In several sterilizer standards, i.e. EN 285, EN 13060, EN 1422, EN 14180, prEN 17180, special tests are described checking gas sterilant penetration characteristics, called type tests. Those tests are cotton packs or helix tube tests which are described in the above-mentioned sterilizer standards and EN ISO/CD 11140-6. Those tests are testing the sterilizer specifications in an empty chamber and have nothing to do testing sterilizer loads, they only assure that the specifications of a sterilizer standard are achieved. The VHPO standard prEN 17180 has not been finished and currently no type test is defined.

Also the following VHPO standards are under development:

1. EN ISO/CD 11138-6:
   Resistance test of biological indicators for hydrogen peroxide sterilization processes

2. prEN 17180:
   Sterilizers for hydrogen peroxide sterilization processes

3. EN ISO/CD 22441:
   Validation and routine monitoring of hydrogen peroxide sterilization processes

A pass of a type test does not guarantee that instruments being sterilized in those sterilizers get sterile or not, because sterilizer loads are quite different in instrument design, packing characteristics and load configuration in comparison to type tests.

To assure sterility of the worst-case configuration of the load has to be tested at the beginning to become sterile. This procedure is called validation. For most of the sterilization processes standards for validation and routine monitoring exist. In the validation standards EN ISO 14937 clause 8, 9, 10 and EN ISO/CD 17665 Version 2:2019 clause 7, 8, 9, 10, A.6.1.2, A.9.4.5, B.3.2, B.4, C.2.1 is a requirement to use PCDs to monitor that the sterilant of a sterilization process can reach the critical area or lumen of complex hollow instruments.

Sterility of difficult to reach areas can be only tested in validation processes using chemical indicators or direct inoculation with biological indicator suspension inside of those areas with difficult sterilant access. For routine monitoring using direct inoculation is no alternative, therefore the use of PCD indicator systems is the only alternative to assure sterility in those complex areas of instruments. The most difficult part in a sterilizer load to reach the sterilant are the lumens of complex MIS instruments and is called worst-case penetration location.

This problem is not only existent in steam sterilization processes, but also an issue for all other low temperature sterilization processes sterilization processes using a gaseous sterilant.

A Process Challenge Device (PCD) alone has no function but require always inside a detector to check if the gaseous sterilant reaches the worst-case penetration area of the PCD. According EN ISO 11140-1 a type 2 indicator system consists of a Process Challenge Device

(PCD) with a chemical, biological or physical indicator inside, called a Type 2 PCD indicator system. More details are explained in the GKE TI 730-171.

All the referenced validation standards require to use such a Type 2 PCD indicator system, however, there is no procedure described which way the validation of those test system shall be carried out.

Biological indicators cannot be located inside packs, also chemical packing indicators cannot be put into narrow lumens of instruments. GKE has developed several type 2 PCD indicator systems which shall represent the most difficult penetration characteristics of the load. They are called “Batch Monitoring Systems (BMS)”, where biological or chemical indicators are put into the worst-case penetration locations (see also TI 730-171). They are used alternatively to BIs or CIs in packs.

The advantage of those BMS is that they are sterilized with the load but positioned outside of the packs and their result can be controlled at the end of a sterilization process without opening any pack and releasing the whole load directly at the end of the process. This procedure only works effectively under the condition that the BMS really represents the load from a worst-case penetration point of view. To assure this requirement it has to be tested that the BMS is equal or more difficult to sterilize than the load and is called validation of the BMS.

However, this way of verification is only valid if it can be secured that the test device represents a higher challenge to air removal and steam penetration than the actual medical device itself or the product family (see EN ISO 17665-1:2006-11, 3.38).

Currently only the German standard DIN 58921 provides information how to validate Type 2 PCD indicator systems to represent complex instruments in steam sterilization processes.

However, this standard does not refer to full load configurations, only instruments.

Validation Procedure

1. Introduction

A complete validation procedure consists of a series of tests called DQ, IQ, OQ, PQ and a routine monitoring procedure at the end. Details are described in the table below:

General Validation procedure to assure sterility and reproducibility of the sterilization process

1.	Process development (Selection of WD, sterilizer, sterilization program, load configuration, packing)	Design Qualification **DQ**
2.	Verification of the specified parameters of the sterilizer that user specifications (e. g. Standards) are met after production	Installation Qualification **IQ**
3.	Verification of specified parameters after installation of the sterilizer at the operating location	Operation Qualification **OQ**
4.	Select the product to be sterilized (each load requires a new validation in industry) Determination of a "Worst Case" load configuration in hospitals	**Job of Tester**
5.	Evaluation of the performance of the whole process Verification if the program used can reproducibly sterilize the defined load configuration using suitable physical methods and/or chemical and/or biological indicators and/or process challenge devices (PCDs) or direct inoculation	Performance Qualification **PQ**
6.	Definition of a suitable routine monitoring to assure long-term reproducibility of the processes	**Job of Tester**
7.	Validation report	**Job of Tester**
8.	Only new PQ necessary, no IQ, OQ Only if anything in IQ, OQ has changed, total new validation	Requalification **RQ**

For further details see in the validation standards:

- EN ISO 14937: General requirements for all validation procedures
- EN ISO 17665-1 Steam
- EN ISO 11135 EO
- EN ISO 25424 LTSF
- EN ISO/CD 22441 H2O2 (in preparation)

IQ and OQ is normally already carried out after installation of the sterilizer. PQ has to be carried out individually with the worst-case load configuration.

2. Principle for PQ

All load configurations have to be inspected to find the most difficult to sterilize instruments. A selection of those instruments has to be assembled as the most difficult load to be sterilized in a sterilization process selected from the customer. This load is called "Worst-Case Load Configuration" (WCLC).

Only this load is tested during validation to represent all instruments sterilized in that process.

To carry out a validation process BIs and/or CIs have to be used to assure sterilization of the most difficult places inside the instruments to test.

A special sterilizer has to be used to simulate the real sterilization conditions normally carried out. These sterilizers are called "resistometers" and are standardized in EN ISO 18472. They can change their parameters to simulate pass or fail conditions. To program fail conditions is necessary to test if insufficient sterilization processes are carried out that the BIs or CIs or PCD indicator systems can show a fail.

3. Materials and test equipment

3.1 Indicators

BIs and suspensions according EN ISO 11138 series

If VHPO sterilization processes are tested the same carrier materials for BIs have to be used as the material of the instruments.

CIs according EN ISO 11140-1 Type 5 or 6

PCD indicator systems according EN ISO 11140-1 selected that their penetration characteristics become equal or better than the worst-case load configuration (WCLC). For details see ***gke*** TI 730-171.

3.2 Preparation of WCLC and BMS

The fail conditions shall be established that type 5 CIs of the process or standard BIs of the process will not pass anymore. For further details see standard DIN 58921 clause 7.

3.2.1 Worst-case load configuration (WCLC)

Select the WCLC according 2. Use the biological or chemical indicators according 3.1 to be put at the worst-case location of the instruments selected. If steam sterilization processes have no type 5 CIs, BIs have to be used. In case worst-case locations in instruments are too small, instead of strips biological indicator suspensions have to be used. Direct inoculation is carried out with a µl-syringe and a long needle. For more information see 5.2 of DIN 58921 or ***gke*** datasheets for load-related BMS.

3.2.2 Selection of Batch Monitoring System (BMS)
As a result of the validation the BMS should be more difficult to sterilize than the WCLC. However, this cannot be known in advance, but must be tested during validation. Therefore it is recommended to use previous experience to select 2-3 PCDs with different penetration characteristics. During the validation procedure (point 4.) the correct BMS must be selected. For more information see 5.3 of DIN 58921.

3.2.3 Packaging
The WCLC shall be packaged in a similar way with the same sterile barrier system complying with EN ISO 11607-1 +-2 and EN 868 series.

3.3 Test equipment
A test sterilizer according EN ISO 18472 shall be used. As pass conditions a copy of the real process shall be simulated.

4. Pre-treatment of WCLC and BMS

4.1 All instruments of the WCLC shall be cleaned according their local cleaning procedure, the BI or CI has to be added according 3.2.1 and packed according 3.2.3.

4.2 The selected 2-3 BMS shall be loaded with the correct chemical indicator for the process used.

4.3 Loading the sterilizer chamber
The packed WCLC and the 2-3 BMS are loaded together into the sterilizer chamber. The BMS should be placed 5 cm above the bottom of the sterilizer, close to the door.

5. Used test cycles

5.1 The standard test cycle of the customer for the process shall be used. Tested load with biological or chemical indicator inside the worst-case locations shall be sterilized with the BMS selected. The following results can occur using different cycles:

5.1.1 BMS + Load pass
The process is accepted to sterilize the load. The BMS can be further tested according 4.2

5.1.3 The load does not pass
The process must be upgraded and tested again until load and BMS pass. For later normal operation the upgraded process has to be used.

5.1.4 The load passes but the BMS fails
The BMS sensitivity shall be downgraded or the process shall be upgraded until loads and BMS pass.

Note 1: If 2-3 PCDs with different sensitivities are tested together, the PCD fulfilling 5.1.1-5.1.3 shall be used.

Note 2: Increasing the process conditions above the requirements of the load is not necessary but it increases the security of the process.

5.2 After both load and BMS have passed the test cycle, the sterilization conditions are changed to provide less good penetration conditions to create a fail of the WCLC and BMS.

Result:

5.2.1 Load passes but BMS fails
The right test procedure and BMS has been selected. Carry out this test three times to get reproducible results.
The correct PCD for routine monitoring is found.

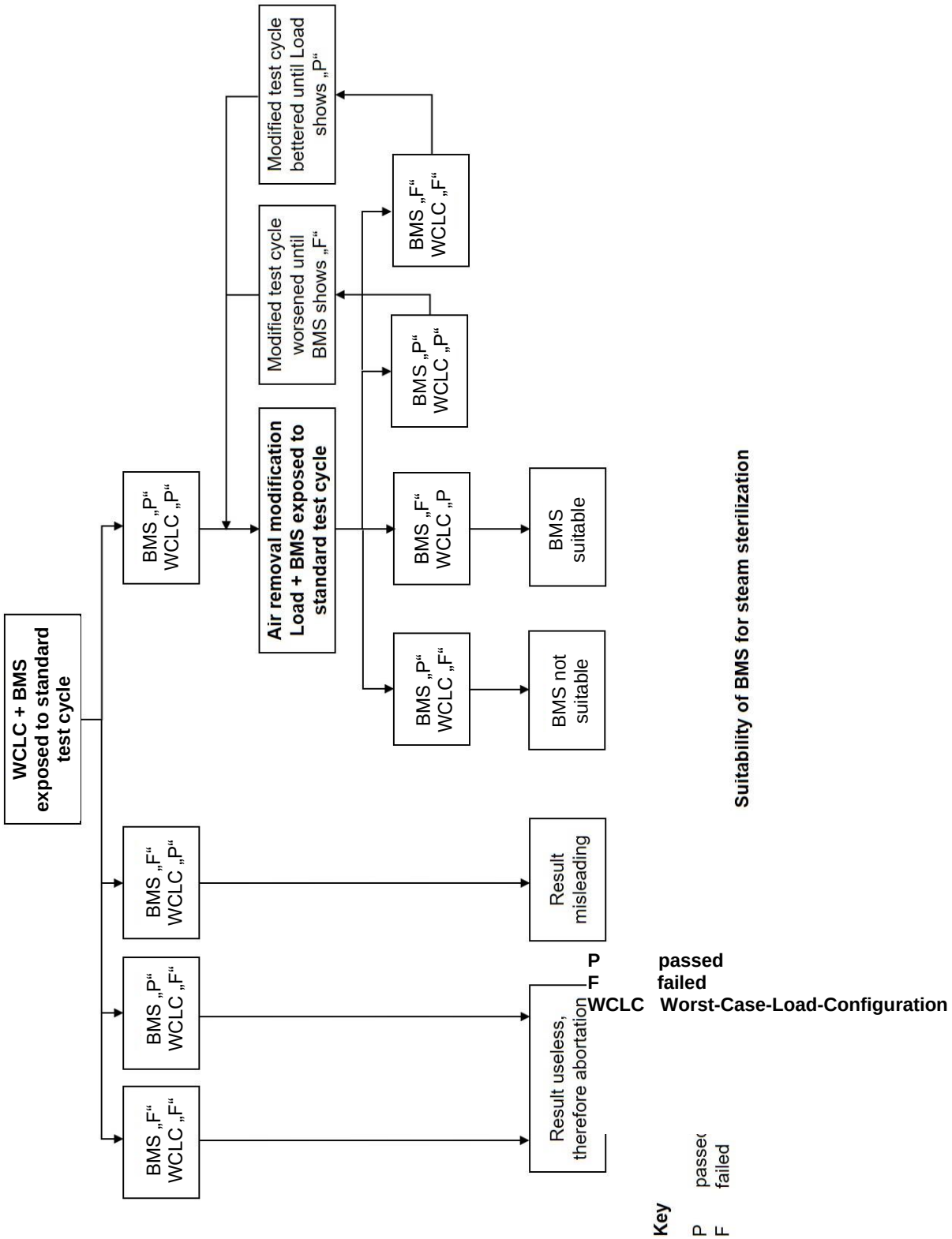
5.2.2 Both load and BMS fail

The process has to be slightly increased that the load passes but the BMS still should fail. If the load and the BMS passes now, the BMS penetration has to be slightly increased so that it will fail in the modified process where the load will still pass.

5.2.3 The load fails but the BMS passes

The penetration characteristics of the BMS have to be upgraded and follow 5.2.1 or 5.2.2.

Annex A


WCLC + BMS exposed to standard test cycle
BMS „P“ WCLC „P“
Air removal modification Load + BMS exposed to standard test cycle
Modified test cycle bettered until Load shows „P“
Modified test cycle worsened until BMS shows „F“
BMS „F“ WCLC „F“
BMS „P“ WCLC „P“
BMS „F“ WCLC „P
BMS suitable
BMS „P“ WCLC „F“
BMS not suitable
BMS „F“ WCLC „P“
Result misleading
BMS „P“ WCLC „F“
BMS „F“ WCLC „F“
Result useless, therefore abortation
Suitability of BMS for steam sterilization
P passed
F failed
WCLC Worst-Case-Load-Configuration
Key
P passed
F failed