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Standard Guide for Assessing the Efficacy of Air Care Products in Reducing the Perception of Indoor Malodor[1]

This standard is issued under the fixed designation E1593; 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 This guide covers standard procedures for the quantitative sensory assessment of perceived olfactory intensity of indoor malodors for the purpose of assessing the deodorant efficacy of air care products. This guide is limited to static conditions only.

1.2 It is recognized that, though sometimes desirable, the use of actual "live" or formulated live malodors is often impractical due to the inherent variability of the malodor sources. A live malodor source may be used when practical. However, the use of a formulated odor source has several advantages, including consistency and availability.

1.3 The reader should be aware of good sensory practices when preparing the test environment or substrate, developing and training the panel.

1.4 The researcher is responsible for identifying the most appropriate test design and using the appropriate statistical tool to address the experimental design.

1.5 This guide is a compendium of information or series of options that does not recommend a specific course of action. This guide is not intended to support claims. If the research objective is claim related, then the researcher needs to refer to Guide E1958.

1.6 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Section 6 and X3.6.3.7.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E253 Terminology Relating to Sensory Evaluation of Materials and Products

E544 Practices for Referencing Suprathreshold Odor Intensity

E1958 Guide for Sensory Claim Substantiation

3. Terminology

3.1 For other definitions, see Terminology E253.

3.2 *Definitions:*

3.2.1 *activation time*—the length of time that a product is permitted to be exposed in a chamber prior to evaluation by assessors.

3.2.2 *assessor*—a general term for any individual responding to a stimuli in a sensory test.

3.2.3 *malodor*—an olfactory stimulus that, when detected, is considered unpleasant or undesirable by the target population.

3.2.4 *malodor control*—a test sample or experimental treatment consisting of a chamber containing a malodor without any additional malodor reducing treatment.

3.2.5 *malodor reduction efficacy*—the degree to which a product treatment or process reduces perceived malodor intensity.

3.2.6 *masking*—the reduction or elimination of olfactory perception of a defined odor stimulus by means of another odorous substance without the physical removal or chemical alteration of the defined stimulus from the environment.

3.2.7 *panel*—a group of assessors chosen to participate in a sensory test.

3.2.8 *product control*—a treatment consisting of a chamber containing product only.

3.2.9 *spray time*—the length of time in seconds for which an air care product is sprayed with the actuator depressed fully.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.10 *synthetic model*—a mixture of chemical components used to represent an odor.

3.2.11 *trained assessor*—an assessor with a high degree of sensory acuity and has experience in the test procedure and an established ability to make consistent and repeated sensory assessments. A trained assessor functions as a member of a sensory panel.

3.2.12 *treatment*—within this guide, treatment refers to the act or manner in which one treats the area or applies to a substrate for testing.

4. Summary of Guide

4.1 This practice is limited to the assessment of a specific malodor intensity by trained assessors under controlled laboratory conditions. Methods that reflect actual consumer environmental conditions are valid for selected sensory tasks, but they may be less sensitive. Methods that include highly controlled environmental conditions will increase the chances of detecting small differences among treatments. The degree of control of extraneous experimental factors in an experiment is variable and is governed by the purpose of the test, amount of resources available to provide that degree of control, and desired level of statistical sensitivity (see Appendix X3).

4.2 The procedures described herein provide for the selection and training of individuals to perform the functions of trained assessors, and for the presentation of treated or untreated samples, or both, to these trained assessors, in order to evoke an assessment of perceived malodor intensity. These assessments are performed under controlled conditions in order to determine the effect of a given product in reducing the malodor intensity.

4.3 Air care products should be tested in a manner that maximizes test sensitivity while remaining consistent with normal product usage.

5. Significance and Use

5.1 The purpose of this guide is to assess the ability of air care products to reduce indoor air malodor intensity from a control state. Several experimental hypotheses are possible, depending on the objective of the test. Possible objectives with respective hypotheses are given in Appendix X1.

5.2 Air care products are sold commercially with the intent of providing a means of improving the odor quality of a volume of air, relative to some existing environmental condition. This typically involves the application of an odorous substance into the air space by means of some mechanical or physical mechanisms (for example, air fresheners). When the existing environment includes some undesirable odor source or malodor, reduction of the perception of the malodor is usually accomplished with other odorous substances by masking. This procedure is also applicable to other mechanisms of odor reduction (for example, air filtration).

5.3 Selection of representative malodor sources is of critical importance. The malodor source must be readily available and of a consistent odor quality. A reasonable malodor source should be chemically and aesthetically correct. The experimenter and client must agree upon the appropriateness of a malodor source before further details of the test design are worked out. Experimental variation will be reduced by using uniform malodor sources. Information collected on malodor reduction will thus be more comparable from experiment to experiment and from laboratory to laboratory.

5.4 The procedure recommended can be used for assessment of the malodor efficacy of air care product (for example, air fresheners and air filtration).

5.5 These procedures can be used to assess efficacy against any standard malodor.

5.6 These procedures are applicable in the assessment of any products that reduce the perception of any malodor, regardless of the mode of action.

5.6.1 These procedures are applicable to aerosol/spray and continuous/solid air freshener products, including candles. It should be noted that while aerosol/spray and continuous/solid and candle product evaluations are fundamentally the same, different treatment or measurement techniques may be necessary because of inherent differences in the product delivery systems.

5.6.2 These procedures are applicable to other air care products, including absorption, chemical reaction, and particulate removal.

5.7 This guide is designed for use for product research guidance in product formulation and new product development, and for quality control issues.

6. Precautions

6.1 Extreme care should be taken when handling and preparing samples under conditions that will maintain the odorless state of the laboratory area.

6.2 Appropriate safety precautions should be taken when handling all chemical compounds.

7. Selection of Assessors

7.1 *Purpose*—The purpose of this series of tests is to screen potential assessors for a malodor efficacy panel. The screening determines olfactory acuity, specific anosmia to malodorants and fragrance ingredients that are likely components in air care products, interest, and, if so, availability for testing. It is very important to know if your assessors have any anosmias and, if so, to what particular odors. This will allow them to be excused from evaluating odor control products used against that particular odor. This screening of potential assessors should be divided into two phases (interview and testing). The two phases should be conducted as separate sessions (see *STP 758* (**1**)[3] for panelist assessors' selection considerations).

7.2 *Panelist Recruitment*—In order to ensure an adequate number of assessors for testing, a larger number should be recruited. This is to offset the attrition experienced in interviewing, testing, and training based on the assumption that roughly half the number of recruits will fail. A final number of assessors should be selected in advance. A panel size of 20 is

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

typically recommended for a scaling experiment. However, through monitoring panel performance, the researcher may determine that fewer than 20 assessors are acceptable. Refer to *ASTM MNL 26*(**2**) or Kraemer and Thieman (**3**), or both, for other considerations affecting sample size.

7.3 *Interview* (15 min)—During the interview, it is important that the trained assessors fully understand the nature of the testing for which he/she is volunteering, including the types of malodors to be used in malodor testing. If the potential assessor does not feel he/she can overcome any negative biases in experiencing such malodors, they should not participate. In addition, he/she should be made aware of and agree to the time commitment expected, scheduling of testing, and "good testing practices" such as the following: refraining from smoking for at least 1 h before testing, refraining from wearing perfume or after-shave on the day of testing, and so forth. A short questionnaire regarding the person's physical health should be administered to determine whether the candidate has nasal or upper respiratory allergies, asthma, or is prone to frequent colds. These conditions may result in a decrease in an assessor's sensitivity and performance.

7.4 *Testing*—The key concept in this phase of screening is to ensure that the panel is able to (*1*) discriminate, and (*2*) detect the designated malodorant(s). A sequential analysis technique is one way to accomplish this (**4**).

7.4.1 Recruits should be tested to determine their ability to detect and discriminate the malodors of interest. Appropriate testing methods for assessing ability include discrimination, ranking, or intensity scaling, or a combination thereof.

7.4.2 The malodorant(s) in question should be the focus of the screening. Several concentrations of each of the malodorant(s) should be chosen for this testing. The concentrations should be representative of intensities experienced during regular malodor efficacy testing to include high and low levels.

7.4.3 Selected concentrations of each of the malodorants should be presented to recruits in a manner consistent with the difference testing procedure described in *ASTM MNL 26*(**2**).

7.4.4 The selection of assessors should first rest on the results of the acuity testing. Additional subjective tests for selected assessors may be necessary to accept or reject them (that is, attitude, timeliness, and compliance). If the number of recruits is greater than required, the additional subjective information gained from the interview process should be applied.

8. Training of Panel

8.1 *Purpose*—The purpose of the experimental procedures discussed here is to recommend a program of training for a group of qualified individuals to perform malodor efficacy assessments.

8.2 Panel training is accomplished in three phases: (*1*) orientation, (*2*) mock deodorancy studies, and (*3*) regular monitoring of panelist performance (see *STP 758*(**1**) for panel training considerations).

8.2.1 *Orientation*—One or more orientation sessions should be held for the trainees. The objective of the orientation is to familiarize the assessors with the task of evaluating malodor efficacy as objectively as possible in order to reduce the experimental error. Orientation should include introducing the assessors to each other and to test personnel involved in conducting malodor efficacy, explaining the purpose of malodor efficacy testing in the company, orienting and training assessors to the selected rating scale, discussing typical testing procedures, describing assessor's responsibilities, and providing a tour of the facilities used to conduct malodor efficacy testing.

8.2.2 *Mock Efficacy Study*—One or more mock studies for training may be arranged to give the assessors the opportunity to practice making efficacy evaluations. Products for testing should have known differences and may include all types of air care products. The study may be similar to an actual efficacy test in order to smooth the transition from training to regular testing. Assessors should be given the opportunity to practice and demonstrate the ability to make odor intensity judgments. In addition, through discussion and feedback, assessors should be trained to "smell through" any extraneous odor(s), such as the fragrance of the product, to evaluate malodor intensity. Individual assessor performance can be monitored during the training phase by analyzing for individual assessor variability. Individuals who exhibit errant results should undergo additional training and monitoring. However, repeated underperformers should be dropped from the panel.

8.2.3 *Replications*—The number of replications obtained varies with the degree of experience of the panel. A group that is being used for the first time or is in the orientation stage may require more replications. The task, the intensity of the malodor, the test facility capacity, and the olfactory fatigue all need to be considered when determining the number of replications. A minimum of two replications is required in order to ensure that the data are reproducible and one can monitor the assessor's performance.

9. Selection and Qualification of Malodor Models

9.1 Synthetic samples of malodors are used widely in odor testing involving the determination of air care product efficacy. Synthetics have several advantages, most of which center on avoiding logistical and safety difficulties associated with using the actual malodor source (for instance, fecal odors). In general, laboratory efficacy testing involves the screening of various materials for their efficacy in reducing the perceived level of malodor intensity. The synthetic malodor is used to represent the actual odor. The validity of results from these types of tests is maximized when the actual malodor source is used under conditions representative of the consumer environment.

9.1.1 When synthetic samples are used, they must be developed to be as similar as possible to the odor experienced by the consumer, in both the chemical and perceptual sense. Thus, any synthetic sample model used should have been tested previously for its validity as a sample of the actual odor.

9.1.2 There are many potential techniques for accomplishing validation. The application of each technique, be it descriptive, discrimination, or consumer testing, must be evaluated on its own merit. It is not within the scope of this practice to enumerate the details of all techniques; however, it

is imperative that the results should indicate clearly that the synthetic mixture is reasonably similar to the actual malodor as experienced by the consumer.

9.2 The following criteria may be used to validate the choice of malodorant(s). One or all of these criteria may be appropriate, depending on the specific mode of action of the products.

9.2.1 *Chemical Composition*—If the product is meant to function by some physical method (other than masking), the chemical composition of the malodor sample is critical. The chemical compositions of the malodor sample and samples of the actual malodor source should be determined by appropriate analytical methods. Similarities and differences should be noted and evaluated for relative importance.

9.2.2 *Multiple Choice Data*—The data generated from a multiple choice descriptor panel can be used to support a potential malodor sample. Malodor samples should be presented at appropriate intensities. The number of assessors, malodor samples, and possible descriptors should be considered before beginning any such test. Other factors to consider include the sample presentation, descriptor terms, and acceptance criteria. For an example ballot and profiles, see Appendix X2.

9.2.3 *Odor Profile Data*—The data generated from an odor profile panel can also be used to support a potential malodor sample. Although this procedure is more time and resource intensive, it will provide more detailed information on major and minor odor descriptors that are detected in a potential malodor sample. The considerations discussed relative to the multiple choice tests should also be considered for odor profile tests. For information concerning odor profiling, see Dravnieks **(5)** or Jeltema and Southwick **(6)**, or both.

9.3 *Toxicological Review*—The synthetic sample should be subjected to a safety review by the appropriate health and safety professionals to ensure that human health is not endangered, and that panelists are not being exposed to regulated substances at levels exceeding those allowed by law.

10. Procedure

10.1 *Sample Preparation:*

10.1.1 Sample preparation is dependent on the use of the product and nature of the individual malodor standard.

10.1.2 Measurement of product performance requires a minimum of two test samples: (*1*) an untreated malodor control and (*2*) a combination of malodor and product. If desired, the test can include a sample consisting of a product alone, that is, without malodor. Several different test samples may be evaluated in the same panel session.

10.1.3 The number of test samples that can be evaluated in a single session will depend on the number of chambers available, nature of the malodor, and skill of the panel. The experimenter will need to determine empirically the limitations imposed by the malodor and by the trained assessors. The trained assessors' evaluations need to be independent from the other assessors. The main factor influencing the number of test samples is sensory adaptation/fatigue in detecting the malodor. Therefore, plan adequate time to prevent adaptation between evaluations of the test samples.

10.1.4 The application of malodor and treatment to the chambers usually occurs chronologically. The application order will depend on the specific treatment use. Typical treatments are as follows: (*1*) malodor is applied first, and product is applied second; and (*2*) product is applied first, and malodor is applied second.

10.1.5 After the appropriate exposure time for the malodorant or product, or both, has elapsed, both the malodorant and the product may or may not be removed from the chamber(s). This decision must be made considering the goal of the specific test. While removing the odorants, take care to preserve the odorless state of the surrounding laboratory.

10.2 *Malodor Treatments:*

10.2.1 The selection of a representative malodor source is of critical importance. No agreed-upon standards exist. Review 1.2, 5.3, Section 9, and Appendix X2.

10.2.2 Tests are typically set up to evaluate a single malodor at a time. Tests in which assessors are exposed to different malodors in different chambers can be confusing and may reduce test sensitivity.

10.3 *Product Treatments:*

10.3.1 The appropriateness of controlled air flow or static air conditions must be determined based on the specific test objectives. A mixer must be used if static conditions are selected.

10.3.2 *Aerosol Spray and Trigger Pump-Type Delivery Systems:*

10.3.2.1 Prior to applying product to the malodor in the chamber, spray the products for 1 to 2 s into a fume hood to clear the dip tubes.

10.3.2.2 There are two generally used methods of application: equal spray time and equal weights. Note the weights when using equal spray time. Adjust the spray time or weight amount according to the volume of the chamber. Regardless of brand, valve type, actuator type, etc., equal spray time will provide an estimate of product efficacy that will be representative of the total product being evaluated (not including appearance attributes).

10.3.2.3 Apply the product to the chamber atmosphere using a broad, sweeping motion and by directing the spray toward the ceiling. This should be completed at least 5 min prior to evaluation by the assessors.

10.3.3 *Continuous/Solid-Type Delivery Systems*—Prior to conducting a test for effectiveness, determine a proper activation time. It is difficult to give a specific value for this time interval since it will vary from a few minutes to several hours, depending on the mode of action and the volume of the test room.

10.3.4 *Air Filtration Products*—Prior to conducting a test for effectiveness, determine a proper operating time and device settings for the air filtration device. This time may vary from several minutes to several hours, depending on the mode of action and the volume of the test room.

11. Sample Presentation

11.1 Samples are presented to assessors in odor evaluation chambers. The chambers should be labeled with randomly generated, three digit codes. Temperature and relative humidity

conditions should be controlled as much as possible. Typical conditions are 22°C and 50 % relative humidity, respectively. Conditions should be recorded and equivalent for all chambers. Each assessor evaluates the chambers following a randomization plan. It should be noted that in order to maintain independence of judgments between samples, assessors should be required to rest in between each sample as described in 11.2. Chambers should be evaluated in a manner that minimizes dilution of the chamber contents. This is usually accomplished by having assessors smell the contents of the chamber through a small port.

11.2 The smelling procedure is as follows:

11.2.1 An initial malodor-only booth, which all assessors smell first, is recommended. This booth is identified as containing the malodor of interest. Assessors then smell each test booth for that particular odor. The data from the initial, malodor-only booth are usually not used in any analyses. In addition to acquainting the assessors with the malodor in question, this approach may reduce the order of presentation effect between samples as well as the effect of fatigue.

11.2.2 Smell the chamber contents and evaluate the intensity of the malodor using an appropriate sensory method (see *ASTM MNL 26*(**2**) or Practices E544). Other attributes such as overall intensity and qualitative change may also be assessed at this time.

11.2.3 The amount of waiting time between each evaluation depends on the time it takes to overcome sensory adaptation/fatigue. The amount of time depends on many factors and should be determined through experience using good experimental techniques. A minimum of 1 min is recommended and the time between samples adjusted up depending on the adaptation of that particular malodor.

11.2.4 Repeat 11.2.1 and 11.2.2 until all of the samples are evaluated. Samples may consist of positive and negative controls (product without malodor and malodor without product), other controls (such as blank chamber), and market targets, as well as test products.

11.3 Whenever possible, the test should be scheduled in such a way that only one panelist is in the chamber area at a time.

12. Data Collection and Analyses and Interpretation of Results

12.1 Sensory malodor intensity evaluations are obtained by using any industry recognized method (paired comparisons, ranking, or scaling).

12.2 The statistical analyses to be conducted depend on the objective of the test and the procedure used as well as test design (see Appendix X1).

12.3 The interpretation of test results after statistical analysis of the data are given in Appendix X1.

13. Keywords

13.1 air care products; indoor air; malodor counteraction; sensory facilities; sensory test chamber construction

APPENDIXES

(Nonmandatory Information)

X1. EXPERIMENTAL DESIGNS AND ANALYSES FOR SELECTED EXPERIMENTAL OBJECTIVES

X1.1 Introduction

X1.1.1 Experimental designs and statistical analyses are given for several experimental objectives that are encountered commonly in malodor counteraction efficacy testing. All of the designs in this section require the use of intensity rating scales. However, designs using ranking or paired comparisons may also be appropriately used. For further information on these techniques, see *ASTM MNL 26*(**2**).

X1.1.2 Before designing any study, several factors should be considered carefully. Factors such as the background of the test, specific use for the data, resources available, and stage of development will influence the choice of experimental design and risk levels. Ideally, the sensory professional should meet with a statistician to consider alternate designs or supplementary objectives.

X1.2 Definitions of Statistical Terms

X1.2.1 *Alpha Level* (α)—Represents the probability of rejecting the null hypothesis when it is true, thus concluding falsely that there is a difference (typically set at $\alpha < 0.05$).

X1.2.2 *Beta Level* (β)—Represents the probability of failing to reject the null hypothesis when it is false, thus concluding falsely that there is no difference (typically set at $\beta < 0.20$).

X1.2.3 *Power of the Test* (1 – β)—Represents the probability of rejecting the null hypothesis when it is false, thus concluding correctly that there is a difference. This can also be viewed as the likelihood of detecting the minimum level of interest (typically set at $1 - \beta > 0.80$).

X1.2.4 *Minimum Level of Interest*—Represents the smallest difference that is important to detect.

X1.2.5 *Product Sample Size*— Should be based on the alpha and beta levels selected, minimum level of interest, and inherent variability of the evaluation (scaling) method. See *ASTM MNL 26*(**2**) or Kraemer and Thiemann (**3**).

X1.3 Basic Test Designs

X1.3.1 *Design No. 1:*

X1.3.1.1 *Objective*—Determine the efficacy of Product A on a given malodor.

X1.3.1.2 *Research Question*—Does Product A reduce the perception of malodor?

X1.3.1.3 *Experimental Design*—Two samples are evaluated: (*1*) malodor alone (MAL); and (*2*) malodor plus Product A (A + MAL).

X1.3.1.4 *Statistical Approach*—Null hypothesis (malodor level): MAL ≤ A + MAL; and statistical test: Student's paired *t* test (one-tailed).

X1.3.1.5 *Possible Outcomes:*

(*1*) *Reject Null Hypothesis*—Conclude that Product A is effective in reducing the perception of malodor.

(*2*) *Do Not Reject the Null Hypothesis*—Conclude that Product A has not been demonstrated to be effective in reducing malodor, within the sensitivity of the experiment.

X1.3.2 *Design No. 2:*

X1.3.2.1 *Objective*—Determine the relative efficacy of two products (A and B) on a given malodor.

X1.3.2.2 *Research Question*—Does one of the products reduce the perception of malodor more than the other?

X1.3.2.3 *Experimental Design*—Two samples are evaluated: (*1*) malodor plus Product A (A + MAL); and malodor plus Product B (B + MAL).

X1.3.2.4 *Statistical Approach*—Null hypothesis (malodor level): A + MAL = B + MAL; and statistical test: Student's paired *t* test (two-tailed).

X1.3.2.5 *Possible Outcomes:*

(*1*) *Reject Null Hypothesis*—Conclude that one product is more effective than the other in reducing the perception of malodor.

(*2*) *Do Not Reject the Null Hypothesis*—Conclude that the two products are similar in effectiveness, within the sensitivity of this experiment.

X1.3.3 *Design No. 3:*

X1.3.3.1 *Objective*—Determine whether assessors are identifying the malodor accurately (this is a panel maintenance and screening test).

X1.3.3.2 *Research Question*—Do the assessors indicate correctly that a malodor difference exists between the malodor alone and the product alone?

X1.3.3.3 *Experimental Design*—Two samples are evaluated: malodor alone (MAL); and Product A alone (no malodor).

X1.3.3.4 *Statistical Approach*—Null hypothesis (malodor level): MAL ≤ A; and statistical test: Student's paired *t* test (one-tailed).

X1.3.3.5 *Possible Outcomes:*

(*1*) *Reject Null Hypothesis*—Conclude that the assessors are identifying the malodor correctly.

(*2*) *Do Not Reject the Null Hypothesis*—Conclude that assessors may not be identifying the malodor correctly. This may indicate the need for retraining of the assessors on that malodor. The malodor level should also be evaluated, as a very low malodor level can cause this type of effect.

X1.3.3.6 This test is often combined with another product and malodor test.

X1.4 Complex Test Designs

X1.4.1 Often, more than one of the objectives discussed in X1.3 may be addressed in a given design. This is achieved by combining the basic test designs that were discussed in X1.3. Some of these are illustrated as follows:

X1.4.2 *Design No. 1:*

X1.4.2.1 *Objectives:*

(*1*) Determine the efficacy of each of three products on a given malodor.

(*2*) Determine the relative efficacy of each product against the other products on a given malodor.

X1.4.2.2 *Research Questions:*

(*1*) Do any of the products reduce the perception of malodor?

(*2*) Do the products differ in their ability to reduce the perception of malodor?

X1.4.2.3 *Experimental Design*—Four samples are evaluated:

(*1*) Malodor alone (MAL);

(*2*) Malodor plus Product A (A + MAL);

(*3*) Malodor plus Product B (B + MAL); and

(*4*) Malodor plus Product C (C + MAL).

X1.4.2.4 *Statistical Approach:*

(*1*) *Statistical Design*—Randomized blocks or balanced incomplete block designs. When conducting an incomplete block design, the researcher must weigh the benefit of providing fewer samples to each assessor against the risk of missing an effect. When using an incomplete block design, product variability and subject variability are combined, resulting in a less sensitive method for detecting product differences.

(*2*) *Null Hypotheses:*

(*a*) *Objective A:*

$$MAL \le A + MAL$$
$$MAL \le B + MAL$$
$$MAL \le C + MAL$$

(*b*) *Objective B:*

$$A + MAL = B + MAL = C + MAL$$

(*3*) *Statistical Tests:*

(*a*) Two-way analysis of variance.

(*b*) Appropriate multiple-comparison procedures for multiple-test products versus control.

X1.4.2.5 *Possible Outcomes:*

(*1*) *Objective A:*

(*a*) *Reject Null Hypothesis*—Conclude that at least one of the products is effective in reducing the perception of malodor. Use an appropriate multiple-range test to determine which differences exist.

(*b*) *Do Not Reject Null Hypothesis*—Conclude that none of the products have been demonstrated to be effective in reducing malodor, within the sensitivity of this experiment.

(*2*) *Objective B:*

(*a*) *Reject Null Hypothesis*—Conclude that at least two of the products differ in their ability to reduce the perception of malodor. Use an appropriate multiple-range test to determine which specific differences exist.

(*b*) *Do Not Reject Null Hypothesis*—Conclude that the three products are similar in their ability to reduce malodor, within the sensitivity of this experiment.

X1.4.3 *Design No. 2:*

X1.4.3.1 *Objectives:*

(*1*) Determine the efficacy of each of two products on a given malodor.