions.

Enclosed for your review is a copy of the Statement of Need and Reasonableness for above proposed rule amendments as required by Minn. Stat. § 14.131 (1994). If you have any questions please contact me at (612)296-7712.

Sincerely,

Norma L. Coleman

Norma L. Coleman
Administrative Rulemaking Coordinator
Air Quality Division
Program Development Section

NLC:lmg

Enclosure

STATE OF MINNESOTA

POLLUTION CONTROL AGENCY

In the Matter of the Repeal of Minn. R. Ch. 7011, Concerning Odorous Emissions, and the Adoption of Minn. R. Ch. 7029 in its Place

STATEMENT OF NEED AND REASONABLENESS

I. INTRODUCTION

A. The Proposed Rules

The Minnesota Pollution Control Agency (MPCA) is proposing to repeal its existing rules governing odorous emissions, Minn. R. 7011.0300 - 7011.0330, which are some 20 years old, and to replace those rules with new rules to be codified at Minn. R. ch. 7029. The MPCA believes that the new rules are more technologically sound than the existing rules, provide a better system for coordinating the interests and concerns of affected persons and governmental entities, and make better use of the MPCA's limited resources.

B. History of Development of the Proposed Rules

At the outset, it may be helpful to clarify that the proposed new rules do not address odors for feedlots. The MPCA is aware that there is considerable interest in and controversy about odors and other environmental issues concerning feedlots. For reasons more fully discussed in later sections of this statement, the MPCA has concluded that feedlot issues should not be resolved in this odor rule but should instead be addressed through rulemaking directed specifically at feedlot issues. MPCA Water Quality staff is now meeting on these issues.

Further information on feedlots can be obtained from David Nelson, of the Water Quality Division.

The MPCA first sought advice from interested persons on the existing odor rules when, on April 27, 1992, it published a Notice of Intent to Solicit Outside Information. The notice generated questions and interest in the establishment of a Technical Advisory Committee (TAC). The MPCA then assembled a TAC including members of industry, consulting firms and local government staff. Representatives of two locally based environmental groups were also invited to attend.

The TAC met on an occasional basis between July 1992, and September 1993. A subgroup (the Odor Task Force) was formed from the members of the TAC, with the objective of working on a more regular basis to improve the draft rule and to present the finished draft to the TAC. The Odor Task Force consisted of two members each from industry, consulting, local government and Air Quality Division (AQD) staff. The members met on a monthly basis between January and August 1993, and presented the resulting draft rule to the TAC in September 1993.

One of the options considered by the TAC was repealing the MPCA's existing odor rule without replacing it. MPCA staff members suggested this approach based on the difficulty the MPCA had experienced in enforcing the existing odor rule and attempting to respond effectively to odor complaints. As support for repealing the rule, MPCA staff cited U.S. Environmental Protection Agency Report 450/5-80-003 (February 1980), "Regulatory Options for the Control of Odors." This report comments on page 5 that: "techniques used to measure odors are considered generally inadequate for regulatory purposes; reliable procedures for relating ambient odor levels to the extent of community annoyance do not exist; [and] state and local odor control procedure relying on nuisance rules appear to be generally adequate." The report recommends that odor issues be regulated on the local level applying nuisance law.

The MPCA staff's proposal to repeal its existing odor rules, leaving odor issues to be regulated locally by nuisance law, was roundly rejected by all interests represented on the TAC. Representatives of local units of government felt that this would place too much of a burden on local authorities. Representatives of industry felt that this would place them at risk of being required to meet inconsistent regulations, varying from community to community. The consensus of the TAC was that the existing rule needed to be rewritten rather than abandoned. The TAC, therefore, focused its efforts on rewriting the odor rule so that it would better address the issues that had surfaced.

The proposed new odor rule is close to the proposed version presented to the TAC in September 1993, with some changes made following further review by individual TAC members, MPCA staff, and other interested parties.[1] The proposed new rule establishes procedures through which the MPCA and local units of government will work together to resolve odor complaints. Under the proposed new rules, the local units of government will receive, record and investigate odor complaints in their communities. Hopefully, some odor problems will be resolved during the initial investigation, without the need for MPCA involvement.

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[1] Due to the length of time necessary to draft the proposed rule and the changes in administrative requirements for rule writing that occurred during that time, the Agency published a second Notice of Solicitation of Outside Information or Opinions in the State Register on August 28, 1995. This Notice described the process by which the draft had been written and stated that the draft was available for review on request. The notice generated several questions and requests for a copy of the rule, as well as written and verbal comments. The Agency reviewed these comments and considered them in the draft of the rule now proposed.

However, if complaints persist, the rule authorizes the MPCA to require regulated sources to identify, quantify and mitigate their odorous emissions.

In the remainder of this document, the MPCA explains its rationale for proposing the repeal of the existing odor rule and the adoption of proposed Minn. R. ch. 7029 in its place.

II. STATEMENT OF AGENCY'S STATUTORY AUTHORITY

The MPCA's statutory authority to adopt, amend and repeal rules concerning air pollution is set forth in Minn. Stat. §116.07, subd. 4 (1994). The term air pollution is defined in Minn. Stat. §116.06, subd. 4 (1994) to mean:

> the presence in the outdoor atmosphere of any air contaminant or combination thereof in such quantity, of such nature and duration, and under such conditions as would be injurious to human health or welfare, to animal or plant life, or to property, or to interfere unreasonably with the enjoyment of life or property.

This definition includes odorous emissions, since odorous emissions are air contaminants that may interfere unreasonably with the enjoyment of life or property. The MPCA, therefore, has the necessary statutory authority to amend its rules regulating odorous emissions.

III. STATEMENT OF NEED

Minn. Stat. §§14.14, subd. 2, and 14.23 (1994) require the MPCA to make an affirmative presentation of facts establishing the need for and the reasonableness of the adoption, amendment or repeal of rules. In general terms, this means that the MPCA must set forth the reasons for its proposed action and the reasons must not be arbitrary or capricious. However, to the extent that need and reasonableness are separate, need has come to mean that a problem exists which requires administrative attention, and reasonableness means that the solution proposed by the MPCA is a proper one. The need for the amended rules is discussed below.

The existing odor rules need to be repealed because they no longer provide a satisfactory tool for regulating odor sources. First, the ambient standards established in the existing odor rules are neither practical nor enforceable because there are no existing test methods that can reliably measure odors in the *ambient air* at the regulated ambient limits. Second, the test method cited in the existing rules is no longer considered a reliable means of measuring odorous *emissions*. Third, the existing rules do not take into account the complaints of the local community. Only by considering local community annoyance will the MPCA be able to best direct its limited resources to resolve odor problems. Each of these considerations is discussed more fully below.

A. The Ambient Standards Established in the Existing Odor Rules Are Neither Practical Nor Enforceable

Minn. R. 7011.0310, item D of the existing odor rules establishes ambient standards for odors. An ambient standard refers to the presence of emissions in the outdoor air generally, as distinguished from the presence of emissions as they are discharged through a discrete point such as a stack.

The problem with the reference to ambient standards in the existing odor rules is that there is currently no test method that can reliably measure odor units at the amount cited. The text accompanying the test method cited in Minn. R. 7011.0315, item D of the existing odor rules --"American Society for Testing Materials (ASTM) Method D-1391-57"-- recommends against using that test method at concentrations less than 25 odor units. The ambient standards established in the existing odor rules are between one and four odor units. Minn. R. 7011.0310, item D(3). Thus, the test method cited in the existing odor rules cannot be used reliably to enforce the cited standards. Moreover, the MPCA is aware of no newer test method that can accurately measure ambient levels at the small amounts stated in the existing rule. In short, existing ambient standards are not measurable and therefore cannot be enforced reliably by the MPCA. They therefore serve no real regulatory purpose.

B. The Test Method Cited In The Existing Rules Is No Longer Considered A Reliable Means Of Measuring Odorous Emissions

In addition to ambient standards described above, the existing odor rules, in Minn. R. 7011.0310, items A - C, establish emission limits. In the past, MPCA staff has enforced these emission limits by using the method cited in Minn. R. 7011.0135, item D -- ASTM Method D-1391-57. However, on March 29, 1985, the American Society for Testing and Materials stopped recognizing this test method, and the method no longer appears in ASTM publications. Accordingly, the MPCA is no longer confident about using this method to measure odorous emissions from a source.

C. Only By Considering Local Community Annoyance Will The MPCA Be Able To Best Direct Its Limited Resources To Resolve Odor Problems

The MPCA receives a large number of odor complaints each year. For instance, for the period 1992 - 1994, the MPCA recorded a total of 2,194 complaints in its database. Of these, 1,062 (48 percent) were odor-related complaints. The sheer volume of the odor complaints received by the MPCA demonstrates the need for odor rules that effectively regulate odors that are an annoyance to people in the community surrounding the source.

The MPCA's existing odor rules are concerned not with community response to odor sources, but to odor detection alone. In other words, the existing odor rules regulate stack emission concentrations and emission rates, but compliance with these limits does not guarantee that there will be no community annoyance. Conversely, exceedence of the limits in the existing odor rule does not mean that the surrounding community will necessarily be offended.

In addition, following up on odor complaints under the existing rules is time consuming for MPCA staff. Further, the MPCA's follow-up is often unsatisfactory for all involved -- MPCA staff, complainants and affected industries -- since the MPCA's enforcement options are limited.

In sum, the MPCA's existing odor rules need to be repealed and revised so that government time is spent more effectively addressing odor issues of concern to the community. If the MPCA is going to have odor rules, it needs to have rules that are meaningful and enforceable.

IV. STATEMENT OF REASONABLENESS

The MPCA is required by Minn. Stat. §§ 14.14, subd. 2 and 14.23 (1992) to make an affirmative presentation of facts establishing the reasonableness of the proposed rules. "Reasonableness" means that there is a rational basis for the MPCA's proposed action. The reasonableness of the rule is discussed below.

A. Reasonableness Of Repealing The Existing Odor Rule And Adopting A New Rule Focused On Community Annoyance

In the need section, the MPCA already has briefly described some of its reasons for proposing to repeal the existing odor rule in its entirety. Here again are those reasons as they relate to each section of the existing odor rules:

Minn. R. 7011.0300. The MPCA proposes to repeal Minn. R. 7011.0300, definitions, and replace it with new definitions better suited to the proposed new rule. It is reasonable to repeal old definitions no longer relevant to or particularly useable for a new rule.

Minn. R. 7011.0305 and 0310. As described above, the MPCA proposes to repeal Minn. R. 7011.0305 and 7011.0310 because they establish ambient standards, emission limits and prohibitions that are largely unenforceable and that do not correlate directly with community perception of and annoyance with odors. The MPCA thinks it is community annoyance that ought to be the trigger for MPCA efforts to help resolve the odor problems (see further discussion below re: using community annoyance as trigger).

Minn. R. 7011.0315. The MPCA proposes to repeal Minn. R. 7011.0315 because the odor testing provisions of that rule are not sufficiently reliable. First (and as described above), ASTM Method D-1391-57 is no longer a published test method. Second, the method cited in Minn. R. 7011.0315, item D as D. M. Benforado et al. in "Development of an Odor Panel for Evaluation of Odor Control Equipment," was based on research at rendering facilities and, as the dispersion characteristics vary from source to source, rendering odors are not representative of all odors. Third, the MPCA proposes to replace the existing reference to odor panels in Minn. R. 7011.0315 with new odor panel requirements that attempt to provide greater consistency and less subjectivity (see discussion below concerning proposed Minn. R. 7029.0080).

Minn. R. 7011.0320. The MPCA proposes to repeal the existing rule concerning equipment breakdown, but proposes to incorporate much of the terms of that rule in a section of the proposed new rule (see discussion concerning proposed Minn. R. 7029.0020, subp. 2).

Minn. R. 7011.0325. The MPCA proposes to repeal the existing agribusiness exception and replace it with a new rule, proposed Minn. R. 7029.0005, subp. 2 (see discussion concerning this proposed new rule).

Minn. R. 7011.0330. The MPCA proposes to repeal the existing reference to civil actions and replace it with a new rule, proposed Minn. R. 7029.0005, subp. 1 (see discussion concerning this proposed new rule).

In its proposed new odor rules, the MPCA takes a different approach than it did in the existing odor rules. While the old rules focused on odor detection, the proposed new rule focuses on community annoyance. Under the new proposed rules, when community annoyance is documented, the MPCA will contact the owner or operator of the emission facility believed to be causing or contributing to the odor problem and will require appropriate odor testing, reduction and mitigation. The MPCA believes this new approach is reasonable because it allows the MPCA to be more responsive to the members of the public and to direct its limited resources to working with odor sources that communities want the MPCA to address.

B. Reasonableness Of The Proposed New Rules Section By Section

In this section, the MPCA discusses the reasonableness of each part of the proposed new rules.

Minn. R 7029.0005 Scope

The MPCA proposes to begin its new odor rules with a part that explains the scope of the rules. Stating the scope of the proposed rules at the beginning of the rules will help orient a person reading the rules to determine how, when and if the rules apply to a source of odorous emissions.

Subpart 1. Effect of rules. The existing odor rules contain a provision that explains the relationship between the rules and other means of resolving odor problems. Specifically, Minn. R. 7011.0330 provides that the existing odor rules do not preclude lawsuits based on a public or private nuisance theory. The MPCA proposes to retain this provision, and to expand it in a new subpart, titled "Effect of Rules." This new subpart explains that the odor rules set out procedures for how the MPCA will respond to odor complaints, further states that the odor rules are not intended to limit or otherwise affect the rights of local units of government to take additional or alternative action to resolve odor problems in their communities, and concludes by making it clear that the rules do not preclude lawsuits to abate public or private nuisances. This new subpart is reasonable because it clarifies that the MPCA does not intend its odor rules to be an exclusive means of resolving concerns about odorous emissions, but simply sets out how the MPCA will respond to those emissions.

Subpart 2. Agribusiness exception. Minn. R. 7011.0325 of the existing odor rules exempts certain agricultural activities from the odor rules under certain circumstances. The MPCA still favors excluding agribusiness area sources from all portions of the odor rules. The agricultural sources that are known to be significant odor sources tend to be area sources (as distinguished from point sources) that cannot be tested for odors easily. In addition, the mitigation provisions in the proposed rules are not well-suited to these agricultural odors. For these reasons, the MPCA does not believe its odor rules are an effective means of resolving odor problems resulting from agribusiness area sources.

Although the MPCA proposes to keep an agribusiness exemption to the odor rules, it does not propose to repeat the precise language of the agribusiness exemption in the existing rules because it has found that language difficult to apply. For example, the existing rules exempt land application of manure, but it is not clear whether related manure storage is also exempt. The MPCA therefore proposes to rewrite and clarify the agribusiness exemption, excluding all but agricultural emission point sources from all parts of the rule. The MPCA believes this exemption is clearer and more easily applied than the wording in the existing rules. The rationale for the wording of the exemption language lies in the planned approach to feedlot odors, which are the primary source of complaints relating to agricultural sources. As the Water Quality Division (WQD) is planning to regulate feedlot odors through a revision to its feedlot rules and through its feedlot permitting program, and as more research is needed on how best to address feedlot odors the MPCA proposes to exclude these and other agricultural sources that are not emission points from all parts of the odor rule. This leaves WQD rule writers free to adopt the community annoyance language of this proposed rule or to write new requirements as appropriate. (see Part VII, "Impact on Agricultural Lands" of this document for more discussion on agricultural odors). Items A and B are derived from the existing odor rules, with references made to definitions of fertilizers in order to help maintain consistency with other program areas. Items C and D exempt remaining area sources not addressed in item A or B.

Subpart 3. Administration of rules by local units of government. The MPCA proposes to adopt a new subpart that would allow a local unit of government to request authority to administer the enforcement provision of the odor rule on its own. It is reasonable to allow local units of government to take a lead in resolving odor problems because odor problems often involve the sort of local issues (zoning, land use) for which local units of government have experience and expertise. The MPCA does not, however, want to require local units of government to undertake a lead unless it wants to do so. The requirement that the local unit of government notify the MPCA of its intentions is therefore reasonable because it assures that the MPCA and local units of government are coordinating and not duplicating their efforts to address odor issues in the state.

Minn. R. 7029.0010 Definitions

Subpart 1. Scope. The odor rules are part of the MPCA's air quality rules and it is reasonable for the MPCA to apply the general definitions in the MPCA's air quality rules (Minn. R. 7029.0020, subp. 1) to the odor rules, unless more specific terms are defined. This is all subpart 1 states.

Subpart 2. Community. Community is defined as the population surrounding an emission facility and as such the community may include residents governed by more than one local unit of government. It is reasonable to define community loosely in terms of the surrounding population as it should reflect the potential dispersion of odorous gases rather than governmental boundaries.

Subpart 3. Community Annoyance. The concept of community annoyance is central to the proposed rule as the MPCA believes that unless unique factors apply, odors should be regulated according to their effects on the surrounding community. To some extent, this is a subjective concept, as are the terms "objectionable" and "offensive." The reaction of individuals, and even whole communities, to a given odor may vary widely. The definition is reasonable as it recognizes the subjective nature of any single odor related complaint but references the reader to Minn. R. 7029.0030, which sets out a standard procedure for recording complaints, filing complaints with the MPCA and for the MPCA to determine if a community annoyance exists.

The procedures are intended to introduce consistency and minimize subjectivity while recognizing that odors are difficult to quantify and that complaints are inherently individualistic. The reasonableness of Minn. R. 7029.0030 which is referenced in the definition of community annoyance is discussed in more detail below.

Both continuous and intermittent odors can be determined as community annoyances, effectively meaning that any odor episode can be a community annoyance. It is reasonable that the presence of a community annoyance be determined by the actual effect on the community and not by considering the duration or frequency of the odors, as any occurrence that generates complaints can be considered to be an annoyance. The terms "objectionable" and "offensive" are subjective but useful in that they illustrate that the rule will only apply to odors that generate complaints. The presence of an odor that the community does not consider worthy of complaint need not, in normal circumstances, require the attention of the MPCA or the local unit of government.

This definition is not linked directly to the concept of nuisance, which is broadly defined in Minn. Stat. § 561.01. The MPCA does not intend application of this rule to be a defense against an actual nuisance action because nuisance is defined in terms of the individual rather than the community. See also discussions concerning Minn. R. 7029.0005 subp. 1.

Subpart 4. Emission point. This term is used in Minn. R. 7029.0005, 7029.0050, 7029.0070, and 7029.0080 to describe the scope of the odor rule and the applicability of mitigation and testing requirements. For the purpose of this rule, the definition is reasonable as it refers to all types of emission points that can be sampled for odorous emissions using the proposed methodology.

Subpart 5. Independent complaint. The term independent complaint is used in Minn. R. 7029.0030, which sets out the criteria according to which the commissioner will find community annoyance. Specifically, at least ten independent complaints for larger communities and a smaller number for less densely populated communities is required for the commissioner to find a community annoyance, a central concept to this rule. The definition of independent complaint in subpart 5, counts complaints on a household or business location basis. The definition is reasonable as it calls for community annoyance to be based on a number of separate complaints but allows repeat complaints for separate odor incidents. For example, ten complaints from one apartment building following a single odor incident would not be considered a community annoyance whereas ten complaints from different buildings or a total of ten complaints from one or more buildings over a period of time would be eligible for a determination of community annoyance. This is reasonable as the odor rule is focused on resolving "community" annoyance and should therefore attach more significance to odors that extend over greater areas or occur more frequently than to single odor occurrences in a localized area.

Subpart 6. Local unit of government. Local units of government are enabled under this rule to submit complaint records to the MPCA for determination of community annoyance. It is therefore reasonable to define the term local unit of government broadly to include all types of local authorities that could be expected to receive and record odor complaints.

Subpart 7. Odor dilution factor. This term is used in Minn. R. 7029.0080 of the odor rules to describe testing and data reduction procedures. This definition is reasonable as it is consistent with the testing methodology that is an integral part of this rule, and which is used for quantifying the odor concentration in a gas sample.

Subpart 8. Odorous emission. This term is used in Minn. R. 7029.0005, 7019.0020, 7029.0030, 7029.0060, 7019.0070, and 7029.0080 to define what causes a violation of the rule and what needs to be documented, tested and mitigated. This definition is a reasonable interpretation of the odorous components of an emission, saying that the odor is a property of one or more components of the total emission. It also says that an emission that is not odorous beyond the property line of the facility is not an odorous emission. The concept of property line is standard in air quality regulations in restricting the applicability of certain air quality rules or standards to areas outside the property boundaries of the emitting facility.

Minn. R. 7029.0020 Odorous Emissions Prohibited

Subpart 1. Community annoyance prohibited. Minn. R. 7011.0305 of the existing odor rules disallows odorous emissions in excess of stated limits. For the reasons stated earlier, the MPCA is proposing to delete those limits. However, the MPCA still believes it is necessary to retain the notion that offensive odorous emissions are prohibited. But, rather than making numerical limits the trigger for finding odorous emissions offensive (as the existing rules do), the MPCA now proposes to use community annoyance as the trigger. Thus, the MPCA proposes in subpart 1 to prohibit the owners and operators of emission facilities from causing or allowing their facilities to emit pollutants that create or contribute to a community annoyance. Making community annoyance the threshold for the prohibition of odor underscores the largely local nature of odor emission problems. Further, by making community annoyance the trigger for the prohibition (rather than numerical standards) the MPCA will be able to better direct its limited resources to resolving those odor issues of greatest concerns to the public. In addition, the

MPCA will avoid the difficulties inherent in trying to measure and quantify odorous emissions. For all these reasons, the prohibition stated in subpart 1 is reasonable.

Subpart 2. Odorous emissions during breakdown. Minn. R. 7011.0320 of the existing rule prohibits the operation of equipment when that equipment is out of repair and is causing odorous emissions. The MPCA proposes to incorporate this prohibition in the proposed new odor rule in Minn. R. 7029.0020, subp. 2. Like the existing rule, the proposed new rule allows the malfunctioning equipment to be used under certain circumstances. However, while the existing rule gives the MPCA the authority to decide if the malfunctioning equipment can be used, the new rules gives the local units of government the authority instead. Thus, local units of government may authorize operation of malfunctioning equipment for up to 30 days if the malfunction does not cause a serious public health or safety hazard and if the local units of government have been promptly notified of a correction program to be implemented within seven days of the start of the breakdown. The MPCA believes it is reasonable to vest in local units of government the authority to manage response to the malfunction since the local units of government are most likely to receive comments or calls from persons asking for resolution of the issues. The MPCA also believes it is reasonable to establish a maximum number of days for the local units of government to allow an owner or operator to use malfunctioning equipment to ensure that the equipment is replaced or repaired as rapidly as possible. A limit of 30 days is reasonable because it is the same limit as in the existing rule and should provide sufficient time to repair the problems promptly.

Minn. R. 7029.0030 Determination Of Community Annoyance

As stated earlier, the MPCA's proposed new odor rules apply to sources that the MPCA has concluded are a "community annoyance." Minn. R. 7029.0030 explains how the MPCA will determine that a community annoyance exists. The MPCA will determine that a community annoyance exists if a local unit of government submits complete documentation of the community annoyance. Subpart 1 requires the submittal of the documentation. Subparts 2, 3 and 4 explain the documentation that is required.

Subpart 1. Commissioner determination. This subpart states that the MPCA will determine that a community annoyance exists upon submittal, from the appropriate local unit(s) of government, of complete documentation demonstrating the presence of a community annoyance as required by the rules. This subpart also requires the local unit(s) of government to send a copy of the documentation to the alleged source(s) of the odor. This is reasonable as it gives the source immediate notice that the process for finding a community annoyance has begun and allows the source owner or operator to immediately address the situation and start to prepare an odor reduction plan or otherwise address the problem. The name, address or telephone number of the complainant must not be forwarded to the alleged source(s) as this is confidential, for use by the local unit of government and MPCA only.

Subpart 2. Documentation of community annoyance. This subpart identifies the documentation necessary for the MPCA to find a community annoyance. Six categories of documentation are required. The reasonableness of each is explained below.

First, item A requires an odor complaint summary stated on the form set out in Minn. R. 7029.0105. The MPCA has concluded that using a standard form to provide basic information will make it easier for the local units of government to provide the information the MPCA believes it needs in a format easy for the MPCA to use. The MPCA seeks only the most basic information on the form: the name and address of the local unit of government seeking a determination of community of annoyance; the number of odor complaints received by the local units of government; the number of complaints verified by inspection; and the time frames for the complaints. This information is reasonable to include on a summary form because it is the essential information needed for the Commissioner to determine the existence of a community annoyance.

Second, item B requires the local unit of government to submit at least ten independent complaints made within a 90 day period from at least five different households or places of business. The minimum of ten within 90 days is consistent with complaint based rules in other states, for example, Bay Area Air Quality Management District (San Francisco, California) Regulation 7, and Connecticut Rules section 22a-174-23, Control of Odors. Regulation 7 is derived from the California Health and Safety Code, section 41700, which prohibits nuisance odors. Connecticut's regulation is also based on odor as a nuisance. The wording of this item and the definition of independent complaint mean that it is possible for a single person or household to register up to six complaints counting towards the ten, provided they are on separate days, but no more than six, as at least five locations must be involved. It is reasonable to have a time period limit in order that facilities which cause odors infrequently do not become subject to the mitigation requirements of the rule. The MPCA believes that it is better to use its limited resources on sources that cause continuing rather than infrequent odor problems for two reasons. First, if a facility is controlling its odors except for sporadic episodes over a long time period it is unlikely that there is significant opportunity for mitigative procedures. Second, the MPCA believes that community concerns about the odorous emissions from a facility are better evidenced by a three month snapshot than an occasional intermittent occurrence over a longer period of time. The proposed new rules includes a form that the local units of government should use in documenting the independent complaints. The form is set out in Minn. R. 7029.0100. The reasonableness of this form is discussed in more detail below (see discussion concerning proposed new rule Minn. R. 7029.0100.)

Third, item C requires that at least five of the independent complaints must have been confirmed by a representative or agent of the local unit of government. This is a reasonable requirement as it helps to prevent frivolous complaints. Confirmation generally means that an inspector would visit the site of the complaint, talk to the complainant, try to detect the odor at the site of the complaint and determine the wind direction. If the odor is no longer present at the time of the visit, the inspector could confirm the complaint by talking to neighbors individually. The method of confirmation is left open to interpretation so that an inspector can employ the best means available at the time of inspection. The Bay Area's Regulation 7 does not require confirmation of complaints but has developed a policy that five of the complaints must be verified by an inspector. (Ref: Technical Paper, "Enforcement Mechanisms for Resolving Community Odor Problems: A Legal Viewpoint," Laurence G. Chaset, Bay Area Air Quality Management District [1987].) The proposed new rules includes a form that the local units of government should use in documenting the investigator's report. The form is set out in Minn. R. 7029.0100. The reasonableness of this form is discussed in more detail below (see discussion concerning proposed new rule Minn. R. 7029.0100).

Fourth, item D requires the local unit of government to submit a map showing the location of the complaints and indicating the wind direction at the time of the complaint. This is reasonable because it allows the reviewer to visualize the location of the complaints and alleged sources of the odors. This information will help the reviewer assess the source of the complaints more easily. Factors influencing odor dispersion, such as wind direction, hills, trees and buildings in the area are important in the assessment of odor complaints and consideration of mitigation options.

Fifth and sixth, items E and F require records showing that the local units of government gave notice of the complaints to the alleged sources and the responses received from the alleged sources. Members of the TAC, during discussions on the proposed rules, stressed the importance of communications to give owners and operators of the sources an opportunity to correct problems without the need for government intervention. The MPCA agrees with the TAC that good communications between the complainants and the sources of odor problems are critical to early resolution of the problems to the benefit of all involved. Requiring records of the required contact between the local unit of government and the alleged source will help assure that this communication takes place. In addition, MPCA staff can consider the communication when they review the odor reduction plan. While space for a summary of the communication is provided within the complaint form given in Minn. R. 7029.0100, the MPCA believes that copies of letters and other more detailed correspondence would be helpful and therefore requires that they be submitted.

Finally, subpart 2 concludes that complaints relating to temporary approved operation as allowed by Minn. R. 7029.0020 (concerning odorous emissions during breakdown) will not be considered as evidence of a community annoyance. This is reasonable as the local unit of government has allowed the operation knowing that odorous emissions during the time period may cause complaints. Further, the local unit of government has the option of denying the operations during this time period; if operations are allowed, the MPCA does not believe it should treat the excess odorous emissions during that time period as evidence sufficient to trigger the MPCA's involvement in attempting to resolve community concerns.

Subpart 3. Documentation of community annoyance in areas not densely populated. This subpart provides a relaxation of the documentation requirements in subpart 2 for smaller communities. This is reasonable as an odor may be a significant problem for a relatively small number, but high percentage, of people in less densely populated areas. Under subpart 3, the local unit of government for a community of less than 1000 persons will need to explain why the MPCA should find a community annoyance based on less than the number of independent complaints required in subpart 2 and will need to verify at least half of the complaints, consistent with subpart 2. A population density of 1000 or less was chosen as the criteria for this relaxation based upon the experience of the representatives of local units of government on the TAC.

Subpart 4. Notification of alleged source of odorous emissions. This subpart requires the local unit of government to contact the alleged source of the odor within one working day of the complaint being made, with an extension allowed if contact was unsuccessful. This is reasonable as it sets up an immediate dialogue between the local unit of government administering the complaint and the alleged source, thereby giving the staff of the alleged source an opportunity to investigate possible reasons for the complaint and rectify the situation with the objective of reducing the possibility of future complaints. The contacts become a part of the odor complaint summary, which is reasonable as it enables MPCA staff to see what efforts have been made by the alleged source to reduce odors. The proposed new rules allow a local unit of government to satisfy the requirements of this rule by sending a letter if immediate contact cannot be made. A further explanation of the importance of the notice requirements is contained in the discussion above concerning subpart 2, items E and F.

Minn. R. 7029.0040 Notice Of Community Annoyance

This part requires the Commissioner to issue a notice to the owner or operator of each emission facility that the commissioner believes to be a source of a community annoyance. This notice triggers a requirement that the owner or operator prepare an Odor Reduction Plan and a Test Plan as described in Minn. R. 7029.0050 and take other action to immediately reduce odorous emissions. The notice requirement is reasonable because it ensures that the owner or operator is aware of the commissioner's determination of a community annoyance and of their obligations to act as provided in Minn. R. 7029.0050.

A Notice of Community Annoyance will be sent to the owner or operator of any facility, except for specifically exempted agricultural sources, even if that facility does not emit odors from emission points. Although only emission point odor sources will be subject to the following parts of the new rule, the determination and notice of community annoyance even for area sources (which are not subject to the mitigation requirements) will provide a standard mechanism for recognizing that a community annoyance exists. The MPCA believes that the Commissioner's determination of community annoyance may be of assistance to local units of government and others seeking other means, such as nuisance action, to resolve odor issues.

<u>Minn. R. 7029.0050 Required Response To Notice Of Community Annoyance</u>

<u>Subpart 1. Applicability</u>. This part describes what the owner or operator of an emission point believed to be a source of a community annoyance must do once the commissioner has determined that a community annoyance exists. As explained below, only emission point sources are subject to the testing and mitigation requirements of this rule. If this part applies, the owner or operator must do two things, as detailed in subparts 2 and 3. If this part does not apply, the owner or operator needs only to submit a written response identifying the actual odor sources and giving any other reasons the owner or operator believes that this part does not apply. This is reasonable as the failure to respond does not necessarily mean that this part does not apply to that facility. The owner or operator must identify all actual odor sources so that MPCA staff can verify that they are not emission points. This information may also be useful when the case is referred back to the local unit of government.

<u>Subpart 2. Immediate odor reduction required</u>. First, the owner or operator must take immediate steps to reduce odors. Specifically, this subpart requires the owner or operator to implement odor reduction procedures immediately where this can be achieved by minor operational or procedural changes. This is reasonable as it may be possible for immediate odor reduction to be achieved at little or no cost to the owner or operator. A quick reaction will show responsiveness to the community annoyance and may help build or restore a level of trust between the annoyed community and the facility. In short, a requirement that the source attempt immediate odor reduction, rather than waiting for the odor reduction plan to be drafted, is a benefit to all parties.

Subpart 3. Odor Reduction Plan and Test Plan. Second, within 30 days after receiving the notice, the owner or operator must prepare and submit to the commissioner for approval a proposed Odor Reduction Plan and a Test Plan. This requirement is reasonable because it ensures that the owner or operator will undertake the analysis and testing necessary to remedy offensive odor problems from its facility. Thirty days is a reasonable time frame because the owner or operator will already be aware, through the requirements on local units of government to inform the source owner or operator of complaints as they occur, that the source has been causing complaints and therefore effectively has more than 30 days to prepare the odor reduction plan. Moreover, all the owner or operator is required to do is prepare and submit a plan of action, not implement that plan. The owner or operator should be able to do this within the time frame provided.

The contents of the Odor Reduction Plan and Test Plan are specified in items A - D of subpart 3. The reasonableness of each of these items is discussed below.

Subpart 3, item A requires the owner or operator to identify measures to be taken or that have been taken to mitigate the community annoyance and the dates for implementing those measures. This provision is reasonable because it ensures that the owner or operator takes a serious look at options to reduce its odorous emissions. Thus, the content of the plan is at the discretion of the owner or operator but it must have enough detail and planned actions to demonstrate a serious response on the part of the owner or operator.

Subpart 3, item B requires the owner or operator to take steps to keep the community informed. The MPCA believes the requirement to keep the community informed of progress is of benefit to all parties - residents will see that action is occurring in response to their complaints and the owner or operator has an opportunity to build good public relations and a cooperative approach to resolving problems. When a facility has good relations with the surrounding community as it implements an odor response plan it is more likely that odor problems will be resolved without the need for regulatory oversight.

Subpart 3, item C requires a detailed description of all potential sources of emissions, including sources that are not emission points, of the odor and submit a diagram of the source location(s). This is an important element of an odor test plan as it allows the preparer and reviewers of the plan to ensure that the test plan addresses all potential sources of the odor. It is reasonable to require the owner or operator to identify area sources, even though these are not subject to testing requirements, because the identification will give the MPCA and interested persons a better understanding of the nature of the sources of the odorous emissions and may help explain why reductions at emission points may not fully resolve an odor problem.

This part also requires submittal of a test plan and schedule for each emission point that could be a cause of the odorous emissions contributing to the community annoyance. This is reasonable as the results of testing before and after the odor reduction plan is implemented are an important measure of the success of the odor reduction plan. The result of this testing could also be used to determine, for a facility with several emission points, which emission points should be addressed first in the odor reduction plan. Minn. R. 7017.2030 is cited for the content of the test plan as this defines in detail the requirements for performance test plans in general and as Minn. R. 7029.0080 states that the performance test rule applies to these odor tests.

Finally, it should be noted that the requirement to take the two actions specified in this part (reduce odors and submit a plan) is limited to owners and operators of emission points. The

MPCA believes it is reasonable to limit its testing, monitoring and mitigation requirements to those sources for which odors can be measured and monitored reliably (i.e., emission points) and that is why only emission points are covered by this part. This is not to say that other types of sources (e.g. area sources such as animal feedlots and open compost sites) should not be regulated, only that non-measurable sources need a different type of regulation with mitigation defined in a manner appropriate to the type of process. Other divisions in the MPCA are now considering appropriate ways of regulating odors from area sources. For instance, the WQD of the MPCA is considering a Best Management Practice approach to feedlot odors which would be incorporated in Water Quality feedlot rules and permits. Persons who want to become involved in odor rulemaking for these specific sources should contact the MPCA to make their interests known.

Minn. R. 7029.0060 Commissioner Review Of Proposed Odor Reduction Plan And Proposed Test Plan

This part requires the commissioner to review the Odor Reduction Plan and Test Plan submitted under Minn. R. 7029.0050 and reject or accept the plans, with changes the commissioner concludes are appropriate. The rule explains the reasons that may cause the commissioner to reject a plan. These reasons are reasonable because they each relate to the effectiveness of the plan. It is reasonable to have the commissioner review a plan before it is implemented to make sure it meets the requirements of the rule and will accomplish the purposes of the test plan. By providing for commissioner review prior to the plan's implementation and by giving the commissioner the ability to require reasonable changes if needed, the MPCA can provide greater assurance that testing and analysis will provide the information necessary to correct the problem identified by the community.

Minn. R. 7029.0070 Implementation Of Approved Odor Reduction And Test Plan; Reporting; Retests; Additional Enforcement Action

This part of the odor rules requires the owner or operator to implement the test plan, to report its results and to conduct retests once mitigation efforts have been implemented. In addition, this part explains when the MPCA will forego additional enforcement actions for odor problems and what enforcement actions remain viable. The reasonableness of each of these provisions is explained below.

Subpart 1. Implementation. This subpart requires the owner or operator to implement the Odor Reduction Plan and to have a qualified testing company implement the Test Plan within the time frames approved by the commissioner under Minn. R. 7029.0060. The term testing company is defined in the MPCA's performance test rule (Minn. R. 7017.2005, subp. 7) to mean "a corporation, partnership or sole proprietorship that conducts performance tests as a normal part of its business activities and that is not the owner or operator of the emission facility... ." It is reasonable to require that a qualified testing company conduct the testing to assure that the test is done properly and to increase the public's confidence in the reliability of the results. It is also reasonable to adopt a rule requiring that the Odor Reduction Plan and Test Plan be implemented, so that the MPCA can enforce this requirement if it becomes necessary to do so. It should be noted that an owner or operator may choose to implement odor reduction procedures before receiving commissioner approval, but may prefer to wait for approval before incurring any significant costs.

Subpart 2. Reporting. This requires that the owner or operator report the results of the testing within 30 days and submit a microfiche of the results within 90 days. The submittal deadlines are shorter than the default in the performance test rule, reflecting the fact that odor samples must be analyzed quickly and the data is more easily compiled than for many pollutant performance tests.

Subpart 3. Retests. Subpart 3 requires a retest of the emission points within 30 days after the requirements of the Odor Reduction Plan and Test Plan have been implemented. The purpose of the retest is to determine the extent of the odor reduction. This is a reasonable time frame in which to schedule a retest and it will give an indication of the relative concentration of the odor emissions before and after mitigation is attempted. The retest should also serve a beneficial community relations purpose in that it will allow the owner or operator to quantify and demonstrate that odor reduction has occurred. Further, the results of the retest will provide a baseline for MPCA regulatory staff to assess odor results from subsequent tests as an indicator of the continued success of the odor reduction plan. This subpart requires the same testing company and, as far as possible, the same panel members, to be used for the retest. This is reasonable as using the same testing company eliminates the significant inter-laboratory variability in test results that occurs due to differences in administering olfactometry methods. Similarly, using the same panel members helps to reduce intra-laboratory variables.

Subpart 4. Additional enforcement action suspended. This subpart explains that the MPCA will suspend additional enforcement action under certain circumstances. This provision is reasonable because it gives owners and operators and the public certainty about the MPCA's involvement in resolving odorous emissions. The criteria established are reasonable because they relate to community annoyance, local government preferences and alternative means of resolving the odor issue. When these criteria are not met, however, and there are continued complaints, the owner or operator may need to take additional steps and prepare and implement another mitigation plan.

The three factors listed in subpart 4 as the basis for a commissioner decision to suspend further enforcement action under the odor rules are reasonable for the following reasons. Item A is reasonable because resolving and preventing community annoyance is the underlying goal of the odor rules. The rules therefore do not require that odors be totally eliminated, which may be unrealistic, but require a reduction in the levels of complaints. It is therefore reasonable to suspend further enforcement action when community annoyance has been resolved. Item B is similarly reasonable because, if local units of government decide not to submit additional complaint summaries, then they have indicated that they do not believe there is a basis for MPCA action. By conditioning further action on local government requests, the MPCA makes local units of government a partner in helping define whether a community annoyance deserving state attention even exists. And item C is reasonable because the rule must define a point where the commissioner can determine that all reasonable steps within the scope of the odor rules have been taken to reduce the odors. Otherwise, continued complaints may lead to the owner or operator being required to submit odor reduction plans beyond the point where all options have been exhausted. Item B gives the local unit of government the option of not following up on complaints at this stage, as it is assumed that local units of government would not want to commit resources to verifying complaints after all reasonable options have been implemented and the owner or operator has been determined to have fulfilled prior odor reduction plans and test plans. However, if the local unit of government does decide to continue processing and verifying these complaints, the commissioner needs similar discretion in dealing with them. Under this item, the commissioner may determine after the third odor reduction plan that residual odor issues would be better resolved at the local level by private nuisance action or by some other non-agency action. In other words, the commissioner at this stage may decide that the options under the odor rules have been exhausted and the issue is best resolved at a local level. It is reasonable to consider alternate methods after three rounds of mitigation efforts and odor testing.

Finally, subpart 4 explains that, even when the MPCA suspends further action under the odor rules, it may take action as is reasonable under its other rules to ensure compliance with other regulatory requirements. It is reasonable to include this provision in subpart 4 to avoid confusion as to the scope of the suspension provided in the rest of the subpart. It is the intention of the MPCA to describe clearly how and when it will take action under its odor rules to resolve a community annoyance. The MPCA does not intend its actions under the odor rules, or its decision to suspend further enforcement action under the odor rules, to limit its ability to act under other applicable rules and programs of the MPCA, including the MPCA's permit program where use of that program would be appropriate to resolve a community annoyance.

Minn. R. 7029.0080 Odor Testing Procedures

This part describes the odor testing procedures to be followed if a test is required under Minn. R. 7029.0050 and Minn. R. 7029.0070. This part contains 10 subparts. The reasonableness of each of the subparts is described below.

Subpart 1. General requirements. Here the general testing requirements are established. This subpart states that odor testing is subject to Minn. R. 7017.2001 to 7017.2045 of the performance test rule. This is reasonable as an odor test meets the definition of performance test as given in the performance test rule. However, as specific methodology and procedures are defined in this proposed rule, it is reasonable to exclude certain generic parts of the performance test rule in favor of the proposed methods and procedures. Therefore, Minn. R. 7017.2050 and Minn. R. 7017.2060 have been excluded as they relate to approval of alternate methods and to procedures for specific methods, which do not apply here. Minn. R. 7017.2020, subp. 5 (test runs) is excluded as the number of test runs and the averaging procedure for odor testing is defined within this proposed rule. Minn. R. 7017.2045, subp. 6 (adjustments for detection limit) is excluded as odor is measured in terms of concentration rather than as a mass emission rate, so adjusting the sample volume does not improve on the detection limit of the method.

Subpart 2. Test Method. This identifies the American Society for Testing and Materials (ASTM) method E679-91 as the test method to be used in odor tests. This method sets out the procedures for presenting an odor sample to a panel and interpreting the results. It was the opinion of the technical advisors on the TAC and Task Force that this method represented the best readily available technology and the most appropriate method of data reduction for incorporation into this rule. A demonstration of this method and the older, repealed ASTM method was provided by Metropolitan Council staff for Task Force members on March 22, 1993. This method, like the method that is incorporated into the existing odor rule, relies on a panel of individuals to quantify the odor concentration by finding the detection threshold for each individual using a series of dilutions of the sample. However, some of the variables in the method referenced in the existing odor rule have been eliminated (e.g. the flow rate of the sample as presented to the panelist is kept constant) and additional quality assurance requirements are incorporated into the new test method in order to make this a much more reliable monitoring tool than the older ASTM method in the existing rule. Note that this method relates only to sample presentation and data reduction. The Task Force found it necessary to define a stack sampling protocol and to amend the method in certain areas in order to make this a complete test method for the purpose of this rule. This subpart also reaffirms that the testing is only applicable to emission points as defined in this rule, which is reasonable as the defined sampling protocols cannot be applied or transferred to other types of sources.

This subpart also provides a process and criteria for the commissioner to approve alternate test procedures. This is reasonable as there is no complete, published method for odor sampling and testing but ongoing research by ASTM and other bodies may eventually lead to such a method. The language in this method would allow such a method to be used without first revising the rule language itself. Flexibility to propose alternate procedures in difficult sampling conditions is provided, which is consistent with Minn. R. 7017.2050 of the performance test rule.

<u>Subpart 3. Sampling Procedure.</u> Subpart 3 details the odor sampling procedure. The rule requires three test runs for the odor performance test. This is consistent with the general requirements of the performance test rule, Minn. R. 7017.2025, subp. 5.

Subpart 3, item A requires each run to consist of an integrated sample taken over a 10 - 30 minute period, which for most cases is anticipated to be sufficient to obtain a representative sample. Also, by requiring a period of at least 30 minutes between test runs, the whole test should cover a representative period of operating time.

Subpart 3, item B specifies a minimum sample volume and sampling rate for collecting samples. The specified sample volume and sampling rate are consistent with other grab sampling methods for pollutants and the appropriate sized bags and materials are readily accessible to testing companies.

Subpart 3, items B and C refer to the types of tubing and bags to be used, identifying Tygon tubing (or equivalent) and Tedlar sampling bags by name. Both Tedlar and Tygon are cited as readily available approved materials for sampling bags and tubes but mention of trade names is not intended to be an endorsement by the MPCA. Nevertheless, it is reasonable to specify materials that have low odor retention properties as odor retention can be the source of significant bias at low concentration levels. And since odor retention is caused by the bonding of odor-causing chemicals to the bag material, inert materials are the best choice. Item C also gives an exception to the general sampling bag requirement for sources with known high concentrations of odors. For these sources, it is reasonable to allow a lower cost bag due to the relatively low influence of odor retention at higher concentrations.

Subpart 3, item D defines a bag pre-filling procedure to purge ambient air from the system and to minimize the effect of odor retention in the bag. This requirement is reasonable because it assures that precautions are taken to minimize bias in the results due to odor retention in the bag.

Subpart 3, item E sets out a special requirement to refine the test protocol for each emission point that has a high gas temperature or high moisture content or any other case where sample collection or storage problems can be reasonably anticipated. This requirement is reasonable because it gives the owner or operator the opportunity to make reasonable adjustments in test protocol to ensure that the test results are as valid as possible in difficult sampling conditions.

Subpart 4. Sample analysis. This subpart sets out the requirements for sample analysis. Samples are to be presented to the odor test panel members within 24 hours after they are taken. Ideally the samples should be presented sooner than this to minimize possible leakage, sample deterioration or odor retention, but for tests that are conducted in remote areas, a sufficient time for sample transportation has been allowed. Additionally, since the Olfactometer described under subpart 7 is portable, it is possible to set up a temporary room for odor sample presentation, for example in a motel conference room, at a remote location. Thus, the 24 hour requirement should be easily attainable. This subpart also sets the minimum number of odor panelists at nine. Testing under the existing odor rule and method has in the past required a minimum of six. However, an increase in the number of panelists provides a panel that is more representative of a cross section of the population and reduces the averaged effect of individuals that are highly sensitive or insensitive to the odor. More than nine panelists can be used and this is recommended both for data quality and so that rejection of a single panelist based on quality assurance data does not reject the whole test. All valid panelists will be used in the data reduction.

Subpart 5. Odor panel instructions and questionnaire. This subpart sets out the procedures that odor panelists must follow. Written instructions are to be provided to the odor panelists, which is reasonable because odor panelists are sometimes volunteers with little or no experience in odor testing. It is necessary that they are aware of the factors that influence sensitivity to odors so that they can answer the questionnaire knowledgeably and can assess their own suitability for panel participation before the sample presentation begins. The panelists' signature acknowledging receipt and understanding of the instructions is included on the questionnaire as verification that instructions were provided.

The questions on the panelist questionnaire (Minn. R. 7029.0110) are based on the quality assurance guidelines of odor test methods, including the old method cited in the existing odor rule. All of these factors tend to reduce the panelist's sensitivity to an odor and will bias the results low. In recognition that panelists have limited time to prepare and in order to encourage truthful answers, an individual panelist will be rejected only if either two or more yes answers are recorded or if a yes response is given to either question seven, eight, or nine. Questions seven, eight and nine have been identified by Task Force members as being the most critical. The increase in the minimum number of panelists from six to nine and the selection criteria in subpart 6 offset this slight relaxation of the acceptance criteria from past practice. The questionnaire also asks for the name, age, address, employer and occupation of the panelist. It is reasonable to ask for this data as it is useful in defining the general characteristics and background of the panel for comparison against the general population and it can also be used to verify the existence of the individuals.

Subpart 6. Panel selection. This subpart explains how panelists are to be selected. Panel selection requires verification of the ability of panel members to detect odors accurately. Subpart 6, item A incorporates by reference ASTM Method E544-75 as a means of screening the odor panel. This is a reasonable requirement as it prevents people with very low sensitivity to odors from participating as part of the panel, which would give a low bias to the test result. The procedure described is a standard screening technique and is used routinely at the Metropolitan

Council odor laboratory. Subpart 6, item B requires each individual's odor detection threshold to be determined and compared to the average value of the panel. The procedure for doing this follows the same sample presentation and data reduction method as described for odor performance test samples. This is to be used only as a long term assessment tool for determining the composition of odor panels and possible screening of highly sensitive or insensitive people. However, this item specifically states that these numbers are not to be used as a measure of the validity of an individual test result, which is reasonable as a panelist's sensitivity to different types of odor may vary and may be expected in some cases not to reflect the relative sensitivity to the odor of butanol (which is to be used under item B to evaluate the relative odor detection thresholds of panelists). Subpart 3, item C states that the screening shall occur once during the 24 hour period prior to the sample presentation part of the test and that at least one hour must elapse between the screening and the sample presentation. This is to ensure that the panelist is screened at a time close to the test, thereby minimizing the effect of, for example, a change in health, while giving the panelist adequate time to rest the olfactory senses prior to starting the sample presentation.

Subpart 7. Triangle dynamic olfactometer operating criteria. Here the instrument operating criteria for the odor tests are described. The equipment used to present diluted odor samples to odor panelists is an Olfactometer. This subpart provides the sequence of events for operation of the Olfactometer. Although some of these are given in the incorporated test method it is reasonable to include both the requirements of the method and the modifications to the methods in this subpart so that the overall sequence is clear. It is also reasonable to specify in detail the type of equipment for use in odor testing as this can be a significant variable when comparing results over time. The criteria of this part are based on the experience of the Task Force and the Metropolitan Council odor laboratory.

Items A and B relate to the number of dilution levels and the dilution ratios to be used. Six dilution levels is standard practice and represents the configuration of available equipment. The range of dilution ratios is necessary to accommodate differences in sensitivity between individuals, to ensure that the dilution threshold of each individual is exceeded. The panel administrator has the discretion of adjusting the dilution ratios for very strong or very weak odors.

Item C specifies an ascending order of concentration of odor (i.e. from most to least dilute) sample presentation. This ensures that the presentation of a strong sample at an early stage does not desensitize the panelist for subsequent samples.

Item D describes the sniffing ports through which the odor sample is presented and specifies that they be identical in appearance in order that the panelist is not given clues as to which is the odorous sample and which are blanks. The ports are also positioned in a symmetrical triangular arrangement. The panel administrator reads from a remote panel whether or not a correct choice is made. Note that if the panelist detects no odor at any port the panelist must still make a guess, so that all of the data points for a panelist are usable. This is known as the "forced choice" technique and is common practice in odor sampling and is intended to overcome reluctance to choose when a panelist is unsure about a sample. As the test method requires at least two consecutive correct choices to be made and the chance of two correct answers by pure guesswork is only one in nine, the "forced choice" method appears to be more likely to be an accurate measure of detection threshold than it is to give a high bias to the results.

Item E requires a well ventilated room that is free of any strong or distinctive odors to be used for the sample presentation. This is reasonable in order that background odors do not influence the panelist. The same room air is to be used for diluting the odor samples, so that the blanks do not smell significantly different from the background air. The Task Force decided not to recommend the use of specially filtered air for the room or for dilution as filtered air can have a distinct odor of its own, which would add another variable to the test.

Item F requires a constant flow through the sampling ports. The specific flow rate was selected based on the design of the Olfactometer. All sniffing ports must be operating simultaneously, which is also a design feature of the olfactometer, in order to maintain the constant flow and dilution level at each port and minimize the input of the panel leader between dilution levels.

Item G describes the system by which the panelist's choice is communicated to the panel leader. It is reasonable to require a completely non-verbal method of communicating choices so that the leader can have no influence on the choices of the panelists.

Item H adds a calibration method for the flow meters regulating the sample and the dilution air. This is reasonable as it is not included in the ASTM Method, yet the flow rate can have a large effect on the dilution threshold of the panelist. In general, the higher the flow rate the more likely the panelist is to detect the odor.

Subpart 8. Panel test procedure. This subpart describes the sequence of events for the panelist to follow during the sample presentation. Although some of these are given in the incorporated test method it is reasonable to include both the requirements of the method and the modifications to the methods in this subpart so that the overall sequence is clear. The criteria are based on the experience of the Task Force and the Metropolitan Council odor laboratory.

Item A states that the panelist starts at the most dilute sample. As stated earlier, this is done so that the panelist is not exposed to a high concentration earlier which may sensitize or desensitize the panelist to lower concentrations and thereby alter that person's dilution threshold.

Item B requires the panelist to sniff from each of the three sniffing ports, which is the only way that the panelist would be able to determine which of the three was the odor containing sample, particularly at lower concentrations.

Item C requires a choice to be made even if the panelist is unsure or cannot distinguish any difference. This "forced choice" principle is discussed under subpart 7 of this part. The method of selection is consistent with the procedures and equipment requirements in subpart 7.

Item D states that the panelist moves to the next port and repeats items A-C until all ports have been assessed. However, the panel leader does have some discretion here as the method requires that two consecutive correct selections be made in order to determine an individual's threshold, so in some cases it may not be necessary for the panelist to sniff the most concentrated samples.

Item E requires the next panelist to follow the same sequence without delay but without observing the previous panelist. This is reasonable as it may be possible for a panelist to judge where the previous panelist had first detected the odor. Waiting panelists should also be kept in a separate room, away from the Olfactometer and from those panelists who have completed the sample presentation. There should be no verbal communication between panelists.

Item F requires the flow calibrations required by subpart 7 to be done immediately before and after the panel procedure. This is reasonable as it is necessary to determine that the flow rate remained constant during the test, as flow rate is a variable with a large effect on an individual's odor threshold.

Item G states that at least 30 minutes must elapse between presentations of samples to a panelist and that a maximum of six samples and one screening procedure can be presented in any one day. This is necessary in order to prevent bias of the results due to olfactory fatigue. This also means that for a source testing multiple sources, the testing may need to take place over more than one day or additional panel members may be needed.

Subpart 9. Calculation of panel test result. This subpart explains how to calculate the panel test results. As mentioned under subpart 8, item D, two consecutive correct choices must be made in order to evaluate a person's odor dilution threshold. It is reasonable to require two consecutive correct choices in order to minimize the potential bias of the forced choice requirement. The chance of a correct answer by guessing is one in three, but the chance of getting two consecutive correct choices by guessing is one in nine. The odor dilution factor, symbolized by the letter Z, is defined for the individual and the panel as a whole in a manner consistent with the test method and is included here for convenience.

Subpart 10. Witnessing. This subpart states that the MPCA may witness performance tests. This provision is consistent with Minn. R. 7017.2045, subp. 1. This subpart specifies that the odor panel procedure may be witnessed in addition to the field sampling, which is reasonable as the panel procedure is a critical part of the test and its procedures are detailed in the rule. MPCA staff witnessing of tests helps to promote consistency between laboratories and improves quality assurance. The option to witness a test is extended to local units of government which is reasonable as they have a regulatory interest in the outcome of the test and because in some cases they may be administering this rule under Minn. R. 7029.0005.

Minn. R. 7029.0100 Complaint Form

This part provides a form to be used by the local unit of government for documenting complaints and recording the results of the investigators follow-up. It is based on the form currently used by AQD staff to document complaints but has been made more specific to odors and incorporates practical suggestions from the TAC.

It is reasonable to provide a standard form so that the local unit of government will know what it is necessary to record and so that MPCA staff will receive information in a consistent format. The forms must be signed by the staff person at the local unit of government who is responsible for handling the complaint, which is reasonable as the signature indicates individual accountability. The complainant detail is clearly marked as confidential. The identities of individuals who register complaints concerning violations of state laws concerning real property are classified as confidential data under Minn. Stat. 13.44 (1994). The complaint form also includes a "Tennesen Warning" to provide the complainant with information on how the complaint may be used under Minn. Stat. 13.04, subd. 2. Part 1 of the form is for recording details of the complaint when received and asks for a description of the odor, when it occurred and for how long. The question on whether the problem has been reported before could be helpful in cases where complaints may be reported to more than one local unit of government, e.g. city and county level or at sites close to city boundaries. The questions are reasonable in that they ask only for basic, non-technical information that is adequate to identify a possible source and for an inspector to verify by inspection.

Part 2 of the form relates to actions taken by the investigator after the complaint is received. The questions are again non-technical and relate directly to the requirements for submittals as given elsewhere in this rule. All questions except "Complaint Confirmed?" can be answered without doing a field inspection. The form indicates that a field inspection is needed in order to verify the complaint. This is reasonable as the inspector needs to detect an odor at the site of the complaint or personally interview complainants in order to determine the validity of the complaint. Wind direction data can be obtained from the meteorological service.

<u>Minn. R. 7029.0105 Summary Form</u>

This form is required as a summary of all the individual complaints. The content is reasonable as it serves as a checklist of criteria for independent complaints as given elsewhere in this rule. A signature by an elected official or delegated representative of the local unit of government is required to verify the complaint record as a whole, which is reasonable as this acts as a certification of the submittal by a responsible party.

<u>Minn. R. 7029.0110 Odor Panelist Questionnaire</u>

This form is to be used in conjunction with the requirements of Minn. R. 7029.0080, subp. 5. It serves three purposes; documenting the name, address and occupation of the panelist; providing an additional screening stage, and requires the panelist to certify an understanding of the panel instructions. The reasonableness of the requirements of this form has been discussed under Minn. R. 7029.0080, subp. 5.

C. Reasonableness of Related Amendments

The following rules are amended in a manner consistent with this rule making.

<u>Minn. R. 7017.2020 Performance Tests General Requirements</u>

<u>Subpart 1. Testing required</u>. This subpart of the performance test rule lists the reasons that the commissioner can cite to require the owner or operator of an emission facility to conduct a performance test. An additional reason (item G) is added to reflect the new odor rule. This item allows the commissioner to require a performance test for a regulated pollutant based on the presence of odorous emissions. This is reasonable as many pollutants, such as hydrogen sulfide and various volatile organic compounds, have characteristic odors. The registering of complaints regarding an emission facility can indicate that an excess amount of such a pollutant is being emitted and a performance test can confirm this.

<u>Minn. R. 7011.2200 to 7011.2220; Processing Animal Matter</u>

<u>Minn. R. 7011.2215 Odor Control Equipment Required On Reduction Processes</u>

Minn. R. 7011.2215 is repealed as the incineration standard would become unfairly restrictive towards rendering facilities upon adoption of the proposed odor rule. The facilities currently subject to Minn. R. 7011.2215 will be subject to odor reduction and mitigation requirements if they are determined to be a community annoyance having emission points. If the source is not a community annoyance, the requirement to incinerate exhaust gases as 1,500 degrees Fahrenheit is unnecessary and burdensome in terms of capital and operating costs for the facility. The Odor Task Force made a formal recommendation that this subpart be repealed. Facilities currently following the incineration requirement would become free to operate the equipment at a lower temperature or to use alternate control measures provided that they did not cause a community annoyance in doing so.

Minn. R. 7011.2220 Other Odor Control Measures Required

Subpart 4. Enclosure of building. This subpart is not being deleted as it applies to area sources that will not be subject to the mitigation requirements of the new odor rule. The reference to the old odor rule is replaced with the new reference to reflect that community annoyance is now the trigger for enforcement of odorous emissions.

Minn. R. Ch. 7035; Ground Water and Solid Waste Division

Minn. R. 7035.2875 Refuse-Derived Fuel Processing Facilities

Subpart 3. Operation and maintenance manual. Item A has been reworded to reflect the fact that the new odor rules, unlike the existing rules, will not contain numerical emission limits. It is reasonable that the affected facilities still comply with the new rules but the reference should be to the provisions rather than limits of the rule.

Minn. R. 7035.2835 Compost Facilities

Rewording similar to that proposed for Minn. R. 7035.2875 would be appropriate for Subpart 3, Item A, of this part. However, as the Ground Water and Solid Waste Division is currently revising its rules related to composting facilities, the change will not be made here. Suggested wording has been suggested directly to Ground Water and Solid Waste Division staff.

V. SMALL BUSINESS CONSIDERATIONS IN RULEMAKING

Minn. Stat. § 14.115, subd. 2 (1994) requires the MPCA, when proposing rules which may affect small businesses, to consider methods for reducing the impact on small businesses. It is likely that some small businesses will be affected by the proposed new odor rules, but these same businesses are already affected by the existing odor rules. The MPCA does not believe that the requirements of the proposed new rules place any higher burden on small or larger business than do the requirements of the existing rules.

Moreover, as application of the proposed new rules is conditioned on community complaints rather than a quantity of emissions and as odor is a quality of the type of operation rather than its size, the MPCA believes that small businesses should be as accountable as larger businesses for their odorous emissions. In consideration of the special concerns of small businesses, however, the rules do allow for the MPCA to be cognizant of the size of the business and its resources, as well as the number and frequency of complaints, in reviewing the appropriate mitigation.

The proposed new odor rules are neither complex nor overly technical. By drafting rules that are reasonably clear and straightforward and that involve all affected interests early, the MPCA intends its proposed rules to avoid the unnecessary, duplicative governmental oversight that aggravates all businesses and stresses small businesses in particular. The MPCA therefore believes its proposed new odor rules are more responsive to the needs of small businesses than its existing rules.

In sum, the MPCA has considered various methods to reduce the impact on small businesses when it considered the proposed new odor rules and believes that the proposed new rules strike the proper balance between, on the one hand, the public's interest in government regulation of conduct affecting the environment and, on the other hand, the public's interest in limiting regulation for small businesses.

VI. CONSIDERATION OF ECONOMIC FACTORS

In exercising its powers, the MPCA is required by Minn. Stat. § 116.07, subd. 6, (1994) to give consideration to economic factors. The statute provides:

> In exercising all its powers, the pollution control agency shall give due consideration to the establishment, maintenance, operation and expansion of business, commerce, trade, industry, traffic, and other economic factors and other material matters affecting the feasibility and practicability of any proposed action, including, but not limited to, the burden on a municipality of any tax which may result therefrom, and shall take or provide for such action as may be reasonable, feasible and practical under the circumstances.

The MPCA anticipates that the proposed new odor rules will provide little or no change in the overall costs to Minnesota business when compared with the existing odor rules. Assuming that the old and new panel test requirements are of approximately equal cost, the requirements of an affected facility to test, mitigate and retest are similar to the approach under the existing rules, which was to test and retest if the first test exceeded the emission limits. Further, by not requiring testing until a community annoyance is established, the MPCA has duly considered when it is reasonable to require testing expenditures for odors. Similarly, the opportunity given under the proposed new rules to owners and operators of an odor source to reduce the odors before they become a community annoyance gives the owners and operators some control over MPCA involvement in resolving odor problems, and the attendant costs that come with MPCA involvement.

The MPCA understands that there may be some perception that costs will increase as a result of the odor mitigation and control requirements in the proposed new rules or as a result of the requirements that local units of government take an active role in documenting violations. The MPCA does not believe these perceptions are fully correct. First, if there is such an increase in mitigation and control requirements, it is only because of the difficulty in enforcing the existing rules and not due to a change in public opinion or MPCA analysis of the need to control particularly offensive sources of odor pollution. Second, the proposed new rules simply require local governments to document problems that are primarily local in nature.

VII. IMPACTS ON AGRICULTURAL LAND

Minn. Stat. § 14.11, subd. 2 (1994) requires that if the agency proposing the adoption of a rule determines that the rule may have a direct and substantial adverse impact on agricultural land in the state, the agency shall comply with specified additional requirements. The MPCA does not believe it is subject to these additional requirements because it has specifically exempted agricultural area sources, which are the major type of odor source within the agricultural sector, from this rule. Agricultural emission point sources are potentially affected by this rule but these type of sources are unlikely to be significant odor sources. Therefore the overall effect of implementing this rule will be minimal for agricultural lands. In short, MPCA staff expects that the new rules will have no more impact on agricultural sources than the existing rules, and the overall impact may be reduced due to expansion of the agribusiness exemption language.

The MPCA does recognize, however, that odors from some types of agricultural operations are a significant source of odor complaints. These sources are primarily area sources such as feedlots. The MPCA is continuing to consider appropriate means of addressing agricultural odors. In addition, the Feedlot and Manure Management Advisory Committee, a body mandated by the Minnesota Legislature, is investigating this problem through its own task force and the University of Minnesota has had state money allocated to it for research into feedlot odors. In sum, while the MPCA realizes that while the number of citizen complaints regarding agricultural sources has increased in the last two years, primarily as the result of an increasing number of large scale hog farms, it does not believe the proposed odor rules -- which historically have been directed to generic sources of odor -- are well-suited to addressing agricultural odor problems. And since efforts are underway to consider more appropriate regulatory approaches, the MPCA has decided to defer further regulation of odors from agricultural area sources operations until these other analyses are more complete.

VIII. COSTS TO LOCAL PUBLIC BODIES

Minn. Stat. § 14.11, subd. 1 requires the MPCA to include a statement of the rule's estimated costs to local public bodies in the notice of intent to adopt rules, if the rule would have a total cost of over $100,000 to all local public bodies in the state in either of the two years immediately following adoption of the rule.

The impact of the proposed rules on local units of government is difficult to estimate as the rule is voluntary at the local level. The cost can be zero or it can be significant, depending on how the local unit of government plans to use this rule. The MPCA sees the proposed rules as a tool for local units of government which provides a statewide, systematic method of handling odor complaints and getting the MPCA involved in the more troublesome cases. As odor is already likely to be an issue as a nuisance at the local level in communities with odor sources, in many cases the local unit of government may be able to follow the new procedures by modifying existing practices rather than adding to the workload.

Some cost increases are likely at the local level if a local unit of government chooses to act thoroughly on all odor complaints, but have been minimized as far as possible at the advice of

TAC members by keeping the procedures simple and non-technical. The procedures in this rule are optional and need only be followed if the local unit of government wants the MPCA to get involved. The verification requirements call only for a visit from the local unit of government to check that an odor event actually occurred. No technical equipment or training is necessary to make these verifications, just a reasonable sense of smell.

IX. LIST OF WITNESSES AND EXHIBITS

A. Witnesses

In support of the need for and reasonableness of the proposed rule amendments, the following witnesses will testify at a rulemaking hearing if one is necessary:

1. Stuart Arkley, Pollution Control Specialist, Compliance Determination Unit, AQD. Mr. Arkley will testify on the detail and technical aspects of the rule.
2. Todd Biewen, Supervisor, Compliance Determination Unit, AQD. Mr. Biewen will testify on the implementation and enforcement aspects of this rule.
3. Individual Task Force members have expressed willingness to testify, subject to availability.

B. Attachments and Exhibits

Attachment 1: List of TAC Members

Attachment 2: List of Odor Task Force Members

Exhibit 1: Letter of support from Henry Friedrich, Odor Task Force Chairman

Exhibit 2: Bill Prokop and Ed Van Hoven letters supporting deletion of Minn. R. 7011.2215

Exhibit 3: Bay Area Air Quality Management District Regulation 7

Exhibit 4: Connecticut Rules section 22a-174-23

Exhibit 5: ASTM Method E679-91

Exhibit 6: ASTM Method E544-75

Exhibit 7: Technical Paper -- "Source Emission Odor Measurement by a Dynamic Forced-Choice Triangle Olfactometer"

Exhibit 8: Technical Paper -- "Air Quality Odor Testing At MWCC - Review of Syringe Dilution and Olfactometer Odor Testing Results and Parameters Affecting Results" (October 17, 1990), Chapter 8, "Conclusions and Recommendations"

X. CONCLUSION

Based on the foregoing, the proposed repeal of the existing odor rules and the proposed adoption of new rules governing odorous emissions are both needed and reasonable.

Dated: November 28, 1995

Charles W. Williams

Commissioner

Attachment 1: List of TAC Members

The following non-MPCA persons attended two or more TAC meetings:

Henry E. Friedrich, MMT Environmental

Bill Prokop, PROKOP Enviro Consulting

Laura Villa, Dakota County

Melba Hensel, MWCC

Ed Van Hoven, Van Hoven Company

Doug Reeder, City Administrator, City of South St. Paul

Kevin Locke, City of New Brighton

Dave Fridgen, City of New Brighton

Kevin Kiemele, Environmental Engineer, Koch Refining Company

Tim Guzek, General Manager, Blue Earth Rendering Company

Mel Roshanraven, Environmental Director, Darling-Delaware

Tom House, Continental Nitrogen and Resources

David Benforado, 3M Environmental Engineering Services

Scott Schuler, Printing Industries of Minnesota

Charles McGinley, McGinley Associates

Attachment 2: List of Odor Task Force Members

The following people attended the Odor Task Force meetings held between January and August, 1993. All members, except for Mr. Nelson, have been active in the TAC meetings. Mr. Nelson was invited to join the Odor Task Force as the delegated representative of the League of Minnesota Cities when a request was made for an additional member to represent local units of government. Stuart Arkley, Ann Foss and Todd Biewen represented the MPCA during the Odor Task Force meetings.

Henry E. Friedrich: Vice President, MMT Environmental. Mr. Friedrich has many years experience in the development of odor sensory methods and he is active in the AWMA odor Committee EE-6. MMT Environmental has conducted odor testing for compliance demonstration with existing Minnesota Rules. Elected by other Task Force Members as Chairman of the Task Force. Provided meeting minutes and meeting agendas.

Bill Prokop: President, PROKOP Enviro Consulting. Mr. Prokop has nearly 25 years of experience in the development of odor sensory methods. He represents the National Renderers Association and is active in the ASTM EE-6 Committee on odors.

John K. Nelson: Senior Environmental Health Specialist, City of Bloomington. Mr. Nelson is an experienced health inspector with the City of Bloomington and has practical experience in responding to odor complaints from citizens regarding a wide range of sources. Mr. Nelson was the delegated representative of the League of Minnesota Cities.

Laura Villa: Environmental Specialist, Dakota County. Ms. Villa is an experienced inspector for Dakota County and has practical experience in responding to odor complaints from citizens regarding both point and area sources.

Melba Hensel: Principal Environmental Scientist, Metropolitan Council. Ms. Hensel is experienced in regulatory compliance issues, including air quality permitting and odor testing requirements. The Metropolitan Council operates an odor testing laboratory for analysis of its own samples from various locations and has the capacity to use both the old, repealed ASTM method and the proposed Olfactometer method.

Ed Van Hoven: Van Hoven Company, Inc. Mr. Van Hoven operates a rendering facility in South St. Paul and is experienced in odor compliance issues from the perspective of a regulated party.

AG:12617 v1

mmt environmental
services, inc.

February 24, 1994

MAR 1994
RECEIVED
Minnesota Pollution Control Agency
Division of Air Quality

Mr. Stuart Arkley
Minnesota Pollution Control Agency
Compliance & Enforcement Section, Air Quality
520 Lafayette Road North
St. Paul, MN 55125-4194

RE: ODOR RULE UPDATE
DRAFT 12/29/93

Dear Stuart:

The above Draft submitted with your February 18, 1994 correspondence has been reviewed.

On behalf of the Odor Task Force, I am pleased to advise that this draft is acceptable as a replacement for the existing regulations. With the replacement of the "numbers" by the alternate criteria, the Rule, as proposed, appears to be workable by both parties; i.e., industry and regulatory.

As discussed yesterday, I feel Part 7011.0325 Agribusiness Exception needs clarification. My concern relates to the subject of fertilizer production, open composting, etc., and the definition of Agribusiness. The concern for fugitive and open sources must still be addressed.

As chairman of the Odor Task Force, I express appreciation and thanks to you the and the MPCA staff for your cooperation in this effort. The fact that our comments of September 20, 1993, and subsequent concerns were favorably addressed is gratifying. Thank you, again, Stuart, for your excellent cooperation.

Sincerely,

H E Friedrich

Henry E. Friedrich
Chairman, Odor Task Force

HEF/b

cc: Todd Biewen, Pollution Control Specialist, MPCA

4610 N. Churchill St. • St. Paul, MN 55126-5892 • 612 / 483-9595 • FAX 612 / 483-2699

PEC

PROKOP Enviro Consulting
P.O. Box 602
Deerfield, Illinois 60015

Telephone
(708) 945-1465

July 31, 1992

Mr. Stuart Arkely
Minnesota Pollution Control Agency
Air Quality Division
520 Lafayette Road North
St. Paul, MN 55155

Subject: Subpart 7005.1030 Odor Control Equipment Required on Reduction Processes

Dear Mr. Arkely:

This subject rule requires incineration of emissions from the rendering process at a temperature of 1500 F for a residence time of 0.3 second. As we discussed, there is ample evidence available that a temperature of 1200 F for a residence time of 0.3 second is adequate. Attached are the following to support this statement:

1) Excerpts from a paper presented at the 1977 APCA Odor Specialty Conference which discusses Rule 64 adopted by the Los Angeles County APCD (now the South Coast AQMD). This rule specifies a temperature of 1200 F and residence time of 0.3 second for incineration of rendering process odors.

2) Excerpts from the Air Pollution Engineering Manual (published by the USEPA as their document AP-40) which clearly show in Table 224 that the combination of surface condensers (either shell and tube or air-cooled, finned tube) and incineration at 1200 F provides highly efficient odor reduction (99.85 % by incineration alone).

3) Excerpts from a report of an odor control performance test conducted by the Los Angeles County APCD in 1972 at a rendering plant in Los Angeles. It should be noted that the afterburner effluent was diluted with an estimated 2.45 equal quantities of ambient air before discharge to the atmosphere. As a result, the odor sensory measurement of 50 odor units/scf for the diluted effluent translates into an estimated 170 odor units/scf for the undiluted effluent from the afterburner at 1200 F. This represents an odor reduction efficiency of 99.4 % which is quite high. The residence time within the afterburner is estimated at 0.7 second.

PROKOP Enviro Consulting

I have also conducted odor sensory performance tests with boiler incineration of the high intensity odor emissions from the rendering process and have obtained similar results with natural gas used as the fuel. When fuel oil is used, particularly with a high sulfur content, a strong pungent, sulfur dioxide smell is observed in the exhaust stack emission and it typically may be threefold higher in odor strength than with natural gas. However, in either case, the odor character of the stack exhaust is that of combustion gases only since a rendering odor is not detected.

You asked about fuel savings if incineration is performed at 1200 F instead of 1500 F. Assuming that 2000 cfm of odorous air is to be incinerated and 20 % excess air above theoretical is used, the following comparison can be made between 1200 and 1500 F:

2000 cfm x 0.075 lb/cf x 287 Btu/lb (enthalpy 1200F) = 43,050 Btu/min

2000 x 0.075 x 369 Btu/lb (enthalpy @ 1500 F) = 55,350 Btu/min

Available heat in Btu/scf of natural gas @ 1200 F = 676.5
" " " " " 1500 F = 585.5

$$\frac{43{,}050 \text{ Btu/min}}{676.5 \text{ Btu/scf}} \times 60 \text{ min/hr} = 3820 \text{ scfh}$$

$$\frac{55{,}350}{585.5} \times 60 = 5680 \text{ scfh}$$

Net increase of 1860 scfh of natural gas required at 1500 F.

This is a significant increase in natural gas usage without any recognizable benefit.

Please don't hesitate to call if you wish to discuss any of this info.

Sincerely,

William H. Prokop

William H. Prokop, P.E.

WHP/jp
Enclosures

cc: Ed Van Hoven

VAN HOVEN

Formulating Premium Protein and Fat Sources

November 16, 1992

Stuart Arkley
Compliance Determination Unit, DAQ
MPCA
520 Lafayette Road
St. Paul, MN 55155-3898

RE: Odor Rule revisions

Dear Mr. Arkley,

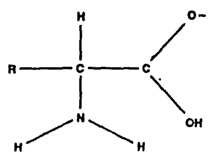
These comments are submitted collectively in response to the MPCA draft odor rule revisions dated 10-20-92 and 10-27-92 by Edward Van Hoven of the Van Hoven Company, Inc., So. St. Paul, Mn., Mel Roshanravan of the Blue Earth Rendering Co., Blue Earth, Mn. and William Prokop, Consulting Director of Engineering for the National Renderers Association, Washington, DC.

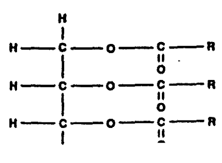
We support the concept that a nuisance be established by the local unit of government before a compliance program is negotiated between the emission source and the local unit of government. Although we are not commenting at this time on the specifics of Section 7005.0922, Nuisance Established, we do wish to have the opportunity to do so at a later date. Also, we do wish to have the opportunity to comment on how a compliance program is to be negotiated and enforced after mutual agreement is reached on the program between the emission source and the local unit of government.

At this time we cannot support the odor emission limits as shown in Section 7005.0920, Odor Emission Limits, the performance tests as shown in Section 7005.0921, Testing Required and the odor testing as shown in Section 7005.0925, Odor Testing. We will provide specific written objections to these three sections if the agency intends to adopt them as written.

Regarding Section 7005.1030, Odor Control Equipment Required On Reduction Processing, we appreciate the agencies decision to reduce the incineration temperature from 1500 °F to 1200 °F. However, we object to this section of the rule being exclusively directed at rendering industry which is the only category of emission source so regulated by the agency.

VAN HOVEN Company, Inc. • 505 Hardman Avenue, P.O. Box 56, So. St. Paul, MN 55075 • (612) 451-6858 FAX (612) 451-6542





We believe this section singles out one potential industrial odor source of many possible sources forcing the targeted industry to apply expensive technology while other odor sources are excluded from any agency scrutiny unless neighbors complain about the odor source. We believe that Section 7005.1000-1040 should be deleted from the odor rules or revised to include all potential odor sources.

For Mel Roshanravan and William Prokop

Yours truly,

Edward G. Van Hoven Jr.

cc Mel Roshanravan
Bill Prokop

Designation: E 544 – 75 (Reapproved 1993)

Standard Practices for Referencing Suprathreshold Odor Intensity[1]

This standard is issued under the fixed designation E 544; 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.

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 may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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.*

2. Referenced Document

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

3. Definitions

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 the Appendix. 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 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

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[1] These practices are under the jurisdiction of ASTM Committee E-18 on Sensory Evaluation of Materials and Products.

Current edition approved May 25, 1975. Published July 1975.

[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.

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 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:*

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

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

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.

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:

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

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:

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

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

7.3 When a panelist indicates that a position between twc scale points is the best match, the concentration value fo this position is calculated as the geometrical mean of the concentrations at the two adjoining scale points. This applie 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:

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

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 ;Im 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.

APPENDIXES

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.

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.

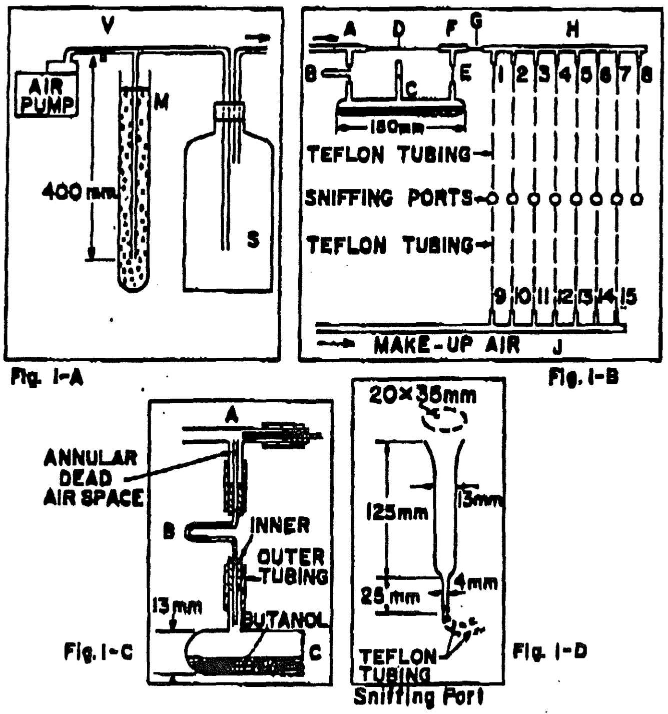

FIG. X1 Butanol Scale Olfactometer

TABLE X1 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)[E,F]	Equivalent Lengths[F,G]
	OD,[C] mm (in.)	ID,[D] mm (in.)		
Stainless steel	1.6 (1/16)	0.76 (0.030)	220	1
Stainless steel	1.6 (1/16)	0.48 (0.019)	45	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] Outside diameter.

[D] Inside diameter.

[E] 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.

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

[G] 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.

[H] PTFE spaghetti tubing of standard wall thickness.

TABLE X2 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					
			0.76		0.48	0.25	0.76	
	Stimulus	Make-Up Air	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

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

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, 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 X1) or from an arrangement (see Fig. X1-A) comprised of an air pump, manostat, and surge bottle, as follows (Note X2):

NOTE X1—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 X2—The air supply shown in Fig. X1-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 X3) which delivers ambient room air (Note X4) into the manostat.

NOTE X3—Some aquarium pumps contain components such as diaphragms, that odorize the pumped air.[6]

NOTE X4—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-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 X5). 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 X5—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-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

[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.

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-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 X6—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 X7). 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 X8).

NOTE X7—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 X8—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-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-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-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 X9—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

[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.

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 X10—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 X11—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 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 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.

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:

$$L_N = L_M\,(V_N/V_M)$$

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:

$$L_{0.48} = 1 \times (43/220) = 0.20$$

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 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 X2 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. 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-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, 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 X2.

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 X2, are calculated similarly.

X4.7.7 Stimulus generator capillaries *D*, *E*, and *G* (Fig. X1-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, is 790 × 0.20 = 158 mm of 0.48-mm capillary tubing.

X4.7.8 After the stimulus generator and the flow splitter 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 (Notes X11 and X12). To increase or decrease all of the flow rates simultaneously, the pressures in the manostats are changed (see X4.4.4).

NOTE X12—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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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 probabiliity 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:*

3.1.1 *sample*—a material in any form that may or may

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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 Sensory Relationships.

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[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.

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

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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

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—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 (concentrations increase →)						Best-Estimate Threshold (BET)	
	3645	1215	405	135	45	15	Value	$\log_{10}$ of Value
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—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).

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(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)

REGULATION 7
ODOROUS SUBSTANCES

7-100 **GENERAL**

7-101 **Description:** This Regulation places general limitations on odorous substances and specific emission limitations on certain odorous compounds. A person must meet all limitations of this Regulation, but meeting such limitations shall not exempt such person from any other requirements of the District, state or federal law. See also Rule 1, Sulfur Dioxide and Rule 2, Hydrogen Sulfide, of Regulation 9, Inorganic Gaseous Pollutants.

7-102 **Citizen Complaints:** The limitations of this Regulation shall not be applicable until the APCO receives odor complaints from ten or more complainants within a 90-day period, alleging that a person has caused odors perceived at or beyond the property line of such person and deemed to be objectionable by the complainants in the normal course of their work, travel or residence. When the limits of this regulation become effective as a result of citizen complaints described above, the limits shall remain effective until such time as no citizen complaints have been received by the APCO for 1 year. The limits of this Regulation shall become applicable again when the APCO receives odor complaints from five or more complainants within a 90-day period. *(Amended May 21, 1980)*

7-110 **Exemptions:** The following buildings, materials and operations are exempted from this Regulation:

110.1 Single family dwellings.

110.2 Restaurants and other establishments for the purpose of preparing food for human consumption employing less than 5 persons.

110.3 Materials odorized for safety purposes.

110.4 Materials possessing strong odors for reasons of public health and welfare, and where no suitable substitute is available and where best modern practices are employed.

110.5 Agricultural operations as described in the California Health and Safety Code, Section 41705.

7-200 **DEFINITIONS**

7-201 **Odor Free Air:** Air which has been passed through a drying agent followed by two successive beds of activated carbon.

7-202 **Kraft Pulp Mill:** Any combination of industrial operations which converts wood to pulp, and which uses in the pulping process an alkaline sulfide cooking liquor containing sodium hydroxide and sodium sulfide.

TABLE I
DILUTION RATES

Elevation of Emission Point above Grade In Meters (Feet)	Dilution Rate (Volumes of odor-free air per volume of source sample)
Less than 9 (30)	1,000
9 to 18 (30 to 60)	3,000
18 to 30 (60 to 100)	9,000
30 to 55 (100 to 180)	30,000
greater than 55 (180)	50,000

7-300 **STANDARDS**

7-301 **General Limit on Odorous Substances:** A person shall not discharge any odorous substance which remains odorous after dilution with odor-free air as specified in Table I. Samples shall be collected and analyzed as prescribed in Section 7-400.

7-302 **Limit on Odorous Substances at or Beyond Property Line:** A person shall not discharge any odorous substance which causes the ambient air at or beyond the property line of such person to be odorous and to remain odorous after dilution with four parts of odor-free air.

7-303 **Limit on Odorous Compounds:** A person shall not discharge concentrations of odorous compounds in excess of those specified in Table II, except that this Section shall not apply to kraft mills.

TABLE II

MAXIMUM ALLOWABLE EMISSION CONCENTRATIONS IN PPM

Compound or Family of Compounds	Type A Emission Point	Type B Emission Point
Dimethylsulfide $(CH_3)_2S$	0.1	0.05
Ammonia NH_3	5000	2500
Mercaptans calculated as methylmercaptan CH_3SH	0.2	0.1
Phenolic compounds calculated as phenol C_6H_5OH	5.0	2.5
Trimethylamine $(CH_3)_3N$	0.02	0.02

7-400 **ADMINISTRATIVE REQUIREMENTS**

7-401 **Collection of Samples:** Samples shall be taken and transported in a manner which minimizes alteration of the samples either by contamination or loss of odorous material.

7-402 **Analysis of Samples:** All samples shall be evaluated as soon after collection as possible in accordance with the procedures set forth in Sections 7-403, 7-404 and 7-405.

7-403 **Evaluation Apparatus:** The evaluation apparatus consists of a dynamic olfactometer (variable dilution device) which accepts a field sample, dilutes it with odor-free air and conducts it to an inhalation mask at a flow rate of approximately 14 liters/minute (0.5 cfm).

7-404 **Evaluation Procedure:** Three subjects, selected by the APCO, are seated out-of-sight of the evaluation apparatus and fitted with the inhalation mask. The subjects shall be selected in accordance with procedures approved by the APCO and which are designed to eliminate prospective subjects who have olfactory sensitivity deemed by the APCO to be unduly sensitive or unsensitive at the time of the test. A signal lamp and a signal switch are in front of each subject. The subjects are given 20 presentations, each of 5 seconds duration and 10 seconds apart, for appraisal. Half the presentations (10) are diluted field sample, and half (10) consist only of odor-free air. The presentations of sample and odor-free air are given in random order. At the time each presentation is made, each subject's response is solicited by lighting the subject's signal lamp. If the subject can detect any odor, he responds by pressing his signal switch. The operator records each subject's affirmative or negative response. If the presentation of a sample elicits an affirmative response in less than 5 seconds, odor-free air is substituted for the remainder of the 5 second presentation period. During the 10 second relaxation period between presentations, odor-free air is supplied to the mask.

7-405 **Evaluation Analysis:** For the purpose of this Regulation, a diluted sample shall be deemed odorous if during evaluation as prescribed in Section 7-404 at least two of the subjects gave negative responses to at least 8 of the 10 odor-free or "blank" presentations and affirmative reponses to at least 8 of the 10 sample presentations. Samples deemed to be odorous in accordance with the evaluation analysis described in this Section shall be deemed to be a violation of the limits established in Sections 7-301 and 7-302.

7-600 MANUAL OF PROCEDURES

7-601 Collection of Samples: Samples of odorous compounds specified in Section 7-303. Table II, shall be collected as prescribed in the Manual of Procedures, Volume IV, ST-1, ST-8, ST-11, ST-16, ST-22.

(Amended March 17, 1982)

7-602 Sampling Equipment and Techniques for Collection: Sampling equipment and techniques for collection purposes in Section 7-401 are prescribed in the Manual of Procedures, Volume IV.

(Amended March 17, 1982)

Sec. 22a-174-23. Control of odors

(a) (1) No person shall cause or permit the emission of any substance or combination of substances which creates or contributes to an odor, in the ambient air, that constitutes a nuisance.

(2) An odor constitutes a nuisance if present with such intensity, characteristics, frequency and duration that:

(A) It is, or can reasonably be expected to be, injurious to public health or welfare, or

(B) It unreasonably interferes with the enjoyment of life or the use of property, considering the character and degree of injury to, or interference with, the health, general welfare, property, or use of property of the people affected, and the location of the pollution source and character of the area or neighborhood affected. Whether the source of the emissions was present in the location first shall not be a consideration.

(3) Except as provided in subsection (b) of this section, in determining whether an odor constitutes a nuisance the commissioner shall review information gathered from any source of information, including but not limited to citizen complaints and site inspections or surveys.

(b) Odor in the ambient air shall be deemed to constitute a nuisance if a representative of the commissioner or at least fifty percent of any group of representatives of the commissioner determines, based upon at least three samples or observations in a one hour period, that after a dilution of seven parts clean air to one part sampled air, the odor is equal to or greater than the odor detection threshold. Each of the three or more samples or observations shall be separated by at least fifteen minutes. The burden of rebutting the presumption of nuisance created by this subsection shall be on the owner or operator of the source.

(c) Odor in the ambient air shall be deemed to constitute a nuisance if any substance or combination of substances is present at a concentration in excess of any concentration stated in Table 23-1 of this section. The burden of rebutting the presumption of nuisance created by this subsection shall be on the owner or operator of the source.

(d) The commissioner may determine that an ambient odor which does not exceed the limits set forth in subsections (b) or (c) of this section nevertheless constitutes a violation of subsection (a) of this section.

(e) If the commissioner finds that a violation of this section has occurred and reasonably suspects that a certain source has caused or contributed to such violation, the commissioner may issue an order requiring the owner and/or operator of such source to investigate whether it has caused or contributed to such violation. The commissioner may reasonably suspect that a source has caused or contributed to a violation based upon one (1) or more of the following: citizen complaints; comparisons of odors upwind and downwind of the source; material handling and storage practices; methods of operation; site inspections; surveys; information gathered from any other source; or actual or estimated stack emissions, fugitive emissions or ambient pollutant concentrations.

(f) The commissioner may use air quality modeling techniques to calculate ambient pollutant concentrations. The commissioner shall not use air quality modeling results as the sole basis for finding a violation of this section, unless the commissioner has received ten or more written complaints within ninety (90) consecutive days from separate households.

(g) Any person who is required to undertake an investigation and remediation pursuant to this section shall assure that all samples and measurements taken in any investigation and remediation are representative of the activity required to be sampled. In calculating ambient air quality impacts, such person shall use applicable air quality models, data bases or other techniques approved in writing by the commissioner for the subject source and any other source which is included in the analysis.

(h) Notwithstanding the provisions of subsection 22a-174-3 (c) of the Regulations of Connecticut State Agencies, in acting on an application for a permit to construct, the commissioner need not perform or review modeling to determine that a proposed source will operate in compliance with subsection (c) of this section.

(i) Nothing in this section shall permit emission of any pollutant in violation of any other section, and compliance with any other section shall not constitute compliance with this section.

(j) An argicultural or farming operation shall be exempt from the provisions of this section to the extent provided by Section 19a-341 of the General Statutes.

(k) The provisions of this section shall not apply to mobile sources or structures which are occupied solely as a dwelling and contain six or fewer dwelling units.

Table 23-1

Odor Limit Value in parts per million, fifteen-minute average

Compound	*Concentration*
Chlorine	0.0240
Ethyl acrylate	0.00037
Ethyl mercaptan	0.00040
Formaldehyde	2.49
Hydrogen sulfide	0.0045
Methyl ethyl ketone	17.0
Methyl mercaptan	0.0010
Methyl methacrylate	0.34
Perchloroethylene	71.0
Phenol	0.12
Styrere	0.15
Toluene	11.0

(Effective October 1, 1990)

Source Emission Odor Measurement by A Dynamic Forced-Choice Triangle Olfactometer

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Current odor emission control regulations specify a syringe dilution technique to determine odor concentration level of exhaust stack emissions. This procedure in practice is cumbersome, slow, and subject to improvisations. Further, there is no satisfactory provision to check reliability of positive-negative responses of panel. An approach is desired where the diluted odor sample is presented to the panel for discrimination from samples of non-odorous air and results can be related to statistically significant confidence levels.

An olfactometer based upon forced-choice triangle statistical design was designed and constructed. One diluted odor sample and two non-odorous air blanks are presented dynamically at each dilution level. Each panelist is required to judge which of three ports is odorous and to signal a choice. The three ports are arranged in a circular symmetrical pattern to achieve a double-blind sample presentation since neither panelists nor panel leader know the correct choice until after the judgment is made. Dynamically diluted stimuli are presented at constant flow in ascending concentration order, increasing by a factor of 3 per step. Three odor dilution steps are available on a continuous basis during the evaluation. Evaluation of one sample is routinely completed by a panel of 9 within less than 15 minutes. Statistical data compilation is achieved by ranking procedures to obtain the average panel odor threshold for each sample. Testing of rendering plant odor emissions resulted in a satisfactory correlation between the dynamic olfactometer and syringe dilution methods.

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Needs exist for a fast, convenient procedure for measuring the odor dilution thresholds of odorous emissions from various sources including rendering plants. Various regulations establish the compliance limit, usually in terms of ASTM odor units. Whenever regulations apply to ambient odors only, the industrial plant needs a measuring device to determine the odor level in stack emissions, particularly where adjustments are required in the plant operation to compensate for a change in atmospheric conditions that could influence compliance with the ambient odor standard. Odor control devices need monitoring to determine their performance to the mutual satisfaction of both purchaser and vendor.

Although the syringe dilution test[1] or its variants[2-4] are extensively used for these purposes, they are subject to improvisation, especially in selecting the order of the dilution presentations. Whenever such procedures are used routinely, there is a tendency to expedite the test and minimize the number of the sample presentations. Data obtained under these conditions are of questionable value.

A study was conducted to alleviate this problem. Principles of sensory evaluation were reviewed. Those which held promise for a practical odor evaluation procedure were selected and an olfactometer was built for their convenient implementation. Tests were conducted to compare the new method with an updated version of the ASTM syringe dilution test. A compatible source emission sampling technique was also evolved.

General Considerations

The simple notion that the odor threshold of a substance is a constant which is measurable as confidently as its melting point has been dissipated by the psychophysical signal detection theory.[5-7] The threshold value varies with the method of the panelist's exposure to the odor stimulus, with the type of the response requested and with the judgment criteria used by the panelist to arrive at his decisions which depend on his motives and on the consequences of the judgment. The number of measurements needed to account for all such effects to the satisfaction of current threshold theory is too large for routine use.

Since the panel-determined odor threshold is a function of the method used, it does not directly measure the odor detectability in the ambient air but merely relates to it in some way. Therefore the laboratory values of the odor thresholds by any technique are expedients subject to interpretation. The desirable techniques are those which are least arbitrary, more reproducible, and require the least effort.

Principle. A requirement that one volume of the effluent diluted to X volumes by air should result in an odor below the threshold can be restated. The *target* is an odorless air. Will one volume of the effluent diluted to X volumes by air be indistinguishable from this target at some prescribed statistical significance level? Such comparisons with a target are common in industrial quality control and are usually solved by multiple choice methods.

Thus, in the triangle method, two target samples and the unknown are presented. The panelist must indicate the odd sample—that which is different from the other two.[8] Such a test would establish whether the subject can reliably detect odor at a selected concentration.

Elimination of Sources of Variability. Odors above the threshold cause a temporary desensitization which requires imposition of certain timing in tests. Ascending order of presentation (with a multiple choice at each dilution) proceeding from the more dilute to more concentrated mixtures of effluent with air circumvents this difficulty. The consistency of response is recognized by the correct choices.

If the panel leader knows the correct choice, he can unconsciously influence the panelist through clues such as gestures, intonations, sample codes, and positions. A double-blind procedure, in which neither the leader nor the panelist knows the correct choice until after the judgment, eliminates the leader/panelist interaction. Positional preferences (e.g., preference of the center sample over the left or the right) may be reduced by a symmetrical design. Clues in the sample code can be prevented by not coding at all.

Speed. Time is wasted when the panelists wait for the preparation of dilutions. All needed dilutions must be ready for presentation before the test and should remain constant during the test. This is possible if several odor levels are simultaneously generated by dynamically diluting the effluent with air. A system in which the leader records panelists' judgments also saves time.

Physical Dimensions. Fast flow rates of diluted effluents have been known to produce lower dilution thresholds (higher number of odor units) and are assumed therefore to be more "correct"; the question remains whether a combination of an odor stimulus and a stimulation of nose by high air flow results in a lower odor threshold.[9] High flow rates require large effluent samples, special ventilation systems, etc. The ventilation and space requirements for the odor evaluation room should be minimized. Portability of the olfactometer is an asset.

Currently, effluent samples are taken in a variety of plastic bags. For routine sampling, smaller and inexpensive bags are preferred. Although an immediate evaluation is desirable, it is often not feasible. Therefore, the samples may need to be stored for 1–2 days and should not significantly deteriorate in storage.

Data Evaluation. Since panels of 10 subjects or less are a rule rather than an exception in industry, the mathematics of the data evaluation should be suitable. An exact calculation, as an alternative to plotting, should assist in avoiding arguments as to the "best straight line."

Correlation with Syringe Dilution Method. Much of the existing odor control technology has been based on odor data obtained by the syringe dilution method. A correlation between the developed method and the ASTM method should exist. This may be in a form of a proportion or a more complex relation. However, for a given ASTM value the corresponding value by the new method should be established.

Standardization of Panelists. A provision for testing the panelists' sensitivity with some known odorant is desirable to avoid panelists who exhibit an abnormal sense of smell at the time of the test.

Experimental

Odor Sampling and Evaluation Methods

Figure 1 shows the sampling method where a peristaltic pump (P) extracts the effluent and delivers it into container (B). The container is a thick-wall (0.020 in. plus) hand-collapsible 18 liter (5 gal) polyethylene container available routinely in commerce with a polyethylene faucet valve. The sampling rate is $\approx$1400 ml/min. The pumping element is a length of a discardable Tygon tubing (low-odor grade, for food) which is rapidly "milked" by the pump rollers. The sampling tubing is first equilibrated by pumping and venting the effluent. The bag is then flushed with a few liters of the effluent, disconnected, and collapsed by hand to expel this preflush. Finally, the bag is filled with the effluent sample.

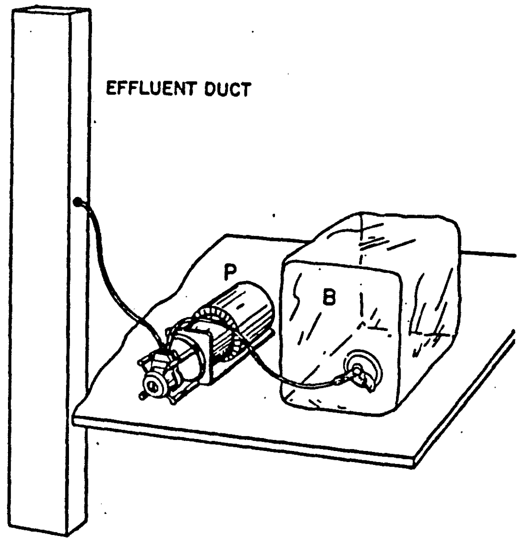

Figure 1. Sampling.

Figure 2 depicts the olfactometric evaluation. Figure 3 shows the internal connections in more detail. A similar peristaltic pump (P), but pumping at a rate of 30 ml/min, delivers the sample from bag B into the splitter of the olfactometer. The splitter consists of 3 different lengths of $\frac{1}{16}$ in. o.d. 0.010 in. i.d. stainless steel capillary tubing and produces effluent flows of 1, 3, and 9 ml/min (L, T, H in Figure 3). Dump tubing is provided to divert the excess effluent into a small active carbon absorber (not shown).

A carbon vane pump (A) delivers room air through an active carbon adsorber (F) to a primitive manostat (M). This consists of a plastic standpipe immersed to an adjustable depth in water. As long as the excess air bubbles at the lower end of the standpipe, the air pressure in the tee (T) is approximately constant. From T, the air is distributed through 0.030 in. i.d. stainless steel capillaries at 600 ml/min to each sniffing port. There are 9 ports mounted in symmetrical circular arrangement in groups of 3 in 3 plastic tumblers.

The connections to the ports consist of AWG 16 Teflon tubing. An electrical pushbutton switch is mounted below each port on the tumblers. The tubing lines and the wires pass from the tumbler to the main apparatus through a flexible neoprene tube which

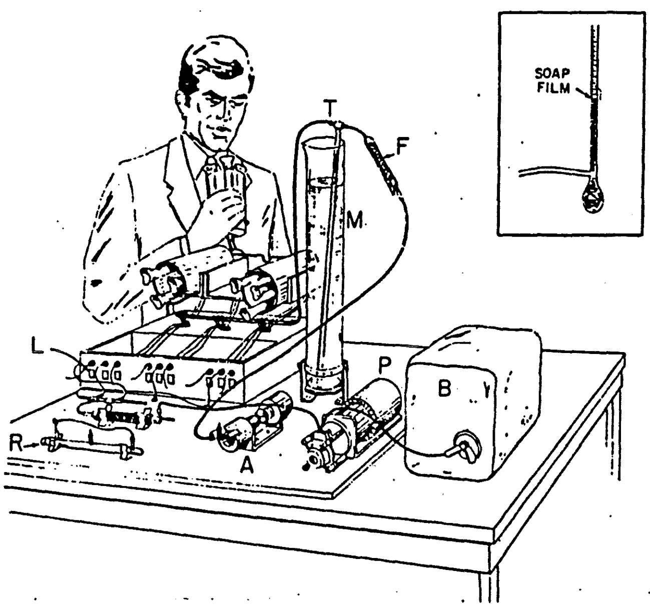

Figure 2. Sample evaluation in the dynamic dilution forced-choice triangle olfactometer.

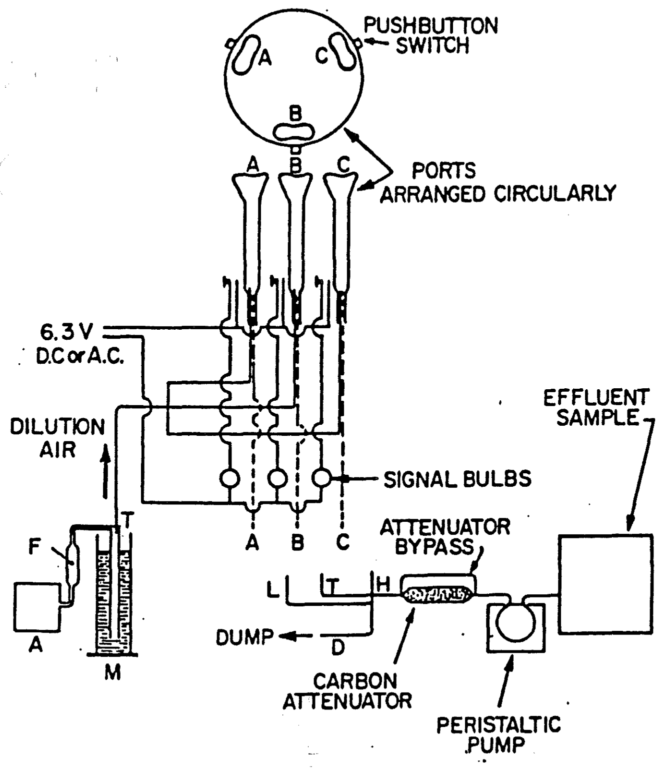

Figure 3. Flows and connections in the olfactometer.

permits a limited rotation of the tumbler. Effluent, e.g., from the middle splitter flow line at 3 ml/min, can be channeled to any port in the same tumbler, but to only one port at a time. The two other ports hold spare idle Teflon lines.

In each tumbler the panelist smells all three ports and must signal his decision by depressing the button corresponding to that port which is judged to be odorous—"different" from the other two in the *same* tumbler. The panel leader observes the signal panel. He knows which line delivers the effluent from the splitter, but does not know to which port this line goes. Signal lamps (L) indicate the panelist's choice. This implements the double-blind feature: neither the panelist nor the leader knows the correct choice, which becomes known to the leader only after the judgment. Provision could be made to record the judgments. The same panelist can repeat a judgment provided that the tumbler is rotated back and forth before the judgment is repeated.

For example, the middle tumbler may supply a nominal dilution of 1:200. The other two tumblers supply dilutions of 1:68 and 1:600—varying by a factor of 3 from the middle concentration. The actual flow rates to be used in the dilution calculations are checked before the test by a conventional soap film flowmeter, shown in the insert of Figure 2. The range can be extended to higher concentrations (lower odor units) by changing the peristaltic pump head. The range can be extended to lower concentrations (more odor units) by inserting one or more attenuators, *cf.* Figure 3. The attenuator is a 1:27 splitter, with 26/27 of flow passing through a small carbon adsorber, and 1/27 of the effluent bypassing. The two flows—the deodorized 26/27 and the odorous 1/27—mix again after the attenuator so that the initial flow rate of the effluent is maintained. With the attenuator in the Teflon line between the pump and the splitter, the dilutions increase by a factor of 27, to 1800, 5400, and 16,200 odor units. Additional attenuators, not shown, permit more dilutions. If intermediate dilution levels are required, appropriate attenuators can be used to supply finer adjustments, e.g., raising the dilutions by a certain percentage.

A reference odorant vapor generator (R) can be inserted into the line between pump P and the splitter to evaluate the sensitivity of the panelists to known odorants.

The apparatus of Figure 2 was intended to explore the method and to compare its odor values with those obtained by the syringe method. The dilution in the middle tumbler could be adjusted to any selected target value. The two other tumblers have their dilutions set at levels above and below the target value. By obtaining panel judgments at these 3 dilution levels, the degree of meeting the target value is evaluated.

Odor Value Calculation

Two questions arise in determining the odor threshold of the panel: how to derive each panelist's threshold and how to combine the panelists' thresholds into a group threshold. It was felt that instead of adhering to the simple cumulative plotting on the logarithmic vs. percentage probability paper, a fresh look should be taken and the best suitable procedure adopted.

Detection Criterion. The experimental design used is known in psychophysics as the ascending method of limits.[10,11] A correct response (indicating the correct stimulus in a choice between blanks and the stimulus) at several consecutive ascending stimulus strength levels is taken to indicate that the lowest strength stimulus in the series has not been selected by chance.

In the ascending forced-choice triangle method used here, a correct choice at two consecutive odor concentration levels can occur by chance in one attempt out of nine. Usually, with an increase in odor concentration by a factor of 3 per step, the panelist is then already positive that he judged correctly. Thus, for example, a panelist missed at 1800 dilutions, but made a correct choice at 600 and again at 200 dilutions. This indicates that the panelist began to detect consistently at 600 dilutions.

Furthermore, it is statistically valid to consider that this ability to detect could have started somewhere between 1800 and 600 dilutions. The overall error is minimized if it is assumed that the ability began at the geometrical mean $(1800 \cdot 600)^{1/2} = 1040$ dilutions. In practice, logarithms are used and the arithmetical mean of the logarithms represents this intermediate level. A term "tolerance level" has been applied to such intermediate value.[12] It is retained here to stress its specific meaning.

Calculating Group Threshold. Within panels of 10 or less subjects, a normal distribution of the individual sensitivities cannot be expected to occur systematically. Ranking procedures are advised in such cases[13] before the conversion to the probability plot coordinates.[14]

Table A in the Appendix simplifies the calculation. It produces plotting values which can be used to enter data on regular rectangular graph paper or to calculate the least squares fit straight line, *cf.* formula in the Appendix. Exact calculations eliminate arguments on the position of the best line.

Example Calculation. Table I shows typical raw data. The log (tolerance level) value is the arithmetical mean of the logarithm of the dilution factor that applies to the given stimulus and of the logarithm of the dilution factor that applies to the next more diluted stimulus. The bottom line summarizes the number of the panelists *beginning* to detect odor "consistently" at the respective tolerance levels.

Table I. Raw data.

	Dilution Levels			
	1	2	3	4
	Log (Dilution Factor)			
	2.02	1.57	1.13	
	Log (Tolerance Levels) = Y			
	2.24	1.80	1.35	0.91
Panelists				
1	−	−	(+(!)	
2	(+	+		
3	−	(+	+	
4	−	(+	+	
5	+	−	(+(!)	
6	−	−	(+(!)	
7	−	(+	+	
8	−	−	−	(+(?)
9	−	(+	+	
Frequency of Thresholds	1	4	3	1

Notes:
+ panelist made a correct choice of port.
(!) panelist very positive that his choice is correct.
(?) this level was not actually presented, but it would not make any difference after ranking, since it will be occupied by the last rank.
(the lowest "consistently detected" level for the particular panelist, per criterion in the text.

Table II converts these values to plotting values. The first column repeats the tolerance levels (Y). The second column transcribes the last line from Table I. The third column ranks the tolerance levels as follows. At the lowest odor concentration, only one panelist began to detect; he occupies rank 1. At the next odor concentration, 4 more began to detect; they occupy ranks 2, 3, 4, and 5, with an average rank of 3.5. At a still higher level, 3 more panelists began to detect, occupying the ranks 6, 7, and 8, or an average rank of 7; etc.

The average ranks are converted to the probability-related plotting values (X) shown in the last column, using the table in Appendix; for information, these are equal to (probits − 5).[15] Here we use the column for 9 panelists. The Y values are plotted vs. the X values on a rectangular graph paper, Figure 4, left and bottom scales. The upper and the right-hand scales illustrate the corresponding log probability paper coordinates. The straight line plot intercepts the X = 0 coordinate at the level of the group threshold, log ED_{50}.

For the exact calculation of the intercept value, refer to the example in Appendix.

Nomenclature. To distinguish the dynamically obtained group threshold values from the ASTM odor units, the term ED_{50} is used.[11,12] This term is a traditional concept and denotes the "Effective Dose at 50% level." ED_{50} is defined as that odor concentration at which half of the panelists would begin to detect odor in the dynamic test.

Table II. Conversion to plotting values.

Log (Tolerance level) = Y	Frequency of threshold distribution	Average rank of tolerance levels	Plotting value from Table A in Appendix = X
2.24	1	1	−1.28
1.80	4	3.5	−0.39
1.35	3	7	+0.58
0.91	1	9	+1.28

ASTM Syringe Dilution Test

Considerations. The text of the ASTM D 1391 method is imprecise regarding certain points. These include the order of stimuli presentation, definition as to when consistency has been reached, and the method of threshold averaging. It is understood that clarifications may be made in its scheduled 1973 reconfirmation.

The basic intent is to maintain a fundamental trend in the order of presentation and to prevent a predictable sequence by frequent presentation of out-of-order stimuli. Convincing evidence exists[10,16−20] that an ascending order of concentrations is better and more practical than a descending or one completely randomized.* It reduces the effects of the temporary olfactory fatigue (adaptation). It also eliminates a carry-over of stronger odors in the equipment. The effect of predictable order is avoided if the panelist must choose between an odor-containing and a blank syringe, presented to him in a randomized order (blank either on the left or on the right).

The ASTM test further requires that a consistency in the panelist's judgment is to be reached. Occasional reports of odor in blanks, termed "false alarms" in the signal detection theory in psychophysics, are a normal part of the judgment matrix.[3,4] Following the statistical reasoning of the method of limits, a simple criterion is available: three correct choices at three consecutively increased odor concentrations indicate that the panelist's odor threshold has been approximately reached at the lowest of these levels. This can occur by change in one case out of 8, or typically once for each panel evaluation, which is of small consequence after averaging the panelists' data.

The ASTM test prescribes averaging the panelists' thresholds. In the geometric presentation series, a geometric averaging is traditional.

These clarifications are within the possible interpretation of the ASTM text and are in accord with sound sensory evaluation practices.

* Lindvall[16] states: "randomized order ... makes it almost impossible adequately to evaluate odor threshold ..." He advocates an ascending dynamic method of limits, with a blank and a stimulus at each odor level.[21]

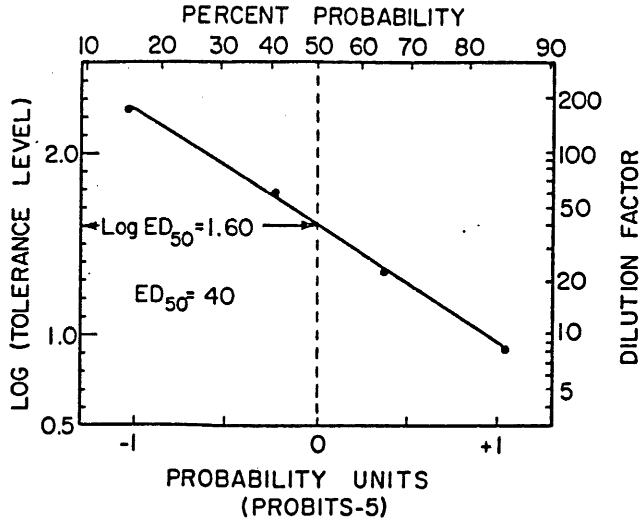

Figure 4. Obtaining ED_{50} by plotting.

Procedure Used. On the basis of the above and in anticipation of the probable clarifications in the D1391 text, the following procedure was used. Each panelist was presented individually with ascending odor concentration samples from syringes. At each concentration, a companion blank syringe was also supplied. The panelist judged both and indicated the odorous syringe. The panel leader monitored the use of the syringes by noting the manufacturer's identification numbers. The leader prepared the dilutions in the panelist's syringe and filled the blank syringe with air behind a screen. The odor concentrations were increased by a factor of 2 per step. When the panelist made the correct choice at 3 consecutive levels, or was positive and correct at the second level, he was excused from further judgments on the same sample. This accelerated the test.

The procedure described was regularly completed on one effluent sample by a panel of nine in less than 50 minutes. The lowest of the correctly selected consecutive odor concentrations was considered as the panelist's threshold. The logarithms of the panelists' thresholds were averaged arithmetically. The antilogarithm of this average is the geometric mean of the thresholds and is equivalent to the odor units.

Experiments Conducted. Odor emissions were obtained from rendering plants in Illinois and Massachusetts using the sampling system described. The sample evaluation was conducted at the Sensory Research Facility of IIT Research Institute in Park Forest, near Chicago, Ill. One sample was taken and evaluated by a local panel at St. Paul, Minn.

For the comparison of the dynamic triangle test with the ASTM test, each sample was evaluated by both methods by the same panelists in the same session. A few samples of the stronger odors were diluted in bags and evaluated to provide additional odor levels.

Samples of 1-butanol and n-pentanal (valeraldehyde) vapors were also dynamically diluted and pumped into similar bags, for the comparison by both methods. This dilution system provided a source for a direct sampling either by the syringe or by the dynamic triangle olfactometer.

Several samples were stored in bags to evaluate the storability of the odors in the thick-wall polyethylene bags used. The same panelists were used as much as possible for the repeated evaluations.

Results and Discussion

Comparison with ASTM Test

Correlation. Figure 5 shows the correlation of the ED_{50} values obtained by the dynamic dilution forced-choice triangle method and by the ASTM syringe dilution method. Each point is based on evaluating the same sample by the same panel at the same session; the plotted point represents their geometric average.

The open circles represent data obtained using the ascending presentation with a stimulus and a blank at each level in the ASTM test. The filled circles represent data obtained by ascending odor concentration series without blanks using an experienced panel trained to be consistent. Here the odor units

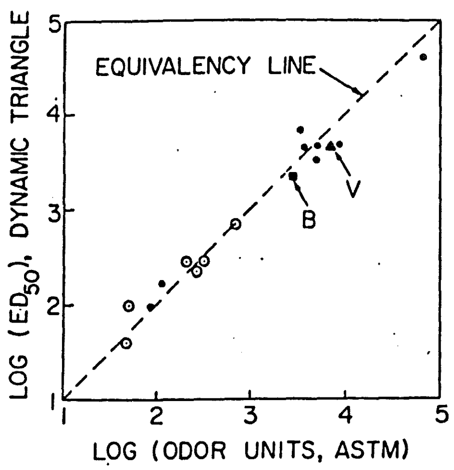

Figure 5. Correlation between the dynamic triangle and ASTM test.

were calculated by utilizing a cumulative positive response percentage plot in log probability coordinates: this is frequently practiced although not within the D1391 test.[2] The butanol (B) and the valeraldehyde (V) points are also shown. The indicated diagonal line would reflect a 1:1 equivalency.

The actual correlation between the two sets of values was evaluated by a computer. The following regression equation was obtained:

$$\text{Log}\ (ED_{50}) = 0.20 + 0.94\ \log\ (\text{odor units})$$

Since the correlation coefficient was 0.98 and the statistical F-ratio[8] was 315, the probability that such correlation would occur by chance is much less than 0.001 (confidence level higher than 99.9%).

The equation yields ED_{50} values which are higher than the ASTM odor unit values: at 1000 o.u. level, by 5%; at 100 o.u., 20%; at 20 o.u., by 33%.

Evaluation of another dynamic method (Hemeon Odor Meter)[21] vs. the ASTM test elsewhere,[22] indicates a similar trend where differences increase at lower concentrations. However, the degree of difference was considerably less in this study compared to the Hemeon study.

Reproducibility. Ten effluent samples from rendering plants were evaluated two or more times by the dynamic triangle method. Five of these were evaluated twice by the syringe method. The average standard deviation of the dynamic log (ED_{50}) values was 0.10 log units, and of the syringe log (odor units), 0.11 log units. This corresponds to approximately 30% in the odor unit value. Thus, the variability is similar although the odor concentrations were increased by a factor of 2 per step in the syringe test and by a higher factor of 3 in the dynamic test. This is in agreement with practice in some industrial sensory evaluations where a factor of 3 per step is found to generate less boredom and to result in data just as reproducible.

Common t-Test[8] indicated no statistically significant differences between the two sets of data for those cases where multiple determinations on the same sample were conducted.

Convenience and Speed. The panelists found the syringe method to be inconvenient. Under less supervision, the panelists would be less rigorously adhering to the rules. The panelists preferred the dynamic triangle method since they could recheck their response to each port and reinforce their original judgmen before signalling their choice.

Under the same conditions, the dynamic triangle test with 9 panelists was routinely completed in less than 15 minutes—more than three times faster than the syringe test. The olfactometer, once connected to the sample bag, supplied the stimuli for several hours. This is an advantage where panelists' judgments can be collected at their convenience without additional preparations by the operator.

The time needed to stabilize the concentrations in the olfactometer was evaluated by panel tests. Judgments stabilized within less than 10 min provided the Tygon tubing in the peristaltic pump was replaced.

Odors from the olfactometer did not accumulate in reasonably ventilated rooms. However, the pump generated an odor and was kept in a ventilated passage. The pump selection needs review.

The olfactometer was portable and durable since it was carried by one person and remained operable after four plane trips.

Storage Experiments

The stability in sampling was explored only with a valeraldehyde/air mixture. A continuously dynamically generated stimulus was evaluated by direct introduction into the olfactometer and also from the bag immediately after filling it from this source. The bag sample was evaluated again after a 48 hr storage in the bag. The values, using the same panelists, were:

log ED_{50} from the source	3.83 (≈6800 o.u.)
from the bag at once	3.70 (≈5000 o.u.)
from the bag after 48 hr	3.67 (≈4700 o.u.)

The slight decrease observed was found insufficient to reach a statistical significance by the t-Test-by-Difference[8] on the individual responses.

Two rendering plant effluent samples were stored in the bags and evaluated 3, 27, and 98 hr after sampling. The results in log (ED_{50}) units were as follows:

Hours After Sampling	Sample I (chlorine free)	Sample II (contained chlorine)
3	3.53	3.65
27	3.63; 3.60 (2 tests)	3.60
98	3.77; 3.77; 3.83 (3 tests)	3.89

These data do not indicate a significant change of the odor in storage.

In an earlier experiment with a simpler olfactometer, a mixture of 5.5 ppm (vol) of hydrogen sulfide and air was evaluated by the same panel immediately after filling the bag and after a 48 hr storage. The ED_{50} increased slightly but the change was statistically insignificant.

Thus, odors seem to be adequately storable for at least a day in the thick-wall polyethylene bags used.

Application as Compliance Method

The dynamic dilution forced-choice triangle method could be used for compliance by performing a one-dilution level test. Assume that a compliance level of X dilution units is specified in the regulations for a stack emission. This would require that one volume of stack sample be diluted to X volumes with non-odorous air and that this diluted odor stimulus be statistically indistinguishable from non-odorous air.

The test then consists of presenting to the panelists an assembly of three sniffing ports where one port delivers the diluted odor stimulus and the other two deliver non-odorous air. The panelist must indicate which of the ports delivers the odor. If a statistically significant fraction of the panel identifies the odorous port correctly, non-compliance is indicated.

To establish a violation at a *0.05 probability of error by chance (95 percent confidence level)*, the following number of panelists must indicate the correct port:

5 in a panel of 7 panelists
6 in a panel of 8 or 9 panelists
7 in a panel of 10 panelists

To establish a violation at a *0.01 probability of error by chance (99 percent confidence level)*, the following number of panelists must indicate the correct port:

6 in a panel of 7 panelists
7 in a panel of 8 or 9 panelists
8 in a panel of 10 panelists

This test would be simple to perform and would quickly establish the proximity to being in compliance. However, if a critical determination of compliance is required, it is proposed that a three-dilution-level test be made. This requires the use of three assemblies of triangular sniffing ports. The odor stimulus port for one assembly has its dilution set at the compliance limit or middle level. The odor stimulus ports for the other two assemblies have their dilutions set at the upper and lower levels with the compliance level being in between. For example, if X dilution units coincides with the compliance limit, the lower dilution level is X/3 and the upper level is 3X. By this approach, the dilution level detected by a statistically significant fraction of the panel could be numerically defined. Thus, the magnitude of variation in being either above or below the compliance level is clearly established.

The procedure for selecting the panel members should be defined in the compliance method. Panel selection was not considered to be within the scope of this study.

Acknowledgment

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Appendix

Aids for Calculation of ED_{50} Values in Olfactometry

Table A. Plotting values for the best fit ("Least squares") straight line.

Explanation: the equation for the straight line is:

$$Y = b + mX$$

Y is log (tolerance level), see text of the paper, Table I
X = plotting value, for the corresponding number of panelists in the panel and the average rank assigned to the respective tolerance level, see text of the paper, Table II
b = intercept on Y at X = 0. It is equivalent to log (ED_{50})

	Number of Panelists				
Average Rank	6	7	8	9	10
1.0	−1.07	−1.15	−1.22	−1.28	−1.33
1.5	−0.79	−0.89	−0.97	−1.04	−1.10
2.0	−0.57	−0.67	−0.77	−0.84	−0.81
2.5	−0.37	−0.49	−0.59	−0.67	−0.75
3.0	−0.18	−0.32	−0.43	−0.52	−0.60
3.5	0	−0.16	−0.28	−0.39	−0.47
4.0	+0.18	0	−0.14	−0.25	−0.35
4.5	+0.37	+0.16	0	−0.13	−0.23
5.0	+0.57	+0.32	+0.14	0	−0.13
5.5	+0.79	+0.49	+0.28	+0.13	0
6.0	+1.07	+0.67	+0.43	+0.25	+0.11
6.5		+0.89	+0.59	+0.39	+0.23
7.0		+1.15	+0.77	+0.58	+0.35
7.5			+0.97	+0.67	+0.47
8.0			+1.22	+0.84	+0.60
8.5				+1.04	+0.75
9.0				+1.28	+0.91
9.5					+1.10
10.0					+1.33

Formula for Exact Calculation

of Log (ED_{50}) Value from Y = Log (tolerance level) and X = Plotting Value from the Preceding Table A.

$$\mathrm{Log}(ED_{50}) = \bar{Y} - (\bar{X})\,\frac{\Sigma(X.Y) - N.\bar{X}.\bar{Y}}{\Sigma(X^2) - N(\bar{X})^2}$$

Here:

$\bar{Y}$ = mean value of Y for the data
$\bar{X}$ = mean value of X for the data
$\Sigma(X.Y)$ = sum of products of each X with the corresponding Y
$\Sigma(X^2)$ = sum of squares of X values
N = number of plotting points

Example of Calculation for Data in Table II of the Paper

Log (Tolerance)	Rank Plotting Value from Table A	Number of points = N = 4	
Y	X	$X.Y$	X^2
2.24	−1.28	−2.8672	1.6384
1.78	−0.39	−0.6942	0.1521
1.35	+0.58	+0.783	0.3364
0.91	+1.28	+1.1648	1.6384
$\Sigma Y = 6.28$	$\Sigma X = +0.19$	$\Sigma(X.Y) = -1.6136$	$\Sigma(X^2) = 3.7653$

$$\bar{Y} = \frac{6.28}{4} = 1.57 \qquad \bar{X} = \frac{0.19}{4} = 0.0475$$

$$\mathrm{Log}(ED_{50}) = 1.57 - (0.0475)\,\frac{-1.6136 - (4)(0.0475)(1.57)}{3.7653 - 4(0.0475)^2}$$

$$= 1.59$$

Discussion

R. E. Nisbet
A. E. Staley Manufacturing Company
Decatur, Illinois

1. We are definite proponents of the dynamic method, but we feel that the olfactometer designed by Dr. Dravnieks is too complicated and probably too expensive for general use.

2. We feel the seeking of the "ultimate" threshold is probably not justified by the objective we are pursuing. Our concern is for annoyance of our neighbors. At any level where the panelist questions whether or not he can detect the odor, it is surely at a level below annoyance and we are not overly concerned beyond this point. The triangle approach introduces psychological aspects which we feel do more harm than good to the decision-making process.

3. We concur in Dravnieks' conclusion about the keeping quality of samples. This should probably be verified for generic types, but for the gases with which we have most concern, we stored a sample in a Sears-Roebuck leaf bag for 30 days and got the same values as measured before storage.

4. One thing we feel should be added to the article is a discussion of the preparation of dilution air. We filter the air, dewater it through Drierite, deodorize it through activated carbon, and then rehumidify the air by bubbling through distilled water. We think the re-humidification is important because dry air gives an unnatural "nose feel." This preparation of the air gives a constant zero value for comparison purposes.

5. We question the value of the higher mathematics and elaborate plotting to obtain ED_{50}. We think the basic reliability of the data does not justify more than a simple average of panelists threshold dilutions. In the case of large panels (+6), the high and low values could be discarded.

6. We would not question the complexities of Dr. Dravnieks' technique for use in enforcement action or litigation. It has checks and balances which offer a measure of protection not needed for the usual in-plant odor panel where process and equipment choices are being made. We do feel some order needs to be brought to the subject of legislation and regulation of odor. Several states in which we do business have regulations requiring "no odor" to be transmitted beyond a plant boundary. In Illinois the EPA has actually solicited complaints from areas surrounding a plant and sued, in the absence of stated limits, based on a claimed nuisance value. We definitely prefer the academic to the emotional or political approach. And we feel that it is the duty of the APCA to lead the way to rationality.

7. We tried the syringe method in the beginning for a brief period, but we didn't like it because not enough sample was available to the panelist. We then modified the technique to use 1 liter plastic squeeze bottles. This was a definite improvement, but it took a lot of operator time to make up all the dilutions required for a 5–6 member panel. Cleaning the bottles was a worse chore. When we discovered the dynamic method developed by Hemeon Associates we became real enthusiasts. This permits a large sample volume and a source of purified air for comparison.

8. One further comment. We do not question the syringe method. Under careful hands comparable results should be obtained. We feel that the dynamic method is simpler, faster, and requires almost no panelist training.

Discussion

W. C. L. Hemeon
Hemeon Associates
Pittsburgh, Pennsylvania

The authors present an interesting dynamic dilution apparatus for quantitative measurement of odor concentrations which will compete for attention with the ASTM small glass syringe method and the high volume dynamic method.[1]

This discussion concerns itself partially with the very large discrepancy of several hundred percent between results by the different methods. This new method yields results in agreement with the ASTM syringe method according to the authors, but the latter commonly understates concentrations of odor by a factor of 5 or 6 to one when compared to results by the high volume dynamic odormeter.

Unfortunately this is a low volume device 0.02 cfm, 0.6 l/min), as is the ASTM method, which provides only a small fraction of air inspirated during a sniff. This would permit unmeasured dilution at the nostril entrance fully sufficient to account for its agreement with the low values of odor concentration that are given by the syringe method.

The principle of the forced-choice feature for refining the derivation of threshold odor values has merit in our opinion. Although different, it is comparable, as to its ultimate result, to the procedures we employ for this purpose.

In order to understand better the typical results given by the authors, we have translated and rearranged the data in their Table I so that they would conform to our system of data recording and handling, and thereby permit comparison. In doing this, we changed the "log (dilution factor)" to the number itself, i.e. dilution ratio, and transformed the authors' symbols to our system of 0-1-2-3, as follows:

—	= 0	(Odor not detected)
(+	= 1	(Very faint, or doubtful)
+	= 2	(Perceptibly stronger than 1)
(+(!)	= 3	(Perceptibly stronger than 2)

Using these transformed data, and rearranging them as shown, makes them comparable to our system for displaying raw test data (Table IA).

Table IA. Raw test data.

Dilution ratio	Panelists: 1	2	3	4	5	6	7	8	9
105	0	1	0	0	2	0	0	0	0
37	0	2	1	1	0	0	1	0	1
11	3	—	2	2	3	3	2	0	2

This method of comparison shows that there is marked disagreement among panelists. The disagreement resembles that typical of the syringe method. The statistical treatment of the data the authors adopted is also employed in the treatment of ASTM syringe data because of the difficulty in establishing an absolute detection level.

The agreement among panelists possible with the high volume systems leads us to the conclusion that the differences among the panelists displayed in the atable above, do not reflect differences in individual sensitivity. We feel it must be a consequence of the particular characteristics of their system.

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Discussion

Howard E. Hesketh
Southern Illinois University at Carbondale

The development of this forced choice dynamic olfactometer can certainly be another step toward obtaining improved odor data. There is no doubt in my mind that portable, dynamic systems such as this can be reliable and consistent; however, I am concerned about the low air flow rate supplied to the panelists by the olfactometer.

Studies at Southern Illinois University at Carbondale show that healthy male adults have a ventilation rate of about 8 liters per minute (lpm) of inspired air when at rest and anywhere from 40 to 80 lpm after a brisk walk when the pulse rate is 150 beats per minute. The 0.6 lpm supplied by the olfactometer *must* lead to dilution errors under even the most ideal conditions.

Most of my odor studies are performed using the dynamic "odor meter" which by contrast produces about 30 lpm to each panelist. This amount of air flow eliminates the possibility of dilution errors when panelists are used to detect odors while at rest and when instructed not to breathe excessively large gulps of air. Air movement across the face of a panelist can create a sensation which may be construed as an odor, so the panelists must be trained and experienced in this fact as well as in the normal odor panel points when working with the odor meter system. I believe the dilution factor must be recognized and large air flows must be used appropriately.

Another factor to be considered is that odor recognition level and odor nuisance level are different. For example, my tests show that low concentrations of hydrogen sulfide (from 0.5 to 6 ppb) can be consistently detected, but it smells sweet (like a bakery) to field panelists who are located in a community downwind from the source and under "continuous" exposure. This is to say that this detected odor is not objectionable even at 6 ppb. Odor measurement systems do not duplicate field conditions needed to establish odor nuisance levels, but these dynamic systems can provide our best data if properly designed and used.

It is noted in the paper that odor samples can be taken and stored for limited periods in "thick-walled polyethylene bags." This should be accepted with caution because odor concentration can change depending on whether (1) the odor or the odor carrier becomes adsorbed by the surfaces of the bag or impurities, (2) a chemical reaction occurs, (3) the odor molecules diffuse through the pores of the bag, and (4) other openings for leakage exist.

Discussion

Charles A. Johnson
Carrier Corporation
Syracuse, New York

Lack of a generally accepted method of odor measurement has deterred promulgation of odor emission regulations by federal, state and local air pollution authorities. The authors have proposed a method for this purpose. The attention to statistical validity is commendable. However, there are other requirements for an odor measurement procedure that should be demonstrated before the method can be generally accepted for uses beyond compliance testing. I hope that the authors will address themselves to these questions in future work.

1. There is need for a method of evaluation of performance of abatement equipment in providing performance guarantees, determining performance equivalence, and continuing operational evaluation. This requires that the discharge odor strength be related to the inlet odor strength by a statistically valid method.

2. It would be advantageous if it could be demonstrated that the odor measurement technique results in odor threshold measurements comparable to the so-called accepted threshold values. If this is the case, it would be possible to use measured odor discharge strengths in conjunction with atmospheric dispersion analysis to predict the strength of odors at observation points down wind of a source. Also, this is necessary if one attempts to relate an odor strength to a measured concentration of a specific contaminant.

3. It would be desirable to be able to measure ambient odor strengths. I would suggest that this be tried and the results reported.

4. There is need for a corroborating testing procedure so that results from different organizations can be compared. It should be possible to develop a metnod of generating a synthetic odor that can be reproduced at will throughout the country.

Closure

We appreciate the detailed comments by Messrs. Nisbet, Hemeon, Hesketh, and Johnson. They cover the entire spectrum of problems in odorous emission measurements, and we would like to respond to them.

Purification of Dilution Air. We feel that the best dilution air is that taken by an odorless pump directly from the odor test room, which has to have essentially odorless air anyway. Any air treatment that makes the dilution air potentially different from the test room air may introduce additional factors.

Sample Storage. In the bags used, samples of rendering emissions and of ppm concentrations of H_2S, or NH_3, or trimethylamine in air were stable for at least 2 days. Nisbet's comment, and Duffy *et al.*[1] mention excellent odorous sample stabilities in similar bags. But of course it would be prudent not to assume, without testing, that all types of samples are equally well storable. Adsorption losses are made practically insignificant by pre-flushing of the bags, *cf.* Duffy.[1]

Flow Rate. We firmly believe that the differences in the detection levels between panelists using the described olfactometer are caused by genuine differences in the sensitivity of panelists, and are not merely a result of the lower stimulus flow rates. We did not pre-select panelists, since we wanted to approximate the sensitivity distribution of population. Wilby[2] used manifold flow rates of 100 cfm and 10 in.[2] sniffing ports, and found differences in the sensitivity between the most and the least sensitive individuals in a ratio from 1:25 to 1:60, well in line with our experience. Duffy[1] discarded the least sensitive candidates, but still observed differences in the pre-selected panelists in a ratio up to 1:10, with stimuli delivered at multiliter/min rates. His study contains a graph which indicates a reasonable (within 50%) agreement between values obtained by his rapid flow olfactometer and those by our slower flow device. He believes that individuals probably adjust to the available sample size. Of course, higher flow rates, or completely open-air stimulus testing, are preferable. We selected lower flow rates to provide portability, to permit using sample sizes that may be conveniently air-shipped, and to permit testing in rooms with lesser ventilation rates. Relating thresholds obtained by any laboratory olfactometer, even that operated at fast flows, to the detectability of odor in open air is a problem for extensive future research.

Annoyance vs. Detectability. We fully agree that different emissions at the same concentrations in terms of the "odor units" may widely differ in the level of annoyance to the population. Much research is needed on this aspect of the odorous air pollution.

In Mr. Nisbet's comments, he refers to the "triangle approach introducing psychological aspects which we feel do more harm than good to the decision-making process." It is not clear what exact point is being made. However, it has been our experience that panel members, as a result of being able to compare the diluted stimulus ports with the two odorless ports, had a greater degree of confidence in their decision as opposed to that associated with the ASTM syringe method.

"Editing" Panel Data. Discarding low and high readings, as suggested by one of the discussors, would introduce arbitrariness. Why not use best available statistical approach to treatment of the data, short of computer technology?

Evaluation of Odor Abatement Equipment Performance. The described olfactometer currently supplies six dilution ranges simultaneously and the range can be significantly extended by utilizing an attenuator to bypass a portion of the sample through an activated carbon/permanganated alumina deodorizer. Both inlet and outlet samples, in an odor abatement device, can be tested using the same panelists; t-Test-by-Difference,[3] which eliminates the effect of different sensitivities of the panelists permits establishing the statistical significance of the difference between the two samples.

Ambient Air Odor Olfactometer. Technique similar to one described in this paper is in the last stages of testing. We hope to report on results in 1975.

Comparison of Methods. We support the suggestion that a technique for reproducible generation of synthetic stimuli is needed to compare methods and panels universally. Comparison of several olfactometers with respect to several odorants in the same laboratory has been conducted by TRC Corporation under a contract from Illinois EPA.

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AIR QUALITY ODOR TESTING AT MWCC

REVIEW OF SYRINGE DILUTION AND OLFACTOMETER

ODOR TESTING RESULTS AND

PARAMETERS AFFECTING RESULTS

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QC - 90-180

Chapter 8. Conclusions and Recommendations

I. Introduction

This report presents a review of air quality odor testing at the Metropolitan Waste Control Commission (MWCC) which provides comparative information on the performance of the standard syringe dilution and the olfactometer methods of odor measurement. Parameters affecting results are considered. A revisiting and possible revising of the Minnesota Air Pollution Control Rule 7005.0930 on Odor Testing (1) is recommended based upon study results and the withdrawal from publication, by the national measurement standards setting professional society, of the syringe dilution method for odor testing (2), ASTM Method D-139-57, which is the procedure specified in the Minnesota Rule.

II. Conclusions

Based upon MWCC experience and review of the literature the following conclusions are made:

1. Odor measurement results are highly dependent upon the choice of individuals who serve on the odor panel of persons used for odor testing. This is due in part to the variation in sensitivities to odors among people. Panel selection procedures and panel size influence results.
2. Syringe dilution and olfactometer odor measurements obtained from testing MWCC sludge incinerator stack gas are not correlated and differ by a factor of 4 on the average. Olfactometer results are consistently higher than syringe results.

3. The syringe dilution data reduction method contributes a constant negative bias to the reported odor concentration unit (the reported value is lower than it should be).

4. The olfactometer forced choice test protocol and data reduction method yield odor values which are biased high (the reported values on average are higher than they should be).

5. The ease by which an odor can be recognized can influence the precision of the reported result, i.e., panel performance is better when the odor is easily recognized as shown in the MWCC H2S olfactometer study. Thus reported values for two different odor containing samples could have equal expectations but different variances. This could lead to more frequent limit failure by chance for the less easily recognized odor.

6. The syringe dilution odor measurement method, American Society for Testing Materials (ASTM) Method D-139-57 (referenced as D-1391-78) was discontinued by ASTM on March 29, 1985 (copies can be purchased from University of Microfilming Service, 300 North Zeeb Road, Ann Arbor, Michigan 48106). The MWCC is not aware of any professional standards setting body which supports use of the syringe dilution procedure. Thus the former ASTM syringe dilution odor measurement method should not be the basis for a regulatory rule.

7. The 1980 conclusion of the United States Environmental Protection Agency (USEPA) (4) that the syringe dilution method was not adequate for regulatory purpose is supported by the above cited action of the ASTM.

8. There is need to reconsider how to protect the public welfare from nuisance odors. If an odor measurement system is needed, minimum performance criteria needs to be defined and system performance varified before the system is adopted for use.
9. In 1985 USEPA (5) reported that "the most widely accepted technique for odor measurement is the triangle olfactometer method." Recent work by an ASTM committee (6) on odor measurement has focused upon the olfactometer method. If a measurement system is needed, the olfactometer method should be evaluated.

III. Framing the Problem

The fundamental problem as viewed by the regulatory body and the community of interest is to develop a rule which will define a minimum level of protection from nuisance odors to some or all persons in a given area.

How do you define a nuisance odor? How do you measure it reliably? Do you want to measure it or even try? What approach should be taken? Three different approaches follow:

1. One approach to defining protection is to regulate point source odor emissions without consideration for the actual impact on persons in a given area, i.e., disregarding population location and density. The present rule essentially does this. The advantages of this approach are that it can be uniformly applied and is easy to administer. Shortcomings include over and/or under regulating unique situations.
2. Another approach is to respond to actual complaints in a preplanned

manner and thus to consider just the immediate surroundings. One advantage is elimination of the use of unreliable odor measurement systems. A shortcoming is the quandry presented to an operating agency with multiple emissions sources of odor and the need for a strategy on how to operate them.

3. Finally, there is the approach to regulating point sources on a case by case basis based upon adjacent populations and their sensitivity to odor. Expected impact on different population areas in relation to the location of the point source can be modeled using dispersion model theory. Optimal operating strategies could subsequently be developed. The advantage of this approach is that it combines the best of both worlds, i.e., satisfactory protection of the public welfare and efficient use of operating agency resources.

IV. Recommendations

1. That the Minnesota Pollution Control Agency (MPCA) acknowledge that the syringe dilution method, ASTM Method D-1391-57, which is used for the determination of odor concentration units as specified in the Minnesota Air Pollution Control Rule 7005.0930 on Odor Testing (2), has been discontinued by its author, ASTM, a national measurement standards setting professional society.
2. That the MPCA recognize the demonstrated variability in odor measurement results as reported in this report as evidence of the unreliability of the measurement systems.
3. That MPCA initiate a process of revisiting and possibly revising the

rules on odorous emissions subsequent to a collaborative effort of scientific study and review by the community of interest.

V. Remarks

The present form of the Minnesota Air Pollution Control Rule 7005.09 appears to have been significantly affected by the article of Benforado et al (3) and values from the article adopted as limits. The authors gave no statistical qualifications for the reported values nor estimates of error which suggest that they never intended their results to be used as regulatory limits.

Some information in the Rule came from the following comments by the authors: "...if the odor strength of the stack gas can be reduced to less than 150 odor units per scf, preferably in the range of 25 - 50 odor units per scf, odor nuisances in a community can be prevented..." and "...it appears that up to about 1,000,000 odor units per minute is acceptable to avoid odor complaints from a single stack...".

The panel selection procedure used by the authors affected a small number of volunteers among a pool of draftsmen. The authors used an odor panel selection procedure in connection with tracking the performance of experimental odor control equipment. Apparently the same trained odor test panel was used during the tracking period.

The article presents average odor strengths for about 40 samples that were tested. There were no estimates of error nor any statistical statements of inference with qualification of results presented.

It has been substantiated by personal communication with the senior author (Robert Polta conversation with David Benforado, 1990) that it was never the intent of the authors that the presented results be used as regulatory limits.

The future form of the Minnesota Air Pollution Control Rule regarding standards of performance for odorous emissions will best serve the public welfare if it is based upon scientific data. The community of interest needs to work together to accomplish this end.

V. References

1. Standards of Performance for Odorous Emissions, Air Pollution Control Rules, Minnesota Pollution Control Agency

2. ASTM, Standard for Measurement of Odor in Atmospheres (Dilution Method) - Designation D1391-78. 1985 Annual Book of ASTM Standards, Volume 11.03, Atmospheric Analysis; Occupational Helath and Safety, American Society for Testing and Materials, Philadelphia, PA, 1985.

3. Benforado DM, WJ Rotella and DL Horton, Development of an Odor Panel for Evaluation of Odor Control Equipment. Journal of the Air Pollution Control Association 19:101-105, 1969.

4. USEPA, Regulatory Options for the Control of Odors. U.S. Environmental Protection Agency Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1980.

5. USEPA, Odor and Corrosion Control in Sanitary Sewerage Systems and Treatment Plants - Design Manual. U.S. Environmental Protection Agency Office of R & D,Washington, DC, 1985.

6. Meilgaard, MC, Chairman, ASTM Task Group E-18.04.25 on Sensory Thresholds, Draft #5, Stroh Brewery Co, Detroit, MI 48207, November 3, 1989.