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Technical Information Report

AAMI TIR25:1999

Chemical indicators—Guidance for the selection, use, and interpretation of results

AAMI
Association for the Advancement of Medical Instrumentation

List of Titles

AAMI Technical Information Report

AAMI TIR No. 25:1999
(Revision of AAMI TIR No. 3:1988)

Chemical indicators—Guidance for the selection, use, and interpretation of results

Approved 18 October 1999

Abstract: This document provides guidance for the selection and use of chemical indicators that are intended for use with sterilization processes employing steam, ethylene oxide, irradiation, or dry heat. This technical information report is based on the ANSI/AAMI ST60:1996 standard for chemical indicators.

Keywords: chemical indicator, CIER vessel, resistometer, steam, ethylene oxide, irradiation, dry heat

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Published by the

Association for the Advancement of Medical Instrumentation
1110 N. Glebe Road, Suite 220
Arlington, VA 22201-5762

Printed in the United States of America

ISBN 1–57020–127–7

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Association for the Advancement of Medical Instrumentation

Sterilization Standards Committee

This Technical Information Report was developed and balloted by the AAMI Chemical Indicators Working Group under the auspices of the AAMI Sterilization Standards Committee. Approval of this Technical Information Report does not necessarily imply that all working group members voted affirmative.

At the time this document was published, the **AAMI Sterilization Standards Committee** had the following members:

Cochairs:
Virginia C. Chamberlain, PhD
William E. Young

Members:
Zoe Z. Aler, RN, Timonium, MD
Trabue D. Bryans, Viromed Biosafety Labs
Virginia C. Chamberlain, PhD, Hendersonville, NC
Anne M. Cofiell, CRCST, International Association of Healthcare Central Service Materiel Management
Neal E. Danielson, Wichita, KS
Dorothy M. Fogg, RN, BSN, MA, Association of Perioperative Registered Nurses
Lisa Foster, Ion Beam Applications
James M. Gibson, Jr., JM Gibson Associates
Barbara J. Goodman, RN, BS, CNOR, Rising Sun, MD
Joel R. Gorski, PhD, NAMSA
Susan Hadfield, Standards Council of Canada
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Gretchen Keenan, 3M Health Care
Sue Kuhnert, STS duoTEK
Byron J. Lambert, PhD, Guidant Corporation
Paul S. Malchesky, STERIS Corporation
Patrick McCormick, PhD, Bausch & Lomb, Inc.
Robert F. Morrissey, PhD, Johnson and Johnson
S. Richard Nusbaum, Pennsylvania Engineering Co.
David Orton, CR Bard
Barry F.J. Page, Garner, NC
Michael H. Scholla, MS, PhD, Dupont Medical Packaging Systems
Janet K. Schultz, MSN, RN, Roswell, GA
Harry L. Shaffer, Titan Corporation
Robert J. Sharbaugh, PhD, CIC, Association for Professionals in Infection Control and Epidemiology
Frank Sizemore, American Society for Healthcare Central Service Professionals
James L. Whitby, MA, MB, FRCP, London, ON
Thelma Wilcott, Becton Dickinson & Company
Steve C. Yeadon, BS, Alcon Labs
William E. Young, Baxter Healthcare Corporation

Alternates:
Bettye Beebe, Alcon Labs
Carl W. Bruch, PhD, Pennsylvania Engineering Co.
Louis M. Glasgow, Bausch & Lomb, Inc.
Joyce M. Hansen, Baxter Healthcare Corporation
Lois A. Jones, Becton Dickinson & Company
Susan G. Klacik, AS, BS, International Association of Healthcare Central Service Materiel Managers
Sandra A. Lee, RN, STERIS Corporation
Chiu Lin, PhD, U.S. Food and Drug Administration
Bruce Schullo, Ion Beam Applications
Phil M. Schneider, 3M Health Care
James Whitbourne, STS duoTek

At the time this document was published, the **AAMI Chemical Indicators Working Group** had the following members:

Cochairs:	Joel R. Gorski, PhD
	Marvin L. Hart
Members:	Richard B. Barrett, PhD, Tempil, Inc.
	Susanna F. Barrett, U.S. Food and Drug Administration, Center for Devices and Radiological Health
	Carl W. Bruch, PhD, Consultant, Hudson, WI
	Martin S. Favero, PhD, Advanced Sterilization Products
	Christopher Fricker, PhD, STERIS Corporation
	Joel R. Gorski, PhD, NAMSA
	Charles Hughes, SPS Medical
	Jim Kaiser, Getinge/Castle, Inc.
	Marvin L. Hart, Marvin L. Hart Associates, Inc.
	Gretchen Keenan, 3M Health Care
	Colleen P. Landers, RN, Timmins and District Hospital, Timmins, Ontario, Canada
	Patrick McCormick, PhD, Bausch & Lomb, Inc.
	Frank E. Platko, PhD, Propper Manufacturing Company, Inc.
	Rose Marie Proietti, RN, MBA, Medical Action Industries, Inc.
	Marimargaret Reichert, RN, MA, Retired, Olmsted Falls, OH
	Jonathan Wilder, H&W Technology, LLC
Alternates:	Karla Byrne, Getinge/Castle, Inc.
	Catherine J. Finocchario, Bausch & Lomb, Inc.
	Steve Kirckof, D.Eng., 3M Health Care
	Paul S. Malchesky, D.Eng., STERIS Corporation
	Candace McManus, PhD, U.S. Food and Drug Administration, Center for Devices and Radiological Health, Office of Compliance
	Shaundrea L. Rechsteiner, NAMSA
	Gary Socola, SPS Medical

NOTE—Participation by federal agency representatives in the development of this Technical Information Report does not constitute endorsement by the federal government or any of its agencies.

Foreword

This Technical Information Report was developed by the AAMI Chemical Indicators Working Group under the auspices of the AAMI Sterilization Standards Committee. The objective is to provide guidance on chemical indicators that are intended for use with sterilization processes that employ steam, ethylene oxide, irradiation, or dry heat.

This AAMI Technical Information Report (TIR) provides guidance regarding the selection, use, and interpretation of results of chemical indicators used to monitor sterilization processes that employ steam, ethylene oxide, irradiation, or dry heat. The procedures described in this document are of a general nature and do not, of themselves, constitute a comprehensive monitoring program with respect to the sterilization of health care products but are intended to be used as supplemental guidelines to ANSI/AAMI ST60, *Sterilization of health care products—Chemical indicators—Part 1: General requirements*. The intent of this document is not to mandate the use of chemical indicators, but to provide guidance for their proper selection, use, and interpretation of results. The information provided in this technical information report is based on a voluntary consensus standard (ANSI/AAMI ST60) that manufacturers may choose to meet.

This TIR supersedes AAMI TIR No. 3:1988, *Selection and use of chemical indicators for steam sterilization monitoring in health care facilities*, and expands the scope of the earlier document. AAMI TIR No. 3:1988 addressed chemical indicators used for monitoring steam sterilization processes and did not, as this TIR does, address chemical indicators used for monitoring ethylene oxide, irradiation, and dry heat sterilization processes. Further, the classes of chemical indicators have been refined on the basis of ANSI/AAMI ST60, and this TIR reflects those changes.

Suggestions for improving this Technical Information Report are invited. Comments and suggested revisions should be sent to AAMI, 1110 N. Glebe Road, Suite 220, Arlington, VA 22201-5762.

Introduction

The complexity of modern medical technology and the wide variety of sterilization processing techniques and equipment available today have made the development of effective sterility assurance programs more challenging than ever before. The need for convenient, inexpensive, and rapid means of detecting sterilization problems has brought about the development of sterilization process monitors that are generally referred to as “chemical indicators.”

All types of chemical indicators develop an observable change in their physical or chemical properties in response to certain known processing conditions. Chemical indicators are designed to change when preset critical parameters have been delivered. They have not been designed to show the causes of the failure when intended indicator changes do not occur. It is up to the user to determine the cause or causes of the chemical indicator failure. Chemical indicators are not intended for use in any process other than that specified by the manufacturer on the product labeling.

The user should select a chemical indicator that is appropriate for the particular process to be monitored. There are wide variations in sterilization processes, and chemical indicator manufacturers are not able to foresee all possible uses of their products. Manufacturers, therefore, label chemical indicators according to their intended use. Users of chemical indicators have the responsibility to select, use, and interpret the results, as appropriate, for the particular sterilization process to be monitored. The stated value (parameters and values to which the indicator is designed to react) on the product, the product insert, or both will assist the user in this process.

Chemical indicators should always be used in combination with physical or biological indicators to demonstrate the efficacy of a sterilizing process. When a physicochemical variable of a sterilization process is outside its specified limits, cycle parameters should be evaluated. It should be noted that measurements may be made during the cycle and may need to be evaluated in the context of the overall cycle. Systems, procedures, or both should be established to evaluate any deviations from the cycle process limits. Reasons for accepting any deviation should be fully documented.

With the adoption of the ANSI/AAMI standard for chemical indicators (ST60:1996), manufacturers and users of chemical indicators have a better understanding of the basic types of chemical indicators, their performance requirements, and the products that are best suited to a particular application.

Chemical indicators—Guidance for the selection, use, and interpretation of results

1 Scope

This Technical Information Report (TIR) is intended to provide guidance on the selection, use, and interpretation of results of chemical indictors that are used to monitor sterilization processes. This document applies to chemical indicators for which ANSI/AAMI standards exist (ST60 and ST66).

This document does not consider those sterilization processes that rely on physical removal of microorganisms (e.g., filtration).

This document is not intended to apply to combination processes (e.g., disinfecting the washer or flushing and steaming the pipelines).

The topic of enzyme indicators is not addressed in ST60.

2 Cited references

The following references are cited in this document. The Association for the Advancement of Medical Instrumentation maintains a register of currently valid AAMI/American National Standards.

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INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. *Sterilization of health care products—Chemical indicators—Part 5: Class 2 indicators for air removal test sheets and packs*. ISO 11140-5 (in preparation).

3 Definitions

For the purposes of this AAMI Technical Information Report, the following definitions apply.

3.1 endpoint: Observable change, specified by the manufacturer, that occurs after the indicator has been exposed to certain predefined physical conditions.

3.2 chemical indicator: System that reveals a change in one or more predefined process parameters on the basis of a chemical or physical change that results from exposure to a process.

3.3 critical parameters: Parameters identified as being essential to the sterilization process (and that require monitoring).

3.4 saturated steam: Water vapor in a state of equilibrium between condensation and evaporation.

3.5 stated value: Value or range of values of a critical parameter to which the indicator is designed to react.

4 General considerations

Chemical indicators are designed to change when preset critical parameters have been delivered. They have not been designed to show the causes of the failure when intended changes do not occur. It is up to the user to determine the cause or causes of the chemical indicator failure. The information provided by a chemical indicator is revealed by means of the occurrence, or nonoccurrence, of a characteristic physical or chemical change that is observable by the user. A number of different classes of chemical indicators have been developed to suit different monitoring needs and to accommodate varying ideas of what is the most useful information about any given sterilization process. Some types of chemical indicators are sensitive to certain specific problems, such as a temperature deficiency, while others may be less sensitive to an individual parameter but may simultaneously test the overall process condition. This document addresses the following classes of chemical indicators identified in ANSI/AAMI ST60:

— Class 1–Process indicators

— Class 2–Indicators for use in specific tests

— Class 3–Single parameter indicators

— Class 4–Multiparameter indicators

— Class 5–Integrating indicators

This classification is based on defined general performance characteristics across several different sterilization processes (per ST60) rather than on chemical or physical changes that are related to any one specific sterilization process.

The basic performance descriptor of any chemical indicator is its endpoint response, which is the observable change after exposure to certain predefined physical conditions. The manufacturer specifies the endpoint for the chemical indicator. The conditions that yield the endpoint response are the basis for the classes of chemical indicators that have been described. The availability of a wide variety of products and claims has led to confusion in the user community about the proper use and interpretation of the chemical indicators' results. The concern stems from a lack of understanding about what the various types of chemical indicators are designed to do and what they show. For example, in a steam sterilization process, some chemical indicators need to be exposed to steam for a minimum length of time to achieve the endpoint; some need to be exposed to a minimum temperature; some are affected by a combination of time and temperature of exposure; and still others are affected by time, temperature, and presence of saturated steam. In all cases, the user compares the response of the chemical indicator to an endpoint that is described by the manufacturer. If the endpoint for the chemical indicator was not met, then the preset cycle parameters were not delivered. The user should investigate possible causes for the failure of the chemical indicator to change (e.g., incorrect choice of packaging, improper packaging or loading technique, sterilizer malfunction, etc.).

Even though other factors can influence the efficacy of a sterilization process, Table 1 shows the critical sterilization parameters that chemical indicators are intended to monitor.

Table 1—Critical parameters for each sterilization method

Method	Parameter 1	Parameter 2	Parameter 3	Parameter 4
Steam	Time	Temperature	Saturated steam	
Dry heat	Time	Temperature		
Ethylene oxide	Time	Temperature	EO gas concentration	Relative humidity
Irradiation	Total absorbed dose			

If the use of the chemical indicator is limited to a specific sterilization cycle, this information should be stated or coded on the product. For example, “steam 15 min 121° C” means that the indicator is intended for use in a 15 minute, 121° C steam sterilization cycle.

Questions regarding the selection of the basic types of chemical indicators that are best suited to a particular application can be answered only in the context of the specific sterilization process to be monitored, the possible problems that prevent sterilization, the performance characteristics of each class of chemical indicator, and the things that constitute an effective sterility assurance program. Once a chemical indicator is selected, its value in the sterility assurance program depends on its correct use, correct interpretation of endpoint response, and compliance with the protocols that were established for unacceptable results.

A chemical indicator is used to directly or indirectly detect whether or not one or more critical physical parameters have reached a certain predetermined level in a given sterilization process. Which physical parameters need to be considered critical and how reliably they should be monitored depend on the tolerances given to specific sterilization parameters. For example, because the temperature in moist heat sterilization is of greater importance than in ethylene oxide sterilization, the requirements for the temperature accuracy of a chemical indicator that is intended for monitoring the processes of moist heat sterilization are far stricter than for a chemical indicator that is intended for use in monitoring an ethylene oxide sterilization process. ANSI/AAMI ST60 specifies the parameters that are considered to be critical for each process, and it gives values for their tolerances. In contrast to biological indicators that may be labeled for use in several different sterilization processes, chemical indicators are usually specific to only one sterilization process.

For a number of sterilization processes, chemical indicators can be used only over a limited range of possible critical parameter values. This range is then labeled on the product. Using the chemical indicator outside the specified range invalidates the result of that chemical indicator.

5 Classes of chemical indicators

5.1 General

The sensitivity of the chemical indicator to the conditions in the sterilizing environment serves as the basis for classifying the chemical indicator into one of five different classes that are recognized in the ANSI/AAMI ST60 standard:

— Class 1–Process indicators

— Class 2–Indicators for use in specific tests

— Class 3–Single parameter indicators

— Class 4–Multiparameter indicators

— Class 5–Integrating indicators

The performance characteristics of each class enable the respective chemical indicators to convey different types of information and, therefore, perform different functions. In a general sense, as one progresses from process indicators to integrating indicators, the chemical indicator conveys more information with greater specificity.

The following definitions for each class of chemical indicator will start with an italicized quote that is taken directly from the ANSI/AAMI ST60 standard, which has been used to define that specific class of chemical indicator.

5.2 Class 1–Process indicators

> *Process indicators are intended for use with individual units (e.g., packs, containers) to demonstrate that the unit has been exposed to the sterilization process and to distinguish between processed and unprocessed units.* (ANSI/AAMI ST60, subclause 4.1)

This class is useful to differentiate loads of items that are yet to be processed from those loads of items that have already been processed. This class should not be used to determine the adequacy of the sterilization process. Class 1 process indicators are typically applied to, or are visible from, the outside of packages or on unit packages. Examples of Class 1 process indicators include sterilization tape and color-changing chemical imprints on pouch packaging or external labels.

This classification replaces what was formerly referred to as "through-put" indicators. Manufacturers of through-put indicators that choose to claim compliance with the voluntary ANSI/AAMI ST60 standard must demonstrate that their indicators, indeed, meet the requirements set forth in that standard.

Class 1 process indicators reach their endpoint when exposed to conditions that are defined in the ANSI/AAMI ST60 standard. The standard also specifies conditions under which the Class 1 process indicator should not reach its endpoint (for further details, see subclauses 6.1–6.4 of ST60 for the specific windows of performance that are required for the four different sterilization processes that Class 1 chemical indicators are intended to monitor).

Chemical indicators that are intended for use in monitoring irradiation exist only as Class 1 process indicators.

5.3 Class 2–Indicators for use in specific tests

> [Class 2] *Indicators are designed for use in specific test procedures as defined in relevant sterilizer/sterilization standards.* (ANSI/AAMI ST60, subclause 4.2)

At this time, the only chemical indicator that is widely recognized in Class 2 is the Bowie-Dick indicator, which is defined in ANSI/AAMI ST66. The purpose of the Bowie-Dick test is to evaluate the effectiveness of air removal during the vacuum phase of the prevacuum sterilization cycle. Class 2 Bowie-Dick indicators are intended to indicate inadequate air removal by measuring insufficient steam penetration.

Bowie-Dick type indicators are commercially available as special test sheets that are to be used in test packs that are constructed in health care facilities or that are contained within disposable packs. Air that is entrapped in the indicator pack in the vicinity of the test sheet interferes with attaining the chemical indicator endpoint, thus revealing that the sterilizer has failed the challenge test.

The Bowie-Dick test is neither designed nor intended to provide information on the efficacy of a steam sterilization process, but it is intended to indicate inadequate air removal by measuring insufficient steam penetration. Note that if the exposure time for the Bowie-Dick test is extended or if the manufacturer's recommendations for how to conduct the Bowie-Dick test are disregarded, the purpose of the test may be entirely defeated because the endpoint development may be misleading.

Background on the Bowie-Dick test

In 1963, a publication by J.H. Bowie and his coworkers (Bowie, Kelsey, and Thompson, 1963, i. 586) described a simple test that was suitable to determine if the vacuum system of a prevacuum sterilizer was functioning correctly. Prevacuum sterilizers present a problem if the system that isolates the chamber leaks or if other malfunctions of the vacuum pumping system occur so that either air is not adequately removed or air leaks occur. The presence of greater-than-critical amounts of air in the chamber can result in the formation of one or more air pockets, which prevent full steam penetration of all the packs to be sterilized. The temperature within such an air pocket is always lower than that of the surrounding steam. Initially, measurements of vacuum system adequacy were made by placing thermocouples within a specified test pack and also in the chamber drain.

The publication by Bowie described a "detector" consisting of a sheet of paper onto which a St. Andrew's cross was made with autoclave indicator tape. The test pack that Bowie described was composed of linen Huckaback (huck) towels, 24 in × 36 in, folded to dimensions of 9 in × 12 in. These towels were stacked to a height of 10 in to 11 in, regardless of the number required. When placed as recommended by the manufacturer in a correctly functioning sterilizer with a holding time of 3½ min with only the test pack in the chamber, the lines on the autoclave tape that were shaped like a St. Andrew's cross would change to a uniform dark color. In the presence of an air pocket, the tape would not change to a uniform color. This procedure is intended to be performed each day after the sterilizer is warmed to operating temperature. Originally, it was intended to enable the operator to verify the effectiveness of the vacuum system in removing residual air.

Properties of the Bowie-Dick test sheet are dictated by the needs of the test:

a) The indicator ink imprint should extend throughout a large percentage of the test sheet because the exact location where the air pocket may occur is not predictable.

b) The indicator ink imprint should be uniform because the outcome of the test is judged by the uniformity of color development.

c) The optimum size of the test sheet should be as close as possible to 9 in × 12 in, the size of the folded towels.

d) The exposed test sheet should have a minimum post-exposure stability of 6 months.

The indicating ink should be sensitive enough that, in a standard towel test pack, it can detect a temperature differential of 2° C between the center of the towel pack and the chamber drain.

When the autoclave tape was used as described in the Bowie publication, the air pocket had to be located at the intersection of the autoclave tape (i.e., the exact center of the test pack) or the air pocket would not be identified. Thus, reprinted test sheets were created because a larger surface area of chemical indicator ink allowed air pockets to be detected anywhere in the test pack. Therefore, the need for a test sheet that was specifically designed for the Bowie-Dick test was recognized soon after Bowie's publication of the test procedure.

In the United States, huck towels are generally made from 100% cotton. The term *huck* came from the European term *Huckaback towels* that were made from flax. Although other fibers are sometimes used, towels with blended fibers are not considered to be suitable for the test. The size of the towels is also somewhat smaller than the European towels and the folded dimensions become somewhat smaller also. Consequently, the test sheet may be smaller than 9 in × 12 in, but it should not be much smaller because it may not capture the air pocket.

The standards for test sheets and disposable test packs have recently been published by ANSI/AAMI in the voluntary standard, ST66, *Sterilization of health care products—Chemical indicators—Part 2: Class 2 indicators for air removal test*.

On the ISO level, there are different standards (ISO 11140-3 and -4, and ISO 11140-5) for use in the Bowie-Dick test because sterilizers are installed and operate differently in various parts of the world. The towel pack described in ISO 11140-3 and -4 is more dense than the towel pack described in ISO 11140-5. The denser towel pack described in ISO 11140-3 and -4 is an appropriate challenge for the European-type sterilizers and installations, and the less dense towel pack described in ISO 11140-5 is a more appropriate challenge to the non-European (e.g., U.S.) sterilizers and installations. In the United States, AAMI has adopted the ISO 11140-5 version of the test (identified as ANSI/AAMI ST66). How the Bowie-Dick test is used and the frequency of use are described in relevant standards (e.g., ANSI/AAMI ST46).

5.4 Class 3–Single-parameter indicators

> *A single-parameter indicator shall be designed for one of the critical parameters…and shall indicate exposure to a sterilization cycle at a stated value of the chosen parameter.* [See Table 1] (ANSI/AAMI ST60, subclause 4.3)

A single-parameter indicator is intended to respond to only one of the critical parameters shown in Table 1. As a practical matter, the one useful independent intensive parameter is temperature. In addition to designating the parameter that is responded to, the stated value of the parameter should be given. The ANSI/AAMI ST60 standard contains tolerances for each critical parameter. That information is reproduced here as Table 2.

Table 2—Tolerances and limiting values for the response to critical parameters for Class 3 indicators

Sterilization Method	Time (min)	Temperature (° C)	Gas Conc. (mg/L)	RH Limiting Values (%)	Saturation LL[a)]	Saturation UL[b)]
Steam	sv[c)] +0/- 25%	sv +0/- 2° C			0.85	1.0
Dry Heat	sv +0/- 25%	sv +0/- 5° C				
Ethylene Oxide	sv +0/- 25%	sv +0/- 5° C	sv +0/- 25%	>30%		

a) LL = lower limit (dryness value)
b) UL = upper limit (dryness value)
c) sv = stated value: reaction value identified for the product with respect to a critical parameter; it is either stated or coded on the product

A temperature-specific chemical indicator is designed to reveal whether a specific minimum temperature was attained at its location in the sterilizing chamber or load (typically inside a package). Temperature-specific chemical indicators cannot show how long the preset temperature was maintained in the chamber. The indicator that is selected according to the use should be appropriate for the minimum temperature of the process.

Temperature-specific indicators for use in steam, dry heat, and ethylene oxide sterilization processes can be used to determine if the preset temperature endpoint was reached. If the endpoint temperature was not reached, the user must determine the cause of failure. Failure may have occurred because of malfunctions in sterilizer temperature-control instrumentation, the presence of air pockets, personnel errors in packaging or loading, or other problems that can prevent the center of a pack from reaching the proper temperature.

If the sterilization process has several critical physical parameters, the information that is provided by monitoring of a single parameter is very limited. For example, a temperature-specific indicator that is used in a steam sterilizer is designed to reveal whether or not a specific minimum temperature was attained at its location in the chamber. It does not supply information about the presence of saturated steam or the exposure time and, therefore, should be used in combination with other chemical indicators to ensure an acceptable sterilization process.

5.5 Class 4–Multiparameter indicators

> *A multiparameter indicator shall be designed for two or more of the critical parameters…and shall indicate exposure to a sterilization cycle at stated values of the chosen parameters.* [see Table 1] (ANSI/AAMI ST60, subclause 4.4)

The conditions under which multiparameter chemical indicators reach their endpoints are stated by the manufacturer on the product or its labeling. These indicators provide more information than either process or single-parameter indicators. Multiparameter indicators can show that preset parameters were not reached and can warn users to investigate the cause, which may be a variety of sterilizer malfunctions and personnel errors. A correct endpoint response does not prove that an item or all items are sterile.

Most multiparameter indicators are based on a chemical change, a physical change, or both, resulting in a color change or in the migration of a chemical. These reactions take place at a defined rate at any given temperature; usually, the rate increases as the temperature of the process increases.

The ANSI/AAMI ST60 standard requires the manufacturer of the chemical indicator to provide stated values for multiparameter chemical indicator performance. See clause 10 of ST60 for three very useful examples that demonstrate how the combination of stated values and tolerances informs the user what the indicator can be expected to show.

The ANSI/AAMI ST60 standard contains tolerances that need to be met for each critical parameter. That information is reproduced here as Table 3.

Table 3—Tolerances and limiting values for the response to critical parameters for Class 4 indicators

Sterilization Method	Time (min)	Temperature (° C)	Gas Conc. (mg/L)	RH Limiting Values (%)	Saturation LL[a)]	Saturation UL[b)]
Steam	sv[c)] +0/- 25%	sv +0/- 2° C			0.85	1.0
Dry Heat	sv +0/- 25%	sv +0/- 5° C				
Ethylene Oxide	sv +0/- 25%	sv +0/- 5° C	sv +0/- 25%	>30%		

a) LL = lower limit (dryness value)
b) UL = upper limit (dryness value)
c) sv = stated value: reaction value identified for the product with respect to a critical parameter; it is either stated or coded on the product

Three examples of the performance associated with multiparameter indicators are given below.

Example 1—Steam sterilization indicator (Class 4 multiparameter indicator)

Stated values: 3.5 min at 134 °C

Table 3 provides the tolerances and limiting values for this Class 4 indicator. The tolerances, using this table, are 3.5 +0/- 25% min and 134 +0/- 2° C when a product is tested in a saturated steam condition with a dryness value between 0.85 and 1.0. Therefore, to reach its endpoint, the time needed shall be at least 2.7 min (i.e., 3.5 – (3.5 × 0.25)) with a temperature of 132° C (i.e., (134–2)) and a dryness value between 0.85 and 1.0. Any time shorter than 2.7 min and any temperature below 132° C must not result in the indicator reaching its endpoint. If the time is 3.5 min or longer, the temperature is 134° C or higher, and the dryness value is between 0.85 and 1.0, the indicator must reach its endpoint.

An indicator with the above stated values will respond as follows when exposed to the conditions below:

Exposed to the following conditions	**Based on the table above, an acceptable indicator**
2.6 min @ 131° C*	must show fail
3.5 min @ 134° C**	must show pass

* or if either one or both are below these values

** or if either one or both are above these values

Example 2—Steam sterilization indicator (Class 4 multiparameter indicator)

Stated values: 15 min at 121° C, saturated steam

Table 3 provides the tolerances and limiting values for this Class 4 indicator. The tolerances, using this table, are 15 +0/- 25% min and 121 +0/- 2° C when tested in a saturated steam condition with a dryness value between 0.85 and 1.0. Therefore, the indicator requires steam with a dryness value between 0.85 and 1.0 for at least 11.3 min (i.e., 15 – (15 × 0.25)) at a temperature of 119° C (i.e., (121–2)) or higher to reach its endpoint. The indicator must reach its endpoint if the time is 15 min or longer and the temperature is 121° C or higher and the dryness value is between 0.85 and 1.0.

An indicator with the above stated values will respond as follows when exposed to the conditions below:

Exposed to the following conditions	**Based on the table above, an acceptable indicator**
11.2 min @ 118° C*	must show fail
15.0 min @ 121° C**	must show pass

* or if either one or both are below these values

** or if either one or both are above these values

Example 3—Ethylene oxide sterilization indicator (Class 4 multiparameter indicator)

Stated values: 60 min at 900 mg/L

Table 3 provides the tolerances and limiting values for this Class 4 indicator. The tolerances, using this table, are 60 +0/- 25% min and 900 +0/- 25% mg/L when tested at a relative humidity > 30%. Therefore, the indicator will not reach its endpoint if the time is less than 45 min (i.e., 60 – (60 × 0.25)), the gas concentration is less than 675 mg/L (i.e., 900 – (900 × 0.25)), and the relative humidity is greater than 30%. If the time is 60 min or longer, the ethylene oxide concentration is 900 mg/L or higher, and the relative humidity is greater than 30%, the indicator must reach its endpoint.

An indicator with the above stated values will respond as follows when exposed to the conditions below:

Exposed to the following conditions	**Based on the table above, an acceptable indicator**
44 min @ 650 mg/L*	must show fail
60 min @ 900 mg/L**	must show pass

* or if either one or both are below these values

** or if either one or both are above these values

5.6 Class 5–Integrating indicators

Integrating indicators are indicators designed to react to all critical parameters over a specified range of sterilization cycles. The stated values are those required to achieve a stated inactivation by referring to a stated test organism with stated D and, if applicable, z values (as described for biological indicators for ethylene oxide sterilization in ANSI/AAMI ST21 and for biological indicators for moist heat sterilization in ANSI/AAMI ST19). (ANSI/AAMI ST60, subclause 4.5)

An integrating chemical indicator is designed to correlate to the performance of biological indicators and should be affected by all the defined critical parameters (see Table 1) within the tolerances shown in Table 4.

Table 4—Tolerances and limiting values for the response to critical parameters for Class 5 indicators

Sterilization Method	Time (min)	Temperature (° C)	Gas Conc. (mg/L)	RH Limiting Values (%)	Saturation LL[a)]	Saturation UL[b)]
Steam	sv[c)] +0/- 15%	sv +0/- 1° C			0.85	1.0
Dry Heat	sv +0/- 20%	sv +0/- 5° C				
Ethylene Oxide	sv +0/- 20%	sv +0/- 5° C	sv +0/- 15%	>30%		

a) LL = lower limit (dryness value)
b) UL = upper limit (dryness value)
c) sv = stated value: reaction value identified for the product with respect to a critical parameter; it is either stated or coded on the product

An integrating indicator, by definition, will be affected simultaneously by a number of critical process parameters. Because the effects of the critical parameters on the integrating indicator are simultaneous, a failure to reach the endpoint may not be assignable to a specific parameter.

6 Role of chemical indicators

6.1 General

Chemical indicators can play a useful role in routine monitoring of sterilization processes, but they cannot eliminate the need for biological monitoring or, more important, the need for careful adherence to proper processing procedures. Similarly, biological monitoring cannot eliminate the need for other types of process monitors such as physical monitors (e.g., pressure gauges, temperature sensors, etc.) and the use of chemical indicators.

The ANSI/AAMI ST60 standard provides both general and additional requirements for each of the five classes of chemical indicators: process, specific use, single-parameter, multiparameter, and integrating indicators. The general requirements include product identification, labeling, and technical information leaflet requirements. Also, a section for each class of indicators, described as “additional requirements,” outlines for the manufacturer the performance requirements for that particular class of chemical indicator. These requirements are specific to the sterilization process for which the indicator is intended.

Not all chemical indicators are required to have tolerances associated with all of their critical parameters. Those critical parameters that are not tested are relative humidity in ethylene oxide sterilization processes and steam saturation in steam sterilization processes. However, the manufacturer of the chemical indicator is required to evaluate the remaining critical parameters of the sterilization process while controlling those critical parameters within preidentified conditions called “limiting values” (see Tables 2, 3, and 4 about chemical indicator Classes 3, 4, and 5 in subclauses 5.4, 5.5, and 5.6).

The user of chemical indicator Classes 3, 4, and 5 will notice that each indicator will have a stated value (sv) printed on the product. This stated value, which is based on the manufacturer’s chosen endpoint for the product, identifies the performance requirements for that specific class of chemical indicators. These performance requirements are characterized by the manufacturer, using a resistometer.

The resistometer is a special vessel designed for very rapid responses to the particular critical parameters that are associated with the given sterilization process. These parameters are very closely controlled during the sterilization exposure process. Because most commercial sterilizers do not have the same precision of exposure conditions as found in resistometers, it may be difficult, if not impossible, for a user to replicate manufacturer label claims when using a standard steam or ethylene oxide sterilizer to perform the exposure. Manufacturers are evaluating their products in precisely controlled resistometers that are designed to deliver “square-wave” performance (e.g., for

steam, rapid heating, and rapid cooling). This square-wave performance allows for a more accurate and consistent characterization of chemical indicators, thus eliminating many of the inconsistencies that were once noted within lots, between lots, and between different products. (See also the discussion of resistometers in 6.3, “Chemical indicators performance evaluation.”)

The basic premise in testing chemical indicators is to subject the products to both adequate and inadequate exposure conditions (relative to what the product is designed to detect) and to confirm that the endpoint response is appropriate and unambiguous. Ideally, several samples of each type of chemical indicator from at least three lots of manufactured product should be used for the evaluation, and the evaluation should be performed over the entire stated shelf life for the chemical indicator product.

6.2 Design considerations (by class)

6.2.1 Process indicators

Although fundamental design considerations are described for process indicators, these same considerations are applicable to all classes of chemical indicators. The most common process indicators are produced by printing chemically reactive inks on a variety of substrates including tape, card stock, and the packaging material itself. The inks have different initial and endpoint colors or appearance. The most desirable attributes for a process indicator are described below.

6.2.1.1 High visual contrast between initial and endpoint appearance

Contrast is particularly important to help eliminate limitations in interpretation.

6.2.1.2 High specificity to the critical parameters of the sterilization method

A steam sterilization process indicator should require the presence of saturated steam for a minimum period of time, not just the equivalent steam temperature, to signal endpoint color. An ethylene oxide process indicator requires time, temperature, relative humidity, and the presence of ethylene oxide gas before signaling endpoint color.

6.2.1.3 Color stability, both before and after processing

Because chemical indicators rely on exposure to the sterilization process to cause color changes in the indicator, any other factor that changes the initial color before processing or that alters the endpoint color after processing can lead to confusion and to an incorrect interpretation of the results of the chemical indicator (false positives and false negatives). To avoid needless reprocessing, the user should know and comply with any expiration date or storage conditions, such as protection of the indicator from temperature or humidity extremes or from exposure to light, as specified by the manufacturer.

6.2.1.4 Consistent and uniform presentation

The reliability of any chemical indicator is a combination of its reproducibility (or precision) and its design target (or accuracy). A particular product is reproducible over the entire course of the product’s shelf life if individual units perform consistently and in accordance with the label claims and if the performance is from unit to unit within a lot and from lot to lot. Reproducibility depends, in part, on the inherent readability and design of a device and, in part, on the effectiveness of the manufacturer’s quality assurance program.

6.2.1.5 Safety

A “safe” chemical indicator is one that does not release any hazardous substances to sterilized items or the environment. The degree of hazard posed by commercially available chemical indicators, when used in the usual manner in hospitals, is a matter of dispute. Some believe that manufacturers should perform acute toxicity testing on common medical device materials that have been steam sterilized in contact with chemical indicators. Others are concerned about the possible long-term effects of exposing personnel or patients to lead (found in many steam indicators). Some believe that any potential toxicity that is associated with the use of chemical indicators is insignificant. Some prefer chemical indicators that are made without the use of heavy metals to avoid the controversy of the potential for human exposure and to alleviate any concern about contaminating the environment with the subsequent disposal of the chemical indicator.

At the time of this writing, there is no scientific consensus on the issue of toxicity, nor do generally recognized testing procedures exist. However, chemical indicators should be placed, to the extent possible, so that the active chemicals are not in direct contact with items that are susceptible to chemical transfer, such as instruments and linens. The appearance of stains on medical goods, directly attributable to the presence of a chemical indicator, is a cause to reject the product for use.

6.2.2 Single-parameter indicators

The most common single-parameter indicators are designed to respond to a specific temperature and, typically, are used in dry heat and steam sterilization processes.

Pellets enclosed in a protective glass ampoule or laminated labels—both containing fusible materials that melt at a specified temperature—are commercially available. Deformation of the pellet and a color change of the label signal that the designated temperature has been reached.

These products give no information regarding either the length of time that the temperature was maintained or the presence of any other critical variable. If they did, they would be defined as multiparameter indicators.

6.2.3 Multiparameter indicators

The manufacturer has the responsibility to designate the specific parameters to which the chemical indicator has been designed and tested. The ANSI/AAMI ST60 standard defines ranges and tolerances for the accuracy and precision associated with the performance requirements for each critical parameter.

6.2.4 Integrating indicators

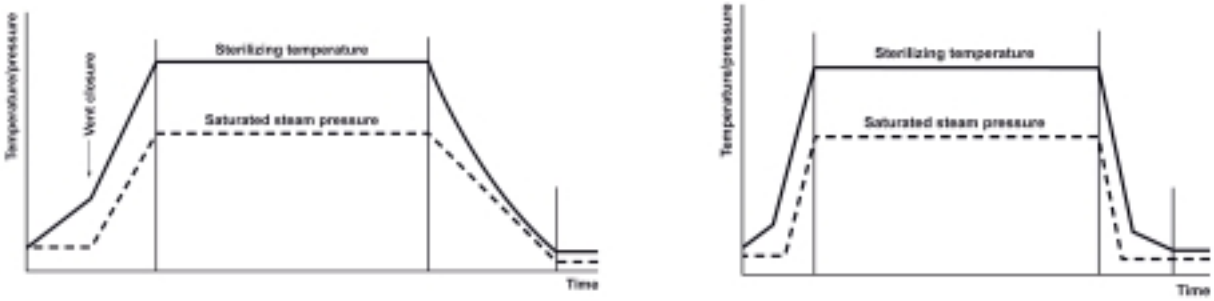
Living microorganisms are affected by all of the complex interrelationships of the critical sterilization process parameters. The ANSI/AAMI ST60 standard defines ranges and tolerances for the accuracy and precision associated with the performance requirements for each critical parameter to which an integrating indicator is intended to respond. Thus, integrating indicators are designed to react to all critical parameters over a specified range of sterilization cycles and are required to achieve a stated value that is associated with microbial inactivation.

6.3 Chemical indicators performance evaluation

Users can perform simple tests to evaluate the performance of different brands of chemical indicators. These tests may be useful in making purchasing decisions and in evaluating the performance of chemical indicators. However, it will not be possible to completely verify a manufacturer's claims, because to do so would require special test equipment such as a resistometer.

The Chemical Indicator Evaluator Resistometer (CIER) vessel is basically the same as the more widely recognized BIER (Biological Indicator Evaluator Resistometer) vessel, but the CIER vessel is intended specifically for use in characterizing the performance of chemical indicators. Resistometers exist for steam, dry heat, and ethylene oxide sterilization processes. Resistometers are designed to control the same critical parameters (for steam: time, temperature, and saturated steam; for ethylene oxide: time, temperature, humidity, and ethylene oxide gas concentration) as do industrial or hospital-type sterilizers, but resistometers are special because they control these critical parameters with much greater precision. Because the resistometer operates with greater precision, its use is necessary for the thorough characterization of performance of chemical indicators.

Figure 1 shows the cycle in standard sterilization equipment compared to that of a resistometer vessel. Before resistometers were available, manufacturers used full-sized sterilizers to characterize biological and chemical indicator performance. Because of the size of the chambers and because of the come-up time, come-down time, and the ability of the components (e.g., transducers, valves, etc.) to control the critical parameters in a timely manner, inconsistencies were noted within lots, between lots, and between different products. Thus, resistometers were developed. Resistometers are designed and manufactured to eliminate much of the variability that was present in larger sterilization vessels. They are also able to deliver square-wave performance with respect to control of the critical parameters that are associated with the specific sterilization process.



a. Standard sterilization cycle

b. Square-wave resistometer cycle

Figure 1—Graph of a standard sterilization cycle compared to that of a resistometer vessel

With the introduction of different classes of chemical indicators that provide for tighter and tighter responses to the critical parameters associated with different sterilization processes, resistometers have become necessary to control the critical parameters associated with the different sterilization processes so that specific performance attributes of the respective class of chemical indicator can be characterized accurately and consistently.

Characterization of a chemical indicator's performance against specific label claims is recommended and encouraged only in resistometer vessels. However, side-by-side comparative testing of chemical indicators in other sterilizers need not be discouraged.

The basic premise in testing chemical indicators is to subject the products to both adequate and inadequate exposure conditions (relative to what the product is designed to detect) and to confirm that the endpoint response is appropriate and unambiguous. Ideally, several samples of each type of chemical indicator from more than one lot of manufactured product should be used for the evaluation.

Testing multiple indicator samples under the same cycle conditions is necessary when evaluating a product's uniformity or variability. For a reliable test, all samples should be exposed to the same conditions. Environmental variations can exist within a sterilization chamber. For this reason, samples should be distributed over as small a chamber area as is practical when testing for uniformity or variability. Samples should not be piled on top of one another because this placement would cause variations in the amounts of sterilizing agent available to each indicator site. The preconditioning of samples is another important consideration in eliminating variability in test results.

Except for tests of Bowie-Dick type indicators (which are designed to be placed inside properly constructed test packs) and certain other specialized tests, chemical indicators that are used in the evaluation of performance claims should be freely exposed to sterilization conditions, not buried inside packs. If indicators are tested within packs, variations in steam penetration may make environmental conditions at the site of the indicator questionable and insufficiently controlled. For testing to be meaningful, the sterilizer operating conditions may be changed temporarily to produce the desired controlled conditions. It may also be necessary, when verifying a product's selectivity, to use a test chamber other than a steam sterilizer. As an example, exposure in a dry-heat oven is necessary to verify a claim that an indicator requires the presence of steam for developing its endpoint response.

Before reaching a final decision to purchase a chemical indicator or to use a chemical indicator for a particular application, the user may wish to conduct tests under actual conditions of use, with chemical indicators placed in packs or other process-challenge devices that are used in routine sterilization loads. The results of such tests should be interpreted with great care. Under actual conditions of use, the sterilizer itself, the sterilization load, the packaging practices, the configuration of the process-challenge device, or other factors are being tested as much as or even more than the chemical indicator samples.

No chemical indicator is intended to prove that articles exposed in a given sterilization cycle are indeed sterile. Rather, they are intended to indicate, to the best of the design for the specific type of chemical indicator used, that exposure to specific parameters have been reached in a given sterilization cycle. Tests should be designed to challenge the specific performance claims made for the chemical indicator being evaluated and (depending on the particular application of interest) to meet the performance needs of the user. Manufacturers can often suggest suitable tests for their products, or advice can be sought from a sterilization expert. Whatever the challenge used, it is advisable to report product "failures" to the chemical indicator manufacturer, who may be able to evaluate the test conditions and to explain the poor results or who may wish to reassess the design or quality control of the product in question. Also, the chemical indicator test results should be assessed by the department manager or the appropriate hospital committee, who then may wish to consult independent sterilization experts for assistance.

7 Selection and use of chemical indicators

7.1 Selecting chemical indicators

7.1.1 General

Various types of chemical indicators are available, each with different response characteristics; that is, they differ in the sterilizing conditions they will detect and verify. The choice of a chemical indicator depends on the specific needs, resources, and sterilization equipment of the individual facility.

Users should obtain data from manufacturers on the reliability, safety, and performance characteristics of their products. In addition, manufacturers of chemical indicators should provide the written information on how to interpret indicator results, the reliability of the indicator in maintaining endpoint color (if applicable) during storage of sterilized items, the sterilization conditions that the indicator has been designed and tested to detect, and the storage requirements for and shelf life of the indicator itself.

7.1.2 External chemical indicators

The purpose of external chemical indicators is to differentiate between processed and unprocessed products. Class 1 process indicators are usually the chemical indicators of choice for use as external chemical indicators.

Sterilizer indicator tape, indicating labels, or an indicating printed legend should be attached to or printed on all packages that are assembled and intended for sterilization. Except for packages that allow visual inspection of an internal indicator, such as paper or plastic packaging, an external indicator should be used on every package. The external chemical indicator should visually denote that the package has been exposed to physical conditions of the sterilization process. The tape, label, or legend should be examined after sterilization and also before use to make sure that it indicates that the item has been exposed to a sterilization process.

7.1.3 Internal chemical indicators

A chemical indicator should be used within each package, tray, or container being processed because variations in position within the sterilizer or contents of each package or sterilizer loading pattern may adversely affect sterilizing agent penetration of all surfaces to be sterilized (and may affect the time needed to attain the required critical parameters at the site of the goods to be sterilized).

The chemical indicator should be placed in that area of the package, tray, or container considered to be least accessible to sterilizing agent penetration. That area may or may not be at the center of the package, tray, or container and may or may not be at the center of the given sterilization chamber. For unwrapped loads, at least one internal chemical indicator should be placed in the tray with the items to be sterilized.

The choice for the type of chemical indicator to be used as the internal chemical indicator should be from Class 3, 4, or 5.

7.2 Retrieval and interpretation

For packaged items, the chemical indicator is retrieved at the time of use and interpreted by the user. For unpackaged items, the chemical indicator is examined at the end of the sterilization cycle. The user needs to be adequately trained and knowledgeable about the performance characteristics of the particular type of chemical indicator being used.

7.3 Chemical indicators showing a “Fail” response

If a chemical indicator is nonresponsive or inconclusive, it is possible that the sterilization cycle parameters were not delivered to the load. The causes for the failure of the chemical indicator to show the appropriate response must be determined by the end user. Appropriate follow-up includes lot identification, review of the physical monitoring information for the sterilization cycle, determination of the endpoint response of chemical indicators from packages placed elsewhere in the load, and, if available, the results of biological monitoring of the sterilizer. This follow-up review will enable the person responsible for sterilization activities to determine the appropriate action.

7.4 Questions to ask the manufacturer about chemical indicator performance characteristics

NOTE—Some of the answers to the following questions may appear on the manufacturer’s product labeling, product inserts, or certification cards.

a) What information does the chemical indicator provide about the sterilization process?

b) What are the critical parameters to which the indicator responds, and what are their values?

c) What is the minimum exposure time for the process being monitored to yield an acceptable endpoint response?

d) What temperature is needed to obtain an acceptable endpoint response?

e) Is there a reference chart or color standard that illustrates an acceptable and unacceptable endpoint response?

f) Are there any intermediate color changes before the endpoint is reached?

g) Does the manufacturer have a documented quality assurance program?

h) Does the manufacturer recommend any in-house test or tests that can be used to verify the performance of the chemical indicator as stated?

i) What are the storage requirements (shelf life, temperature, humidity, lighting, other)?

j) Does the response (endpoint color) remain stable after exposure? If so, how long will it remain stable?

k) If the endpoint color does not remain permanent after exposure, what condition or conditions will change the endpoint color response?

l) Are there any chemicals in or on the indicator that may pose a safety hazard?

m) Are data available on biocompatibility and toxicity?

n) Are there any specific precautions that should be taken when handling or using the product?

7.5 Interpretation of chemical indicator responses

A comprehensive sterility assurance program incorporates every aspect of processing to include cleaning, decontaminating, preparing and packaging, loading the sterilizer, handling the item after sterilization, maintaining sterile storage, distributing, and handling to the point of use. Monitoring the sterilization process plays a key role in sterility assurance. If used according to manufacturers' recommendations, chemical indicators can provide useful information on various aspects of the sterilization cycle. The ANSI/AAMI recommended practices, *Good hospital practice: Steam sterilization and sterility assurance* (ANSI/AAMI ST46, now currently under revision) and *Ethylene oxide sterilization in health care facilities: Safety and effectiveness* (ANSI/AAMI ST41:1999), provide comprehensive guidelines for sterility assurance in steam and ethylene oxide sterilization processing.

7.6 Use of chemical indicators in sterility assurance procedures

Chemical indicators, whether applied externally or internally, provide physical evidence that certain critical parameters have been achieved. Devices that show visible soil or that are improperly cleaned or otherwise contaminated may remain nonsterile even after processing in a correctly functioning sterilizer that is operating at commonly accepted sterilization parameters. If the device is not clean, it cannot be sterilized. Because chemical indicators do not respond to either cleanliness or microbial presence, they cannot measure either condition.

The processing department should have written procedures for all processes. It is imperative that means be established to differentiate the status of all items during each phase of the process because the sterilization process comprises multiple steps that may include cleaning, decontaminating, disassembling, inspecting, reassembling, packaging, maintaining terminal sterilization, providing storage, and handling.

The overall sterility assurance program should include product (sterilized goods) identification and traceability; sterilizer calibration, maintenance, and efficacy testing; periodic product monitoring; and mechanical, chemical, and biological monitoring of sterilization cycles. No single element of a sterility assurance program, including the various sterilization monitors, can be relied on, by itself, to ensure sterility. Sterility assurance requires continuous attention to all aspects of sterilizer performance, the sterilization process, and compliance with established policies and procedures.

Proper use of mechanical, biological, and chemical sterilization monitors requires an understanding of what each type of monitor is designed to do and what each reveals about the sterilization cycle or process. Mechanical or physical sterilization monitors (which include time, temperature, and pressure recording devices and gauges) provide real-time assessment of the sterilization cycle conditions and allow many sterilizer malfunctions to be detected as soon as possible. However, mechanical indicators cannot determine if appropriate conditions were achieved throughout the sterilizer, and they cannot detect problems related to improper load configuration or package composition. Chemical indicators are designed to respond with a characteristic chemical or physical change to one or more of the physical conditions (e.g., time, temperature, presence of saturated steam, humidity, ethylene oxide gas concentration, radiation dose) within the sterilizing chamber. An endpoint of a chemical indicator does not prove that the item accompanied by the indicator is sterile. It merely demonstrates that the item has been subjected to certain known processing conditions. Chemical indicators are designed to change when preset critical parameters have been delivered. They have not been designed to show the causes of the failure. It is up to the user to determine the cause or causes of the chemical indicator failure.

A planned program for placing and evaluating chemical indicators may

— be part of the sterilizer installation, operation, and performance qualification protocol;

— be part of the process validation protocol;

— be part of the routine process monitoring protocol;

— assist in the diagnosis of process malfunctions;

— detect packaging problems (e.g., excessively large or dense packs);

— detect loading problems (e.g., tipped basins that can trap air or water if not properly oriented);

— reveal unprocessed loads;

— detect sterilizer malfunctions in air removal or temperature, dwell attainment;

— detect problems with the sterilizing agent supply.

The sterilizer operating specifications are designed to achieve sterilizing conditions that are effective when processing medical devices that have been cleaned thoroughly and packaged for sterilization. In health care facilities, sterilizers are designed to use the “overkill” method whereby a margin of safety is included. A quality assurance system demands that deviations from these set conditions be detected and corrected before nonsterile items result.

8 Labeling of chemical indicators

Labeling of chemical indicators should include all of the information outlined in ANSI/AAMI ST60, subclause 5.6. These requirements are reproduced in annex A.

9 Personnel training

There should be written procedures for selecting and using the chemical indicators. The responsibility for using and interpreting endpoint responses should be assigned to qualified individuals who have been adequately trained and have demonstrated their competence.

10 Storage and handling

The supplier of the chemical indicators is responsible for providing information on the proper transportation, handling, and storage of the chemical indicators before and after exposure.

The performance of a chemical indicator can be affected by the following: the conditions that are encountered during shipping or storage before its use, the method of use, the sterilizer operating parameters, the techniques used after exposure to the sterilization process, and the stability of the chemical indicator following its exposure to the sterilization process. Therefore, the recommendations of the chemical indicator manufacturer for shipping, storage, use, and filing (records) should be followed. Failure to follow these recommendations could adversely affect the integrity and performance of the chemical indicator and lead to incorrect assumptions. The information provided by the manufacturer as to expiration date of the chemical indicator should also be followed.

11 Recordkeeping

Chemical indicators may be kept as part of the sterilization records. The most common chemical indicators to keep are the Class 2 results. Test results should be evaluated by a responsible, trained person and should include date, sterilizer identification, load number, and sterilizer parameters. Depending on national regulations, other indicators (internal and external) may be kept for varying periods of time. Chemical indicator results may be kept manually or electronically.

Annex A
(Normative)

Labeling requirements—ANSI/AAMI ST60, subclause 5.6

Each package of indicators or the technical information leaflet that is supplied with the package shall state the following information:

a) the change that is intended to occur and, for color change indicators, where the color change cannot be adequately described, along with samples of the expected color range for both changed and unchanged indicators;

b) the critical parameter or parameters to which the indicator will respond and, where applicable, their values;

c) the type (classification) of the indicator, stated as process indicator, specific test indicator, single-parameter indicator, multiparameter indicator, or integrating indicator;

d) the storage conditions;

e) the manufacturing date and shelf life or expiry date under the specified storage conditions;

f) a number or code that allows the manufacturing history to be traced;

g) instructions for use that are essential to ensure proper functioning of the indicator;

h) the name and address of the manufacturer or supplier;

i) the storage conditions for the indicator after use, if the indicator is intended to be retained as part of a record.

Annex B
(Informative)

Chemical indicators for use in new sterilization processes

During the past 5 to 10 years, numerous new sterilization processes have been introduced in the market, some as replacements for the traditional practice of steam or ethylene oxide sterilization. Successful use of new sterilizing agents and sterilization processes depends on the use of the appropriate chemical and biological indicators to monitor these processes. Chemical and biological indicators that are intended for use by health care facilities are regulated by the FDA as medical devices (21 CFR 880.2800). Furthermore, the FDA requires not only that all new sterilization systems have a 510(k) clearance but also that the appropriate chemical or biological indicators used to monitor these systems have 510(k) clearances before marketing those products. The manufacturer of the new sterilization process must, thus, make available an FDA-cleared chemical indicator that is intended to monitor the new sterilization process.

These chemical indicators should be responsive to the critical parameters of the specific sterilization process being monitored. Just as a chemical indicator for steam sterilization is capable of monitoring the critical parameters of the steam sterilization process—time, temperature, and saturated steam—similarly, a good chemical indicator should be responsive to the critical parameters of the new sterilization process.

Because no performance requirements for chemical indicators that are intended for use in the new sterilization processes have been included in the ANSI/AAMI ST60 standard, it is incumbent on the manufacturer to develop performance requirements that evaluate the critical parameters of the sterilization process for which the chemical indicator is intended to be used. As a user of these chemical indicators, one would be wise to request documentation to support the manufacturer's performance claims. Even though the critical parameters may be different from those described in ANSI/AAMI ST60, the manufacturer should follow the same basic principles described in this standard:

a) classification of the chemical indicator as defined in the standard according to the use of the product (i.e., Class 1, 2, 3, 4, or 5);

b) identification of the critical parameters that the chemical indicator will evaluate (e.g., time, sterilizing agent concentration, etc.);

c) tolerances (accuracy) for the specific critical parameter or parameters that the chemical indicator is intended to monitor;

d) ability of the indicator to monitor all critical parameters of the sterilization process;

e) stability of the chemical indicator following exposure to the sterilization process.

When the above considerations are taken into account for evaluating the performance of a chemical indicator for use in a new sterilization process, one should be able to have a level of confidence that the chemical indicator is appropriate for the user's intended purpose.

