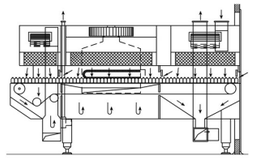
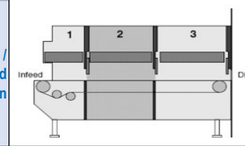
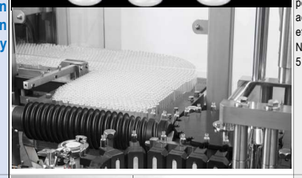
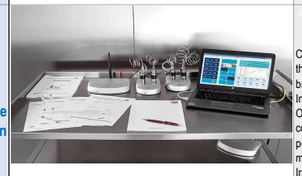
Study Name	Pictorial demonstration	Why to perform ?	What to verify ?	What will be the Test Frequency ?	What will be the potential cause for failure ?	Test Methodology
Airflow Velocity Test	 Anemometer	The purpose of this test is to measure airflow velocity and uniformity, and supply airflow rates through the HEPA filter.	Air velocity should be maintained within 90 fpm ± 20% of mean unit velocity for even distribution of temperature.	6 Monthly considering a critical attribute to determine the tunnel performance	HEPA filter integrity failure Adjustment for air supply damper	Follow the standard ISO 14644-3
Filter system leakage Test	 Aerosols Photometer	The purpose of this test is to confirm that the filter system is properly installed and that leaks have not developed during use	Photometer reading downstream of the HEPA filtration unit caused by the leakage should be less than0.01% of the upstream challenge concentration of the aerosol 100%	6 Monthly considering a critical attribute to determine the tunnel performance	Physical damage of filter media Ageing/ replacement frequency Improper installation /or alignment or/ potential gaps between filters	The standard ISO 14644-3 suggests a penetration of 0.01% of the test challenge concentration but allows alternative criteria to be agreed between customer and supplier. The FDA Guidance, however, indicates that 0.01% penetration is a leak. The ISO 14644-3 standard suggests a concentration ranging 10µg/l and 100µg/l should be used for the photometry test method. It also suggests that concentrations lower than 20µg/l reduces sensitivity, and concentrations over 80µg/l give filter fouling. It is best to use the lower recommended concentration to minimize the potential for blockage or a bleed-through event.
Differential pressure		The Tunnel zones are balanced per the manufacturer specifications. Air does not move from dirty to clean.	Individual differential pressure of individual zone are maintain with in predefined operational limit /or design limit	Can be monitor Daily during the batch processing with certain logical frequency /or interval	Failure in Filter integrity will be the potential cause Pressure balance in between Clean room/or isolator adjacent to preheating and cool zone	N/A
Air flow visualization		To understand and verify the uniformity and pressure cascading	To review and visualize the pressure cascade in washing to preheating , heating to preheating and cool zone and filling to cool zone The entry hot and cooling zones demonstrate laminar air flow.	During Initial qualification After major modification or breakdown e.g. HEPA replace , Blower malfunction Periodic verification after 2-3 year , based on the risk retirement plan	Consider all the elements mentioned under Air velocity, Filter integrity and Differential pressure category	Place smoke generator near pre heating zone to visualize the flow from preheating to washing area. Place smoke generator near cool zone to visualize the flow from filling to cool zone area. Hot zone or/ sterilization zone is more pressurized than pre heating and cool zone , therefore the smoke flow will be both the side during entering or exit from sterilization zone Pressure cascade will be follows, Washing Area <Preheating zone <Sterilization zone >Cool Zone <Filling area
Tunnel Belt / Conveyor speed verification		Tunnel conveyor speed will help to establish a desire exposure time under the high temperature. Both will help to achieve predefine Depyrogenation effect.	To ensure the tunnel conveyor belt speed meets the requirements as specified by OEM (original equipment manufacturer) design qualification, installation qualification, operational qualification, and performance qualification, as well as annular-qualifications. . Conveyor speed shall not vary more than 3% of the set speed	During Initial Qualification and periodic qualification	Conveyer motor change or frequent trip / over load and damage	Mark the conveyer belt and run the tunnel conveyer belt for 30 second to 1 min (check with calibrated stop watch) Stop the conveyor and measure with calibrated measuring scale. Perform 3 time and consider the mean for final value
Nonviable Particle Count (NVPC) Test		The purpose of this test is to provide a cleanliness in the supplied air.	The particle counts taken under the HEPA filter in the different zones of sterilizing tunnel should meet the requirement of ISO 5/class A.	The oven must meet specifications for total particulates, . less than or equal to 100 for less than 0.5 micron per ft3 or less than or equal to 3,500 for less than 0.5 micron per m3 and 0 for 5 micron per m3	Consider all the elements mentioned under Air velocity, Filter integrity and Differential pressure category	The particle count test should be performed by qualified or trained person. Start blower of the sterilizing tunnel. Calculate the number of location need to be tested. Switch on particle counter and place the iso-kinetic suction probes at specified location under the filter of conveyor belt of tunnel and observe the reading, record in reports.
Empty Heat distribution study		To understand the uniformity of empty tunnel heat distribution pattern in empty condition. It gives confidence on the over all design and control philosophy and shows how healthy is your tunnel.	Distribution in the tunnel less uniform than autoclave. Therefore distribution thermocouples are within a range of ± 15.0°C or more can be appropriate consideration based on the OEM (original equipment manufacturer) specification in design document.	During Initial Qualification and periodic qualification (Industry practice is once 2 yearly frequency) After major breakdown or/ maintenance activity of heating and conveyor system based on the risked based approach Apart from the Qualification in alternate way this test can be considered as maintenance check during preventive maintenance.	Failure in the heater blank Variation/or misalignment in individual pressure Improper air flow Air floe within tunnel and adjoining area	Use zig plate to hold vial with the probes (sensor) in place as it help smooth travel through the tunnel. Attach the connecting cable of probes (sensor) to data logger, which can scan the date, time and temperature of probes at every 10 seconds.
Heat penetration and Endotoxin challenge study	 	To ensure that heat is sufficiently penetrating into the inner most portion of the vial subjected for sterilization and Depyrogenation to achieve desired heat Penetration and endotoxin log reduction efficiency of the Tunnel Sterilizer Note: Challenge thermal probe and endotoxin unit should not less than 5 unit.	Study Approach 1: Heat penetration/load mapping study: All the container configuration must be evaluated initially but later on container configuration shows least FH value can be consider as worst one to challenge for periodic qualification. Confirmatory study for Depyrogenation: Endotoxin study to be considered for the lowest FH configuration with least time-temperature condition from the nominal (routine) cycle. Required to demonstrate minimum 3 log reduction. This is considered as worst case challenge to confirm Depyrogenation efficiency. Performance Qualification: If time and temperature criteria is consistently meeting the require FH, then endotoxin challenge may be leverage considering confirmatory study out come. Study Approach 2: All temperature measured in the chamber is ≥ 300°C. Minimum cumulative FH location will be determined for informational purposes only. The recovery of endotoxin concentration after in sterilization and Depyrogenation should at least 3 log reductions.	At least one heat penetration study using thermocouples will be performed for complex load configuration. (6 monthly/or NMT 1 year) Temperature uniformity and delivery of heat will be documented. These studies can be combine with endotoxin challenge or individual endotoxin studies can be performed with different frequency identified with risk based approach.	Container enters to tunnel are wet therefore must be evaluated for uniformity based on the drying efficiency at washing machine by purging compressed air to get uniform thermal input. Container complexity must be evaluated based on the load mass and type of container (tubular or molded).	The temperature sensor should to be place into direct contact with the glass item at the bottom-most the container. Sensor should to be placed to cover the tunnel width extreme right/ left corner and middle (highest density) to get temperature measurement across width of conveyor belt. Get the spiked vials with approx. 10,000 EU/vial of bacterial endotoxin from microbiology. The recovery of endotoxin concentration after exposing to Depyrogenation tunnel should show more than 3 log reduction.
Cool Zone sterilization		Cool Zone sterilization cycle provides better sterility assurance to avoid the microbial contamination after sudden stoppage of machine or breakdown /or routine maintenance program . In routine it is recommended to switch on the tunnel in Blower On/Night mode to maintain the Grade A (ISO 5) condition after completion of batch activity. When machine is completely stopped for performing preventive maintenance or sudden break down maintenance cool zone sterilization cycle need to be considered. Irrespective of maintenance a periodic qualification can be a way to review and understand the reproducibility.	Temperature not less than 170 °C for 1 hr. to be observed. The most common time-temperature relationships for sterilization with hot air sterilizers are 170 °C (340 F) for 60 minutes, 160 °C (320 F) for 120 minutes, and 150 °C (300 F) for 150 minutes. Bacillus atrophaeus spores should be used to monitor the sterilization process for dry heat because they are more resistant to dry heat than are G. stearothermophilus spores. Minimum 6 log reduction of biological indicator Bacillus atrophaeus.	Options include a sterilizable cool zone for improved sterility assurance. Industry practice for requalification is NMT 2 yr. but can be different based on the practices and procedure followed by individual firm.	Firm should look into all the element which can impact the heating. Ensure adequate closure of cool zone from sterilization zone and filling area to reduce potential heat loss. Calibration of sensors and data logger. Selection , qualification and validity of biological indicators.	Dry heat sterilization typically done in 160-190 °C where objective is sterilization rather than Depyrogenation. It will perform in empty condition only as expectation to sterilize the zone not the containers. Distribute sufficient numbers of thermocouples and Bacillus atrophaeus (ATCC No. 9372) biological indicators throughout the conveyor in the cool zone. Review temperature data after completion of cycle, collect the BI's and submit the BI's to micro for incubation.

Revision 01 , typographical correction , dated 16 Dec 2020