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Subject :Airworthiness Procedures for clean rooms and environments for aircraft system/accessories shops.

1. PURPOSE:

1.1 Aircraft Rule 57 requires that every aircraft shall be fitted and equipped with instrument and equipment including radio apparatus as may be specified according to the circumstances under which the flight is conducted.

Sub Rule 2 of Rule 57 further states that such instrument and equipment shall be maintained in a serviceable condition. In order to ensure high standard of maintenance, servicing and overhaul of equipment, accessories and instrument installed on an aircraft, it is imperative that various shops associated with these accessories must be relatively free of dust and other contaminants.

1.2 The higher reliability requirements specified for aircraft system components and in particular, those associated with complex electronic instrumentation and mechanical system, necessitated the development of techniques for controlling contamination which in various forms is a common cause of components premature failure. It has, therefore, become necessary to apply these techniques to selected areas of manufacturing and aircraft operating organizations in which the various processes of manufacture, overhaul and testing can be carried out under controlled environmental conditions. Such selected areas are referred to as `Clean Rooms', the design and construction of which form part of an independent and highly specialized field of work are normally specified by the manufacturers of equipment or laid down in British Standard BS 5295 Parts 1,2 and 3. This part of CAR lays down the various standards for clean room conditions and means to control the dust level.

2. INGRESS/PRODUCTION OF CONTAMINATION:

2.1 Air - The air which continually surrounds the components may be considered as a contamination storehouse containing dirt and dust particles, organic and inorganic vapours.

2.2 Manufacture - Contaminants are produced during all manufacturing processes, and particles, such as swarf resulting from a machining operation, or particles forced into the surface of a component during a pressing or heating process, can be of such a nature that their effect can be

immediate or delayed. Depending on the composition of the particle and component materials, the alloys or compounds formed by interaction can result in serious loss of a components structural strength over a period governed by the rate of diffusion.

2.3 Assembly - During the assembly process the possibility of introducing contaminants is probably greatest because of exposure to the highest levels of contaminant sources. In the soldering process for example, the vaporization of flux causes particles to escape into the surrounding air which,

on cooling, condense as droplets on a nearby cold surface of the component. Depending on the location of the particles and the forces applied to them, they can act as a contaminant with an immediate or delayed effect.

2.3.1 The use of jointing adhesives can also produce contamination similar to that of a soldering process. In addition, vapours can be given off which can migrate to other portions of an assembly and act as a delayed action contaminant.

2.3.2 Assembly of components using threaded joints can produce fibre-shaped fragments or flakes as a result of an effect similar to wire drawing. For extremely close fit or for balancing purposes, it may be necessary to fit individual parts of a component together by grinding, lapping or honing operations. In any such operation, contaminant particles can be dispersed in the atmosphere, suspended in fluids, adhere to the surfaces of component parts, or become embedded into the surfaces.

2.3.3 Assembly of components in jigs or while being handled or supported by tools, may result in deformation of surfaces and production of contaminant particles. For example, if during tightening of bolt, slippage of the spanner jaws occurs, particles are produced from the bolt head. Particles are also produced from the heads of bolts or screws and component surfaces during final tightening.

2.4 Storage and Transit - During the storage period of assembled components and of associated independent parts, contamination can occur in several ways notwithstanding the use of protective covering or containers. Particles from the air may be deposited as a result of gravitational settling and also as a result of electrostatic effects. Improperly cleaned containers or covers may transfer particles to components, in particular where padded containers and plastics containers are used. In the first case, the contours of the container may trap particles which are not released until the component causes deformation of the padding. In the second case, plastics containers may pick up particles from the air due to electrostatic charging, and hold them until transferred to the packed component.

2.4.1 Containers which are not hermetically sealed are subject to a `breathing' cycle as the temperature of the container varies. During the intake portion of the cycle, particles in the air surrounding the container may be drawn into a position where they can contaminate the component.

2.4.2 The movement of packed containers during transit is also a source of contamination since it may dislodge contaminant particles not previously cleaned off, or create new particles by abrasion.

2.5 Component Cleaning Processes - A cleaning process is actually a process of transforming contamination from a high level of concentration to a lower one; therefore, tolerance levels must be considered relative to the components' function and required operational accuracy.

2.5.1 The transfer of contaminant particles is dependent on

the methods used in the cleaning process, i.e. whether wiping or polishing with an absorbent or collecting material (dry cleaning transfer) or cleaning by means of a liquid (wet cleaning transfer). Problems exist in each of these processes.

2.5.2 The ways in which dry cleaning can contaminate include the following:

a) Removal of fibrous particles from the cleaning material.

b) The material, after use, may have a particle concentration sufficiently high so that as much contamination is left on the component as is removed.

c) Wiping or polishing action can cause particle adhesion as a result of electrostatic charges.

d) Particles can be moved about on a component surface without necessarily being lifted from the surfaces.

2.5.3 In the wet cleaning process, the contaminated surfaces are exposed to clean fluid which will wet the particles and the surfaces. The fluid or the component is then agitated so as to pull particles from the surfaces. After a specified period the component is withdrawn and the surfaces are dried. The ways in which wet cleaning can contaminate include the following:

a) It is often difficult to obtain clean fluid and to keep it clean when handling it.
b) Agitation of the fluid is normally done by ultrasonic means, but there is a possibility of recontamination if the amplitude of agitation is

not large enough to remove particles an appreciable distance from the surface of the component.

c) Often a wet surface may have particles in the liquid layer that can easily be moved laterally over the surface but are removed from the liquid layer only with great difficulty.

d) Until the component is dried, any airborne particles will collect on the wet surface and remain.

2.6 Personnel Activity - The activity of personnel is probably the greatest single cause of contamination which arises from several sources. The act of walking, or other movements required at a work bench, produces transient air currents which redistribute airborne particles and the brushing off of particles from many surfaces. Another contaminant source is the shedding of skin and hair particles. The outer layers of skin flake off almost continuously, the flake rate and size depending on the amount of abrasion to which the skin is exposed and its condition.

2.6.1 Exhaled air is another source of contamination since it contains moisture retaining solid particles and is usually acidic in nature. Perspiration from the skin is a similar hazard.

3. CONTROL OF CONTAMINATION:

Control of contamination is effected in two ways by establishing a clean room which will provide a clean atmosphere and working conditions and by rigid routines adopted by personnel to prevent process, transfer and associated sources of contamination by working within the area of the clean room.

3.1 The construction of a clean room and its air handling system (see paragraph 8) must be designed to control airborne particles over a range of sizes and suited to the nature of the work performed in the room. Control is accomplished by filtration of the air entering the room, changing the air to remove generated particles, designing walls, floors and furnishings to be resistant to particles generation and retention, protecting components from impact and settling of particle and providing additional areas for cleaning of parts and personnel.

4. SIZE OF CONTAMINANTS:

The degree to which contaminants are effectively controlled is determined by measurements of the size of particles and the number in a given volume. The conventional unit of measurement is the micrometer (mm). In general, the filtration systems of clean areas are designed to control particles of 0.5 mm and larger in size.

5. CLASSIFICATION OF AIR CLEANLINESS:

In addition to all principles of airconditioning, certain specialized cleanliness requirements are defined by standards which establish classes of contamination levels to be achieved in the design of a clean room for a specific task. Classifications relate to the number of contaminant particles 0.5 mm and larger in size, present in one cubic metre of air. Four classes of contamination level are generally adopted and these are shown in descending order of cleanliness in Table 1. Special classifications may used for particle count levels where special conditions dictate their use. A summary of the cleanliness requirements for some typical products is given in Table 2.

TABLE 1

Controlled Environment (Clean room, work station or clean box)	Recommended Air Flow configurations	Recommended Periodicity for Air sampling and Particle counting	Max. Permitted Number of Particles per cubic micron(equal to, or greater than, stated size)					Final Filter Efficiency %
			0.5 um	1 um	5 um	10 um	25 um	
Class 1	Unidirectional	Daily or continuous by automatic equipment	3,000*	N/A	Nil	Nil	Nil	99.995
Class 2	Unidirectional	Weekly	300,000	N/A	2,000	30	Nil	99.95
Class 3	Unidirectional or Conventional	Monthly	1,000,000	20,000	4,000	300	95,00	
Class 4	Conventional	3-Monthly			200,000	40,000	4,000	70.00

Controlled Area	Normal Ventilation	-	-	-	-	-	-	-	-
Contained Work Station	Unidirectional	To suit required class and application							99.997
Portable Clean Boxes	As selected	To suit required class and application	To suit required class						To suit required class

* Subject to maximum particle size of 5 micron

TABLE 2

Class	Particles/cubic micron	Product
2	0.5 um to 10 um	Air bearings Miniature ball bearings Miniature contacts Floated gyros Hydraulic and pneumatic systems Optics Semi-conductor networks Miniature timing devices
3	1 um to 25 um	Hydraulic and pneumatic systems Precision timing devices Stable platforms Gyros
4	5 um to 25 um	Ball bearings Electronic components Engine pumps Aerospace instruments Printed circuits Valves Hydraulic and pneumatic systems Precision measuring equipment

NOTE :Class 1 is outside the scope of this part of CAR and would not normally be used.

6. CLASSIFICATION OF CLEAN ROOMS:

The cleanliness achieved by a clean room is dependent on the air-handling systems' capacity to purge the room of contaminant particles. This includes not only effectiveness of the filters and number of air changes per hour but also the distribution of the air within the room. There are two main methods of distributing air into clean rooms namely, conventional clean rooms and unidirectional flow clean rooms and these also serve as the basic clean room classification. It is up to the operator to select clean room based on the recommendation of the Vendors/Manufacturers or he may take the guidelines from the British Standard Specification BS 5295.

6.1 Conventional Clean Rooms. Conventional clean rooms are based on recognized air-conditioning techniques. The conditioned air is highly filtered and distributed through ceiling-mounted diffuser outlets, and then exhausted from

return airducts located near the floor around the periphery of the room. In addition to direct emission from the diffuser outlets, spreading of conditioned air throughout the room is obtained by secondary mixing of the air caused by thermal effects of warm and cool air currents. This is an advantage from the point of view of maintaining conformity of room temperature conditions, but the turbulence created gives rise to the problem of contaminant

particles being re-introduced to the airstream.

7. ENVIRONMENT AND COMFORT CONTROL

The temperature, humidity and pressure characteristics of the air passing through the air handling system(see paragraph 8) should be controlled to established and environment suitable for work processes to be carried out in a clean room and for the comfort of clean room personnel.

7.1 Temperature and Humidity. The selection of temperature and humidity ranges to be controlled are dependent on the design of the component or system and the effects on their functional accuracy under varying environmental conditions. Normally a suitable temperature for working condition is 20 +2 degree C. Humidity should be controlled and maintained at a relative humidity of 35 to 50% for all classes of clean rooms, contained work stations and clean boxes.

7.2 Pressure. Clean rooms are always slightly pressurized in order to maintain the required outward flow of air under closed working conditions and to prevent the entry of contaminant airborne particles when entry ways or doors are opened.

7.2.1 Unidirectional -flow rooms should normally have an air velocity of 0.45+0.1 m/s for horizontal flow rooms and 0.30+0.05 m/s for vertical flow rooms. Air pressure for conventional flow rooms should be such that the number of air changes, including recirculated air, should not normally be less than 20 per hour except for class 4 rooms where not less than 10 changes per hour may be acceptable.

7.2.2 Arrangements should also be made to ensure that excessive turbulence is not produced and every precaution should be taken to obviate the possibility of contaminated air being carried back to the work stations. Contained work stations and portable work boxes should normally conform to the requirements of the type of air flow selected. Air pressure and graduations between successive pressure areas should not normally be less than 15 pa (1.5 mm water gauge).

NOTE: 25 Pa(2.5 mm water gauge) is normally regarded as adequate but when selecting the actual pressure, care should be taken to ensure that leakage is prevented.

8. AIRHANDLING SYSTEMS:

The primary function of an air handling system for any type of clean room is to control the level of airborne contaminant particles by constantly filtering and recirculating the air. The arrangement of a system depends on whether it is to be a conventional clean room, the basic form, however, it consists of a fan, ducting for inlet and exhaust air and an air filtration system. In some instances, the use of ducting may be minimized by adopting a

false ceiling arrangement and by flowing air through the plenum chamber formed between two ceilings, and also be adopting a twin cross-flow system (see paragraph 6.2.1). The air is conditioned to the required temperature and humidity values (see paragraph 7.1) by adopting recognized air-conditioning principles and by the integration of an appropriate air -conditioning plant.

8.1 Fans-Fans are usually of the electrically operated type designed to deliver a constant airflow rate through the clean room as the filter pressure drop increases. They should be mounted external to the ducting where possible, to avoid heat loading of the air and introduction of further contamination. Care should also be taken to avoid contamination of the atmosphere by gaseous effluents.

8.2 Ducting-Ducting is constructed from materials which are non-flaking and corrosion -resistant, stainless-steel and aluminium being commonly used, or should normally be treated to prevent the introduction of contaminants from the duct.

8.3 Filtration System-Filtration of airborne contaminant particles is selected on the basis of cleanliness level required and, generally a system is made up of two required and, generally, a system is made up of two principal stages: pre-filter stage and final filter stage. Pre-filtering is carried out at the inlet to the air handling system and at one or more points upstream of the clean room, and final filtering directly at the inlet to the clean room. The filters are specifically designed for clean room systems and are graded at each stage, thus providing control of diminishing size particles. Filtering action depends on the particles contacting and adhering to the fibres or collecting surface of the filter medium which is made from such materials as glass-fibre and asbestos. The filters utilized for final filtering are variously known as super-inspection, absolute or high-efficiency particulate air (HEPA) filter, and maybe used as individual units or assembled to form filter bank or module. In the latter case, each unit is connected to a common plenum chamber incorporating its own fan. The number of individual units in a bank is governed by design requirements for the air handling system.

9. LAYOUT OF CLEAN ROOMS:

The layout of a clean room is governed by many factors arising principally from the manufacturing processes and test procedures to be carried out on specific types of equipment. As a result there are a variety of design and layout specification to meet the requirements of individual manufacturers and operators of equipment. In their basic form, however layouts are directly related to the unidirectional flow and conventional.

9.1 Unidirectional Clean Rooms. The area devoted to the

facility is arranged in accordance with-the operating practices common to all clean rooms, i.e. components and personnel flow progressively from an uncontrolled or dirty' environment to one in which the desired level of cleanliness is maintained.

9.1.1 Personal Cleaning. Entrance to the clean room is via a change room the purpose of which is to decontaminate personnel without introducing removed contaminant

particles into the clean room. A change room is divided into three distinct areas; an uncontrolled or 'dirty' area, a wash-up (Semi-contaminated) area and a change (uncontaminated) area. These area are arranged so that personnel must follow a definite path for entry into the clean room.

a) In the uncontrolled area lockers are provided for housing out door clothing such as overcoats and raincoats, and also shoe cleaning machines. From the uncontrolled area, entry to the wash-up area is made via an air shower compartment the purpose of which is to remove gross contaminant particles from personnel. The size of the compartment may be large enough to accommodate only one person of a group of persons depending on the number that must enter the clean room in a given length of time.. The design of the air shower may vary but in general, it consists of an air inlet system operated by independent fans. Air flows through the compartment from air inlet nozzles or louvers mounted in the ceiling or in one wall of the compartment. The entrance and exit doors of the compartment are interlocked so that only one of them can be opened at a time. The closing of the entrance door starts the fan and, until the cleaning cycle is completed, the exit door remains locked. The cycle may in some cases, be interrupted by a safety override system in the event of an emergency. Air velocities are sufficiently high to cause flapping of clothing but without discomfort to personnel.

b) On leaving the air shower, personnel proceed to the changes area via the semi-contaminated area in which washing and toilet facilities are located. These facilities include foot controlled washstands, liquid-soap dispensing units and heated air hand-drying machines to prevent contamination from toweling. A section of the change area is provided for changing into special clean room garments(see paragraph 12) stored in racks or lockers. The entrance to this section is remove residual contaminant particles from the undersurfaces of shoes. Entrance to the clean room after changing is made via another air shower compartment.

9.1.2 Parts Cleaning. Prior to entry into a clean room, all parts, tools, equipment, and material must also be decontaminated and it is therefore necessary to provide an additional are adjacent to the clean room. The layout of a parts cleaning room depends largely on the types of component and the number of work processes involved. Similarly, the cleaning methods adopted depend on the type of contaminant, the materials used in the construction of components, and the level of cleanliness required. In general, the room is equipped with the required number of work tables, specialized equipment, cleaning machines and washing facilities for personnel.

a) The transfer of cleaned components to the clean room is effected by means of a pass -through box forming an air lock in the wall dividing the

appropriate areas. Boxes are provided with double windows and doors; an interlock system ensures that only one door can be opened at a time. In some clean room facilities a pass-through box maybe of the circular type with a single opening so that the box must be rotated through 180 degree to insert or remove a component. Since the boxes are designed to prevent a direct opening between rooms, a means of verbal communication between relevant personnel must be provided adjacent to the box. This can be an intercommunication system, a voice diaphragm, or a specking tube.

9.1.3 Additional Support Rooms- Since unidirectional clean rooms require more rigid control to prevent contamination entering, it is usual to make provision for additional support rooms such as offices, lunch rooms, rest rooms, etc. The construction of these rooms follows a similar pattern to that of a clean room (see paragraph 10) although the air handling system is usually not so elaborate.

9.2 Conventional Clean Rooms-The use of conventional flow clean rooms eliminates the necessity for support areas such as air showers and special changing rooms and, as may be seen from the typical conventional layout, increased working area is available and entry procedures are much a simpler. The main entrance is situated at the air outlet or 'dirty' end of the room and personnel can pass through this directly from a locker room and change area. Work benches and equipment are disposed so that the cleanest operations are carried out closest to the filter bank forming the end wall while dirty operations such as soldering, cleaning etc. are performed toward the outlet end of the room. Parts cleaning and preparation may be performed in a manner similar to that adopted for a unidirectional clean room(see paragraph 9.1.2) or carried out in a parts cleaning room situated within the

clean room itself.

10. CONSTRUCTION OF CLEANROOMS:

The construction of clean rooms involves the application of specifically developed building techniques, air-conditioning installation particles and careful selection of construction materials. This is normally undertaken by a specialist organization working to the detailed BS 5295 Parts 1,2 and 3 and the specification of a user organization. However, the following factors are to be taken into consideration while constructing clean room.

Noise and Vibration shall be minimum but in no case noise level shall exceed 65 db. Floors, walls, ceilings, lighting and other utilities shall be of acceptable standard.

11. CLEAN ROOM CONDITION:

Furnishing such as work benches, chairs and containers for components parts require careful selection, design and choice of materials for their construction. However the main structure of work benches and chairs should be of metal and designed in such a way that contaminant particles cannot accumulate and adhere to.

12. CLEAN ROOM GARMENTS:

Clean room products can be readily contaminated by particles from clothing and it is therefore necessary to make provision for the wearing of protective garments. These take the form of smocks, overalls, caps and hoods. In addition, 'boottee' type shoe covers, separate clean room shoes and gloves must also be provided. The extent to which all the garments are used depends on the type of clean room, class of cleanliness to be achieved and the work processes carried out.

12.1 Design-The garments are of special design to prevent the transfer of contaminant particles from personnel and at the same time to provide the maximum of comfort. The materials from which they are fabricated are usually selected from the range of available man made fires which exhibit such properties as non-flammability, limited linting, and negligible electrostatic generation. These materials are available under a variety of trade names. Typical design requirements for clean room garments are given in the following paragraphs.

12.1.1 Smokes -Smokes should be of simple design, with no pockets and with a few seams as possible. Seams should leave no open end of material which might become frayed and give off lint or loose strands. In addition, seams should be double-stitched with thread of the same fibre as the garment. Adjustable neck bands and cuffs should be provided in preference to collar and loose sleeves and must provide a snug fit when worn.

12.1.2 Overalls-Overalls should have a full-length zip fastener with flap front and be provided with adjustable neck bands and cuffs. If overalls are to be used with shoe covers, the overalls should fit inside the covers. Overalls to be used with clean room shoes should be designed so that the legs of the overalls meet and slightly overlap and shoes.

12.1.3 Caps - These should be of the style worn in hospital operating rooms. They should fit snugly around the head, covering the hair to prevent air particles and dandruff falling into the clean room area.

12.1.4 Hoods - Hoods should be designed to confine all hair under them to eliminate contamination by hair particles and dandruff and to fit snugly inside overalls to provide complete coverage of personnel; if beards are permitted, masks must also be provided.

12.1.5 Shoe Covers and shoes- Covers should be worn over normal shoes and should be high enough to hold the legs of overalls. Covers should have a reinforced sole and be of a type which will prevent personnel from slipping and falling on smooth floors and, for reasons of durability and economy, nylon is recommended as the achieve optimum cleanliness, covers should be provided the legs and above the ankles. As an alternative to shoe covers, shoes can be issued to personnel for exclusive wear in the clean room. They should be simply designed, comfortable, washable and fabricated from materials which will not shed particles due to abrasion and wear.

12.1.6 Gloves-When there is a risk of contamination from contact with the hands or fingers, gloves or fingers stalls must be used. Such coverings should be comfortable and

should enable the user to maintain a delicate finger touch. If plastics is necessary for the 'touch' portion of gloves the remainder should be made of a material that will allow breathing thus preventing overheating of the hands.

12.2 Garment Storage and Cleaning-When not in use, clean room garments should not be allowed to come into contact with any possible contaminant. They should always be stored on individual hangers in the lockers provided in changing rooms. Three sets of garments per person should normally be provided; one set in use, one set being cleaned, and one set in reserve.

12.2.1 Cleaning of garments is a specialized technique based on conventional laundering and dry cleaning processes- Ideally, a laundry should established as a specialized unit supporting clean room operations, and functioning under similar conditions of decontamination as a clean room. T typical unit is divided into three distinct areas; soiled garment receiving area, washing and dry-

Soiled garments are placed in polythene bags and transferred to the receiving area through an air lock. The garments are then emptied into specially built tubs equipped with the appropriate machines. After cleaning and drying, the garments are transferred to the third area for inspection, sampling of contamination level and packaging and sealing in polythene bags.

13. CLEAN WORK STATION:

These stations are work benches specifically designed to incorporate their own filtered air supply system. They may be utilized in a clean room, in addition to benches or tables based on conventional patterns, or in an uncontrolled environment.

13.1 The design of work stations has been developed from bench-mounted dust free cabinets. Although these cabinets provide low contamination levels, depending on the type of filter, the problem of contamination while operations are performed inside arises. Contaminants move about in turbulent air and find their way out of the cabinet only at random intervals. Another design is commonly referred to as a 'glove box'. It utilizes a recirculating air system and although it produces lower contamination levels than other forms of cabinet, it has the disadvantage of requiring an operator to work through arm ports and the attached gloves.

13.2 Work, stations overcome the deficiencies of 'dust free' cabinets by incorporating an air distribution system which operates on principles similar to those employed in a unidirectional-flow clean room (see also paragraph 6.2). The air distribution system consists of a fan and a pre-filter mounted below the work surface, and an outlet with a super-interception filter, mounted so as to produce either a horizontal flow or a vertical flow over the work surface. Glass panels form the sides of the work area which on account of the unidirectional flow technique is open at the front thus permitting unrestricted movement at the work surface. Illumination of the work area is provided by lighting units enclosed i,n the canopy above the work surface. Individual switches foe lighting units and fans are located at convenient points as also are the controls for the various services required for relevant work processes.

13.3 The selection of a work station best suited to a specific application involves such factors as type of airflow, size of work area, space available, and design and performance of the air distribution system. Units employing horizontal flow are generally less costly than vertical flow units for equal size of work area and can usually be provided with lower overall heights thus making them more suitable when vertical space is a critical factor. When work processes require the exhausting of fumes from the work area, or when recirculation of the air is required, vertical flow units provide for these functions more easily than

horizontal flow units. Horizontal flow units on the other hand, provide better 'clean up' of a work area than vertical flow units of equal size.

13.4 The most important consideration in selecting a particular size of work station is to ensure that it will provide unidirectional flow over a work area of sufficient width, depth and height to accommodate the component being assembled or tested, and the necessary associated equipment. If several items of equipment must be sited around a component, a vertical flow unit tends to produce less turbulence and moves clean air in the most direct fashion from the filter to the component. The filters are of a type similar to those used in unidirectional clean rooms (See paragraph 8.3).

14 CLEAN ROOM OPERATION:

In addition to the air handling system, the contamination level in a clean room is kept at an acceptable level by two other methods, namely limiting the contamination entering the room and limiting the contamination generated within the room. Both these methods are controlled to a large extent by the personnel selected for clean room operations. The contamination entering the room is limited by the wearing of proper garments (See paragraph 12) personnel cleaning, parts and equipments cleaning, etc. The contamination generated is limited by restricting movement, proper work techniques etc. It is therefore, necessary to establish routines and disciplines related to personnel selection, personal hygiene, entry procedures, and control of working activities. The extent to which certain of these routines and disciplines are applicable depends on the type of clean room; for example, and unidirectional flow clean room requires more rigid control of entry and clothing procedures than a conventional clean room due to the air handling system used (see paragraph 9.1 and 9.2).

14.1 Personnel Selection- The selection of personnel for clean room duties involves consideration of both physical and human factors, including manual dexterity visual appearance, patience, concern for details, attitude towards repetitive operations, and reaction to the rigid disciplines that accompany confinement in a controlled environment. Certain physiological problems must also be considered and some examples which are detrimental to clean room operations are: allergies to synthetic fabrics; allergies to solvents used in cleaning processes; profuse nasal discharge; skin conditions that result in above normal skin shedding or flaking and dandruff; high amounts of acid found in the hands; severe nervous conditions such as itching, scratching or claustrophobia.

14.2 Person Hygiene- The development of personal hygiene is of a

great importance in clean room operations, not only to limit contamination of vital components but also to maintain a healthy working environment. Personnel with colds,

temporary coughing and sneezing should be assigned to temporary jobs outside the clean room until they are sufficiently recovered. This also applies to personnel have received severe sunburn, to prevent peeling skin from contaminating a component or the surrounding area.

14.3 Entry Procedures- Clean rooms are necessarily restricted area and entry must only be allowed to personnel assigned to them. The procedure to be adopted is governed by the type of clean room. Typical activities associated with entry procedures are as follows:

a) Removal of outdoor clothing such as overcoats and raincoats and stowage in the lockers provided in the 'dirty' or uncontrolled area.

b) Checking clothes and shoes for visible contamination such as mud, dirt, sand etc. Removal of such contamination.

c) Washing of face and hands using foot-controlled washstands, liquid soap dispensers and air driers.

d) Passing through air showers and air locks to ensure adequate air scrubbing.

e) Walking over sticky or tacky mats.

f) Changing into the requisite clean room garments. In connection with unidirectional flow clean room operations, changing is done in the uncontaminated section of the change room adjacent to the clean room. In conventional clean rooms changing is done in an area located at the 'dirty' end of the clean room.

14.4 General Rules for Operation. The following are general rules which should be enforced to assist in the successful operation of clean rooms.

14.4.1 Personal Activities:

a) Hands should be washed often and fingernails kept clean.

b) The specified clothing should always be worn in the approved manner.

c) Personal items such as keys, coins, cigarettes, matches, pencils, handkerchiefs and combs should be deposited in lockers prior to changing into clean room garments. Valuable items such as wallets may be carried into a clean room in jacket or trouser pockets provided they are not removed inside the clean room.

d) Foodstuff should not be taken into a clean room

e) Smoking is strictly forbidden.

f) The wearing of jewellery such as large rings, bracelets,

watches, necklaces, earrings, lockets etc. should be avoided.

g) Nervous mannerisms such as scratching the head, rubbing of hands or similar action should be avoided. h)

Movement of personnel should be avoided.

h) Movement of personnel should be restricted as much as possible to prevent stirring settled particles on the clean room floor. This applies particularly to conventional clean rooms.

i) Solvent contact with hands should be avoided as many solvents remove natural skin oils causing excessive skin 'peeling' or flaking.

k) female personnel should not wear or apply fingernail polish or cosmetics in a clean room.

l) Visitors or clean room maintenance personnel must be authorized to enter a clean room and must follow the specified entry procedures.

14.4.2 Work Activities:

a) All tools including personal tool kits should be kept clean and in good condition and should undergo cleaning processes in accordance with a periodic cleaning schedule. Tools not essential to specific work processes should be excluded from tool kits.

b)Paper materials should not be allowed in a clean room unless the paper is plastic-coated or covered, sprayed to prevent linting or is a special limited-linting paper. Paper should not be subjected to excessive shuffling, handling, rolling or bending as they can generate excessive amounts of small particles under these conditions.

c) Pencils and erasers are not allowed. All writing should be with ball-point pens.

d) Parts of components should be kept in their individual containers until ready for assembly. They should not be left exposed on a work bench or station.

e) Containers and any component parts surplus to requirements should always be returned to a parts cleaning area for cleaning and re-issue.

f) Metal objects such as wire clippings and solder splashes should be deposited in waste boxes at the end of each process.

g) Where cleaning of parts is to be carried out insides a clean room, the type of cleaning equipment and its location within the room should be carefully selected.

15. MAINTENANCE OF CLEAN ROOMS:

In order to maintain clean rooms to the necessary standards, good house keeping particles and monitoring of the air handling system are of prime importance. The frequency of cleaning is usually determined by taking into account the change in contamination level that can occur due to the cleaning operation, and the number of air changes per hour. Monitoring of the air handling system should be carried out at the time a clean room is put unto initial operation and at regular periods thereafter, when filters have been changed, and when it is evident that down-grading of its operating level is taking place (see table 3)

15.1 Cleaning- Rooms should be cleaned when no work processes are being performed. Minor dry floor and bench vacuuming can be done, if necessary during normal room operation if the equipment and procedures used ensure a minimum of disturbance to settled particles.

15.1.1 Cellulose mops and sponges can be used with water which meets specific particle-count requirements. High-grade plastics buckets which are not subject to falking should be used. If ladders are required, they should preferably be of the anodised aluminium type. The use of detergents should be restricted to those which produce the minimum amount of residue after drying. F9or vacuum cleaning, a central vacuum cleaning system or a specially designed portable vacuum cleaner should be employed.

15.1.2 Cleaning apparatus and utensils are prevalent sources of contamination and their movement in and out of clean rooms should be carefully scheduled. They should be thoroughly cleaned and vacuumed prior to their entry.

TABLE 3

Controlled Environment	Sampling for Particulate Contamination	Temperature	Humidity	Air Pressure
Class 1	Daily or continuous by automatic equipment	Continuous	Continuous	Continuous
Class 2	Weekly	Continuous	Continuous	Continuous
Class 3	Monthly	4-hourly	4-hourly	Continuous
Class 4	3-monthly	12-hourly	12-hourly	Continuous
Contained Work Station	Daily or to suit the product or as Class 2	Dependent on use		Not applicable

Controlled Area	Dependent on use	To meet requirements of personnel and product	Not applicable

15.1.3 The responsibility for cleaning work benches or stations should be delegated to personnel assigned to the benches to prevent improper handling of components and equipment by room maintenance personnel.

15.1.3 Inspection, maintenance and testing of air handling system components should be carried out i,n accordance with the relevant maintenance instructions at periods determined by the type of clean room operations, and when down grading of the contamination level begins to occur.

15.2 Monitoring of clean rooms-Monitoring refers to the procedures adopted for checking the factors influencing clean room environment. Such factors are the level of contamination, temperature, humidity and pressure. The exact requirements f9r monitoring and methods to be employed depend on the type of clean room and classification of cleanliness level, and are therefore determined on an

individual basis (see table 3).

15.1 Contamination Monitoring_ This is the most difficult monitoring problem of clean room operation owing to the variations in contamination level through out a room and also to the many factors which must be considered in selecting a specific monitoring technique. Some of the factors causing variations in contamination level are filtered air entering a room at one or more locations; contamination being generated in various amounts throughout a room; contaminated air exhausted from a room at one or more locations. The highest level of exhaust locations, since air from a highly contaminated area may be diluted with filtered air prior to its being exhausted. Higher and lower levels of contamination can thus readily exist within a given room. The areas of most concern are those immediately surrounding the component of which work processes are to be carried out.

a) The locations within a clean room at which sampling of the air is to be taken should be carefully considered in order to obtain a representative contamination level. Samples should be taken at identical times or as near as possible, since contamination level of areas vary at different periods.

b) Various techniques may be applied to contamination monitoring and some of those most widely accepted, together with details of principles as listed in BS 5295 Parts 1,2, and 3.

15.2.2 Humidity Monitoring - This may be achieved by the use of conventional wet and dry bulb thermometers and psychometric charts. The thermometers may be

supplemented, if necessary by automatic recording devices. Humidity can become troublesome if it is allowed to reach a level where static charges are generated by personnel or where corrosion may be a problem. In general, a humidity level of not less than 40% is desired. For those components where humidity tolerance is critical, special control measures should be employed.

15.2.3 Pressure Monitoring-A clean room should always be slightly pressurised and it is therefore necessary to monitor the pressure difference between the room and its outside surroundings. Monitoring may be achieved by a simple U-tube manometer, or a differential pressure gauge calibrated in mm water gauge.

Premature failure of may instruments, equipments and accessories have been attributed to ingress of contaminants during overhaul manufacturing, assembly stages. It is essential that accessories are tested, overhauled and assembled in controlled environmental condition in the various shops in accordance with the conditions in the preceding paragraphs. All operators are, therefore to adhere to these standards in their various shops forthwith and document the procedure so adopted in their Quality Control Manual.

Sd/-
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Dy. Director General of Civil Aviation