International Technical Data Monograph

V-PRO® maX
Low Temperature Sterilization System

STERIS®

Table of Contents

1 Introduction

This Technical Data Monograph illustrates the principles of operation and demonstrates the safety and efficacy of the V-PRO maX Low Temperature Sterilization System. The summary test data for microbicidal efficacy, material compatibility, and biocompatibility testing performed on the V-PRO maX Sterilization System are included.

The V-PRO maX Sterilizer is intended for use in terminal sterilization of cleaned, rinsed, and dried metal and nonmetal medical devices used in healthcare facilities. The V-PRO maX Low Temperature Sterilization System performs three pre-programmed sterilization cycles; the **Non Lumen, Lumen and Flexible Cycles**.

The **Non Lumen Cycle** can sterilize instruments/devices with the following features[1]:

- Non-lumened instruments including non-lumened general medical instruments, non-lumened rigid, semi-rigid and flexible endoscopes and non-lumened instruments with stainless steel or titanium diffusion-restricted areas such as the hinged portion of forceps or scissors.

The **Lumen Cycle** can sterilize instruments/devices with the following features[2]:

- Lumened and non-lumened instruments with diffusion-restricted spaces such as the hinged portion of forceps and scissors.
- Medical devices, including single, dual and triple channeled rigid and semi-rigid endoscopes, with the following configurations:
  - Single channeled devices with a stainless lumen that is ≥ 0.77mm internal diameter (ID) and ≤ 500mm in length
  - Dual channeled devices with stainless steel lumens that are ≥ 0.77mm ID and ≤ 527mm in length
  - Triple channeled devices with stainless steel lumens that are
    - ≥1.2 mm ID and ≤ 275 mm in length
    - ≥1.8 mm ID and ≤ 310 mm in length

      or
    - ≥2.8 mm ID and ≤ 317 mm in length

The **Flexible Cycle** can sterilize single or dual lumen surgical flexible endoscopes (such as those used in ENT, Urology and Surgical Care) or bronchoscopes in either of two load configurations:

1. Two flexible endoscopes with a light cord (if not integral to the endoscope) and mat with no additional load[3]. The flexible endoscopes may contain either:
   - A single lumen that is ≥ 1 mm ID and ≤ 1050 mm in length
   - Or two lumens with:
     - One lumen that is ≥ 1 mm ID and ≤ 990 mm in length
     - And the other lumen that is ≥ 1 mm ID and ≤ 850 mm in length
2. One flexible endoscope with a light cord (if not integral to endoscope) and mat and additional non-lumened instruments including instruments with diffusion-restricted areas such as the hinged portion of forceps or scissors[4]. The flexible endoscopes my contain either:
   - A single lumen that is ≥ 1 mm ID and ≤ 1050 mm in length
   - Or two lumens with:
     - One lumen that is ≥ 1 mm ID and ≤ 990 mm in length
     - And the other lumen that is ≥ 1 mm ID and ≤ 850 mm in length

Single-use, medical grade polyethylene (PE) and Teflon® (polytetrafluoroethylene) tubing with internal diameter ≥ 1 mm and length ≤ 4 meters may be sterilized in the Flexible Cycle. Up to 26 pieces of tubing with no additional load may be sterilized.*

The principle features of the V-PRO maX Low Temperature Sterilization Systems include:

- Large, easy to use touch screen control panel that is used to initiate and monitor the validated sterilization cycles.
- Proprietary hydrogen peroxide based sterilant which is provided in a multi-cycle container.
- Process monitoring and cycle documentation.
- Automatic load aeration.

* Tubing claims have not been reviewed by the Food and Drug Administration.

- System designed for ease of use and maintenance.
- Easy installation – no utilities other than electricity required; no special venting required.
- Specially designed conditioning phase that aids in removal of residual moisture. All loads should be thoroughly dried before packaging and placing into the sterilizer.

The V-PRO maX Low Temperature Sterilization System consists of several components. These components include:

- The V-PRO maX Sterilizer
- VAPROX® HC Sterilant
- Self-Contained Biological Indicator
- Biological Indicator Test Packs
- Chemical Indicator Tape
- External Process Indicators and Chemical Indicator Strips
- Record Cards and Record Keeping Systems
- Sterilization Trays, Instrument Organizers, and Silicone Mats
- Tyvek®[5] Packaging

1. The validation studies were conducted using a validation load consisting of two instrument trays and two pouches for a total weight of 22.7 kg (50 lbs).
2. The validation studies for all channel/lumen configurations were conducted using a maximum of twenty (20) lumens per load. Hospital loads should not exceed the maximum number of lumens validated by this testing. The validation studies were performed using a validation load consisting of two instrument trays and two pouches for a total weight of 8.9 kg (19.65 lbs).
3. The validation studies were conducted with two flexible endoscopes, each packaged into a tray with silicone mat and light cord (if not integral to endoscope).
4. The validation studies were conducted with a flexible endoscope in a tray with silicone mat and light cord (if not integral to endoscope). Also included in the load were an additional instrument tray and one pouch for a total load weight of 10.9 kg (24 lbs).
5. Tyvek® is a registered trademark of DuPont.

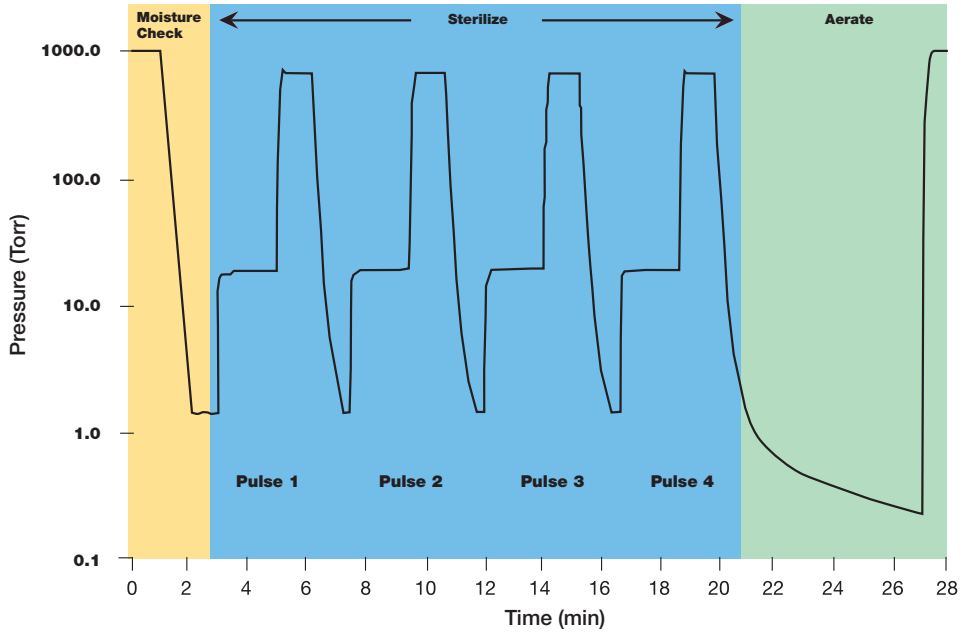
2 V-PRO maX Low Temperature Sterilization System: Principle of Operation

The V-PRO maX Low Temperature Sterilization System uses vaporized hydrogen peroxide or VHP to sterilize medical instruments. Prior to sterilization, cleaned and dried instruments are packaged in wrapped trays, rigid containers or Tyvek pouches that are specifically designed for use with the V-PRO maX Sterilizer. The packaged instruments are placed on the Sterilizer's two shelves and the sterilizer door is shut. Non Lumen, Lumen or Flexible Cycle is selected to initiate the sterilization process.

Non Lumen Cycle

The approximately 28-minute Non Lumen Cycle is used to sterilize instruments without lumens (i.e. surface sterilization) such as defibrillator paddles, cables, cords, non-lumened rigid endoscopes (telescopes), batteries and cameras. The Non Lumen Cycle can be used to sterilize instruments with stainless steel or titanium mated surfaces such as the hinged portion of forceps or scissors. If the load contains a stainless steel lumened instrument, the Lumen Cycle[6] must be selected. If the load contains a flexible endoscope with lumens the Flexible cycle[7] must be selected. If the load contains a mated surface other than stainless steel or titanium, the Lumen Cycle or Flexible cycle must be selected. The prepared and packaged load is processed through a short moisture check phase during which the chamber pressure is reduced to 1 Torr (or 0.13 kPa) and the moisture content of the load is verified to be acceptable. If the moisture content is not acceptable, a short conditioning phase is initiated during which the chamber is evacuated to less than 1 Torr (0.13 kPa) to aid in removal of excess moisture. After the optional conditioning phase, the moisture content of the load is verified to be acceptable. The pressure in the sterilizer chamber is then reduced to 1 Torr (0.13 kPa) in preparation for injection of the VHP. The sterilizer automatically vaporizes the correct amount of liquid hydrogen peroxide from the multiple-cycle VAPROX HC Sterilant cup. After a two-minute hold segment, filtered air enters the sterilization chamber, increasing the chamber pressure to 500 Torr (or 66.7 kPa). After an additional 1 minute hold segment, the chamber pressure is again reduced to 1 Torr (0.13 kPa) in preparation for the next injection of VHP. VHP is injected four times during each sterilization cycle. Each injection is called a sterilization pulse. After completion of the last VHP injection hold segment, the load is automatically aerated in the sterilizer. The chamber VHP is exhausted through a catalytic converter that decomposes the VHP to water and oxygen. No special venting is required for operation of V-PRO maX Sterilizer. At completion of the sterilization cycle, the load is removed and can be immediately used or stored prior to use. The cycle is presented graphically in Figure 1.

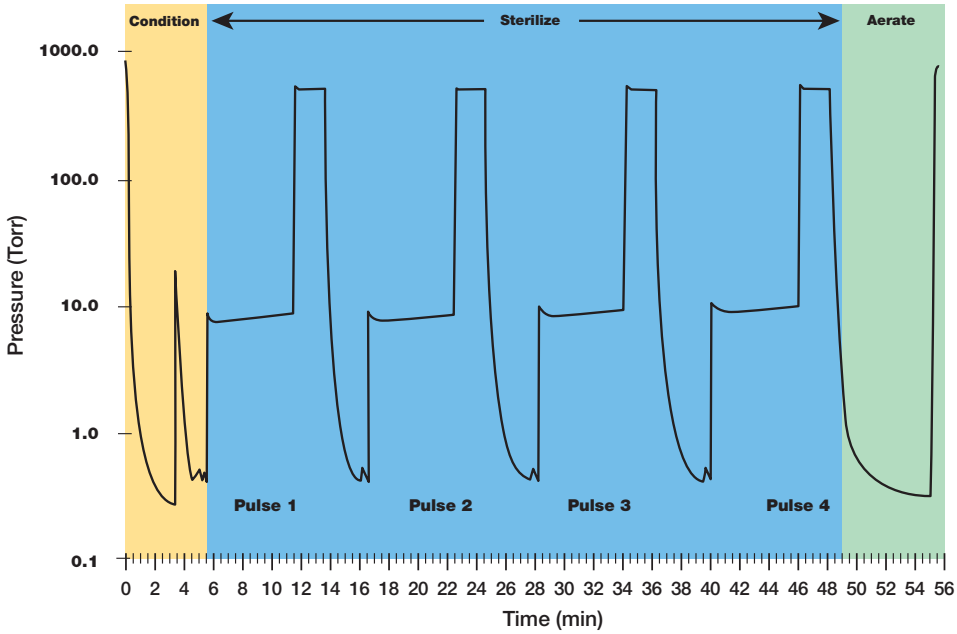
Figure 1. Pressure Graph of the V-PRO maX Sterilizer's Non Lumen Cycle



Lumen Cycle

The approximately 55-minute cycle is used to sterilize instruments with stainless steel lumens[6] and mated surfaces. The prepared and packaged load is processed through a short conditioning phase during which the chamber is evacuated to less than 1 Torr (or 0.13 kPa). After the conditioning phase, the moisture content of the load is verified to be acceptable. The pressure in the sterilizer chamber is then reduced to 0.4 Torr (or 0.05 kPa) in preparation for injection of VHP. The sterilizer automatically vaporizes the correct amount of liquid hydrogen peroxide from the multiple-cycle VAPROX HC Sterilant cup. After a six-minute hold segment, filtered air enters the sterilization chamber, increasing the chamber pressure to 500 Torr (or 66.7 kPa). After an additional 2-minute hold segment, the chamber pressure is again reduced to 0.4 Torr (or 0.05 kPa) in preparation for the next injection of VHP. VHP is injected four times during each sterilization cycle. Each injection is called a sterilization pulse. After completion of the last VHP injection hold segment, the load is automatically aerated in the sterilizer. The chamber VHP is exhausted through a catalytic converter that decomposes the VHP to water and oxygen. No special venting is required for operation of the V-PRO maX Sterilizer. At completion of the sterilization cycle, the load is removed and can be immediately used or stored prior to use. The cycle is presented graphically in Figure 2.

Figure 2. Pressure Graph of the V-PRO maX Sterilizer's Lumen Cycle



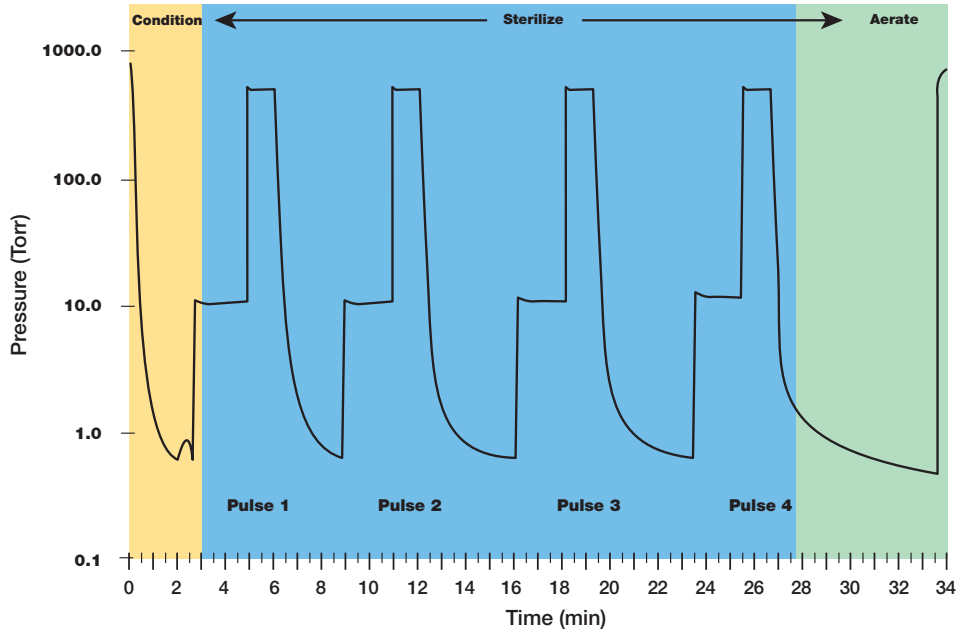
6. Only stainless steel lumen configurations identified on page 3 can be sterilized using the Lumen Cycle.
7. Only flexible surgical endoscopes or bronchoscopes with dimensions identified on page 3 can be sterilized using the Flexible Cycle.

Flexible Cycle

The approximately 35-minute Flexible Cycle is used to sterilize surgical flexible endoscopes (such as those used in ENT, Urology and Surgical Care) and bronchoscopes with lumens and other non-lumened devices (i.e. surface sterilization) such as defibrillator paddles, cables, cords, non-lumened rigid endoscopes (telescopes), batteries and cameras. The Flexible Cycle can be used to sterilize either two single or dual channel flexible endoscopes in a cycle or a single flexible endoscope and non-lumened devices, inlcuding mated surfaces [up to a total of 10.9 kg (24 lbs) per cycle].[7] Stainless steel lumened instruments[6] cannot be processed in the Flexible Cycle.

The prepared and packaged load is processed through a short moisture check phase during which the chamber pressure is reduced to 0.4 Torr (or 0.05 kPa) and the moisture content of the load is verified to be acceptable. If the moisture content is not acceptable, a short conditioning phase is initiated during which the chamber is evacuated to less than 0.4 Torr (or 0.05 kPa) to aid in removal of excess moisture. After the optional conditioning phase, the moisture content of the load is verified to be acceptable. The pressure in the sterilizer chamber is then reduced to 0.4 Torr (or 0.05 kPa) in preparation for injection of the VHP. The sterilizer automatically vaporizes the correct amount of liquid hydrogen peroxide from the multiple-cycle VAPROX HC Sterilant cup. After a two-minute hold segment, filtered air enters the sterilization chamber, increasing the chamber pressure to 500 Torr (or 66.7 kPa). After an additional 1 minute hold segment, the chamber pressure is again reduced to 0.4 Torr (or 0.05 kPa) in preparation for the next injection of VHP. VHP is injected four times during each sterilization cycle. Each injection is called a sterilization pulse. After completion of the last VHP injection hold segment, the load is automatically aerated in the sterilizer. The chamber VHP is exhausted through a catalytic converter that decomposes the VHP to water and oxygen. No special venting is required for operation of V-PRO maX Sterilizer. At completion of the sterilization cycle, the load is removed and can be immediately used or stored prior to use. The cycle is presented graphically in Figure 3.

Figure 3. Pressure Graph of V-PRO maX Sterilizer's Flexible Cycle



3 Consumables

Sterilant

VAPROX HC Sterilant is a proprietary, 59% liquid hydrogen peroxide sterilant that is contained in a multi-cycle cup. The sealed cup is placed into the sterilizer's cup interface and the door is closed. The sterilizer confirms that the sterilant cup is within its expiration date prior to automatically opening the sterilant cup. The sterilant cup has been engineered for safe and easy handling.

Sterility Assurance and Sterile Packaging

The VERIFY™ biological and chemical indicator products and Tyvek Packaging have been designed and validated for use with the V-PRO maX Low Temperature Sterilizer. Each product is designed to meet applicable International Standards. Only use products that have been validated for the V-PRO maX Low Temperature Sterilization System. Failure to do so may result in a non-sterile device or ineffective monitoring of the load.

Equipment Control

Equipment Control Products monitor the critical performance characteristics of the sterilization process. As part of any Sterility Assurance Program, these products confirm that the equipment used is functioning correctly. Biological indicators, such as the VERIFY™ V24I Self-Contained Biological Indicator, offer a fast means of weekly or daily microbial monitoring while test packs such as the VERIFY™ V24I Challenge Pack provide assurance following installation, relocation or major repair.

Load Control

The V-PRO maX Low Temperature Sterilization System provides cycle printouts for verification of critical performance parameters. A place is provided for the cycle reviewer's initials or signature. Biological indicators such as the VERIFY V24I Self Contained Biological Indicator may also be used to monitor and release loads.

Pack Control

Chemical Indicator strips such as the VERIFY HPI Vaporized VH2O2 Process Indicator confirm that sterilant is able to penetrate the packs to be sterilized. Each indicator provides the last check prior to use of the device. The indicator strips are designed to fit in sterilization pouches or trays.

Process Control and Record Keeping

A variety of external process indicators, record cards, record envelopes and logs are available for use with the V-PRO maX Low Temperature Sterilization System. These items are used to prevent the mix up of sterilized items by labeling the packs prior to processing and to ensure complete documentation of sterilization processes.

4 Performance Evaluation

Microbicidal Efficacy Testing

STERIS Corporation conducted tests to validate the microbicidal efficacy of the three cycles of the V-PRO maX Low Temperature Sterilization System. Testing has been completed in the USA, France, Germany and Spain. The V-PRO maX Sterilizer is compliant to ISO EN 14937 Sterilization of health care products – General requirements for characterization of a sterilizing agent and the development, validation and routine control of a sterilization process. The following summarizes the test data demonstrating that these cycles and VAPROX HC Sterilant are effective.

VHP Antimicrobial Efficacy

VHP has been used as a high level disinfectant and sterilant for over 20 years. VHP is known to be virucidal, bactericidal, fungicidal, mycobactericidal, cysticidal and sporicidal. VHP has also been shown to safely reduce the risk of surface prion contamination. The antimicrobial efficacy of VHP has been widely and independently published, with the following references given as examples:

- Kahnert et al (2005). Decontamination with vaporized hydrogen peroxide is effective against *Mycobacterium tuberculosis*. Letters in Applied Microbiology. 40: 448-52
- Klapes and Vesley (1990). Vapor-phase hydrogen peroxide as a surface decontaminant and sterilant. Appl. Environ. Microbiol. 56: 503-506.
- Graham and Rickloff (1992). Development of VHP sterilization technology. J Healthc Mater Manage.10(8):54, 56-8.
- Gustin et al. (2002). The efficacy of vapour phase hydrogen peroxide against nematode infection. Contemporary Topics in Laboratory Animal Sciences. 41, 77-78.
- Heckert et al (1997). Efficacy of vaporized hydrogen peroxide against exotic animal viruses. Appl. Environ. Microbiol. 63: 3916-3918.

- Hall et al (2007). Deactivation of the dimorphic fungi Histoplasma capsulatum, *Blastomyces dermatitidis and Coccidioides immitis* using hydrogen peroxide vapor. Med Mycol. 46(2):189-91
- Johnston et al (2005).Evaluation of hydrogen peroxide vapour as a method for the decontamination of surfaces contaminated with *Clostridium botulinum* spores. J Microbiol Methods. 60(3): 403-11
- Fichet et al (2004). Novel methods for disinfection of prion-contaminated medical devices. The Lancet 364: 521-526.
- Fichet et al (2007). Prion inactivation using a new gaseous hydrogen peroxide sterilisation process. J. Hosp. Infect. 67: 278-386.
- Kokubo et al (1998). Resistance of common environmental spores of the genus *Bacillus* to vapor hydrogen peroxide vapor. PDA J. Pharm. Sci. Technol. 52: 228-231.
- McDonnell et al (2002). Vapor phase hydrogen peroxide decontamination of food contact surfaces. Dairy, Food Environ. Sanit. 22: 23-28.
- McDonnell et al (2001) Room Decontamination with Vapor Hydrogen Peroxide VHP for Environmental Control of Parvovirus. Contemporary Topics in Laboratory Animal Sciences 40, 60-6.
- McDonnell (2007). In, Antisepsis, Disinfection, and Sterilization: Types, Action, and Resistance. ASM Press, Washington DC.
- Meszaros et al. (2005). Area Fumigation with Hydrogen Peroxide Vapor. Applied Biosafety, 10(2):91-100.

Testing with the V-PRO maX Sterilizer, using test conditions described in the EN antimicrobial test methods with modification for testing a gas-based system, has confirmed this efficacy (based on EN14561, 2006). In this testing various microorganisms were inoculated onto either stainless steel coupons or glass slides in the presence of 10% serum to simulate 'dirty' conditions (unless otherwise specified below). The inoculated coupons ($\geq 10^6$ cells or spores/coupon, unless otherwise stated below) were dried for ≥ 30 minutes (until visibly dry) and subjected to a half sterilization cycle in the Lumen Cycle. Coupons were then transferred into growth media and incubated under the appropriate environmental conditions for each test organism. A summary of the results are shown in Table 1.

Table 1. Microbicidal Efficacy of the Lumen Cycle

Organism	Culture Conditions	Log_{10} Reduction
Acinetobacter baumannii	Brain heart infusion, aerobic, 37°C	>6
Burkholderia cepacia	Trypticase soy, aerobic, 37°C	>6
Clostridium difficile (spores)	Reinforced clostridial medium, anaerobic, 37°C	>6
Escherichia coli	Trypticase soy, aerobic, 37°C	>6
Enterococcus faecalis, vancomycin-resistant (VRE)	Trypticase soy, aerobic, 37°C	>6
Enterococcus faecium, vancomycin-resistant (VRE)	Trypticase soy, aerobic, 37°C	>6
Klebsiella pneumoniae	Trypticase soy, aerobic, 37°C	>6
Pseudomonas aeruginosa	Trypticase soy, aerobic, 37°C	>6
Staphylococcus aureus, methicillin-resistant (MRSA)	Trypticase soy, aerobic, 37°C	>6
Streptococcus pneumoniae	Trypticase soy, aerobic, 37°C	>6
L. pneumophila (9 isolates)	Grown by co-cell culture with A. castellanii as a sensitive culture method	>6
Acanthamoeba (2 strains)	Trophozoites or cysts, grown in cell culture	>5*
Mycobacterium species (9 strains)	Inoculated directly	>6
Mycobacterium species (6 strains)	Encysted within Acanthamoeba cysts	No survivors**

* 5 to 6 logs of amoebal cysts were deposited

** Log reduction cannot be accurately calculated. It is not feasible to count the viable mycobacteria within untreated cysts, it is estimated that at least 1 mycobacteria was present for 10 cysts, resulting in > a 4 log reduction.

Complete reduction or a >6 log_{10} reduction of test organism was achieved for all of the tested organisms.

Conclusion

The V-PRO maX Sterilization System is effective against all test organisms, at half cycle and under soiled ('dirty') conditions.

Sterility Assurance Level (SAL) Testing

The V-PRO maX Sterilizer is compliant to ISO EN 14937 Sterilization of health care products – General requirements for character-ization of a sterilizing agent and the development, validation and routine control of a sterilization process. As part of the demonstration of compliance, an SAL of 10^{-6} was established for the V-PRO maX Sterilization System by performing ½ cycle testing using inoculated test articles to simulate medical instruments under worst case sterilization conditions.

Worst Case Test Conditions-Most Resistant Organism:

STERIS conducted vaporized hydrogen peroxide (VHP) resistance testing under greatly reduced exposure conditions with a variety of organisms (Table 2) and bacterial endospores (Table 3) to identify the most resistant organism to VHP.

Table 2. Microbial Resistance to VHP*

Test Organism	Log of Recovered Population at Exposure Time (min)			
	0	1	2	5
***Geobacillus stearothermophilus* spores, ATCC 7953**	**5.8**	**4.5**	**4.6**	**3.8**
Mycobacterium terrae, ATCC 15755	5.9	5.2	4.2	†
Staphylococcus aureus, ATCC 6538	5.0	4.4	2.1	†
Pseudomonas aeruginosa, ATCC 15442	5.7	3.2	0.8	†
Salmonella choleraesuis, ATCC 10708	5.3	3.4	0.8	†
Aspergillus niger spores, ATCC 6275	5.1	2.6	†	†
Klebsiella pneumoniae, ATCC 4352	4.2	3.2	†	†
Trichophyton mentagrophytes spores, ATCC 18748	5.4	2.9	†	†

* Exposure to 1.8 g/min VHP in a 0.6m^3 Isolator

† No organism recovered

Table 3. Bacterial Spore D-Values*

Test Organism	D-Value (seconds)
***Geobacillus stearothermophilus* spores, ATCC 7953**	**42.3**
Bacillus subtilis spores, ATCC 19659	18.7
Clostridium sporogenes spores, ATCC 3584	15.6
Bacillus circulans spores, ATCC 4513	14.4
Bacillus cereus spores, ATCC 12826	9.9

* Exposure to 1.8 g/min VHP in a 0.6m^3 Isolator

Conclusion

Geobacillus stearothermophilus endospores are the most resistant organism and therefore were used to validate the SAL and microbicidal efficacy of the V-PRO maX Low Temperature Sterilization System.

Sterilizer Load

The SAL microbial tests were conducted in the presence of a validation load appropriate for the cycle. Additionally, in the Flexible Cycle, single use PE and Teflon tubing were packaged in either double Tyvek pouches or double wrapped trays. Up to 26 pieces of tubing were processed at one time, with no additional load‡.

½ Cycle

For the SAL studies, ½ cycle evaluation was conducted. The ½ cycle consisted of a moisture check/conditioning phase, 2 sterilization pulses, and an aeration phase. This exposes the test articles to ½ the amount of vaporized hydrogen peroxide (2 sterilization pulses vs. 4 for a full cycle) for ½ of the total sterilant exposure time.

‡ Tubing claims have not been reviewed by the Food and Drug Administration.

Medical instrument material coupons (Table 4 and 8), mated configuration medical instrument coupons (Table 5), stainless steel lumens (Table 6), Teflon lumens (Table 7 and 8), or PE and Teflon tubing (Table 9) were challenged with 10^6 Geobacillus stearothermophilus spores and dried. The test articles were placed within the validation load and exposed to a Lumen ½ Cycle, Non Lumen ½ Cycle or Flexible ½ Cycle. After exposure, the test articles were cultured and the number sterile versus number tested determined. All of the medical instrument materials, mated configuration materials, lumens and tubing were sterile after exposure to ½ Cycles of the V-PRO maX Sterilizer. (Tables 4-8).

Due to the similarities between the Non Lumen and the Flexible Cycles, device materials evaluations conducted in the Non lumen Cycle support the microbicidal efficacy of the Flexible Cycle.

Table 4. ½ Cycle Microbicidal Efficacy Evaluation – Medical Instrument Materials

Medical Instrument Material	# Sterile/# Tested	
	Non Lumen Cycle*	Lumen Cycle
Aluminum	15/15	20/20
Brass	15/15	20/20
Delrin	15/15	20/20
Ethyl vinyl acetate (EVA)	15/15	20/20
Glass	15/15	20/20
Kraton	15/15	20/20
Neoprene	15/15	20/20
Noryl (Polyphenylene Oxide)	15/15	20/20
Nylon	15/15	20/20
Polyether Ether Ketone (PEEK)	15/15	**
Polymethyl methacrylate (PMMA)	15/15	20/20
Polycarbonate	15/15	20/20
Polyethylene	15/15	20/20
Polypropylene	15/15	20/20
Polystyrene	15/15	20/20
Polyvinyl chloride (PVC)	15/15	20/20
Polyurethane	15/15	20/20
Radel	15/15	20/20
Silicone	15/15	20/20
Stainless Steel	15/15	20/20
Teflon	15/15	20/20
Titanium	15/15	20/20
Ultem (Polyetherimide)	15/15	20/20

* Tests conducted in the Non Lumen Cycle qualify materials for sterilization in the Flexible Cycle.

** Tests conducted in the Non Lumen Cycle qualify materials for sterilization in the Lumen Cycle.

Table 5. ½ Cycle Microbicidal Efficacy Evaluation - Mated Instrument Materials

Material	Coupon Pairs Sterile/Pairs Tested	
	Non Lumen Cycle	Flexible Cycle**
Stainless Steel	6/6	***
Titanium	6/6	***
Delrin	N/A*	6/6
Ultem		6/6
Radel		6/6
Noryl		6/6

* N/A = Not Applicable. The Non Lumen Cycle is only intended to sterilize stainless steel or titanium mated surfaces.

** Tests conducted in the Flexible Cycle qualify materials for sterilization in the Lumen Cycle.

*** Tests conducted in the Non Lumen Cycle qualify materials for sterilization in the Flexible and Lumen Cycles.

Table 6. ½ Cycle Microbicidal Efficacy Evaluation for theV-PRO maX Lumen Cycle with Stainless Steel Lumens

Medical Instrument Material	Lumen Size (ID** x Length mm)	# Sterile/# Tested		
		Trial 1	Trial 2	Trial 3
Single	0.77 x 500	12/12	12/12	12/12
Dual	0.77 x 527	1/1	1/1	1/1
	1.17 x 500	1/1	1/1	1/1
Triple	1.2 x 275	1/1	1/1	1/1
	1.2 x 275	1/1	1/1	1/1
	1.8 x 310	1/1	1/1	1/1
Triple	(2x1.5)* x 285	1/1	1/1	1/1
	1.8 x 300	1/1	1/1	1/1
	2.8 x 317	1/1	1/1	1/1

* Oval channel
** Internal Diameter

Table 7. ½ Cycle Microbicidal Efficacy Evaluation for the Flexible Cycle with Flexible Endoscope Load

Lumen Size (ID x Length mm)	# Lumens Sterile/# Tested
1 x 1050	30/30

Table 8. ½ Cycle Microbicidal Efficacy Evaluation for the Flexible Cycle with Mixed Load

Test Article	# Sterile/# Tested
1 mm ID x 1050 mm Length Lumens	15/15
Worst Case Material Coupons	9/9

Table 9. ½ Cycle Microbicidal Efficacy Evaluation for the Flexible Cycle with Polyethylene and Teflon Tubing

Worst-case Test Article	No. of Test Articles Sterile/No. Tested
Double Pouched Teflon Tubing	3/3
Double Pouched Polyethylene Tubing	3/3
Double Wrapped Teflon Tubing	3/3
Double Wrapped Polyethylene Tubing	3/3

Conclusion

All of the device materials, mated device materials and lumens challenged with 10^6 *Geobacillus stearothermophilus* spores were sterile after exposure to a Lumen ½ Cycle, Non Lumen ½ Cycle, or Flexible ½ Cycle, as applicable, thereby establishing a SAL of 10^{-6} for the V-PRO maX Low Temperature Sterilization System.

Modified Total End Point Kill (VHP Dose Evaluation)

Using the inoculated steel lumen test articles described in Table 6 that had been placed within the validation load, various amounts of hydrogen peroxide were introduced into the chamber under Lumen ½ Cycle conditions. The number of sterile test articles versus number tested was determined. All lumens were sterile at the normal sterilant concentration of 8.6 mg/L VHP as well as at the lower concentration of 6.0 mg/L VHP (Table 10).

Table 10. VHP Dose Evaluation of the V-PRO maX Sterilizer's Lumen Cycle

VHP Concentration* (mg/L)	# Sterile Lumens /# Tested
0.5	0/60
2.5	50/60
5.0	57/60
6.0	60/60
8.6	60/60

* Calculated Chamber Concentration

A similar experiment was conducted in the Non Lumen Cycle. Tests established the worst case challenge material to the Non Lumen Cycle. The inoculated and dried worst case challenge material coupon test articles were placed within the validation load. Various amounts of hydrogen peroxide were introduced into the chamber under Non Lumen ½ Cycle conditions. The number of sterile test articles versus number tested was determined. All worst case material coupons were sterile at the normal sterilant concentration of 8.6 mg/L VHP as well as at the lower concentration of 6.0 mg/L VHP (Table 11).

Table 11. VHP Dose Evaluation of the V-PRO maX Sterilizer's Non Lumen Cycle

VHP Concentration* (mg/L)	# Sterile Coupons /# Tested
2.5	9/18
5.0	16/18
6.0	18/18
8.6	18/18

* Calculated Chamber Concentration

The two load configurations for the Flexible Cycle, 2 flexible endoscopes and 1 flexible endoscope with non-lumened load (≥ 24.0 lbs, 10.9 kg), were exposed to varying concentrations of VHP and the number of sterile articles versus number tested was determined. All lumens were sterile at the normal sterilant concentration of 8.6 mg/L VHP as well as at the lower concentration of 6.0 mg/L VHP (Tables 12 and 13).

Table 12. VHP Dose Evaluation of the V-PRO maX Sterilizer's Flexible Cycle with Flexible Endoscope Load

VHP Concentration* (mg/L)	# Sterile Lumens /# Tested
0.5	0/30
2.5	2/30
5.0	29/30
6.0	30/30
8.6	30/30

* Calculated Chamber Concentration

Table 13. VHP Dose Evaluation of the V-PRO maX Sterilizer's Flexible Cycle with Mixed Device Load

VHP Concentration* (mg/L)	# Sterile Lumens/ #Tested	# Sterile Coupons/ # Tested
0.5	0/15	0/9
2.5	0/15	7/9
5.0	10/15	9/9
6.0	15/15	9/9
8.6	15/15	9/9

* Calculated Chamber Concentration

Conclusion

The Non Lumen, Lumen and Flexible Cycles effectively kill 10^6 *G. stearothermophilus* spores, the most resistant organism, in a half cycle evaluation at concentrations below the normal minimum injected concentration of 8.6 mg/L VHP.

AOAC Sporicidal Test Evaluation

The V-PRO maX sterilizer passes the current EN test methods for sporicidal activity, although these methods were modified to allow for testing of a gas based sterilization process. Therefore, as an alternative test, the AOAC sporicidal carrier testing was performed *in situ* to demonstrate the sporicidal efficacy of the V-PRO maX Low Temperature Sterilization System. The AOAC sporicidal test is considered one of the most challenging international tests for evaluating antimicrobial efficacy. The test uses two types of test organisms (spores of *Clostridium* and *Bacillus*), in the presence of gross test soil (dirty conditions), on two different porous surface carrier types (penicylinders and sutures).

Testing was performed as defined in the Official Methods of Analysis of the AOAC International Association of Official Analytical Chemists, 17th Edition, 2000/2006, AOAC Official Method 966.04, "Sporicidal Activity of Disinfectants." It is required that a combination of at least 720 carriers are tested and all to demonstrate the absence of growth following exposure and incubation. All 720 carriers were confirmed to be sterile following exposure to the Non Lumen sterilization cycle using three separate lots of VAPROX HC Sterilant (Table 14). Sporicidal testing conducted in the Non Lumen Cycle verifies efficacy in the Flexible Cycle. The same evaluation conducted in the Lumen Cycle yielded all sterile results.

Table 14. AOAC Sporicidal Carrier Evaluation in the Non Lumen Cycle*

Carrier	#Sterile/#Tested			
	21 Days		24 Days (post heat-shock)	
	1° Tube	2° Tube	1° Tube	2° Tube
Bacillus subtilis penicylinder	180/180	180/180	180/180	180/180
Bacillus subtilis suture loop	180/180	180/180	180/180	180/180
Clostridium sporogenes penicylinder	180/180	180/180	180/180	180/180
Clostridium sporogenes suture loop	180/180	180/180	180/180	180/180
Total	**720/720**	**720/720**	**720/720**	**720/720**

* Tests conducted in the Non Lumen Cycle also qualify the Flexible Cycle

Conclusion

The V-PRO maX Low Temperature Sterilization System effectively inactivates bacterial endospores when evaluated by the AOAC carrier method. VAPROX HC Sterilant is sporicidal.

Medical Instrument Testing

STERIS Corporation conducted tests to validate the V-PRO maX Low Temperature Sterilization System's ability to sterilize medical instruments. Testing has been conducted under laboratory conditions in the USA, as well as in clinical testing in the USA, Germany and Spain. Examples of these tests are given below. The following summarizes the test data demonstrating that the V-PRO maX Sterilizer and VAPROX HC Sterilant are effective under simulated worst case use and clinical use conditions.

Simulated Use Evaluation

Worst case medical instruments with regard to size and features that are challenging to sterilize, were inoculated with 10^6 *G. stearothermophilus* spores with 5% fetal bovine serum and 300 ppm AOAC hard water. The inoculated and dried medical instruments were processed through the Lumen, Non Lumen or Flexible Cycles. After exposure, the medical instrument sites were sampled and evaluated for growth of the test organism. The number of sterile devices tested versus the number of devices tested was determined (Tables 15, 16, 17, and 18). All devices were sterile under worst case simulated use conditions.

Table 15. Non Lumen Cycle Simulated Use Evaluation

Medical Instrument	Inoculation Site	# Sterile / # Tested
Cavity Clip	Surface	3/3
Colorectal Intestinal Dilator	Surface	3/3
Slide for Cannula Tubing	Surface	3/3
Defibrillator	Spoon	3/3
High Frequency Cord	Surface	3/3
Light Cable	Cable	3/3
Ocular Lens	Lens	3/3
Electrosurgical Forceps	Surface	3/3
Telescope	Ocular Surface	3/3
Surgical Scissors	Hinge (Mated Surface)	3/3
Camera	Lens	3/3
Battery	Housing	3/3
Non Lumened Flexible Endoscope	Insertion Tube	3/3

Table 16. Lumen Cycle Simulated Use Evaluation

Medical Instrument	Inoculation Site	# Sterile / # Tested
Surgical Scissors	Hinge (Mated Surface)	3/3
Towel Forceps	Clamp	3/3
Fixation Hooks/Retractor	Tines	3/3
Light Cable	Cord	3/3
Camera	Lens	3/3
Pacemaker Cables	Lead Connector	3/3
Batteries	Housing	3/3
Cystoscope	Contact area with organizer	3/3
	Ocular	3/3
Defibrillator Paddles	Handle	3/3
	Spoons back	3/3
Ureteroscope (dual channel)	0.77 ID* x 527 mm length lumen 1.17 ID x 500 mm length lumens	3/3 3/3
Hysteroscope (triple channel)	1.2 ID x 275 mm length lumen	3/3
Sheath (triple channel)	2.8 ID x 317 mm length lumen	3/3

* ID = Internal Diameter

Table 17. Flexible Cycle Simulated Use Evaluation with Flexible Endoscope Load

Medical Instrument	Inoculation Site	# Sterile / # Tested
Flexible Epiduroscope	1 mm ID* x 1075 mm length lumen	3/3
Flexible Dual Channel Bronchoscope	1.5 mm ID x 700 mm length lumen	3/3
	2 mm ID x 730 mm length lumens	3/3

* ID = Internal Diameter

Table 18. Flexible Cycle Simulated Use Evaluation with Mixed Device Load

Medical Instrument	Inoculation Site	# Sterile / # Tested
Flexible Epiduroscope	1 mm ID* x 1075 mm length lumen	3/3
Flexible Dual Channel Ureterorenoscope	1 mm ID x 990 mm length and 1 mm ID x 850 mm length lumens	3/3
Cavity Clip	Surface	3/3
Colorectal Intestinal Dilator	Surface	3/3
Flexible Nasopharyngoscope	Surface	3/3
Scissors	Hinge (Mated Surface)	3/3

* ID = Internal Diameter

Conclusion

The V-PRO maX Low Temperature Sterilization Systems utilizing VAPROX HC Sterilant reproducibly sterilizes challenging medical instruments inoculated with high levels of the most resistant organism, *G. stearothermophilus* spores.

Clinical Use Evaluation

The cycles of the V-PRO maX Low Temperature Sterilization System were evaluated in a clinical setting with medical instruments that had been used in clinical procedures. The instruments were cleaned, dried, packaged and exposed to either the Non Lumen, Lumen or Flexible Cycles. After exposure, selected medical instrument sites were sampled and evaluated for growth of organisms. The number of sterile instrument sites versus the number of instrument sites tested was determined. All instruments were sterile under clinical use conditions (Tables 19, 20, 21, and 22).

Table 19. Non Lumen Cycle Clinical Use Evaluation

Medical Instrument	Selected Site	# Sterile / # Tested
Surgical Scissors	Hinge	3/3
Colorectal Intestinal Dilators	Surface	3/3
Syringe Plunger	Tip	3/3
Defibrillator Paddle	Spoon	3/3
Light Cord	Cord	3/3
Bipolar Cable	Cable	3/3
Electrosurgical Forceps	Surface	3/3
Camera	Lens	3/3
Batteries	Housing	3/3
Telescope	Ocular Surface	3/3

Table 20. Lumen Cycle Clinical Use Evaluation

Medical Instrument	Selected Site	# Sterile / # Tested
Surgical Scissors	Hinge	3/3
Towel Forceps	Clamp	3/3
Skin/Fixation Hooks/Retractor	Tines	3/3
Defibrillator Paddles	Handle	3/3
	Spoon back	3/3
Light Cable	Cord	3/3
Camera	Lens	3/3
Pacemaker Cables	Lead Connector	3/3
Batteries	Housing	3/3
Telescope	Contact area with organizer	3/3
	Ocular	3/3
Ureteroscope (dual channel)	0.77 ID** x 510 mm length lumen, 1.17 ID x 500 mm length lumens or 0.85 ID x 520 mm length lumen, 1.4 ID x 520 mm length lumens	6/6
Hysteroscope (triple channel) or Sheath (triple channel)	1.2 ID x 275 mm length lumen, 1.2 ID x 275 mm length lumen, 1.8 ID x 310 mm length lumens or 2.8 ID x 317 mm length lumen 1.8 ID x 300 mm length lumen (2 x1.5)* ID x 285 mm length lumens	9/9

* crescent shaped lumen

** ID = Internal Diameter

Table 21. Flexible Cycle Clinical Use Evaluation with Flexible Endoscope Load

Medical Instrument	Selected Site	# Sterile / # Tested
Flexible Laryngoscope	1.5 mm ID* x 768 mm length lumen	3/3
Flexible Dual Channel Bronchoscope	1.5 mm ID x 700 mm length and 2.0 mm ID x 730 mm length lumen	3/3 3/3

* ID = Internal Diameter

Table 22. Flexible Cycle Clinical Use Evaluation with Mixed Device Load

Medical Instrument	Selected Site	# Sterile / # Tested
Flexible Endoscopes	1.5 mm ID* x 768 mm length or 1.0 mm ID x 825 mm length lumen	3/3
		3/3
	Insertion Tube Surface	3/3
Colorectal Intestinal Dilator	Surface	3/3
Surgical Scissors	Hinge	3/3
Syringe Plunger	Tip	3/3
Flexible Dual Channel Ureterorenoscope	1 mm ID x 990 mm length and 1 mm ID x 850 mm length lumens	3/3
		3/3

* ID = Internal Diameter

Conclusion

The Non Lumen, Lumen and Flexible Cycles utilizing VAPROX HC Sterilant reproducibly sterilize clinically used medical instruments.

Overall Conclusions of Microbicidal Efficacy Evaluations

STERIS Corporation has validated the microbicidal efficacy of the V-PRO maX Low Temperature Sterilization System:

- VHP (vaporized hydrogen peroxide) or hydrogen peroxide gas is a well-recognized antimicrobial with efficacy shown against viruses, bacteria, fungi (molds and yeasts), protozoa, prions, and bacterial spores. Bacterial spores, and in particular *Geobacillus stearothermophilus* spores are known to be the most resistant organisms to VHP.
- An SAL of 10^{-6} has been established through ½ cycle testing and modified total end point kill analysis, in accordance to ISO EN 14937.
- The System passed the AOAC Sporicidal Test, considered to be the most challenging sporicidal efficacy test internationally.
- Simulated and Clinical use testing has shown that instruments are sterile when processed in the V-PRO maX Low Temperature Sterilizer utilizing VAPROX HC Sterilant.

5 Materials Compatibility

The sterilization process of the V-PRO maX Sterilizer is compatible with a wide range of medical instruments and materials. STERIS Corporation performed medical instrument materials compatibility evaluations to ensure that the V-PRO maX Low Temperature Sterilization System is safe for medical instruments. Representative medical instruments composed of a variety of materials were subjected to 50 Lumen Cycles (worst case, longest sterilant exposure) with functional evaluations performed before and after the tests. Table 23 lists the materials and type of instruments evaluated for material compatibility.

Table 23. Material Compatibility

Materials	Instrument Evaluated	Cosmetic Change	Functionality
Aluminum	Telescope	None	Pass
	Wide Field Vitrectomy Lens	Loss of black color	
Brass	Resectoscope Working Element	None	Pass
	High Frequency Cord		
	Defibrillator		
	Bridge Adapter		
Delrin	High Frequency Cord	None	Pass
	Defibrillator		
EVA	Slide for Cannula Tubing	Slight yellowing	Pass
Glass	Telescope	None	Pass
	Wide Field Vitrectomy Lens		
Kraton	Cavity Clip	None	Pass
	Piston Syringe with Thumb Control Ring		
	Non-vented Luer Dispenser Tip Cap		
	Pediatric Tuohy Borst Adapter		
Neoprene	Neoprene Rubber Tubing	None	Pass
Noryl	STERIS V-PRO Sterilization Tray	None	Pass

Table 23. Material Compatibility (continued)

Materials	Instrument Evaluated	Cosmetic Change	Functionality
Nylon	High Frequency Cord	Yes	Fail after 39th Cycle*
	Resectoscope Sheath	Fading	Pass
	Resectoscope Obturator		
	Pediatric Tuohy Borst Adapter	None	
PEEK	Endoscope	None	Pass
PMMA	Contact	None	Pass
Polycarbonate	Reusable Nebulizer	None	Pass
Polyethylene	Piston Syringe with Thumb Control Ring	None	Pass
Polypropylene	Defibrillator	None	Pass
	Forceps		
	Piston Syringe with Thumb Control Ring		
	Reusable Nebulizer		
	STERIS V-PRO Sterilization Tray		
Polystyrene	Non-vented Luer Dispenser Tip Cap	None	Pass
Polyurethane	Flexible Endoscope	None	Pass
PTFE	Working Element	None	Pass
	High Frequency Cord		
PVC	Pediatric Tuohy Borst Adapter	None	Pass
	Reusable Nebulizer		
Radel	Adapter for STERIS SYSTEM 1	None	Pass
Silicone	Resectoscope Working Element	None	Pass
	High Frequency Cord		
	Defibrillator		
	Forceps		
	Wide Field Vitrectomy Lens	Slight Discoloration	
	Reusable Nebulizer	None	
Stainless Steel	Resectoscope Working Element	Slight discoloration	Pass
	Microsurgical Scissors	None	
	Telescope		
	Resectoscope Sheath		
	Resectoscope Obturator		
	Forceps		
	Bone Chisel		
	Bridge Adapter		
	Probe Tip		
	STERIS V-PRO Sterilization Tray		
Titanium	Bulldog Clamp	None	Pass
Ultem	Instrument Tray	None	Pass

* See Operator Manual for specific information on compatible materials. Some grades of Nylon, Delrin, and Radel devices may have limited life after repeated sterilization.

Conclusion

Exposure to numerous cycles in the V-PRO maX Sterilizer does not significantly affect the appearance or functionality of most medical instruments.

6 Safety

The toxicology of hydrogen peroxide (H_2O_2) is well understood in the scientific literature. A thorough risk assessment of hydrogen peroxide was completed in 2003 by the European Union. The by-products from hydrogen peroxide sterilization, formed upon decomposition, are water (H_2O) and oxygen gas (O_2).

$$2\ H_2O_2 \longrightarrow 2\ H_2O + O_2$$

These by-products do not present toxicity concerns to the user. Safeguards are in place to protect against potential exposure to hydrogen peroxide.

Liquid Peroxide

Under normal conditions of use, the Sterilizer operator is not exposed to the contents of the VAPROX HC Sterilant cup (59% hydrogen peroxide). The sterilant cup is sealed, and the user cannot access the sterilant without physically damaging the cup. A SDS is provided to advise the user on safe handling practices.

Hydrogen Peroxide Vapors

The user places a sealed, vented sterilant cup into the Sterilizer. The Sterilizer automatically dispenses and injects hydrogen peroxide into the low pressure chamber. At the end of each sterilization pulse, hydrogen peroxide vapor is removed from the chamber through a cata-lytic converter which converts the hydrogen peroxide into water and oxygen. To confirm this, the environment around the sterilizer was monitored under simulated use conditions for acceptable VHP levels during typical sterilization cycle conditions. The levels were >20 times lower than the OSHA hydrogen peroxide gas Time Weighted Average (TWA) limit of 1 ppm. Testing with multiple V-PRO Sterilizers verified that the sterilizers' PEL was less than the 1 ppm TWA limit and, in a 15-minute evaluation of the user’s breathing zone, there was no detectable hydrogen peroxide.

Hydrogen Peroxide on Medical Instruments or Packaging

Biocompatibility testing was conducted for commonly used medical device materials after sterilization in the V-PRO maX Sterilizer to verify effective removal of residuals. As part of the testing, cytotoxicity screening evaluations were conducted. Cytotoxicity is an extremely sensitive methodology that can identify a material as causing a positive cytotoxic response even though that material has an established history of safe clinical use. Therefore, the results obtained after processing in the V-PRO maX Sterilizer were compared to those obtained using a similar technology that has been in clinical use for over fifteen years. In addition to cytotoxicity evaluations, ocular irritation, acute systemic toxicology, intracutaneous irritation and blood compatibility evaluations were performed. The results from these tests demonstrate that items processed in the V-PRO maX Sterilization System do not have their innate biocompatible characteristics altered or compromised.

In accordance with ISO EN 10993-17 Biological evaluation of medical devices- Part 17: Establishment of allowable limits for leachable substances, a risk analysis was conducted and safe levels of residual hydrogen peroxide were established. A risk assessment completed by the European Commission (2003) was used as primary source document for this assessment. The V-PRO maX Sterilization System was shown to reduce the levels of residues on representative medical devices (12 medical devices including flexible endoscopes, resectoscope and forceps) to well below the established residue limits (greater than 9 to 800 fold lower than the allowable residue limit for internal tissue contact established in accordance with ISO 10993-17) proving that the V-PRO maX Sterilizer effectively eliminates toxic process residuals.

7 Conclusion

The V-PRO maX Low Temperature Sterilization System can be used to safely and effectively terminally sterilize properly prepared (cleaned, rinsed and dried) metal and nonmetal medical devices used in healthcare facilities.

Document #10248284 Rev. B (M3665GB)

STERIS Corporation
5960 Heisley Road
Mentor, OH 44060-1834 • USA
440-354-2600 • 800-548-4873
www.steris.com

NOT FOR USE IN USA