STERRAD™ 100NX
STERRAD NX™

with ALLClear™ TECHNOLOGY

TECHNICAL WHITE PAPER

INTRODUCTION

This document describes the technology, concepts, operating theory and testing of the STERRAD™ 100NX System with ALLClear™ Technology and STERRAD NX™ System with ALLClear™ Technology. The STERRAD™ Systems with ALLClear™ Technology, developed by Advanced Sterilization Products (ASP™), represent the next generation of low-temperature hydrogen peroxide gas plasma sterilizers. STERRAD™ Systems with ALLClear™ Technology have both hardware and software enhancements made to provide customers with a sterilization solution that minimizes unexpected delays and downtime.

Key features of the STERRAD™ Systems with ALLClear™ Technology include:

- Ability to sterilize heat and moisture-sensitive instruments due to low moisture environment and load temperatures of 56°C or less.
- Multiple cycle options dedicated to sterilizing distinct types of loads, including those containing lumens and endoscopes. The cycle times range from 24 to 60 minutes.
- Simple, easy-to-use system that reduces operator error. Increased usability with an intuitive hydrogen peroxide cassette* insertion and a wide-angle touchscreen monitor.
- ALLClear™ Technology, which reduces cycle cancellations through fast, accurate detection and correction of load and system issues.
- Compatibility with the STERRAD VELOCITY™ System, which provides a rapid and reliable readout in 15 minutes to verify the effectiveness of the STERRAD™ System sterilization cycles.**

The core technology used by the STERRAD™ Systems with ALLClear™ Technology can quickly and reliably sterilize a wide range of medical devices currently sterilized with steam, ethylene oxide, formaldehyde, or peracetic acid. The sterilization process is as follows: A solution of hydrogen peroxide and water
(59% nominal hydrogen peroxide by weight) is delivered to the sterilizer, then vaporized into the chamber. The solution surrounds and interacts with the devices and creates a biocidal environment that inactivates microorganisms with chemical interactions at multiple biologically important reaction sites.1 A strong electrical field is applied to the chamber and creates a hydrogen peroxide gas plasma that dissociates hydrogen peroxide molecules into energized species. Once the electrical field is turned off, the energized species recombine, which turns the hydrogen peroxide into water and oxygen.

TECHNOLOGY OVERVIEW

The STERRAD™ Systems with ALLClear™ Technology are designed for maximum efficiency, reliability, and usability. They are compatible with ASP™ terminal sterilization consumables such as the
STERRAD VELOCITY™ Biological Indicator / Process Challenge Device (BI/PCD), The STERRAD™ Systems with ALLClear™ Technology have been developed to be compliant with ISO14937:2009 once installed and validated according to ASP™ specifications.

01 STERRAD™ Systems with ALLClear™ Technology System Design

This product features the same low-temperature hydrogen peroxide gas plasma technology[1] as previous generations of STERRAD™ Systems, with software and hardware upgrades. The STERRAD™ Systems with ALLClear™ Technology consist of rectangular sterilization chambers and external touchscreen monitors. The touchscreen has on-screen instructions that simplify the system operation, reducing the potential for operator error. Both the STERRAD™ 100NX System with ALLClear™ Technology and STERRAD NX™ System with ALLClear™ Technology easily integrate within the available facility space. Both STERRAD™ Systems have similar hardware and software, with key features highlighted below.

* As a precaution, when handling any part of the system or load items that have been exposed tohydrogen peroxide, please wear the appropriate PPE (chemical-resistant latex, PVC/vinyl or nitrilegloves). Refer to the glove manufacturer's instructions for use for more information.
**15 minutes or 30 minutes to results dependent on software version. Refer to the IFU for actual time to results.

Components and Features of STERRAD NX™ System with ALLClear™ Technology

Components and Features of STERRAD™ 100NX System with ALLClear™ Technology

Table 1
Components & Features of the STERRAD™ Systems with ALLClear™ Technology

	STERRAD NX™ System with ALLClear™ Technology	STERRAD™ 100NX System with ALLClear™ Technology
Chamber	52 L total volume Single door option	152 L total volume Single and double door option
Touchscreen	8.4" diagonal touchscreen	12.1" diagonal touchscreen
	Projected capacitive touch resolution: 800 x 600 pixels Allows user to select cycle Alerts the user if system encounters a problem	
Cassette Insertion	Cassette insertion and removal is automatic and intuitive	
Instrument Tracking System	An optional bar code scanner for reliable instrument tracking Connectivity through ASP ACCESS™ Technology	
Data Recording	Electronic data storage up to 50 cycles	Electronic data storage up to 200 cycles
	Internal printer for manual recordkeeping Electronic cycle data and records via ASP ACCESS® Technology. USB port allows for data upload and download	
Additional Features	Portable Can be placed on cart	Foot activated door allows for hands-free operation

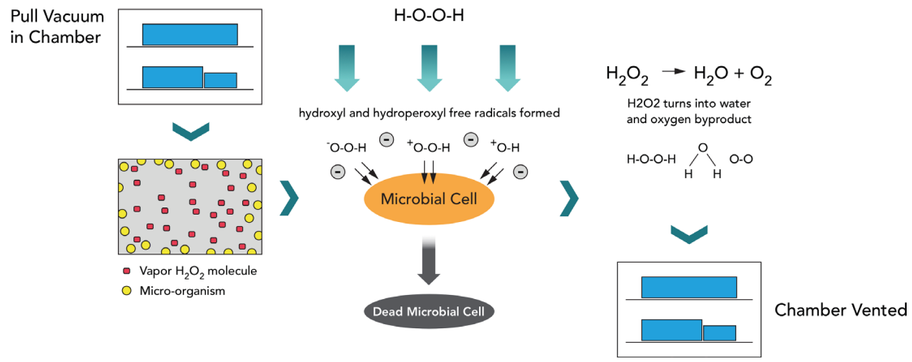
1.1 STERRAD™ Systems Sterilization Process

The STERRAD™ 100NX System with ALLClear™ Technology and STERRAD NX™ System with ALLClear™ Technology involve the combined use of hydrogen peroxide and low-temperature gas plasma to safely and rapidly sterilize medical devices and materials.

Hydrogen peroxide is an oxidizing agent that effects sterilization by oxidation of microorganisms' key cellular components. Hydrogen peroxide is a bactericidal, virucidal, sporicidal, and fungicidal agent, even at low concentration and temperature. Gas plasmas are highly ionized gases, composed of ions, electrons, and neutral particles that produce a visible glow.

A solution of hydrogen peroxide and water (59% nominal hydrogen peroxide by weight) is delivered to the sterilizer. In the STERRAD NX™ System with ALLClear™ Technology STANDARD and ADVANCED cycles, as well as the STERRAD™ 100NX System with ALLClear™ Technology STANDARD and FLEX cycles, the hydrogen peroxide is further concentrated. This does not occur in the STERRAD™ 100NX System with ALLClear™ Technology EXPRESS and DUO cycles. The hydrogen peroxide solution is then vaporized into a gas and transferred to the chamber, where it surrounds the devices and creates a biocidal environment that inactivates microorganisms with chemical interactions. Applying a strong electrical field then creates hydrogen peroxide gas plasma. The plasma is a "cloud" of highly energized species. Once the electrical field is turned off the energized species recombine, turning the hydrogen peroxide into water and oxygen.[1]

Figure 1
Hydrogen Peroxide Gas Plasma Sterilization



1.2 STERRAD™ Systems Sterilization Procedure

Instruments must be cleaned, dried, reassembled, and wrapped in gas permeable packaging material prior to sterilization. The system requires the use of nonwoven polypropylene wraps or Tyvek™ Pouches with STERRAD™ Chemical Indicator (CI) Strips and specially designed trays available from ASP™. Chemical indicator strips and chemical indicator tape are included in loads to confirm exposure to hydrogen peroxide.

Once instruments are ready, operators can use the touchscreen monitor to select one of the sterilization cycles (Section 1.3) or scan a STERRAD VELOCITY™ Biological Indicator / Process Challenge Device (BI/PCD) to begin.

The STERRAD™ System Sterilization Process consists of a sterilization phase that is repeated twice for maximum sterility assurance.

1. The ALLClear™ Technology process is an optional feature that runs before advancing to the sterilization cycle. It includes three steps that are completed in parallel: load check, load conditioning, and system check. The ALLClear™ Technology process takes approximately 5 minutes to complete for a typical load, and it helps to ensure a successful sterilization cycle.
2. Next, the sterilization cycle begins. Aqueous hydrogen peroxide is delivered to the vaporizer/condenser.
3. Chamber pressure is reduced. In the STERRAD NX™ System with ALLClear™ Technology STANDARD and ADVANCED cycles, as well as the STERRAD™ 100NX System with ALLClear™ Technology STANDARD and FLEX cycles, water is removed from the peroxide solution to concentrate it. This does not occur in the STERRAD™ 100NX System with ALLClear™ Technology EXPRESS and DUO cycles.
4. Chamber pressure is further reduced, after which the hydrogen peroxide solution is vaporized to the gas phase and transferred to the sterilization chamber.
5. Hydrogen peroxide diffuses throughout the chamber, surrounds the items in the load, and initiates the inactivation of microorganisms.
6. Low-temperature gas plasma is generated by applying energy to create an electric field.
7. Plasma causes the hydrogen peroxide vapor to break apart into reactive species known as free radicals.
8. Plasma power is then terminated, which causes the free radicals to lose their high energy and recombine as oxygen and water vapor.
9. Steps 2 – 8 consist of one half cycle. They are repeated for the second half cycle, and then the cycle is complete.

Once the cycle is complete, the plasma power is turned off and HEPA-filtered air is introduced to bring the chamber back to atmospheric pressure. When the load is removed, the accompanying STERRAD VELOCITY™ Biological Indicator / Process Challenge Device (BI/PCD) can be activated and incubated in the STERRAD VELOCITY™ Reader at 57±2°C for 15-minute rapid readout detection of any surviving spores.*

1.3 STERRAD™ Systems Cycles

The STERRAD NX™ System with ALLClear™ Technology STANDARD and ADVANCED cycles, as well as the STERRAD™ 100NX System with ALLClear™ Technology STANDARD and FLEX cycles, have a vaporization system that concentrates the hydrogen peroxide solution before it is transferred to the sterilization chamber. This feature reduces cycle times and allows for processing of longer lumened devices. The STERRAD™ 100NX System with ALLClear™ Technology EXPRESS and DUO cycles do not further concentrate the 59% hydrogen peroxide solution delivered from the STERRAD™ System cassettes.

The STERRAD NX™ System with ALLClear™ Technology has two cycles: STANDARD and ADVANCED.
An overview of the two cycles and their processing abilities is in the table below.

Table 2
STERRAD NX™ System with ALLClear™ Technology Cycles

Cycle	Time	Sterilization
STANDARD	28 minutes	- Most surgical instruments - PE/PTFE tubing
ADVANCED	38 minutes	- Single-channel rigid endoscopes - 1 single-channel flexible endoscope

The STERRAD™ 100NX System with ALLClear™ Technology has four cycles: STANDARD, EXPRESS, FLEX, and DUO. An overview of the cycles and their processing abilities is in the table below.

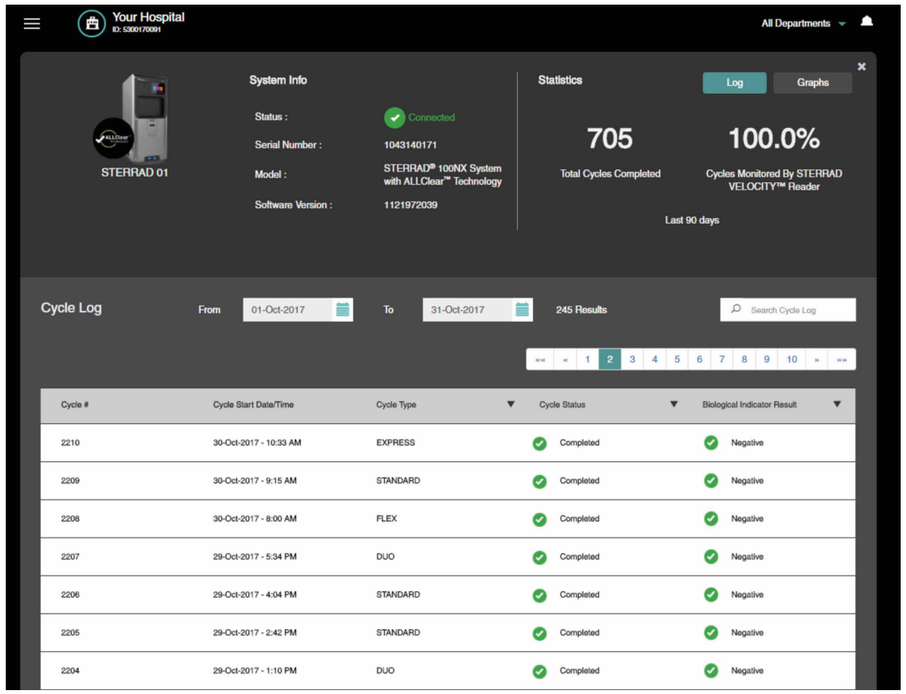
Table 3
STERRAD™ 100NX System with ALLClear™ Technology System Cycles

Cycle	Time	Sterilization
STANDARD	47 minutes	- Most surgical instruments
EXPRESS	24 minutes	For fast turnaround of: - da Vinci® 3-D endoscopes - Rigid telescopes - Rechargeable batteries - Many other instruments
FLEX	42 minutes	- For single-channel flexible endoscopes
DUO	60 minutes	- Can process flexible endoscopes and cameras together - Non-lumened endoscopes

1.4 STERRAD™ Systems with ALLClear™ Technology Process Control and Monitoring Feature

Process Parameter Monitoring The STERRAD™ Systems are controlled by a microprocessor. All critical process parameters are monitored during the operation of the sterilizer. The STERRAD™ Systems feature a control system with a fully integrated hydrogen peroxide monitor as STANDARD equipment for direct measurement of the chamber sterilant concentration. The hydrogen peroxide monitor provides data to the process controller. The process controller uses this data, and information on acceptable cycle limits determined by statistical analysis of microbiological efficacy testing, to make decisions regarding the acceptability of each cycle and ensure a minimum sterility assurance level (SAL) of 10^{-6}.

ASP ACCESS™ Technology ASP ACCESS™ Technology allows the STERRAD™ Systems to connect with other ASP™ products for better workflow efficiency, process control and audit readiness. The connectivity (1) enhances traceability of Biological Indicators, (2) simplifies documentation by keeping STERRAD™ System cycle records in a digital repository, and (3) automatically reconciles STERRAD™ System records to Biological Indicator result record. The system also provides statistics, updates, and performance data for users to assess productivity. ASP ACCESS™ Technology allows staff to monitor data via network computer or receive alerts via email and text message through its secured, redundant application cloud. ASP ACCESS™ Technology stores data for up to a year in its cloud and can transmit STERRAD™ Systems reprocessing data to a hospital's network server and instrument tracking systems (ITS).



Printer A record of the process parameters can be printed on demand through the ASP ACCESS™ Web Application at the end of each cycle. If the sterilization cycle was canceled, the printed record for the cycle will state the reason for the cancelation.

Instrument Tracking Systems (ITS) The STERRAD™ Systems have an optional bar code scanner for reliable instrument tracking, as well as an option to record the load description in the printout and data file.

Independent Monitoring System (IMS) An optional IMS is also available. The IMS provides additional sensors to monitor temperature, pressure, and plasma power to provide independent confirmation that process specifications were achieved. The IMS system supports compliance with
ANSI/AAMI/ISO 14937.**

1.5 ALLClear™ Technology

ALLClear™ Technology is a pre-cycle process that includes a load check, system check, and load conditioning in 5 minutes or less for typical loads. It removes excess moisture and trapped gas and warms the instrument loads. When the system is unable to self-correct, customers are informed prior to beginning the sterilization cycle and provided details about the error. Both the STERRAD NX™ System with ALLClear™ Technology and the STERRAD™ 100NX System with ALLClear™ Technology have improved processing efficiency compared to the STERRAD NX™ System and STERRAD™ 100NX System. The STER-RAD NX™ System with ALLClear™ Technology has greater than a 75% reduction in cancelled cycles com-pared to the STERRAD NX™ System. Likewise, the STERRAD™ 100NX System with ALLClear™ Technology has greater than a 62% reduction in cancelled cycles compared to the STERRAD™ 100NX System.

1.5.1 ALLClear™ Technology Process

The Load Check, System Check and Load Conditioning features work in parallel to automatically diagnose and correct issues prior to starting a sterilization cycle. These features form the core of the ALLClear™ Technology's upgraded reliability and usability.

The Load Check detects issues with outgassing in the sterilization load, and assesses whether these issues can be corrected or if the load must be reworked. It also checks for residual moisture in the load, that the hydrogen peroxide monitor is not blocked, and that nothing is touching the electrode. During the Load Check, the chamber pressure is reduced and an algorithm monitors the chamber pressure pump curve and time to identify any irregularities. The system attempts to auto-correct the load by removing gases or residual moisture. If correction fails, the system will abort the process before beginning the sterilization cycle and alert the user of the error via the graphical user interface (GUI).

The System Check checks the sterilizer for issues with subsystems that could contribute to sterilization cycle cancellations. General systems such as the vacuum subsystem, Low Frequency Power Supply (LFPS) power/ circuit, valve operations, and air flow through the vent filter are tested. As chamber pressure is lowered, the hydrogen peroxide monitor signal is checked to ensure it is within the expected range. The plasma subsystem is also verified to ensure it is operating within specifications and that its ignition is successful and stable.

The Load Conditioning works to correct load issues identified during the Load Check. A plasma is generated to warm surfaces inside the chamber, and then chamber pressure is decreased to remove gases from the load. The chamber is then vented to atmospheric pressure to allow air molecules to transfer energy from warm surfaces inside the chamber to the load. This process is repeated up to two times until the load is successfully conditioned or until the system determines the issue cannot be corrected and the process is aborted.

1.5.2 ALLClear™ Technology System Hardware Features

The Cassette Insertion system provides hydrogen peroxide to the STERRAD™ System during each cycle. After the user inserts the cassette, the system accepts and automatically pulls in the cassette only if it is correctly positioned. This ensures that hydrogen peroxide is correctly dispensed throughout the sterilization cycle. The system also has a hands-free cassette disposal container, which was designed to enhance operator safety.

The Display Assembly Subsystem has an in-plane switching LCD with a wide viewing angle. It includes a Projected Capacitance Touch Sensor (PCAP) and a LCD scaler board with an on-screen display board. The subsystem can be operated with a finger, even when the user is wearing gloves, or with a conductive stylus.

The UV Lamp Assembly provides a stable UV light source for the Hydrogen Peroxide Monitor.
A reliable light source results in accurate measurements. The UV source stability depends on multiple factors, including temperature. To control the temperature of the lamp, the UV lamp housing material is made from an insulating material. An insulation cover provides further thermal insulation. Both the housing material and insulation cover limit the lamp's exposure to environmental temperature effects and increase the temperature stability.

1.6 Biological Monitoring with the STERRAD VELOCITY™ System

The STERRAD VELOCITY™ Biological Indicator / Process Challenge Device (BI/PCD) can be used with both STERRAD™ Systems with ALLClear™ Technology. STERRAD VELOCITY™ BI/PCD uses G. stearothermophilus spores, which are the same species used to validate the STERRAD™ Systems to an SAL of 10-6 (Section 3.1). The STERRAD VELOCITY™ BI/PCD is comprised of a capped plastic vial that has the following components: (1) an inoculated glass fiber disc at the bottom of the vial with at least 106 G. stearothermophilus spores; (2) a Tyvek™ liner at the open end to act as a hydrogen peroxide permeable microbial barrier. The STERRAD VELOCITY™ BI/PCD also have a Class 1 chemical indicator disc on the cap that change color from red/pink to yellow after exposure to hydrogen peroxide. The chemical indicator disc on top of the biological indicator indicates that hydrogen peroxide has been introduced into the sterilization chamber. The STERRAD VELOCITY™ BI/PCD is compatible with the STERRAD VELOCITY™ Reader, which has an easy-to-use touchscreen interface. It takes 15 minutes to read the results*.

02 Ecosystem

The STERRAD™ Systems with ALLClear™ Technology are designed to work seamlessly with other ASP™ products to create an integrative sterilization experience. Automatic communication, data collection, and record-keeping between the STERRAD™ System, STERRAD VELOCITY™ Reader, ASP ACCESS™ Technology, instrument tracking system, and hospital network enhances compliance. The user is notified after an incomplete cycle via the STERRAD™ Systems with ALLClear™ Technology touchscreen as well as through other monitoring devices via the ASP ACCESS™ Technology.

2.1 Compliance

The STERRAD™ Systems with ALLClear™ Technology incorporate multiple features to automatically enhance compliance. It features a touch screen graphical user interface that includes on-screen notifications including automatic BI reminders, a graphic display that indicates proper load placement for the selected cycle, and cycle information screens describing the types of devices that can be processed in each cycle. Automatic communication of information between the STERRAD™ System, ASP ACCESS™ Technology, STERRAD VELOCITY™ System, and an instrument tracking system or hospital network enhances compliance through BI usage reminders, automatic and immediate reconciliation of sterilizer cycle and BI results, and automated record keeping.

03 Testing and Validation

A sterilization process must inactivate a broad spectrum of microorganisms, including resistant bacterial spores. Previous studies conducted with the STERRAD™ 100 Sterilizer, which also uses hydrogen peroxide gas plasma technology, have demonstrated its sterilization ability. These studies were conducted against vegetative bacteria (including mycobacteria), bacterial spores, yeasts, fungi, and viruses. The selection criteria for each organism and the test results are presented in Table 4 below. All the organisms shown in Table 4 were inactivated by an abbreviated STERRAD™ System cycle.

The two viruses tested, Poliovirus Type 1 and Herpesvirus Type 1 represent the major classes of viruses, hydrophilic and lipophilic, respectively. The hydrophilic group normally exhibits a greater resistance to chemical sterilants than the lipophilic group. The log10 virus titers of 3.98, 3.20, and 2.84 represent the minimum concentration of viruses in these tests. Due to the nature of the virucidal test, a minimum virus concentration is determined but the actual concentration is not. In all virucidal tests, there was no infectivity after exposure to the abbreviated STERRAD™ System cycle. This shows that the STERRAD™ Systems are capable of inactivating both hydrophilic and lipophilic viruses.

Table 4
Spectrum of Activity – Vegetative Bacterial, Spores, and Fungi

Microorganism	Type	Interest in Testing	Control*	Results†
Geobacillus stearothermophilis	Bacterial spore	H_2O_2 Resistance; Steam Indicator Organism	2.04×10^6	0/9
Bacillus atrophaeus	Bacterial spore	H_2O_2 Resistance; EtO Indicator Organism	2.69×10^6	0/9
Bacillus pumilus	Bacterial spore	Ionizing Radiation Resistance; Indicator Organism	1.82×10^6	0/9
Staphylococcus aureus	Gram Positive	H_2O_2 Resistance; Clinical Significance	2.82×10^6	0/9
Deinococcus radiodurans	Gram Positive	Ionizing Radiation Resistance	3.10×10^6	0/9
Pseudomonas aeruginosa	Gram Negative	Clinical Significance	1.32×10^6	0/9
Escherichia coli	Gram Negative	Clinical Significance	9.23×10^5	0/9
Serratia marcescens	Gram Negative	H_2O_2 Resistance; Clinical Significance	1.85×10^6	0/9
Moroxelia osloensis	Gram Negative	Ionizing Radiation Resistance	3.14×10^6	0/9
Mycobacterium bovis	Acid Fast	Chemical Resistance; Clinical Resistance	4.20×10^6	0/9
Candida albicans	Yeast	H_2O_2 Resistance	3.95×10^6	0/9
Candida parapsilosis	Yeast	H_2O_2 Resistance; Clinical Significance	1.07×10^6	0/9
Trichophyton mentagrophytes	Filamentous Fungus	Clinical Significance	1.25×10^6	0/9
Aspergillus brasiliensis	Filamentous Fungus	H_2O_2 Resistance; Clinical Significance	1.46×10^6	0/9

* Average titer recovered from nine samples
† # Positive/ # Tested

Microorganism	Type	Interest in Testing	Virus Titer log 10	Infectivity
Poliovirus Type 1 (Brunhilde)	Hydrophilic (non-enveloped)	Chemical Resistance; Clinical Significance	Test 1 ≥ 3.98 Test 2 ≥ 3.98	Not detected Not detected
Herpesvirus Type 1	Lipophilic (enveloped)	Clinical Significance	Test 1 ≥ 3.20 Test 2 ≥ 2.84	Not detected Not detected

Additional sterilization tests for the STERRAD™ Sterilizer were conducted with hospital pathogens.
In one study, clinical isolates of a wide variety of clinically significant organisms were processed in an abbreviated STERRAD™ System cycle consisting of 40 minutes of diffusion with 3 mg/liter of hydrogen peroxide and 10 minutes of plasma at a power of 300 watts. In these tests, conducted in a hospital, approximately 2.5x106 organisms in a serum solution were inoculated onto a paper strip and sealed in Tyvek™ /PET/PE film pouches. One-half the samples were in 5% serum and one-half were in 10% serum. The results of these tests, which are presented in Table 5, show that total kill was obtained with all clinical isolates tested.

Table 5
Clinical Isolates Tested in an Abbreviated STERRAD™ System Cycle‡

Microorganism	# Positive/ # Tested§
Pseudomonas aeruginosa	0/10
Burkholderia cepacia	0/10
Xanthomonas maltophilia	0/10
Serratia marcescens	0/10
Klebsiella (encapsulated)	0/10
Methicillin-resistant Staphylococcus aureus	0/10
Slime-producing Staphylococcus epidermidis	0/10
Listeria monocytogenes	0/10
Enterococcus faecalis	0/10
Acinetobacter calcoaceticus	0/10
Salmonella sp.	0/10
Shigella sp.	0/10
Campylobacter sp.	0/10
Aeromonas sp.	0/10
Clostridium perfringens	0/10
Clostridium tetani	0/10
Clostridium difficile	0/10
Bacillus subtilis spores	0/10
Micrococcus sp.	0/10
Mycobacterium tuberculosis	0/10
Mycobacterium chelonei	0/10

Microorganism	# Positive/ # Tested§
Bacteroides fragilis	0/10
Fusobacterium sp.	0/10
Anaerobic cocci	0/10
Candida albicans	0/10

Based on the spectrum of activity studies, G. stearothermophilus spores have been determined to be the most resistant to the process. Therefore, the tests conducted to validate the efficacy of the STERRAD NX™ System and the STERRAD™ 100NX System were all conducted with this organism.
The efficacy of the STERRAD™ Systems was established by demonstrating the ability of the system to:
(1) provide an SAL of 10-6 with G. stearothermophilus spores using established validation methods,
(2) sterilize devices with long, narrow lumens, (3) kill over 106 G. stearothermophilus spores on a mated surface, (4) sterilize flexible endoscopes, and (5) pass the AOAC Sporicidal test.

3.1 Validation of 10^{-6} SAL

Two well recognized references detail requirements and methods for validation of sterilization processes:
1) AAMI TIR No. 12-2010 Designing, testing, and labeling reusable medical devices for reprocessing in health care facilities: A guide for medical device manufacturers[2]
2) ANSI/AAMI/ISO 14937:2009, Sterilization of health care products -- General requirements for characterization of a sterilizing agent and the development, validation and routine control of a sterilization process for medical devices[3]

These test methods must demonstrate at least a 10^{-6} SAL for the sterilization process. Since sterilization is a probability function, a minimum SAL of 10-6 means that the probability of having a nonsterile device after completing the sterilization process is less than one in one million. This is the commonly accepted threshold for a sterilized device.

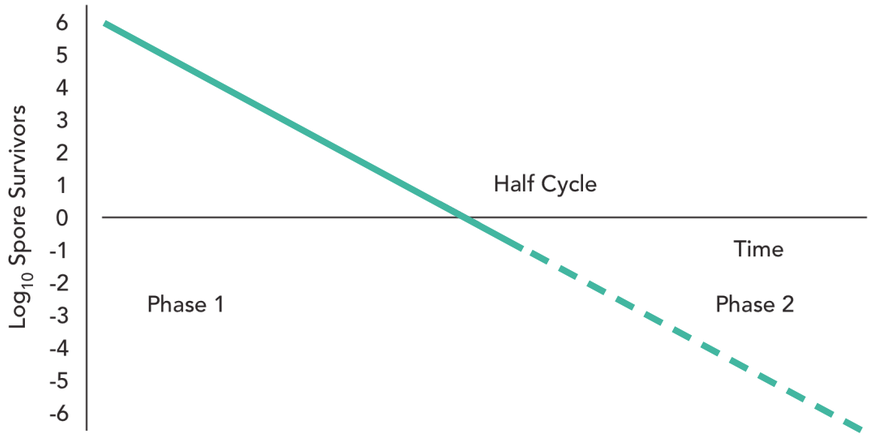
A reproducible biological monitor is needed to demonstrate 10^{-6} SAL. The organism used in the biological challenge should represent a widely recognized test microorganism that is appropriate for the sterilization process.[2,4] The AAMI guidelines recommend that G. stearothermophilus be used at a population of 10^3 to 10^6 per carrier, and a biological challenge of at least 10^6 G. stearothermophilus spores were used for all STERRAD NX™ System and STERRAD™ 100NX System validation tests.[2, 4]

Spore suspension and carrier preparation are critical to having a consistent biological challenge. An unsuccessful inoculation of spores on surfaces can produce a high concentration of spores in a small area, known as clumping and occlusion. Causes of occlusion include using nonwetting hydrophobic materials, inoculations on cracked or irregular surfaces, or the organic or inorganic debris in spore suspensions. Occlusion of spores extends spore survival during the sterilization process. Since the degree of occlusion is not reproducible, a consistent endpoint will not be obtained for the characterization of a sterilization process. For consistent biological test results, relatively clean suspensions of spores need to be uniformly deposited on appropriate substrates. A biological indicator (BI) must meet these criteria for acceptable validation of a sterilization process.

One of the most commonly used methods of sterilizer validation is the half-cycle overkill method.
This method divides the sterilization process into two half cycles. In the first half cycle, linear semilogarithmic kill kinetics are demonstrated for a total of a 6 log reduction. An idealized “kill curve,” which is the inactivation kinetics of spores on a carrier, is shown in Figure 2.[4]
This method requires an understanding that the same kill kinetics occur during the second half cycle. Extrapolating the first half cycle inactivation to the second half cycle provides an additional 6 log reduction, for a total of 10^{-6} SAL for the full cycle.

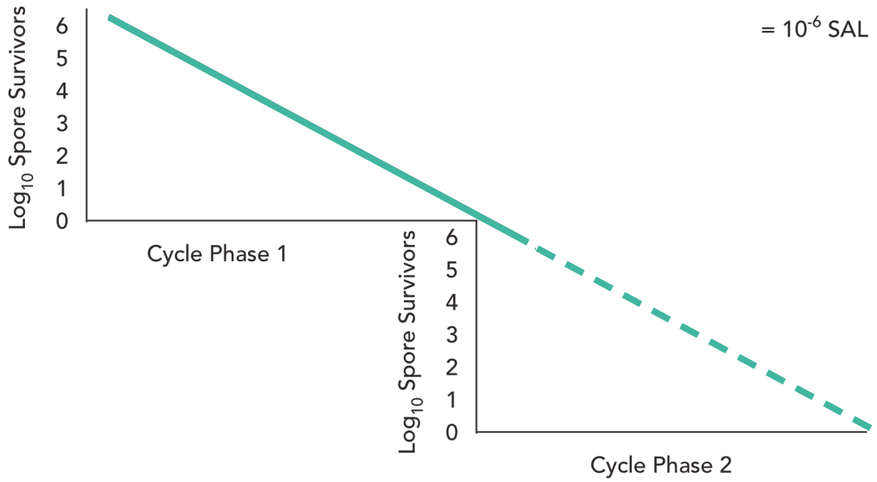
‡ Clinical Isolates tested in an abbreviated STERRAD™ System Cycle. Abbreviated cycle consisted of 40 minutes of diffusion with 3 mg/ liter of hydrogen peroxide and 10 minutes of plasma at a power of 300 watts. § Five tests were conducted in the presence of 5% serum and five tests were conducted in the presence of 10% serum. The third-party trademarks used herein are the properties of their respective owners.

Figure 2
Graphic presentation of half-cycle method of sterilization



Since the STERRAD™ Systems have multiple stages, the demonstration of straight-line, time-based semilogarithmic microbial destruction kinetics is difficult. For this reason, the validation of the STERRAD™ 100NX System and STERRAD NX™ System double injection system was conducted with a variation of the half-cycle method. With this method, the sterilization process has two consecutive, identical phases. The first phase demonstrates a six log reduction of the resistant bacterial spore. Since the second injection cycle has identical process parameters to the first, an additional six log reduction is obtained at the end of the second phase, and the total process provides a 12 log spore reduction or 10^{-6} SAL. The graphical representation of the two-phase method can be seen in Figure 3 below.[4]

Figure 3
Graphic presentation of the two-phase cycle



3.2 STERRAD™ Systems with ALLClear™ Technology Claims

The STERRAD™ 100NX System with ALLClear™ Technology and the STERRAD NX™ System with ALLClear™ Technology are designed for sterilizing both metal and nonmetal medical devices at low temperatures. Because the cycle operates within a dry environment and at low temperatures it is especially suitable for heat and moisture sensitive instruments. The STERRAD™ Systems can also sterilize instruments which have diffusion-restricted spaces, such as the hinged portion of forceps and scissors, as well as lumened flexible endoscopes. The addition of the ALLClear™ Technology does not affect the function of the Biological Indicators and Chemical Indicators.

To test any effect on residual levels, the STERRAD™ Systems were tested with polyurethane, nylon/polyamide, and polyacetal/Delrin® , the three plastic/thermoplastic materials known to be the worst-case for hydrogen peroxide absorption. The STERRAD NX™ System was tested using the ADVANCED sterilization cycle and the STERRAD™ 100NX System was tested using the STANDARD sterilization cycle. Tests were performed with worst-case parameters, and both STERRAD™ Systems were tested with and without the ALLClear™ Technology process.

The residual test results determined that each material's mean hydrogen peroxide residual level was statistically significantly less ($p < 0.05$) than the threshold level of 9100 µg/cm.2 The test results also showed that the average residual levels of all materials were less with the ALLClear™ Technology process compared to without the ALLClear™ Technology process.

3.3 Validation Testing with Lumen Devices

Spore population reduction was measured as a function of time and peroxide concentration. Testing was conducted using the plate count (enumeration) method as well as the fraction-negative method (sterility test).

3.3.1 ALLClear™ Technology with Lumen Devices

The chart below lists the medical devices each STERRAD NX™ System with ALLClear™ Technology cycle can process.

Table 6
STERRAD NX™ System with ALLClear™ Technology Lumen Claims

Type of Cycle	Lumen claims
STANDARD	Single channel stainless steel lumens with: - Inside diameter ≥ 1 mm and length ≤ 150 mm - Inside diameter ≥ 2 mm and length ≤ 400 mm Single channel PE/PTFE tubing with: - Inside diameter ≥ 1 mm and length ≤ 350 mm
ADVANCED	Single channel stainless steel lumens with: - Inside diameter ≥ 1 mm and length ≤ 500 mm Single PTFE lumen tubing with: - Inside diameter ≥ 1 mm and length ≤ 1000 mm Single channel PE/PTFE flexible endoscopes with: - Inside diameter ≥ 1 mm and length ≤ 850 mm

The worst-case devices were identified as the 1 mm X 350 mm Teflon™ (PTFE) lumens for the STANDARD cycle and the 1 mm X 500 mm stainless steel lumens for the ADVANCED cycle. A 10-6 SAL for these worst-case lumens was demonstrated by placing inoculated carriers containing at least 106 G. stearothermophilus spores at the midpoint. The lumens with spore carriers are called biological test units.

The test procedure was as follows: ten biological test units were placed in a standardized hospital tray containing medical devices. Each tray was double wrapped with Halyard™ H400 Sterilization Wrap and placed in the STERRAD NX™ System. The biological test units were exposed to the STERRAD NX™ System half-cycle process at reduced concentrations of hydrogen peroxide. After exposure, the carriers were enumerated or placed in broth media, as appropriate. Enumeration plates were incubated 48 hours at 55 - 60°C and then the plates counted. Sterility test samples were transferred to Tryptic soy broth, incubated for 21 days at 55 - 60°C, and scored for growth (positive) or no growth (negative).

The results of these tests, which are presented in Table 7 and Table 8, demonstrate that the microbial kill depends on the concentration of hydrogen peroxide injected into the chamber and that no spores survived the nominal first half-cycle process conditions, respectively. Surviving organisms were only found when the amount of hydrogen peroxide in the half cycle test was about fifty percent (50%) or less of the nomInal hydrogen peroxide concentration. Since at least a 6 log reduction was obtained at the end of the first half cycle, and the second half cycle is identical to the first, the total STERRAD NX™ System Sterilization process provides a 10^{-6} SAL.

Table 7

Half-Cycle Validation Test with G. stearothermophilus Spores on Stainless Steel Carrier in 1 mm by 350 mm Teflon™ (PTFE) Lumens in a Standardized Validation Load with Reduced Concentrations of Hydrogen Peroxide.

STERRAD NX™ System STANDARD Cycle

Half-Cycle Number	ml of H_2O_2 Injected 53%	Enumeration Test Spore Log Reduction	Biological Results # nonsterile / # tested
1	0.19	1.40	-
2	0.28	3.15	-
3	0.37	-	2/10
4	0.75	-	0/10
5	0.94	-	0/10
6	1.12	-	0/10
7	1.31	-	0/10
8	1.50	-	0/10

Table 8

Half-Cycle Validation Test with G. stearothermophilus Spores on Stainless Steel Carrier in 1 mm by 500 mm Stainless Steel Lumens in a Standardized Validation Load with Reduced Concentrations of Hydrogen Peroxide.

STERRAD NX™ System ADVANCED Cycle

Half-Cycle Number	ml of H_2O_2 Injected 53%	Enumeration Test Spore Log Reduction	Biological Results # nonsterile / # tested
1	0.19	0.82	-
2	0.28	1.49	-
3	0.37	-	10/10
4	0.75	-	0/10
5	0.94	-	0/10
6	1.12	-	0/10
7	1.31	-	0/10
8	1.50	-	0/10

3.3.2 STERRAD™ 100NX System with ALLClear™ Technology with Lumen Devices

The chart below lists the medical devices each STERRAD™ 100NX System with ALLClear™ Technology cycle can process.

Table 9

STERRAD™ 1000NX System with ALLClear™ Technology Lumen Claims

Type of Cycle	Lumen claims
STANDARD	Single channel stainless steel lumens with: - Inside diameter ≥ 0.7 mm and length ≤ 500 mm Single channel PE/PTFE instruments with: - Inside diameter ≥ 1 mm and length ≤ 1000 mm
FLEX	Single channel PE/PTFE flexible endoscope with: - Inside diameter ≥ 1 mm and length ≤ 850 mm
DUO	Single channel PE/PTFE flexible endoscope with: - Inside diameter ≥ 1 mm and length ≤ 875 mm Non-lumened flexible endoscope
EXPRESS	Non-lumened sterilization only

The STANDARD cycle worst-cases were identified as a 0.7 mm X 500 mm stainless steel lumen and a 1 mm x 1000 mm stainless steel lumen. A 10^{-6} SAL for these worst-case lumens was demonstrat-ed by placing inoculated carriers containing at least 106 G. stearothermophilus spores at the lumen midpoint. The lumens with spore carriers are called biological test units.
A similar test procedure to the STERRAD NX™ System lumen validation procedure was performed, with ten biological test units for each worst-case scenario. The results of these tests, which are presented in the tables below, demonstrate that the microbial kill obtained is dependent on the concentration of hydrogen peroxide injected into the chamber and that no spores survived the nominal first half-cycle process conditions. Surviving organisms were only found when the amount of hydrogen peroxide in the half cycle test was about fifty percent or less of the hydrogen peroxide concentration. Since the first half cycle achieved a six log spore reduction, and the second half cycle is identical to the first, the total STERRAD™ 100NX Sterilization process provides an SAL of 10^{-6} for the worst-case scenario.

Table 10

Half-Cycle Validation Test with G. stearothermophilus Spores on Stainless Steel Carriers in 0.7 mm X 500 mm Stainless Steel Lumens in a Standardized Validation Load with Reduced Concentrations of Hydrogen Peroxide.

STERRAD™ 100NX System STANDARD Cycle

Half-Cycle Number	ml of H_2O_2 Injected 53%	Enumeration Test Spore Log Reduction	Biological Results # nonsterile / # tested
1	0.62	1.39	-
2	0.93	3.94	-
3	1.23	-	5/10
4	2.45	-	0/10
5	3.10	-	0/10
6	3.68	-	0/10
7	4.26	-	0/10
8	4.90	-	0/10

Table 11

Half-Cycle Validation Test with G. stearothermophilus Spores on Stainless Steel Carriers in 1 mm X 1000 mm Polyethylene and Teflon™ Tubing with Reduced Concentrations of Hydrogen Peroxide.

STERRAD™ 100NX System STANDARD Cycle

Half-Cycle Number	ml of H_2O_2 Injected 53%	Biological Results # nonsterile / # tested
1	0.93	0/10
2	1.23	0/10
3	2.45	0/10
4	3.10	0/10
5	3.68	0/10
6	4.26	0/10
7	4.9	0/20

3.4 Validation Tests with Mated Surfaces

The STERRAD™ Systems' ability to sterilize mated surfaces to an SAL of 10^{-6} was demonstrated by exposing double-wrapped trays containing the mated surfaces and a standardized load of medical devices to half cycle conditions. The mated surface biological challenge consisted of two material samples inoculated with 10^6 G. stearothermophilus spores sandwiched between them. Stainless steel, titanium, and the polymers Ultem®, Delrin® , and Radel® , have been validated.

3.4.1 STERRAD NX™ System Mated Surfaces

The STERRAD NX™ System was validated for mated surfaces in the STANDARD cycle since the ADVANCED cycle has more lethal conditions. G. stearothermophilus spores were inoculated between two identical mated material samples. One tray was used per test and the test results are presented in Table 12 below. All samples exposed to one half STANDARD cycle showed no growth after incubating for 21 days at 55 - 60°C in tryptic soy broth, while all positive control samples consisting of the unprocessed mated surface biological challenge were positive. The results demonstrate an SAL of 10^{-6} with mated surfaces for the complete STERRAD NX™ System Process.

Table 12

G. stearothermophilus Spores between Mated Surfaces in a Standardized Validation Load at Half-Cycle Conditions

Material	Test 1 #Positive/#Tested	Test 2 #Positive/#Tested	Test 3 #Positive/#Tested
Stainless Steel Blades	0/4	0/4	0/4
Titanium	0/4	0/4	0/4
Polyacetal (Delrin®)	0/4	0/4	0/4
Polyetherimide (Ultem®)	0/4	0/4	0/4
Polyarylsulfone (Radel®)	0/4	0/4	0/4

3.4.2 STERRAD™ 100NX System Mated Surfaces

The STERRAD™ 100NX System was validated for mated surfaces for both the STANDARD and EXPRESS cycles. G. stearothermophilus spores were sandwiched between the two identical mated surfaces, and two trays were used per test.

The results of the STANDARD half-cycle tests are presented in Table 13. All samples exposed to the STANDARD half-cycle showed no growth after incubating for 21 days at 55 - 60°C in tryptic soy broth, while all positive control samples consisting of the unprocessed mated surface biological challenge were positive. The results demonstrate the ability of the full STERRAD™ 100NX System STANDARD cycle, consisting of two consecutive half cycles, to provide an SAL of 10-6 with mated surfaces of these materials.

Table 13

G. stearothermophilus Spores between Mated Surfaces in a Standardized Validation Load at Half-Cycle Conditions

Material	Test 1 #Positive/#Tested	Test 2 #Positive/#Tested	Test 3 #Positive/#Tested
Stainless Steel Blades	0/10	0/10	0/10
Titanium	0/10	0/10	0/10
Polyacetal (Delrin®)	0/10	0/10	0/10
Polyetherimide (Ultem®)	0/10	0/10	0/10
Polyarylsulfone (Radel®)	0/10	0/10	0/10

The STERRAD™ 100NX System EXPRESS cycle was also validated for mated surfaces. Sterilization was achieved at half-cycle with 4.9 ml injection of 53% hydrogen peroxide, which is equivalent to the worst--case delivery of hydrogen peroxide at the end of the shelf life. The positive controls showed growth and the negative controls showed no growth, meeting the acceptance criteria.

Table 14

Verification Test BI Results of Mated Surface Materials

Materials	Injection Volume of 53% H_2O_2 (ml)	Biological Results # Non-sterile / # Tested
Mated Titanium	4.9	0 / 30
Mated Stainless steel	4.9	0 / 30

This demonstrates that an SAL of 10-6 will be achieved in the STERRAD™ 100NX System EXPRESS full cycle.

3.5 Validation Test with Flexible Endoscopes

The STERRAD™ Systems' ability to sterilize flexible endoscopes to an SAL of 10-6 was demonstrated by exposing biological test units to half cycle conditions. The flexible endoscope biological challenge consisted 106 G. stearothermophilus spores placed at the center of each device.

3.5.1 STERRAD NX™ System with ALLClear™ Technology Flexible Endoscopes

The following table shows flexible endoscope claims for the STERRAD NX™ System with ALLClear™ Technology.

Table 15

STERRAD NX™ System with ALLClear™ Technology Flexible Endoscope Claims

Type of Cycle	Lumen claims
ADVANCED	Single channel PE/PTFE flexible endoscopes diameter with: - Inside diameter ≥ 1 mm and length ≤ 850 mm

Instruments such as choledochoscopes, bronchovideoscopes or ureterorenofiberscopes were processed as individual loads under ADVANCED half-cycle conditions, each with at least 106 G. stearothermophilus spores. A BI was inserted and positioned at the center of the channel of each device. The load, a tray with one device, was processed through an ADVANCED half-cycle with reduced hydrogen peroxide concentration. The results of these tests, presented in Table
16 below, demonstrated sterility of all BIs throughout the 21-day, 55 - 60°C incubation period. This confirms a SAL of 10^{-6} was achieved in the devices when processed through the STERRAD NX™ System ADVANCED sterilization cycle.

Table 16

Half-Cycle Validation Test with G. stearothermophilus Spores on Stainless Steel Carrier in 1 mm by 850 mm. Flexible Endoscope with Reduced Concentrations of Hydrogen Peroxide.

STERRAD NX™ System ADVANCED Cycle

Cycle # (per device)	Biological Results: # nonsterile / # tested		
	Choledochoscope	Bronchovideoscope	Ureterorenofiberscope
1	0/1	0/1	0/1
2	0/1	0/1	0/1
3	0/1	0/1	0/1

3.5.2 STERRAD™ 100NX System with ALLClear™ Technology Flexible Endoscopes

The following table shows the flexible endoscope sterilization claims for the STERRAD™ 100NX System with ALLClear™ Technology .

Table 17

STERRAD™ 100NX System with ALLClear™ Technology Flexible Endoscope Claims

Type of Cycle	Flexible Endoscope Claims
FLEX	Single channel PE/PTFE flexible endoscopes diameter with: - Inside diameter ≥ 1 mm and length ≤ 850 mm
DUO	Single channel PE/PTFE flexible endoscopes diameter with: - Inside diameter ≥ 1 mm and length ≤ 875 mm Non-lumened flexible endoscopes

These claims represent instruments such as choledochoscopes, bronchovideoscopes, ureteroscopes, or ureterorenofiberscopes.
The FLEX cycle worst-case is a 1 mm X 850 mm polyethylene or TeflonTM flexible endoscope lumen. During FLEX testing, the devices were processed in half-cycle conditions with reduced hydrogen peroxide concentration, each with at least 106 G. stearothermophilus spores. A BI was inserted to the center of the channel of each device. Each load consisted of two trays containing one device each. Sterility of all BI's is demonstrated throughout the 21-day, 55-60°C incubation period. The results, presented in Table 18, confirm a SAL of 10^{-6} when a 1mm x 850 mm flexible endoscope lumen is processed through the STERRAD™ 100NX System FLEX sterilization cycle.

Table 18

Half-Cycle Validation Test with G. stearothermophilus Spores on Stainless Steel Carriers in 1 mm X 850 mm Flexible Endoscope with Reduced Concentrations of Hydrogen Peroxide.

STERRAD™ 100NX System FLEX Scope Cycle

Cycle # (per device)	Biological Results: # nonsterile / # tested			
	Choledochoscope	Ureteroscope	Bronchovideoscope	Ureterorenofiberscope
1	0/1	0/1	0/2	0/1
2	0/1	0/1	0/2	0/1
3	0/1	0/1	0/2	0/1

Testing for the DUO half-cycle was performed using a 1 mm x 875 mm flexible endoscope with light cords. BIs made from stainless steel carriers were inoculated with at least 106 G. stearothermophilus spores were placed in the mid-point position of the channel of the flexible endoscopes. The flexible endoscope load with BIs was processed in the STERRAD™ 100NX System with ALLClear™ Technology DUO half-cycle with 1.42 mL of 53% hydrogen peroxide, equivalent to the worst-case delivery of hydrogen peroxide at the end of shelf life, with hydrogen peroxide transfer times equivalent to 10%, 25%, and 50% of total exposure. Upon cycle completion, the processed samples were recovered by the direct culture method.

Table 19

STERRAD™ 100NX System DUO Cycle

Phase	% of Transfer Time	Transfer Time (in Seconds)	Biological Results # Nonsterile / # Tested
Transfer	10	36	6/6
Transfer	25	90	5/6
Transfer	50	180	0/6

Growth was observed at 10% and 25% of the transfer time. There were no survivors at half-cycle condition processed with 50% of the transfer time. The positive controls showed growth and the negative (media) controls showed no growth.

3.6 AOAC Sporicidal Test

The AOAC Sporicidal Test is a test listed in the United States Food and Drug Administration (FDA) Guidance Document for the evaluation of sterilization systems. AOAC tests were conducted with
B. subtilis ATCC® 19659TM spores and Clostridium sporogenes ATCC® 3584TM spores on porcelain penicylinders and polyester suture loops** according to Official Methods of Analysis 966.04 of the AOAC. The tests stipulate that large numbers of carriers, contaminated with high numbers of spores of aerobic and anaerobic bacteria, must be sterilized without failure. These tests include a significant organic challenge due to the presence of dried, spent growth media with the spores. Additionally, the sterilizing agent must be able to penetrate small crevices to kill spores on the porous porcelain penicylinders and in the knotted portion of the polyester suture loops.

3.6.1 AOAC Sporicidal Test for STERRAD NX™ System with ALLClear™ Technology

The study results show that, when exposed to a full STERRAD NX™ System STANDARD cycle, no growth was obtained in three separate tests comprising a total of 720 carriers. The results are
in Table 20 below. By passing the AOAC sporicidal test, the STERRAD NX™ System has met a fundamental FDA requirement for sterilization systems and has demonstrated that it is capable of sterilizing large numbers of porous carriers inoculated with resistant aerobic and anaerobic spores in the presence of organic soil and inorganic salts. Testing was repeated for the STERRAD NX™ System ADVANCED Sterilization process with identical results.

Table 20

AOAC Sporicidal Test with STERRAD NX™ System STANDARD Cycle

Test #	Carrier	# of Failures/# Tested	
		B. subtilis	*C. sporogenes*
1	Suture Porcelain	0/60 0/60	0/60 0/60
2	Suture Porcelain	0/60 0/60	0/60 0/60
3	Suture Porcelain	0/60 0/60	0/60 0/60

3.6.2 AOAC Sporicidal Test for STERRAD™ 100NX System

The study results show that, when exposed to a full STERRAD™ 100NX System, no growth was obtained in three separate tests comprising a total of 720 carriers. The results are in Table 21.
By passing the AOAC sporicidal test, the STERRAD™ 100NX System has met a fundamental FDA requirement for sterilization systems and has demonstrated that it is capable of sterilizing large numbers of porous carriers inoculated with resistant aerobic and anaerobic spores in the presence of organic soil and inorganic salts. Testing was repeated for the FLEX, DUO, and EXPRESS Sterilization cycles with identical results.

** Polyester suture loops have been recognized as a viable alternative carrier for an oxidizer sterilant by AOAC and FDA Office of Science and Technology. Polyester suture loops are low hydrogen peroxide absorbers and are more suitable carriers for hydrogen peroxide concentrating technology.

Table 21
AOAC Sporicidal Test with STERRAD™ 100NX System STANDARD Cycle

Test #	Carrier	# of Failures/# Tested	
		B. subtilis	C. sporogenes
1	Suture Porcelain	0/60 0/60	0/60 0/60
2	Suture Porcelain	0/60 0/60	0/60 0/60
3	Suture Porcelain	0/60 0/60	0/60 0/60

04 STERRAD™ Systems Safety

4.1 Effect of Sterilization Cycles on Medical Devices

Sterilization systems must not alter the functional properties of medical devices. Since the STERRAD™ Systems use a secondary plasma, surface modification is minimized. Laboratory tests were conducted on many medical devices to quantify the effect of exposure to repeated STERRAD NX™ System and STERRAD™ 100NX System Sterilization Cycles on the functional properties.

4.1.1 Laboratory Functionality Tests

Laboratory functionality tests were conducted on devices that represent a wide range of materials including metals, plastics, rubber, and optical surfaces, which must retain properties including sharpness, flexibility, optical clarity, and electrical discharge, after repeated sterilization. The list of devices evaluated is presented in Table 22. The table also describes the property measured and the total number of sterilization cycles to which the devices were exposed.

In all tests, the devices were manipulated between sterilization cycles to simulate actual use of the product. The total number of 50 cycles was chosen for devices that normally undergo repeated sterilization and use. If no adverse effect is seen in 50 cycles, it is unlikely that any effects would occur because of additional exposures. Functionality tests were conducted per the device manufacturer's protocol, when available, or by a quantifiable test procedure developed by ASP™.

After exposure to the specified number of STERRAD™ 100NX System or STERRAD NX™ System Sterilization cycles, all test devices passed the manufacturer's functionality test and showed no statistically significant change in the measured functional property. These test results demonstrate that the functional properties of the test devices are not impaired by exposure to repeated STERRAD™ System Sterilization cycles.

Table 22
Representative Medical Devices Evaluated for Compatibility with the and STERRAD NX™ System

Device	Property Mesaured	Total Cycles
Resectoscope	Power Output	50
Forceps	Mechanical Properties	50
Defibrillator Handle and Internal Electrodes	Power Output Compared to Charge Taken	50
Microsurgical Instruments	Subjective Evaluation of Instrument Appearance and Sharpness by Visual Observation, and Mechanical Function of Moving Parts	50
Fiberoptic Ureteroscope	Optics, Mechanical Properties, Subjective Evaluation of Instrument Appearance	50
Rigid hysteroscope	Optics, Mechanical Properties, Subjective Evaluation of Instrument Appearance	50

ASP™ has an extensive evaluation program and has worked with over 200 medical device manufacturers to establish the material compatibility of their devices with the STERRAD™ System Sterilization Process. The online STERRAD™ Sterility Guide (www.sterradsterilityguide.com) has over 23,000 authorized device listings.
Additionally, assessments documenting the material compatibility of these devices with the STERRAD™ Systems are kept up to date. This program provides the STERRAD™ Systems user with the most complete material compatibility information possible and helps to ensure that future medical devices are compatible with the STERRAD™ Systems.

4.2 Worker Safety

4.2.1 Exposure to Hydrogen Peroxide

The STERRAD™ Systems have been designed to prevent hospital personnel from contacting hydrogen peroxide in either the liquid or vapor phase. The 59% nominal hydrogen peroxide solution required for the sterilization process is packaged in a sealed cassette. The patented cassette design contains a chemical leak indicator, visible through a clear plastic overwrap, that changes color should a leak occur. In the unlikely event of a leak, the overwrap further protects operators from exposure to any hydrogen peroxide solution. Once the cassette has been inserted in the sterilizer, it is automatically ADVANCED by the machine, eliminating any danger of exposure to liquid hydrogen peroxide through handling of the cassette. After several sterilization cycles, the used cassette is automatically discarded into a collectionbox for disposal.
The sterilizer injects the hydrogen peroxide into the system where it is concentrated and vaporized.

By the end of the plasma phase, the hydrogen peroxide turns into water and oxygen. Additionally, during the STERRAD™ System cycles all vapor removed from the chamber passes through a filter that is specially designed to decompose hydrogen peroxide into nonhazardous water and oxygen. Monitoring of the area around the STERRAD™ Systems during operation has demonstrated that the concentration of hydrogen peroxide in the atmosphere is less than the OSHA-established limit of 1.0 ppm (8 hour time weighted average). The normal use of the STERRAD™ Systems, therefore, do not emit harmful, toxic chemicals into the atmosphere.

4.2.2 Toxicity of Hydrogen Peroxide

Concentrated hydrogen peroxide liquid will irritate skin and, like other oxidants, can cause severe damage to eyes if direct contact occurs. The safeguards built into the STERRAD™ Systems make any direct contact with hydrogen peroxide unlikely. In the vapor phase, concentrated hydrogen peroxide is irritating to the eyes, nose, throat, and lungs. Generally, this irritation subsides soon after exposure to the vapor ceases. Because hydrogen peroxide has a low vapor pressure, the concentration of hydrogen peroxide vapor above a hydrogen peroxide solution at atmospheric conditions is very low and presents no special safety hazard. A significant concentration of hydrogen peroxide vapor occurs only at the reduced pressure conditions that exist inside the sterilization chamber during the STERRAD™ Systems cycle. This means that hydrogen peroxide vapor will not leak out of the chamber under normal operating conditions.

Hydrogen peroxide has been commonly used as a general disinfectant for many years. The widespread use of hydrogen peroxide and extensive laboratory testing has shown that hydrogen peroxide is not mutagenic or carcinogenic.

4.2.3 Electronic Emissions

The plasma power supply used to generate the low-temperature gas plasma in the STERRAD™ Systems can only be turned on when the sterilization chamber door is closed and the chamber is under vacuum. The power supply operates at a frequency of 49 to 54 KHz. The STERRAD™ Systems complies with the following STANDARDS:

- CAN/CSA-C22.2 No. 61010-1/R:2009; Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use.
- UL 61010-1/R:2008-10; STANDARD for Safety for Electrical Equipment for Laboratory Use.
- EN 61010-1: 2001; Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use.
- EN 61010-2-040: 2005; Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Particular Requirements for Sterilizers and Washer Disinfectors Used to treat Medical Materials.
- EN 60601-1-2: 2014; Medical Electrical Equipment, Part 1: General Requirements for Safety, Section 2: Collateral STANDARD: Electromagnetic Compatibility.
- EN 55011, Group I Class A limits, based on CISPR 11:2010, Group I Class A limits.

4.3 Safety for Patient Use

Medical devices and commonly used medical materials sterilized by the STERRAD® Systems were subjected to extensive toxicological tests as part of the original biocompatibility studies. These tests included:

- Cytotoxicity: Cytotoxicity testing is valuable as a method to screen for biocompatibility of materials intended for use in medical devices. Because cytotoxicity tests are so sensitive, some materials with a history of safe clinical use in medical devices can produce positive cytotoxic responses.

- Medical devices and materials were tested by the extraction/minimal essential medium (MEM) elution tissue culture response cytotoxicity method. In all these tests, the bioreactivity of devices and materials, after processing in the STERRAD™ 100 Sterilization System, was comparable to the bioreactivity of materials and devices before sterilization.

- Acute Systemic Toxicity: Acute systemic toxicity tests demonstrate the symptomatology and lethality caused by a substance. No toxic responses were seen in mice injected with extracts of materials sterilized in the STERRAD™ 100 Sterilization System.

- Ocular Irritation: Ocular irritation tests are a sensitive means of identifying substances that can cause local surface irritation or mucosal irritation. Extracts of materials sterilized by the STERRAD™ 100 Sterilization System were non-irritating in this test.

- Intracutaneous Test: The intracutaneous test is used to determine the irritant effect of any leachables present in extracts of test materials. No irritation was observed in rabbits injected intracutaneousl with extracts of materials sterilized in the STERRAD® 100 Sterilization System.

- Blood Compatibility: Tests for hemolysis and complement activation were conducted to establish the compatibility of materials processed in the STERRAD™ Systems with blood. These tests are designed to detect the potential of materials to cause blood cells to lyse and to initiate certain inflammatory responses. Test results demonstrated that the STERRAD™ Systems do not result in blood compatibility issues with safe materials.

Additionally, the STERRAD™ Systems have been tested for material biocompatibility and found to be safe. The extensive biocompatibility data available for the STERRAD™ Systems provides historical precedent that devices processed in the STERRAD™ 100NX System and STERRAD NX™ System will also be safe.
To confirm this, a range of materials was processed in the STERRAD™ 100NX System and evaluated for biocompatibility. The biocompatibility evaluation included cytotoxicity, acute systemic toxicity and intracutaneous tests and demonstrated that the STERRAD™ Systems are biocompatible. The medical devices processed in the STERRAD™ Systems do not pose a risk to the health of patients or personnel handling the devices.

05 CONCLUSION

The development of the STERRAD™ Systems with ALLClear™ Technology is a continuation of ASP™'s leadership in the development and validation of sterilization processes. ASP™ is a leader in infection prevention and has a long legacy of hydrogen peroxide gas plasma sterilization that began with the launch of the STERRAD™ 100 Sterilization System in 1993. Now, over 20,000 STERRAD™ Systems are processing instruments worldwide, impacting millions of patients annually.

The STERRAD™ Systems with ALLClear™ Technology enhance productivity, compliance and usability. It is the only sterilization system with upgradable technology that enhances system capability, and it has full network integration between the STERRAD™ Systems, STERRAD VELOCITY™ System and ASP ACCESS™ Technology. Refer to the STERRAD™ 100NX System with ALLClear™ Technology and STERRAD NX™ System with ALLClear™ Technology User's Guide for a complete description of the operation of this sterilizer.

REFERENCES

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4 Pflug, I. J. Microbiology and Engineering of Sterilization Processes. Eighth ed. Minneapolis, MN: University of Minnesota Environmental Sterilization Laboratory, September 1996 printing.

STERRAD™ 100NX
STERRAD NX™

with ALLClear™ TECHNOLOGY

Please refer to the STERRAD™ 100NX System with ALLClear™ Technology and STERRAD NX™ System with ALLClear ™ Technology User's Guides for detailed information on how to effectively use your system. If you have questions about whether a particular device can be sterilized in the STERRAD™ 100NX System with ALLClear™ Technology and STERRAD NX™ System with ALLClear™ Technology, consult with the device manufacturer or visit www.sterradsterilityguide.com. For more information, please contact an ASP™ representative.

As a precaution, when handling any part of the system or load items that have been exposed to hydrogen peroxide, please wear the appropriate PPE (chemical-resistant latex, PVC/vinyl, or nitrile gloves). Refer to the glove manufacturer's instructions for use for more information.

asp.com

ASP Advanced Sterilization Products

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