
	Manufacturing, testing and supply of vacuum vessels for HNB3 (Beam Line Vessel and Beam Source Vessel) and DNB <i>Annexure 7: Cleaning and cleanliness</i>	INDUS Ref No II-VKCT5P5- v1.1
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1. Scope

This annexure provides guidelines for (1) cleanliness requirements to be followed during the manufacturing of DNB Vessel and HNB3 Vessel and (2) the post cleaning handling requirements to maintain the achieved cleanliness.

These guidelines are based on ITER Vacuum Handbook, [Appendix_13_Cleaning_and_Cleanliness_2ELUQH_v1_2](#) and is intended to assist the manufacturer of the DNB Vessel and HNB3 Vessel in the preparation of a clean work plan and cleaning procedures for submission to ITER-India / IO for acceptance at the time of MRR. Following the guidance in this Annexure should help suppliers to achieve the requirements of the ITER Vacuum Handbook (IVH).


The supplier is at liberty to utilise other techniques not described in this Annexure provided that the components manufactured comply with the requirements of the ITER Vacuum Handbook. However, such techniques shall be implemented with prior approval of ITER-India and IO.

2. References


ITER Vacuum Handbook: [Appendix_13_Cleaning_and_Cleanliness_2ELUQH_v1_2](#)

3. General Cleaning Requirements

- 3.1 Cleanliness is required during the whole manufacturing process and the preservation of cleanliness is good practice for any component to achieve the necessary vacuum standards and to minimise the time required to recover from any contamination incident.
- 3.2 All components shall be subjected to a rigorous cleaning procedure, consistent with the Vacuum Classification of that particular component.
- 3.3 A detailed Clean Work Plan shall be submitted for prior acceptance to the ITER-India and ITER Vacuum RO before any cleaning operations are undertaken at the supplier's site. The plan shall specify how cleanliness will be maintained throughout the manufacturing process. It shall state when specific cleaning procedures will be applied and all of the controls which will be in place to maintain cleanliness, including handling.
- 3.4 Parts and sub-components shall be degreased using solvents or alkaline detergents, rinsed with demineralised water, and dried in hot gas or an oven to accepted procedures. The use of halogenated solvents is forbidden at any stage. Lists of accepted cleaning fluids can be found in [ITER Vacuum Handbook: Appendix_4_Accepted_Fluids_2ELN8N_v1_14](#).
- 3.5 All components classified as VQC1 will need cleaning to Ultra High Vacuum standards. It is the responsibility of the supplier to satisfy themselves that they understand fully the implications of cleaning to the requisite standard.

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- 3.6 Any proposed deviation from the procedures and processes described in this Annexure need to be accepted in writing by ITER-India and IO. This is particularly important where the use of any chemical product (solvent, etchant, detergent, etc.) other than those specified is proposed.
- 3.7 All items (shielding plates, outer shell plates, tools, jigs and fixtures etc.) shall be thoroughly degreased, cleaned and sealed in a suitable envelope (polythene, etc.) prior to being introduced into the clean conditions assembly area.
- 3.8 An inventory of all items entering or leaving the clean area shall be maintained. This includes tools, welding machines, protective clothing (welding gloves, overshoes etc.), containers for transporting tools or components etc.
- 3.9 The surfaces of jigs, fixtures and tools that come into contact with the NB Vessels components shall in general be constructed of stainless steel
- 3.10 The surfaces of jigs, fixtures and tools that come into contact with the NB Vessels components shall never be made of carbon steel. Direct contact of carbon steel or zinc coated slings or chains, and the use of tools containing lead, bronze copper or zinc is not permitted
- 3.11 Lead or other low melting metals (tin, antimony, mercury, zinc, arsenic, cadmium, etc.) their compounds or materials containing low melting metals as a basic chemical constituent shall not be used in direct contact with the surfaces of the component be exposed to vacuum at any time. This ban includes tooling, fixtures, marking materials, dyes, fluxes, paints, coating and sealing compounds used during fabrication and assembly operations
- 3.12 Tooling or equipment that produces oil, grease, flux or any substance considered a harmful contaminant shall not be permitted. Only water soluble, non-halogenated, sulphur and phosphorus free machining fluids accepted by ITER are permitted
- 3.13 Overhead cranes and lifting equipment shall be arranged to avoid the dripping of oil in the clean conditions assembly area
- 3.14 After cleaning all surfaces shall be “metal clean” and free from, oil, grease, ink, paint, dust, rust spots, abrasive particles, chips and any other gross discontinuities or imperfections as defined in EN-ISO(2003) 15607. All surfaces show a uniform metallic colour and are absent from evaporation patches from cleaning agents.
- 3.15 Stainless steel surfaces shall be protected to avoid further contamination
- 3.16 The NB Vessels parts and components shall be wiped or brushed (or flushed in the case of the cooling channels) with solvent or alkaline detergents, rinsed with demineralised


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water and wiped dry with clean lint-free cloth or air dried. The use of halogenated solvents is forbidden.

- 3.17 Handling equipment, such as slings, hooks, etc., shall be sheathed or protected with accepted plastic (not PVC), clean wood etc., to avoid contact of the stainless steel pieces with metallic (non S.S.) surfaces. Contact with lifting and handling devices made from ferritic steel is prohibited.
- 3.18 Any tooling which can come in contact with the stainless steel pieces shall be made of stainless steel and cleaned before use.
- 3.19 Final cleaned pieces made of stainless steel shall to be stored directly on the ground or bare floor. They shall be stored on clean surfaces, or surfaces covered with materials such as wood, plastic (not PVC), etc. No nails or resins are to be present on the wood.
- 3.20 Once a component is cleaned and inspected for acceptance it shall be handled with the utmost care to preserve the cleanliness condition in preparation for packing.
- 3.21 All components shall be visually inspected, , with the use of cameras and fibre optics if necessary, to check that the cleanliness condition is preserved.
- 3.22 Prior to packing, all components shall be covered with accepted plastic film (not PVC) to avoid the accumulation of dust or unwanted debris.
- 3.23 Personnel working in the clean area shall be trained in the correct procedures. ITER-India / IO can request personnel contravening the clean area requirements are excluded from the clean area. The ITER-India will retrain and if necessary replace the offending operative.
- 3.24 Bidder shall submit proposals for achieving and maintaining these standards of cleanliness.
- 3.25 Prior to joining metallic part, a cleaning of these parts shall be done as required by subsequent clauses of this annexure.
- 3.26 During assembly and cleaning, particular attention shall be given to the removal of weld spatter, debris and other foreign matter, particularly from the coolant passages and sealing surfaces.

4. Health and Safety

Some of the chemicals or equipment used in cleaning processes may be classified as hazardous.

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It is the responsibility of the supplier to satisfy themselves that any cleaning procedure complies fully with local legislative and regulatory standards regarding health and safety of any or all processes used and that all operatives have received the necessary training.

The supplier shall have the responsibility of ensuring that all staff fully understand all health and safety information issued by the manufacturer or supplier of any chemical or equipment to be used. Neither ITER-India / IO nor any of its agents shall be held responsible for any consequences arising from the application of any cleaning process described in this specification / IVH unless it is under their direct control.


5. Proprietary Items and Trademarks

Where propriety items from particular manufacturers or suppliers are mentioned in this specification / IVH, any or all trademarks are duly acknowledged. Manufacturers or contractors are free to suggest alternative items from other manufacturers or suppliers provided that they are chemically identical. Any such substitutions need to be accepted in writing by ITER-India and IO.

6. Initial Inspection and Preparation

Prior to cleaning any item, the following inspection should take place:


- 6.1 All vacuum flanges or covers should be removed and the item stripped down as much as is permissible, ideally to single components.
- 6.2 All items should be clearly identified by scribing a suitable identification mark on an external surface (never a vacuum surface). This identifier will often be a drawing number with component identifier or some such which is carefully recorded. Alternatively, for items which are either small and are to be exposed to a vacuum, a suitable metal label, preferably of the same material as the component and bearing a scribed identifier may be tied with clean bare wire to the component. If none of this is possible, the items should be stored in a suitable container which is marked with an identifier before and after the cleaning process. After cleaning, these items should be packed in such a way that they will not be re-contaminated by the container.
- 6.3 The item should be inspected visually to identify any possible traps, etc. which could affect the vacuum performance of the item, taking into account the specified cleaning process and vacuum regime in which the item is to be used.
- 6.4 All vacuum sealing faces should be inspected to ensure that there is no damage to the seal area such as scratches, pitting or other defects. If the seal is of the knife edge type, the knife edge should be carefully examined for damage which could affect the sealing properties.

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- 6.5 Any adhesive tape attached to surfaces of the item whether or not they are to be exposed to vacuum must be removed and any adhesive residue carefully removed with the solvent isopropyl alcohol or ethanol.
- 6.6 Any marker pen or paint or similar on any surfaces of the item whether or not they are to be exposed to vacuum should be carefully removed by scraping if necessary followed by washing with the solvent isopropyl alcohol or ethanol and rinsing in demineralised water.
- 6.7 Any threaded holes, etc., whether or not they are to be exposed to vacuum, should be examined to see if there are traces of lubricants, cutting fluids or swarf left inside. Any such should be removed carefully using brushing or blowing out with clean compressed air or nitrogen and/or washing with a suitable solvent followed by rinsing with demineralized water, taking care that no residue is transferred to a vacuum surface.

7. Mechanical Processes on Vacuum Surfaces

- 7.1 Abrasive techniques to clean or to attempt to improve the appearance of the surfaces of vacuum components must be kept to an absolute minimum and are preferably avoided. For all VQC the use of files, harsh abrasives, sand, shot or dry bead blasting, polishing pastes and the like is prohibited under normal circumstances and may not be used without prior agreement.
- 7.2 Stainless steel wire brushes, cleaned to the standards of this specification, may be used only when it is considered essential to do so.
- 7.3 If grinding is essential on VQC 1 systems, the grinding wheel shall be free of organic components and shall have been manufactured in an oil-free, clean environment.
- 7.4 The material and manufacturing process of the grinding wheel shall be accepted by the ITER Vacuum RO before use.
- 7.5 Abrasive techniques to clean or to attempt to improve the appearance of the surfaces of vacuum components should be kept to an absolute minimum and are preferably avoided. The use of grinding wheels, wire brushes, files, harsh abrasives, sand, shot or dry bead blasting, polishing pastes and the like is prohibited under normal circumstances and certainly without prior acceptance by ITER.
- 7.6 Accepted techniques are slurry blasting with alumina or glass beads in a water jet; gentle hand use of a dry fine stone or a fine stone lubricated with isopropyl alcohol or ethanol; hand polishing using fine mesh alumina in an isopropyl alcohol or ethanol carrier on a lint free cloth; hand polishing with ScotchBrite™ (Alumina loaded, Grade A).
- 7.7 If any such surface finish technique is employed, care must be taken that any powder or other residues are removed by copious washing in hot water.

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7.8 Any other such operations may be carried out only with prior acceptance.

8. Use of acids

8.1 Acid treatment of any sort is to be avoided wherever possible and may only be carried out with specific prior acceptance by the ITER Vacuum RO. Most acid treatments are for cosmetic purposes only and may result in degradation of vacuum performance.

8.2 Where the use of acids is accepted, then exposure of the component must be kept to a minimum and must be followed by copious washing in hot demineralised water.

8.3 The use of sulphur-bearing fluids shall be strictly controlled to minimise the risk of corrosion in stainless steel

9. Treatment of Weld Burn

One particular use of acid pastes is in the removal of weld burn. In general, such burns do not affect vacuum performance and are best left alone. Any scaling (i.e. loose oxides) should be removed using the techniques of **Clause 7**. If it is desired to remove burns, then slurry blasting with alumina in water or hand burnishing with alumina powder is a satisfactory alternative. Heavy abrading, grinding or wire brushing is prohibited. Hand finishing with ScotchBrite™ or a dry stone is also acceptable.

10. Electropolishing for VQC1 Applications

10.1 Electropolishing should only be carried out where it is necessary to produce a smooth surface for reasons of electrical discharge or field emission minimisation, emissivity or similar purposes. It is usually unnecessary from a pure vacuum point of view and indeed can be detrimental to vacuum performance.


10.2 Electropolishing should be carried out in clean polishing tanks, using fresh electrolyte. Local electropolishing can be carried out with tampons. Fresh clean pads dipped in clean electrolyte should be used and excessive pressure should be avoided.

10.3 After electropolishing, the item should be washed with copious quantities of hot demineralised water.

10.4 If required, vacuum items for use in Class VQC 1 may be baked to 450 oC for at least 24 hours to remove the residual hydrogen and other contaminants introduced into the surface layers by the electropolishing process.

11. Handling and Packing

Handling and packaging of components should be in accordance with the following requirements specified in the ITER Vacuum Handbook. Specifically:

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- 11.1 Once components have completed initial rough cleaning care should be taken that vacuum surfaces are never touched by bare skin. Powder free latex or nitrile gloves (over cotton or linen if desirable) should always be used when handling components. Coloured gloves are not acceptable.
- 11.2 Once components have started the cleaning process they should complete the cycle without a break. If it is unavoidable that a delay occurs between stages, then care must be exercised that the component is thoroughly dry before storage, and all seal faces and ports must be protected as **clause 11.3** below. There must never be a break between any chemical cleaning stage and a subsequent water washing stage.
- 11.3 After the component has been cleaned and is completely dry, it should be packed carefully to ensure that it remains clean and free from damage. All vacuum sealing faces should be protected with a clean metal plate or a hardboard or similar fibre free board covered with clean aluminium foil held in place by a number of bolts through the fastener holes. Knife edges should be protected with clean metal gaskets (which may have been used previously, but they should be completely free from loose oxide scale). All ports should be covered with strong clean new aluminium foil and plastic covers. Small items should be wrapped in clean aluminium foil and sealed in a polyethylene bag, under dry nitrogen if possible.

12. Spray washing

Where an item is cleaned by spray washing, it should be ensured that all hoses, lances, spray heads, etc are thoroughly cleaned out with clean hot water before the cleaning process starts.

Washing should start at the top of the item and the spray should be worked down to the bottom, ensuring good run-off.


13. Standard Cleaning Procedure for Stainless Steel Components

13.1 Preclean

All debris, such as swarf, should be removed by physical means such as blowing out with a high pressure air line, observing normal safety precautions. Gross contamination, e.g. greases or cutting oils, etc., should be removed by washing, swabbing and rinsing with any non-halogenated general purpose solvent. Scrubbing, wire brushing, grinding, filing or other mechanically abrasive methods may not be used (**clause 7**).

13.2 Wash

- 13.2.1 The item should be washed down using a high pressure jet of hot town water (at approx. 80°C), using a simple mild alkaline detergent. The detergent should then be switched off

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and the item rinsed thoroughly with hot water until all visible traces of detergent have been eliminated.

- 13.2.2 If necessary, any scaling or deposited surface films should be removed by stripping with alumina or glass beads in a water jet in a slurry blaster.
- 13.2.3 The item should be washed down with a high pressure hot demineralized water jet (at approx. 80°C), with no detergent, ensuring that any residual beads are washed away. Particular attention should be paid to any trapped areas or crevices.
- 13.2.4 The item should be dried using an air blower with clean dry air, hot if possible.

14. Chemical Clean for Stainless Steel, or similar Items

With the addition of the relevant safety precautions, the cleaning process below can also be applied.

- 14.1 Where possible, the item should be immersed completely in an ultrasonically agitated bath of hot clean liquid solvent for at least 15 minutes, or until the item has reached the temperature of the bath, whichever is longer. The temperature should be the maximum specified by the supplier of the solvent.
- 14.2 Halogenated solvents are not permitted.
- 14.3 Suitable solvents need to be accepted by ITER before use. Isopropyl Alcohol, Ethyl Alcohol, Acetone, Axarel 9100™, Citrinex™, P3 Almeco™ P36 or T5161 are accepted for this purpose.
- 14.4 Where technically feasible, after the liquid immersion stage, the item should be immersed in the vapour of the solvent used for at least 15 minutes, or until the item has reached the temperature of the hot vapour, whichever is longer.
- 14.5 It must be ensured that all liquid residues have been drained off, paying particular attention to any trapped areas, blind holes etc.
- 14.6 The item is then be washed down with a high pressure hot (approx. 80°C) water jet, using clean demineralised water. Detergent must not be used at this stage.
- 14.7 The item is dried in an air oven at approx 100oC or with an air blower using clean, dry, hot air.
- 14.8 If the item is too large to be cleaned by immersion the item may be cleaned by washing it down with a high pressure jet of P3 Almeco™ P36 or T5161.
- 14.9 The item is cooled to room temperature in a dry, dust free area conforming clean conditions as defined in **ITER Vacuum Handbook / this specification.**

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- 14.10 The item is inspected for signs of contamination, faulty cleaning or damage.
- 14.11 The item is baked to a temperature of 300°C or whatever other temperature has been specified for a minimum period of 24 hours at temperature in accordance with **Annexure 9: Baking**.
- 4.12 The item is packed and protected as in **clause 11** above.

15. Air Baking

- 15.1 Items manufactured from stainless steel and the like may be air baked to provide a low hydrogen outgassing surface.
- 15.2 Note that this procedure is not suitable for materials that form a loose oxide, e.g. copper.
- 15.3 Items should be chemically cleaned using the procedures of **clause 13** above. Items should then be heated in air at a temperature of 450°C for a period of 24 hours in accordance with **Annexure 9: Baking**.

16. “Snow” Cleaning


- 16.1 A final clean after assembly of components into a large vacuum system may be achieved by the use of “snow” cleaning.
- 16.2 Snow cleaning uses a high velocity stream of soft microscopic particles of solid CO₂ to wash the surface and is effective for removing particulates and some organic contamination from surfaces.
- 16.3 Operatives undertaking this procedure must wear suitable protective clothing and personal safety equipment.
- 16.4 The procedures used will be as specified by the suppliers of the equipment.

17. Cleanliness control of the component

17.1 Wipe Test for Cleanliness

Gross contamination of a vacuum component may be assessed by means of a wipe test. This may be carried out “dry” or “wet”. Gross contamination may also manifest itself as an “oily” or “solvent-like” smell. Note that these tests are of a somewhat subjective nature and may not be conclusive and therefore should only be used as a guide to cleanliness and as a marker for subsequent cleaning operations should the tests result in a failure of cleanliness.

17.1.1 “Dry” test

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The surface of the component is wiped gently with a clean lint free cloth. If there is any evidence of a deposit on the cloth (i.e. a stain or a change in colour) then the item should be regarded as unclean. Similarly, if the surface of the component which has been wiped shows any evidence of a change in colour or reflectivity of light, then the item should be regarded as unclean.

17.1.2 "Wet" test

This uses a clean lint free cloth dipped in a solvent which evaporates at room temperature, such as isopropanol, ethanol or acetone. Appropriate safety precautions against fire hazard, breathing in of solvent fumes, eye and skin protection must be taken.

- (i) The cloth is dipped in the solvent which is then be allowed to evaporate in a safe manner. There should be no change in the appearance of the surface of the dry cloth.
- (ii) The cloth is dipped in the solvent and the surface of the component is wiped gently while the cloth is still wet.
- (iii) The solvent is allowed to evaporate from the cloth and the surface of the component until they are dry.
- (iv) If there is any evidence of a deposit on the cloth (i.e. a stain or a change in colour) then the item should be regarded as unclean.
- (v) Similarly if the surface of the component which has been wiped shows any evidence of a change in colour or reflectivity of light, then the item should be regarded as unclean.
- (vi) If required, the deposit on the cloth may be analysed by a suitable means to determine the chemical nature of the contamination.

17.2 Additional Test (from Appendix RF2 of RCC-MR)


Test A:

Surfaces shall be visually examined under a lighting equal to at least 500 lux (equivalent to the luminance directly beneath a 100 watt light bulb held 30 cm from the surface) provided that this does not dazzle the operator.

Criterion 2:

The metal shall be "metal clean". Very thin oxide films (detected by iridescence) resulting from welding, heat treatment, etc., shall be acceptable.

Scattered areas of oxidation, including surface rust stains of either the base metal or caused by contamination, shall be unacceptable.

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- 17.3 Pouring on demineralised water – the water shall spread out evenly across the surface (not form globules)
- 17.4 Temper films and discolorations resulting from welding are acceptable
- 17.5 Outgassing test and residual gas analysis can also be used as additional information of cleanliness

18. Design Rules for Cleanability (Only for information)

At the design stage for a vacuum component, careful consideration shall be given to how the item is to be cleaned. In particular, crevices, blind holes, cracks, trapped volumes, etc., shall be avoided as these will act as dirt and solvent traps and it can be very difficult to remove contaminants from such areas. Fortunately, good vacuum practice regarding trapped volumes will also usually result in a component which is cleanable.

19. Pickling/passivation of Steels

Refer **annexure 8**.

20. Final Cleaning requirements

Final cleaning is the cleaning to be done just before packing

Final cleaning shall ensure effective cleaning without damage to the surface finish, material properties or metallurgical structure of the materials.

The demonstration of meeting the final cleaning requirements given in this chapter represents an Authorization-To-Proceed Point (ATPP).


After final cleaning, the cleanliness shall be preserved.

21. Cleanliness of the Work Areas

A work area shall be taken to mean the surrounding environment in the immediate vicinity of a component or component part (for example, internal or external surfaces).

Level II work areas (according to RCC-MR) are required for working on class B components.

The concept of work areas shall be applicable subsequent to initial component (or component part) cleaning operations and to later operations which may adversely affect component cleanliness particularly in inaccessible zones. Work areas may be permanent or temporary and shall be applicable to fabrication shops and construction sites.

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The surrounding environment in the immediate vicinity of a component which is designated as a work area may, as the case may be, consist of an entire building or workshop, a delimited area inside a shop or on a construction site, or the wall of a component with respect to internal surfaces when adequate means of blanking off this wall are provided.


Steps are taken to limit sources of pollution (in particular, creation of dust and emission of gaseous effluent) in zones adjoining regulated working areas.

The following conditions are required for level II work areas.

- a. Special clothing: Personnel shall wear clean clothes and clean shoes or overshoes.
- b. No smoking, eating or urinating shall be allowed.
- c. Floors, walls and ceilings: Floors shall be covered with a smooth coating (permanent or removable). If the enclosure is permanent all walls and ceilings shall not produce dust.
- d. Creation of dust: Inside the work area measures shall be taken to prevent dust penetrating into components already cleaned or in the process of being cleaned. Accordingly, work on the concrete shall be avoided on the construction site.
- e. Cleaning of floors: Floors shall be cleaned daily. This interval may be reduced or increased according to the type of work performed.
- f. Identification of work areas: The boundaries of work areas shall be marked off physically.

22. Post-Cleaning Handling of DNB Vessel and HNB3 Vessel

After final cleaning, the handling of DNB Vessel and HNB3 Vessel shall be strictly controlled to preserve cleanliness. General area cleanliness requirements pertaining to Vacuum Classifications are summarised in **below table**. The continuing suitability of any given area used for handling DNB Vessel and HNB3 Vessel should be checked on a regular basis by monitoring the airborne particulate count, which should not exceed 5×10^6 particles of size $> 0.5 \mu\text{m}$ per m^3 for VQC 1.

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Cleanliness requirements	Personnel	Area Cleanliness	Monitoring
<ul style="list-style-type: none"> • Segregated clean area. • Limited Access to authorised personnel. • Authorised equipment operated to approved procedures. • Management of equipment (e.g. no vacuum pumps exhausting into clean area) 	<ul style="list-style-type: none"> • Trained personnel. • Protective hair nets. • Powder free latex or nitrile outer gloves. • Clean white overalls. • Overshoes. • Clean job specific footwear 	<ul style="list-style-type: none"> • Daily Cleaning of area Including floors and surfaces. • Sticky mats at area entry 	<ul style="list-style-type: none"> • Daily air quality checks. • Results stored in Component document package. • Weekly cleanliness test of area with results stored in component document package

23. Cleaning final report

A report shall be drawn up for each component or system cleaned. The report shall specify the cleanliness tests performed and the results obtained.