

ISO 14644-4

Cleanrooms and associated controlled environments

Part 4: Design, construction and start-up

1 Scope

This part of ISO 14644 specifies requirements for the design and construction of cleanroom installations but does not prescribe specific technological or contractual means to meet these requirements. It is intended for use by purchasers, suppliers and designers of cleanroom installations and provides a checklist of important parameters of performance. Construction guidance is provided, including requirements for start-up and qualification. Basic elements of design and construction needed to ensure continued satisfactory operation are identified through the consideration of relevant aspects of operation and maintenance.

NOTE Further guidance in respect of the above requirements is given in annexes A to H. Other parts of ISO 14644 may provide complementary information.

Application of this part of ISO 14644 is restricted in the following:

- _ user requirements are represented by purchaser or specifier;
- _ specific processes to be accommodated in the cleanroom installation are not specified;
- _ fire and safety regulations are not considered specifically; the appropriate national and local requirements should be respected;
- _ process media and utility services are only considered with respect to their routing between and in the different zones of cleanliness;
- _ regarding initial operation and maintenance, only cleanroom construction-specific requirements are considered.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 14644. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 14644 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 14644-1:1999, *Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness*.

ISO 14644-2:2000, *Cleanrooms and associated controlled environments — Part 2: Specifications for testing and monitoring to prove continued compliance with ISO 14644-1*.

ISO 14644-3:—¹⁾, *Cleanrooms and associated controlled environments — Part 3: Metrology and test methods*.

ISO 14698-1:—¹⁾, *Cleanrooms and associated controlled environments — Biocontamination control — Part 1: General principles*

ISO 14698-2:—¹⁾, *Cleanrooms and associated controlled environments — Biocontamination control — Part 2: Evaluation and interpretation of biocontamination data*.

ISO 14698-3:—¹⁾, *Cleanrooms and associated controlled environments — Biocontamination control — Part 3: Measurement of the efficiency of processes of cleaning and/or disinfection of inert surfaces bearing biocontaminated wet soiling or biofilms*.

¹⁾ To be published.

3 Terms and definitions

For the purposes of this part of ISO 14644, the terms and definitions given in ISO 14644-1 and the following apply.

3.1 changing room

room where people using a cleanroom may change into, or out of, cleanroom apparel

3.2 clean air device

stand-alone equipment for treating and distributing clean air to achieve defined environmental conditions

3.3 cleanliness

condition of a product, surface, device, gas, fluid, etc. with a defined level of contamination

NOTE Contamination can be particulate, non-particulate, biological, molecular or of other consistency.

3.4 commissioning

planned and documented series of inspections, adjustments and tests carried out systematically to set the installation into correct technical operation as specified

3.5 contaminant

any particulate, molecular, non-particulate and biological entity that can adversely affect the product or process

3.6 non-unidirectional airflow

air distribution where the supply air entering the clean zone mixes with the internal air by means of induction

3.7 particle

minute piece of matter with defined physical boundaries

NOTE For classification purposes refer to ISO 14644-1.

3.8 pre-filter

air filter fitted upstream of another filter to reduce the challenge on that filter

3.9 process core

location at which the process and the interaction between the environment and the process occurs

3.10 start-up

act of preparing and bringing an installation into active service, including all systems

EXAMPLE Systems may include procedures, training requirements, infrastructure, support services, statutory undertakings requirements.

3.11 unidirectional airflow

controlled airflow through the entire cross-section of a clean zone with a steady velocity and approximately parallel streamlines

NOTE This type of airflow results in a directed transport of particles from the clean zone.

4 Requirements

4.1 The parameters listed in 4.2 to 4.18 shall be defined and agreed between purchaser and supplier:

NOTE In the requirements stated below, references are made to annexes A to H which are for information only.

4.2 The number, edition and date of publication of this part of ISO 14644 shall be given.

4.3 The role of other relevant parties to the project (e.g. consultants, designers, regulatory authorities, service organizations) shall be established (see examples in annex C).

4.4 The general purpose for which the cleanroom is to be used, the operations to be carried out therein and any constraint imposed by the operating requirements (see examples in annexes A, B and D).

4.5 The required airborne particulate cleanliness class or demands for cleanliness in accordance with the relevant International Standard (ISO 14644-1, ISO 14698-1, ISO 14698-2 and ISO 14698-3) (see examples in annex B).

4.6 The critical environmental parameters, including their specified set points, alert and action levels to be measured to ensure compliance, together with the measurement methods to be used, including calibration (ISO 14644-2 and ISO 14644-3) (see examples in annex F).

4.7 The contamination control concept, including installation, operating and performance criteria, to be used to achieve the required cleanliness level (see examples in annex A).

4.8 The methods of measurement, control, monitoring and documentation required to meet the parameters agreed (see examples in annexes C and F).

4.9 The entry or exit of equipment, apparatus, supplies and personnel required to support the installation (see examples in annex D).

4.10 The specified occupancy states selected from "as-built", "at-rest" and "operational" under which the required parameters shall be achieved and maintained including variations with time, and the methods of control (see examples in annex C).

4.11 The layout and configuration of the installation (see examples in annex D).

4.12 Critical dimensions and mass restrictions, including those related to available space (see examples in annex D).

4.13 The process and product requirements that affect the installation (see examples in annexes B and G).

4.14 The process equipment list with utility requirements (see examples in annexes D, E and H).

4.15 The maintenance requirements of the installation (see examples in annexes D and E).

4.16 The assignment of tasks for the preparation, approval, execution, supervision, documentation, statement of criteria, basis of design, detailed design, construction, testing, commissioning and qualification (including the performance and witnessing) of tests (see examples in annexes E and G).

4.17 The identification and evaluation of external environmental influences (see examples in annex H).

4.18 Additional information required by the particular application (see examples in annex H).

5 Planning and design

5.1 Planning procedure

5.1.1 A project plan shall be developed, in consultation with the user and all other involved parties, to define the requirements of the products, the processes and the scope of the installation.

5.1.2 In order to determine the needs of an installation, a process equipment list shall be compiled, and shall include the critical requirements for each piece of process equipment.

5.1.3 Diversity factors shall be defined, considering peak and average demand for each utility and environmental control system.

NOTE A system may include multiple subsystems which require individual diversity-factor determination.

5.1.4 A contamination control concept shall be developed for each zone of an installation (see examples in annex A).

5.1.5 The specifications as defined in clause 4 shall be reviewed and refined based on financial and timescale requirements.

5.1.6 The project plan shall include the following elements:

- a) design documentation with support calculations;
- b) cost evaluation;
- c) timescale evaluation;
- d) an outline of anticipated project complications;
- e) design options with records of advantages and disadvantages and any recommendations;
- f) a review of maintenance requirements of the installation;
- g) a review of the degree of flexibility to be included in the installation;
- h) a review of the stand-by capacities to be included in the installation;

- i) a review of the constructability of the design of the installation;
- j) a quality plan.

The use of a quality system, such as the ISO 9000 family of international standards (e.g. ISO 9000 and ISO 9001), should be considered, in conjunction with industry-specific quality assurance strategies.

5.1.7 The completed project plan shall be reviewed and agreed upon between purchaser and supplier.

5.2 Design

5.2.1 The design shall accommodate all of the relevant product and process requirements in conjunction with the selected contamination control concept (see examples in annex A).

5.2.2 The purchaser and supplier shall formally accept the design in accordance with predetermined acceptance criteria.

5.2.3 The design shall conform to an agreed list of requirements, such as building, environmental and safety regulations, good manufacturing practice guidelines (e.g. ISO 14001 and ISO 14004).

The design should be reviewed at periodic stages of development, including final completion, to ensure compliance with the specifications and the acceptance criteria.

6 Construction and start-up

6.1 Construction of an installation shall comply with the drawings and specifications.

6.2 Any changes required during the course of construction shall be checked for acceptance, approved and documented prior to implementation of the change in accordance with a change control procedure.

6.3 Construction work, whether performed at a manufacturing location or in situ, shall observe the specific contamination control requirements of the quality plan.

6.4 A clean construction protocol and cleaning procedures shall be developed as part of the quality plan and enforced to achieve the specified contamination control requirements. Security and access control is essential to maintain the clean construction protocol.

6.5 The cleaning methods and methods to determine and approve the achieved cleanliness shall be defined and documented in the quality plan.

6.6 The cleaning of the air systems shall be specified and shall be carried out at assembly, before initial operation and whenever rebuilding work, repair work and maintenance work are performed.

6.7 In the case of start-up of new installations or re-starting existing installations after repair or modification, final cleaning of the cleanroom is necessary and provisions shall be made for the removal of adherent, imported or released contamination.

6.8 Before commencing any operational activities, the complete and satisfactory function of the installation shall be determined by tests carried out in accordance with clause 7.

NOTE In the case of packaged units, such as clean air devices, a manufacturer's certificate of compliance with the requirements of this part of ISO 14644 may be sufficient, provided that the supplier is qualified (i.e. knowledgeable of or competent in cleanroom requirements) and the risk of damage during transport, storage and installation can be controlled adequately.

6.9 During acceptance testing, commissioning and initial operation, the personnel in charge of the installation shall be trained. Testing, approval of the installation and training shall include all relevant practices for proper cleanroom operation, maintenance and in-process control. The responsibility for providing training shall be defined.

When training is carried out, all relevant persons such as operators, maintenance and service personnel should be included.

7 Testing and approval

7.1 General

During and upon completion of the construction of an installation, an agreed series of documented tests shall be specified and undertaken prior to operational use of the installation. Annex C gives examples of the design, testing and approval processes.

7.2 Construction approval

A systematic range of inspections, adjustments, measurements and tests shall be carried out to ensure that each part of the installation complies with the design requirements.

7.3 Functional approval

A series of tests and measurements shall be carried out to determine that all parts of the installation operate together to achieve the required conditions in the "as-built" or "at-rest" states.

7.4 Operational approval

A series of tests and measurements shall be carried out to determine that the complete installation achieves the required "operational" performance with the specified process or activity functioning, and with the specified number of personnel present working in the agreed manner.

8 Documentation

8.1 General

Details of a completed installation (including instrumentation calibration) and all operation and maintenance procedures shall be documented. Documents shall be made readily available to all personnel responsible for startup, operation and maintenance of the installation.

Such personnel should fully understand the documentation.

8.2 Record of an installation

Details of the completed installation shall be provided and shall contain:

- a) a description of the installation and its function;
- b) a set of final and approved performance test data, derived from the tests carried out in accordance with clause 7 of this part of ISO 14644, recording the values of all conditions defined in the specification for the installation and achieved during the commissioning, testing and start-up procedures;
- c) a set of drawings, diagrams (e.g. layout of wiring, piping and instrumentation) and specifications describing the completed and approved "as-built" installation and its components;
- d) a list of parts and equipment and any recommendation for stocking spare parts.

8.3 Operational instructions

Each installation or system shall be provided with a clear set of operating instructions. Such operating instructions shall contain:

- a) schedules of checks and inspections to be completed prior to the start-up of an installation;
- b) schedules of the acceptance range of the critical performance parameters specified;
- c) procedures to start and stop the installation under normal and failure mode situations;
- d) procedures to be adopted in the event of alert or action levels being reached.

8.4 Instructions for performance monitoring

Performance-monitoring of an installation is essential to demonstrate satisfactory operation. Documentation shall include:

- a) test and measurement frequency;
- b) description of test and measurement methods, (or reference to standards and guidelines);
- c) action plan in the event of non-compliance;
- d) frequency required for assembly, analysis and retention of performance data to enable trends to be analysed.

8.5 Maintenance instructions

Maintenance shall be implemented in accordance with a specified method and programme.

Maintenance and repairs shall be carried out during the construction, commissioning, testing, start-up and normal operation of an installation. The following items shall be considered:

- a) definition of safety procedures prior to carrying out maintenance or repairs;
- b) specification of maintenance actions to be taken when the acceptance range of any critical performance parameter is exceeded;

- c) agreed definition of permitted adjustments;
- d) methods of making permitted adjustments;
- e) methods of checking and calibrating control, safety and monitoring devices;
- f) requirements for checking and replacing all wearing parts (e.g. driving belts, bearings, filters);
- g) specification for cleaning of the installation or components prior to, during and after maintenance work;
- h) definition of actions, procedures and tests required after maintenance is completed;
- i) inclusion of any user-specific or relevant regulatory authority requirements.

8.6 Maintenance record

A documented record of any maintenance carried out upon the installation during construction, commissioning and start-up shall be maintained. The following items shall form part of the record:

- a) definition of the maintenance tasks;
- b) identification and approval of personnel undertaking the maintenance;
- c) date of carrying out the maintenance;
- d) a condition report prior to undertaking the maintenance;
- e) a list of spare parts used;
- f) a report upon completion of the maintenance.

8.7 Record of operation and maintenance training

A documented record of training shall be maintained. The following items shall form part of the record:

- a) definition of the training content;
- b) identification of personnel providing and receiving the training;
- c) training date and duration;
- d) a report upon each period of training as it is completed.

Annex A (informative)

Control and segregation concepts

A.1 Contamination control zones

For economic, technical and operational reasons, clean zones are often enclosed or surrounded by further zones of lower cleanliness classification. This can allow the zones with the highest cleanliness demands to be reduced to the minimum size. Movement of material and personnel between adjacent clean zones gives rise to the risk of contamination transfer, therefore special attention should be paid to the detailed layout and management of material and personnel flow.

Figure A.1 illustrates an example of a contamination control concept. In this configuration, the clean zone would be regarded as a more stringently controlled portion of the cleanroom.

A.2 Airflow patterns

A.2.1 Cleanroom airflow patterns can be categorized as either unidirectional or non-unidirectional. When a combination of the two is used it is frequently called mixed airflow. Airflow patterns for cleanrooms of ISO Class 5 and cleaner in operation are often unidirectional, while non-unidirectional and mixed flow is typical for cleanrooms of ISO Class 6 and less clean in operation.

A.2.2 Unidirectional airflow may be either vertical or horizontal (see Figure A.2). Both types of unidirectional airflow rely upon a final filtered air supply and air return inlets which are nearly opposite one another in order to maintain the airstream in as straight a flow pattern as possible. In both designs, the important design feature is the ability to ensure that the airflow pattern is disrupted as little as possible at the process core.

In a working plane perpendicular to the clean airflow, all positions offer the same cleanliness level. Hence, horizontally integrated or distributed processes require vertical airflow and vertically integrated pro-

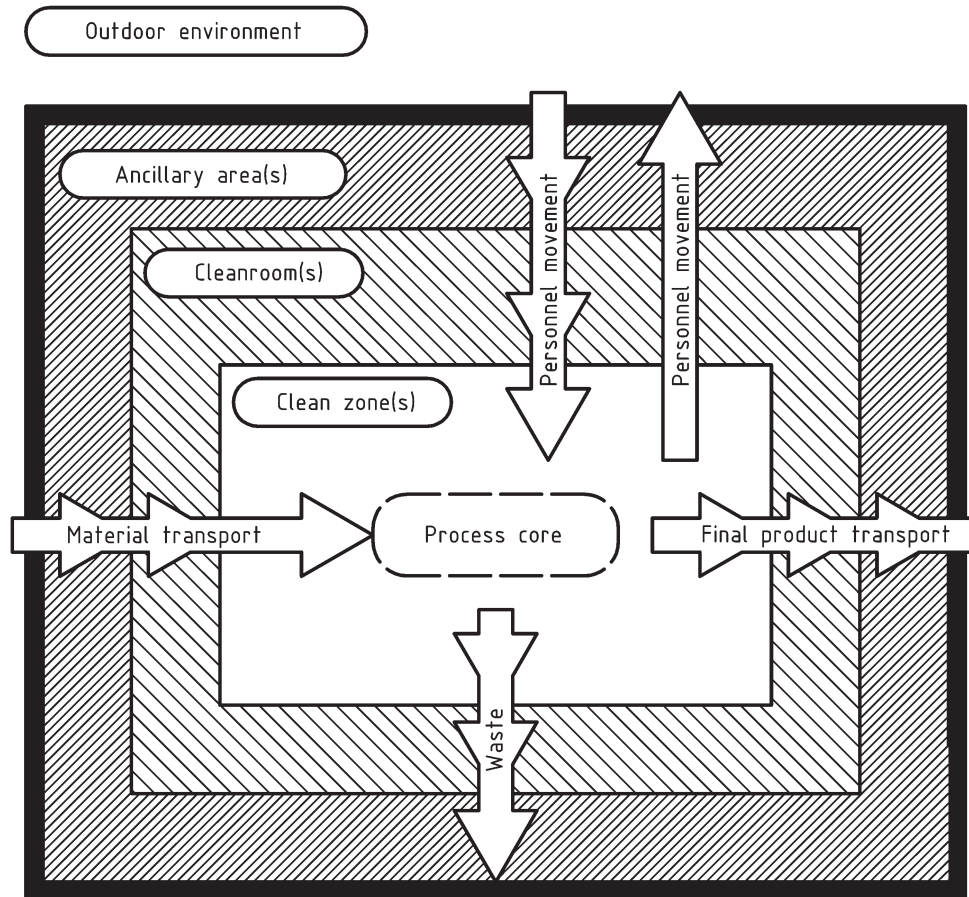


Figure A.1 — Shell-like contamination control concept

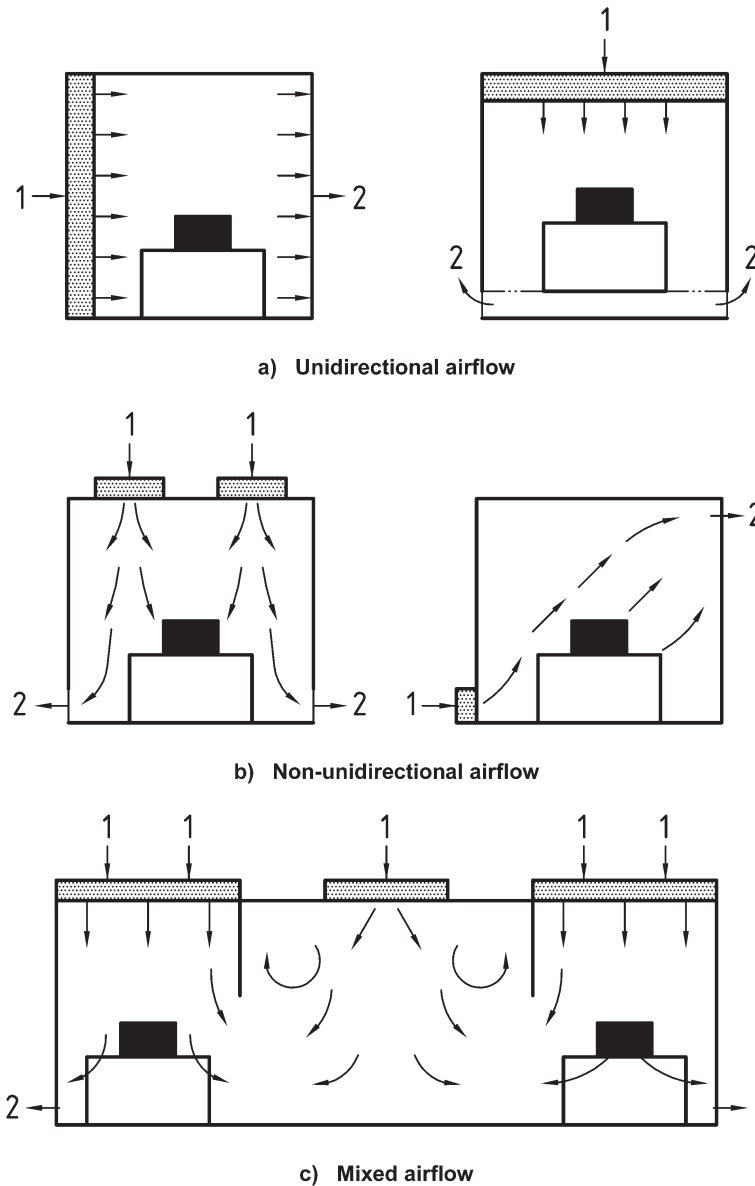
cesses require horizontal airflow. Working positions immediately adjacent to the clean air supply offer optimal contamination control conditions, because working positions downstream of these positions may be subject to particles generated upstream. Personnel placement should be therefore downstream of clean processing.

A.2.3 In non-unidirectional airflow cleanrooms, air flows from filter outlets located in multiple positions distributed across the inlet plane and is returned through remote locations. Filter outlets may be distributed at equal intervals throughout the cleanroom or clean zone or grouped over the process cores. The location of filter outlets is important for the cleanroom performance. The final filter location may be remote, but special precautions should be taken to avoid contamination ingress between these filters and the cleanroom (e.g. monitoring of the surface cleanliness and airtightness of ventilation ducts and supply air inlets to avoid induction of contamination as well as the deployment of decontamination procedures). While return air locations in non-unidirectional airflow systems are not as critical as those in unidirectional applications, care should be taken to distribute the returns, as is done with the supplies, to minimize dead zones within the cleanroom.

A.2.4 Mixed-airflow cleanrooms combine both unidirectional and non-unidirectional airflow in the same room.

NOTE Some special designs are available that provide protection to specific working zones by other managed airflow techniques.

Figure A.2 gives examples that illustrate the different airflow patterns in cleanrooms. (Thermal effects are not considered.)



Key

- 1 Supply air
- 2 Return air

Figure A.2 — Airflow patterns in cleanrooms

A.3 Disturbance of unidirectional airflow

In unidirectional airflow cleanrooms, the design of physical obstacles such as the process equipment, and the operating procedures, personnel movements and product handling, should consider basic aerodynamic requirements to prevent serious turbulence in the vicinity of the contamination-sensitive activity. Appropriate measures should be taken to avoid flow disturbances and cross-contamination between different work stations.

Figure A.3 shows the influence of physical obstacles (on the left) and appropriate measures for minimizing the impact of these (on the right).

A.4 Contamination control concepts

To select the proper technique for a given contamination control problem, Figures A.4 and A.5 show some different contamination control concepts that may be considered.

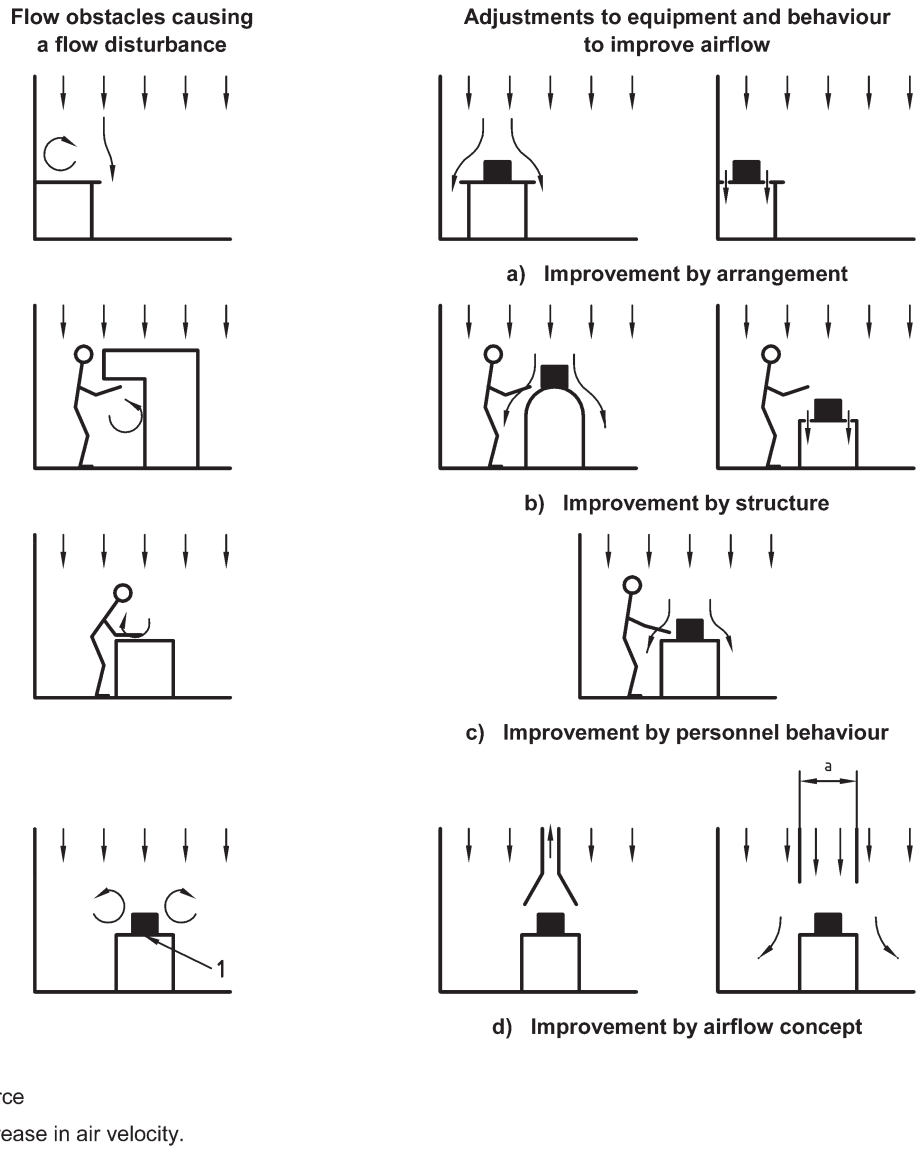


Figure A.3 — Influence of personnel and objects on unidirectional airflow

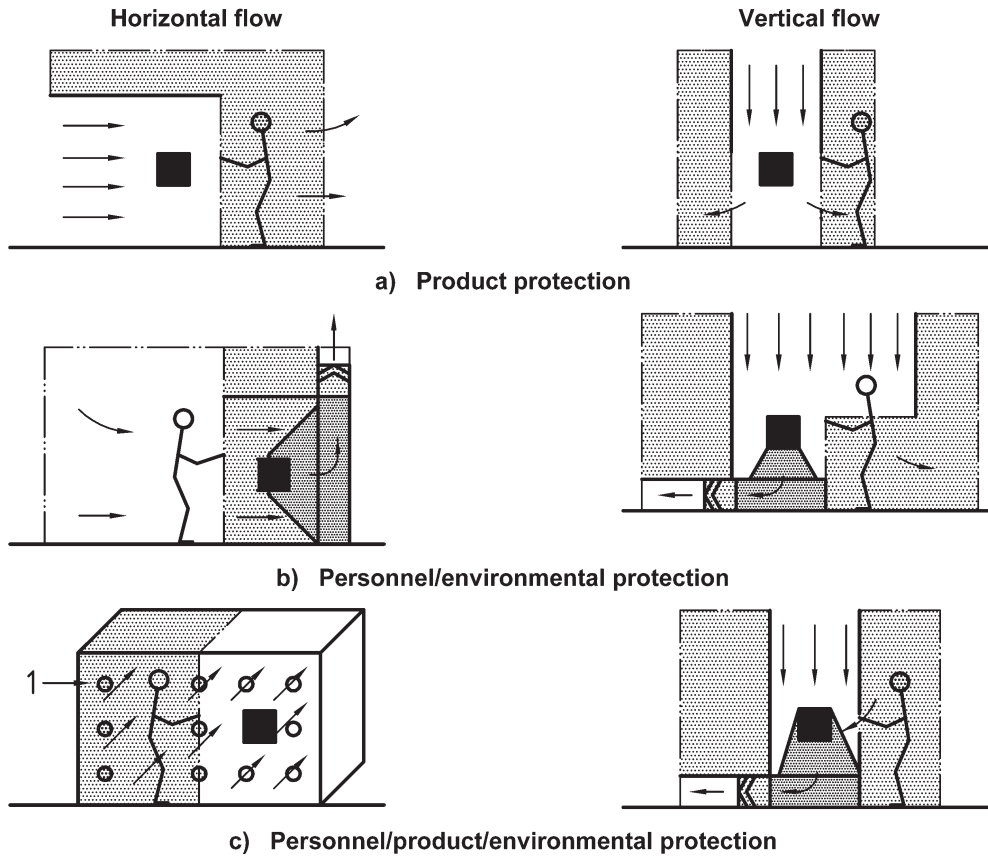
The transfer of contaminants into a zone protecting a process and/or personnel can be prevented by using aerodynamic measures, i.e. by arrangement and flow direction (Figure A.4), or by physical barriers, i.e. by both active and passive isolation (Figure A.5), if any contact between product and operator/environment is to be prevented.

If necessary, process exhaust should be treated to prevent contamination of outdoor environment.

A.5 Concepts to achieve segregation of cleanrooms and clean zones

A.5.1 General

A suite of cleanrooms can consist of multiple rooms with different requirements for contamination control. The objective of the design can be to protect the product or process, or to contain the product, and in some cases a combination of these requirements. In order to protect cleanrooms from contamination from adjacent less clean spaces, the cleanroom should be maintained at a higher static pressure than the adjacent spaces, or alternatively a controlling air velocity should be established across the leakage paths between the spaces flowing from the cleaner to the less clean space. The converse can be applied to contain a hazard. In both cases, an impervious physical barrier can be used as an alternative.

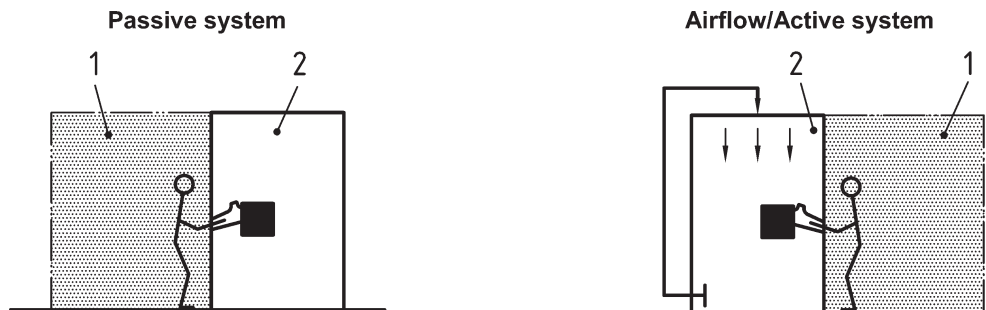


Key

1 Flow direction perpendicular to graphic plane

NOTE In particular cases (e.g. dry atmosphere, shielding and protecting gas or extreme temperatures), the gas flow routing chosen should be adapted to the process.

Figure A.4 — Contamination control concepts using aerodynamic measures



Key

1 Personnel safety zone
2 Product protection zone

Figure A.5 — Contamination control concepts using physical segregation for product and personnel protection

The quantity of make-up air should be sufficient for ventilation purposes and to compensate for the leakage of air from the boundary of the cleanrooms or clean zones and any exhaust air for other purposes.

The following comparison of three basic concepts has been prepared to facilitate the selection of a suitable cleanroom or clean zone segregation concept.

A.5.2 Displacement concept (low pressure differential, high airflow)

A low pressure differential can effectively separate clean and less clean adjacent zones, i.e. by means of a low turbulent "displacement" airflow, e.g. larger than 0,2 m/s (see Figure A.6).

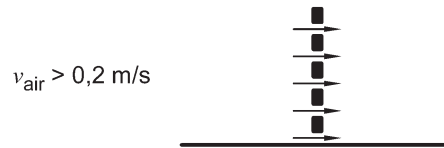


Figure A.6 — Displacement concept

Displacement airflow velocity should be typically above 0,2 m/s, from the cleaner zones towards the less clean zones. The necessary airflow velocity should be selected considering important conditions such as physical obstacles, heat sources, exhausts and contamination sources.

A.5.3 Pressure differential concept (high pressure differential, low airflow)

A pressure differential exists across the barrier between the cleaner zone towards the less clean zone. A high pressure differential between adjacent zones can be easily controlled but care is recommended to avoid unacceptable turbulence (see Figure A.7).

The pressure differential should be of sufficient magnitude and stable to prevent reversal of airflow direction from that intended. The pressure differential concept should be carefully considered, whether used alone or in combination with other contamination control techniques and concepts.

The pressure differential between adjacent cleanrooms or clean zones of different cleanliness level should lie typically in the range of 5 Pa to 20 Pa, to allow doors to be opened and to avoid unintended cross-flows due to turbulence.

The static pressure between cleanrooms of different class, and cleanrooms and unclassified areas can be established and maintained using various airflow balancing techniques. These include both active/automated and passive/manual systems that are configured to adjust the relative quantities of air that are delivered and removed from each space by the ducted air system, air transfer system and losses.

In situations when pressure differentials at the lower end of this range are accepted, special precautions should be taken to ensure accurate measurement of separating flow or pressure and to prove the stability of the installation.

NOTE Flow visualization, either experimentally or by computation, can be used to demonstrate both the effectiveness of the displacement flow concept and the pressure differential concept.

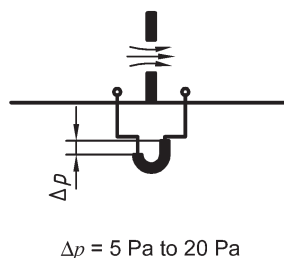


Figure A.7 — High pressure differential concept

A.5.4 Physical barrier concept

This concept involves the use of an impervious barrier to prevent contamination transfer to a clean zone from a less clean zone.

NOTE All three concepts can be applied in the healthcare products, semiconductor, food and other industries.

(to be continued)

ISO14644-4 洁净室和相关受控环境

第四部分:设计、建造和启动

韩融 译

1. 范围:

ISO14644 第四部分明确了洁净室设施的设计和建造要求,但未阐明满足这些要求的特殊的技术和方法。该部分供洁净室设施的采购方、供应方和设计方参考使用,并提供了重要的性能参数清单。建造指南包含了启动和鉴定合格的要求。通过考虑操作和维护因素,该部分明确了设计和建造基本要素,这些要素确保了持续的、符合要求的操作。

注意:进一步阐明以上要求的指南详见附录 A 到 H。ISO14644 的其余部分提供了相关补充信息。

ISO14644 此部分的应用受到限制的情况如下:

采购方或要求制订方明确了用户要求

洁净室设施具体建造工艺未明确

未具体考虑消防安全规定以及国家和地区的要求

只考虑工艺媒介和公用设施在不同洁净区内部和之间的流向

关于最初的操作和维护,只考虑洁净室建造要求

2. 规范性参考

在本文的参考中,以下规范性文件包含了组成 ISO14644 第四部分条款的相关条款。就过期限的参考而言,修订版、修正版不适用。然而,应鼓励参与各方达成共识(基于 ISO14644 此部分),研究以下最新版规范性文件应用的可行性。就无期限的参考而言,最新版的规范性文件应适用。ISO 和 IEC 成员继续成为现行有效的国际标准注册会员。

ISO14644-1:1999, 洁净室和相关受控环境第一部分:空气洁净度等级划分。

ISO14644-2:2000, 洁净室和相关受控环境第二部分:为保障 ISO 14644-1 连续性和一致性提供检测和监控规范。

ISO14644-3: 出版, 洁净室和相关受控环境第三部分:计量和测试方法。

ISO14698-1: 出版, 洁净室和相关受控环境-生物污染控制第一部分:通则。

ISO14698-2: 出版, 洁净室和相关受控环境-生物污染控制第二部分:生物污染数据的评价和解释。

ISO14698-3: 出版, 洁净室和相关受控环境-生物污染控制第三部分:测验清洁工艺以及表面带有生物污染的潮湿玷污物或生物膜的消毒效果。

3. 术语和定义

以下阐述了 ISO14644 中相关的术语和定义及其应用。

3.1 更衣室

人们用于更换洁净服的洁净房间。

3.2 洁净空调设备

处理和分配洁净空气从而满足确切的空气环境条件的独立设备。

3.3 洁净级别

产品、表面、设备、气体、液体等条件,附带明确的污染级别。

注意:污染可能是微粒、非微粒、生物、分子或其他物质。

3.4 试运行

按计划系统地开展一系列的检查、调整和测试并存档,将设施调试到正确的技术操作状态。

3.5 污染

任何对产品和工艺产生有害影响的微粒、分子、非微粒和生物实体。

3.6 非单向气流

进入洁净区的空气与室内空气通过引导方法混合在一起的空气分配。

3.7 微粒

有明显物理边缘的极小块物质。

注意:分类参照 ISO14644-1。

3.8 预过滤器

安置在另一个过滤器上游的空气过滤器,旨在减少下游过滤器的负担。

3.9 工艺核心

工艺以及工艺与环境之间相互作用的区域。

3.10 启用

准备并使设施(包括所有系统)投入实际生产中的行为。

范例:系统包括程序、训练要求、基础设施、供应体系、法定承诺要求。

3.11 单向气流

以稳定的速度和相对平行的流线通过整个洁净区的横断面的可控气流。

注意:这种类型的气流导致来自洁净区的微粒定向的传输。

4. 要求

4.1 买卖双方协商确定 4.2 到 4.18 项中的参数清单。

注意:在以下声明的要求中,附件 A 到 H 仅作为参考信息。

4.2 应提供 ISO14644 此部分的号码、版本和出版日期。

4.3 确定项目相关方的职责(如咨询方、设计方、监管部门、服务组织)(详见附件 C)。

4.4 使用洁净室的一般目的,进行室内操作以及操作条件下的限制约束(详见附件 A、B 和 D)。

4.5 要求的悬浮微粒洁净度级别或与相关国际标准一致的洁净级别要求 (ISO14644-1、ISO14698-1、ISO14698-2、ISO14698-3)(详见附件 B)。

4.6 测量关键的环境参数,包括具体的设定值、报警级别和行动级别,与包含校验在内所使用到的测量方法相一致。(ISO14644-2、ISO14644-3)(详见附件 F)。

4.7 使用包括设施、操作和性能标准的污染控制概念,满足各洁净级别要求(详见附件 A)。

4.8 所需的测量、控制、监控和建档方法应满足参数要求(详见附件 C 和 F)。

4.9 应有支持设施所需的设备、仪器、供给和员工的出入口(详见附件 D)。

4.10 明确的状态标示,如“刚建成”、“静态”和“动态”。在这些状态标示下,应完成包括与时间相关的变化因素和控制方法在内所需参数的制定和保存(详见附件 C)。

4.11 设施的安排和布局(详见附件 D)。

4.12 包含有效空间在内的限制和约束(详见附件 D)。

4.13 影响设施的工艺和产品要求(详见附件 B 和 G)。

4.14 带有功用要求的工艺设备清单(详见附件 D、E 和 H)。

4.15 设施的维修要求(详见附件 D 和 E)。

4.16 准备、审批、执行、监管、建档、标准制定、设计依据、详细设计、建造、测试、试运行、测验确认(包括性能和对比)等工作任务的分配(详见附件 E 和 G)。

4.17 外部环境影响的鉴定和评估(详见附件 H)。

4.18 特殊应用所要求的额外信息(详见附件 H)。

5. 规划设计

5.1 规划程序

5.1.1 项目规划应当具有可发展性,应与用户和涉及的各方进行协商,明确产品要求、工艺要求和设施的范围。

5.1.2 为了确定设施需要,应制定工艺设备清单,该清单需包含工艺设备各部分的关键要求。

5.1.3 明确差异因素,考虑各项功能和环境控制系统的高峰期和平均需求量。

注意:一个系统可能包含了多个要求独立明确差异因素的子系统。

5.1.4 设施的各个区域均需制订污染控制概念(详见附件 A)。

5.1.5 从经济和工期要求方面汇总并提炼在条款 4 中明确的详细说明。

5.1.6 项目规划需要包含以下要素:

- a) 设计文件,并有数据支持
- b) 成本估算
- c) 工期估算
- d) 项目纠纷预期纲要
- e) 带有优缺点和推荐建议的设计选项
- f) 设施的维修要求汇总
- g) 设施适应度汇总
- h) 设施后备能力汇总
- i) 设施设计的施工能力汇总
- j) 质量方案

如 ISO9000 质量标准(即 ISO9000 和 ISO9001)这类质量体系的使用应考虑与工业质量担保策略相结合。

5.1.7 已完成的项目规划需要进行汇总,并由买卖双方达成共识。

5.2 设计

5.2.1 设计应适应所有相关产品和工艺要求,并与所选污染控制概念相结合。

5.2.2 买卖双方应根据事先确定的标准正式的承兑设计。

5.2.3 设计应确定包含各项要求的协议清单,如建筑、环境和安全规范,GMP 指南(如 ISO14001 和 ISO14004)。

在各发展阶段中,设计方案应进行汇总,包含最终完成,确保与详细说明和可接受标准一致。

6. 建造和启用

6.1 设施的建造要按照图纸和详细说明进行。

6.2 建造期间的任一变更应在变更实施前按照变更控制程序进行许可、审批和建挡的检查。

6.3 无论是生产场地还是在原地,建造施工都应遵守质量方案中具体的污染控制要求。

6.4 作为质量方案的一部分,应发展并强化清洁建造协议和清洁程序,满足具体污染控制要求。安保和出入控制对维护清洁建造协议十分重要。

6.5 应在质量方案中明确清洁方法以及确定并审批已完成的洁净级别的方法,并建立档案。

6.6 在装配期间、初始运行之前和重新建造、修理和维护期间,应确定并执行空调系统的清洁。

6.7 在启动新设施或在维修和改装后重新启动已有设施,洁净室最终清洁很有必要,

并采取措​​施去除粘滞性的、外界进入或释放出来的污染。

6.8 在任一操作活动前,应通过测试明确设施功能的完整性和舒适性,这些测试应与条款 7 一致。

注意:如洁净空气设备,应充分审核制造商的资质是否与 ISO14644 此部分一致,提供相关资料,如供应商的资格审核(即洁净室要求的相关知识和能力)以及在运输、储存和安装期间足够的损坏风险控制。

6.9 在许可测试、试运行和初始操作期间,应进行与设施变更有关的人员培训。测试、审批和培训应包括所有与适宜的洁净室操作、维修和过程控制有关的相关规范。明确授训职责。

培训的相关人员包括操作人员、维修人员和服务人员。

7. 测试和审批

7.1 简介

在设施建造完成时,一系列各方认可的需要存档的测试应在设施操作使用前规定并执行。附件 C 提供了设计、测试和审批程序的范例。

7.2 建造审批

进行系统性的检查、调整、测量和测试,保障设施各部分与设计要求一致。

7.3 功能审批

进行一系列的测试和测量,明确设施各部分系统运转,满足“刚建成”和“静态”条件下的各项要求。

7.4 操作审批

进行一系列的测试和测量,明确已完成的设施能完成所需的“动态”性能,包括具体工艺或活动功能,以及在一致的方式下配备具体数量的人员。

8. 文件档案

8.1 简介

已完成安装的设施(包括仪器校验)和所有操作、维修程序的细节均应存档。启动、操作和维修设施的人员均可使用这些档案文件。

这些人员应完全了解这些档案文件。

8.2 设施记录

应提供已完成安装的设施的细节,并应包括:

- A) 设施描述及其功能;
- B) 一系列通过批准的最终性能测试数据(按照 ISO14644 此部分的第 7 条款来进行的测试),记录设施标准条件下以及试生产、测试和启动程序下产生的数据;
- C) 一系列图表、图解(如管、线、仪表分布图)和描述了已完成和已获批的“刚建成”设

施及其组成部分的详细说明；

D) 一份零件、设备和建议储备零件的清单。

8.3 操作指南

各设施和系统应有明确的操作指南。这些操作指南应包括：

- A) 启动设施之前应完成的检查和检验的安排表；
- B) 具体关键性能参数的可接受范围的表单；
- C) 在正常和故障模式情况下,启动和停止设施设备的程序；
- D) 达到警报或行动级别下应采取的程序。

8.4 性能监控指南

设施的性能监控对于证明舒适操作至关重要。档案文件应包括：

- A) 测试和测量频率；
- B) 测试和测量方法的描述(或标准和指南的参考)；
- C) 应急方案；
- D) 性能数据的汇编、评估和保留所需的频次,使之能分析趋势。

8.5 维修指南

按照规定的方法和大纲进行维修。

在设施的建造、试运行、测试、启动和正常操作期间进行维护和修理,并考虑以下几项：

- A) 明确维修前的安全性程序
- B) 当任一关键性能参数超标时,应执行的具体维修方案
- C) 许可后调整的定义
- D) 做出许可调整的方法
- E) 检查和校验控制、安全和监测设备的方法
- F) 检查和更换易损零部件的要求(如传送带、轴承、过滤器)
- G) 在维修工作之前、期间、之后,设施或其组件清洁的详细说明
- H) 维修完成以后所需的行动、程序和测试
- I) 需涵盖任何用户指定或相关管理部门的要求

8.6 维修记录

一份保存了设施建造、试运行和启动期间维修情况的文档记录。该记录包含以下内容：

- A) 明确维修任务；
- B) 维修人员的资格鉴定和批准；
- C) 进行维修的日期；
- D) 维修前的状况报告；

E) 备用零部件的清单；

F) 已完成维修的报告。

8.7 操作和维修培训记录

保留培训记录。这些记录应包含：

A) 明确培训内容；

B) 提供和接受培训人员的资格鉴定；

C) 培训日期和期限；

D) 关于各阶段已完成培训的报告。

附件 A 控制和隔离概念 (仅供参考)

A.1 污染控制区

出于经济、技术和操作考虑,洁净区通常被低级别洁净区密闭或包围,使最高洁净度要求的区域最小化。相邻洁净区之间的物料和人员的流动增加了污染传播的风险。因此,需要加强对人流和物流的具体布置和管理。

图表 A.1、物料控制概念的范例。在该结构图中,洁净区应该作为洁净室比较严格控制的一部分。(图见原版,下同)

Outdoor environment	室外环境
Ancillary area(s)	辅助区域
Cleanroom(s)	洁净室
Clean zone(s)	洁净区
Process core	工艺核心
Material transport	物料转运
Final product transport	最终产品转运
Personnel movement	人流
Waste	废料

A.2 气流类型

A.2.1 洁净室气流类型可以分为单向和非单向两类。当两者结合作用时通常称为混合气流。动态下,ISO5 级或以上洁净室气流类型通常是单向的,而相同条件下,ISO6 级或以下洁净室气流类型通常是非单向或混合型的。

A.2.2 单向气流可能是垂直或者水平的(见图表 A.2)。这两种类型的单向气流均依靠最终过滤的送风和回风设备实现,送风、回风口应相对应并靠近安装以便尽可能使气流呈直

线运动。这两种单向气流设计的特征是确保在工艺核心区域该气流类型尽可能不受干扰。

在洁净气流和操作台面相垂直时,所有的位置均提供相同的洁净级别。因此,水平集成和分布的工艺要求垂直气流,而且垂直集成的工艺要求水平气流。近送风口的操作位置的污染控制条件最佳,因为上游所产生的微粒会污染下游。因此,人员的位置应置于洁净工艺流程的下游。

A.2.3 在非单向气流洁净室内,气流通过不同位置的过滤器出口扰流至远处的入口。过滤器出口等距离分布于洁净室或洁净区或者成组安置于工艺核心区上方。过滤出口对于洁净室性能至关重要。最终过滤器的位置可以稍远,但要采取特殊的预防措施,避免过滤器和洁净室之间的污染(如对空气管道和送风入口的表面清洁度和光亮度进行监测,避免污染产生,同时采取去污措施)。在非单向气流体系中,回风的布置并没有像单向气流体系中这样重要,但仍要注意回风的布局需要结合送风考虑,使洁净区的死角最小化。

A.2.4 混合洁净室是在同一房间内既有单向气流又有非单向气流。

注意:一些特殊的设计可以通过其他的气流技术保护特定的操作区域。

图表 A.2 洁净室内不同气流类型的范例(不考虑热效应)

A) 单向空气流

B) 非单向气流

C) 混合气流

1. 送风

2. 回风

A.3 单向气流的干扰

在单向气流洁净室内,障碍物的设计,如工艺设备、操作流程、人流和产品处置应考虑基本的空气动力学要求,防止在污染敏感活动周围产生严重的紊流。采取适当的措施避免在不同的工作台之间产生紊流和交叉污染。

图表 A.3 障碍物的影响(左)和减少这些影响的适当措施(右)

Flow obstacles causing a flow disturbance 气流障碍引起气流干扰

Adjustment to equipment and behaviour to improve airflow 调整设备和行为,改善气流

A) 调整布局

B) 调整结构

C) 调整人员行为

D) 调整气流概念方面

1. 热源

a. 局部风速增强

A.4 污染控制概念

选择合适的技术来解决特定的污染控制问题,图表 A.4 和 A.5 提供了一些可以考虑的不同污染控制概念。

通过采用空气动力学方法,即分布和流向(图表 A.4)或物理隔离,即主动和被动隔离(图表 A.5)阻止污染流入需要保护工艺和人员的区域,从而防止产品和操作/环境之间的接触。

如有必要,应对工艺废气进行处理,防止污染室外环境。

图表 A.4 利用空气动力学进行污染控制的概念

Horizontal flow 水平气流

Vertical flow 垂直气流

A) 产品保护

B) 人员/环境保护

C) 人员/产品/环境保护

气流方向与图示水平面垂直

注意:在特殊情况下(干燥环境、保护气体或极端温度)应结合工艺选择气流路线。

图表 A.5 利用隔离器保护产品和人员的污染控制概念

Passive system 被动系统

Airflow/active system 气流/主动系统

1. 人员安全区域

2. 产品保护区域

A.5 完成洁净室和洁净区域隔离的概念

A.5.1 简介

一整套洁净室由不同污染控制要求的各类房间组成。设计的目的在于保护产品或工艺,或者容纳产品,以及在某些情况下综合考虑以上要求。为了防止来自相邻低级别洁净空间的污染进入洁净室,洁净室应保持比相邻空间更高的静压值,或者确定可控的空气流速,穿越各空间之间的通道,使空气从高级别流向低级别洁净空间。反方向使用则会引起危害。以上两种情况下,密闭的隔离器可以选择性使用。

应有足够多的补偿空气量用于通风换气,以及补偿洁净室或洁净区域边缘泄漏的空气或其他目的排放的空气。

下面提供三种基本概念的比较,便于选择合适的洁净室或洁净区域的隔离系统。

A.5.2 移位概念 (低压差、高气流)

低压差能有效分离相邻的洁净区域和非洁净区域,即大于 0.2m/s 的低紊流“移位”气流的方法(见图表 A.6 移位概念)。从高级别洁净区向低级别区,移位的气流流速应大于 0.2m/s。

选择必要的气流速度应考虑如障碍物、热源、废气和污染源等重要条件。

A.5.3 压差概念 (高压差, 低气流)

高级别洁净区通向低级别区需要有压差存在。虽然相邻区域之间的高压差容易控制,但也要避免不可接受的紊流(见图表 A.7 高压差概念)。

压差应该足够巨大并且稳定,防止气流逆向而行。不管是单独使用还是与其他污染控制技术联合使用,均应仔细考虑压差概念。

相邻洁净室或不同洁净级别区域之间的压差值应设在 5 帕到 20 帕之间,能够开门的同时,避免了紊流引起的交叉流。

通过使用各类气流平衡技术来确认各级别洁净室之间,以及洁净室和非洁净室之间的静压差值。这些技术包括主动/自动和被动/手动系统,通过设置这些系统来调节由管道空气系统、空气传输系统从各空间输入和排出的相对空气量和损失量。

当压差值处在该范围下限时,应采取特定的预防措施,确保分流和分压的精确测定,并保障设施的稳定性。

注意:不管是实验还是计算机模拟,气流可视化可以用来阐明移位气流概念和压差概念的有效性。

A.5.4 物理屏障概念

预防污染从低级洁净区转向高级洁净区转移的非渗透性屏障使用等概念。

注意:三种概念均适用于保健产品、半导体、食品和其他工业。

(未完待续)