AIV Facilities Verification Matrix

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1 Applicable Documents

ID	Title	Author	Reference	Date
AD1	SPIRE AIV Test Facility Requirements Specification	D.L. Smith	SPIRE-RAL-PRJ-000463 Issue 1.3	10-April-2001

2 Scope of Document

This document takes the requirements for the AIV Facilities as set out in AD1 and indicates how each requirement will be verified.

3 Definition of Terms

The verification matrix gives the reference and a short description of the requirement, and the verification method. The definition of the verification methods is given in table 1.

Method	**Definition**
Design	The requirement will be incorporated in the design of the subsystem.
Demonstration	Although not explicitly designed, the project will ensure provision of items that conform to the stated requirements. For example, temperature sensors will be used that have been calibrated to the required accuracy.
Inspection	Items delivered to the project will be subject to an incoming inspection and includes a review of accompanying documents (CofCs, Waviers, Test reports…)
Analysis	Where it is not possible to directly design or test to show conformance. For example a thermal analysis of the cryostat will be performed to demonstrate that the proposed design will meet the requirements.
Test	Conformance to the requirements will be demonstrated by test.

Table 1: Verification Methods

2. Verification Matrix

Section	Ref.	Requirement	Verification					Comments
			Design	Demo	Insp.	Analysis	Test	
General	R0-1	Facilities are required to enable the SPIRE AIV plan to be executed		X				
	R0-2	The AIV facilities shall be available to SPIRE until the launch of Herschel		X				
Cryostat General	R1.1	The calibration cryostat must be able to accommodate the SPIRE instrument and two JFET filter boxes.	X		X			The cryostat design has been based around the mechanical interface drawings for the SPIRE instrument.
	R1.2	The cryostat will also house a cold blackbody source operating between 4K and 40K for use during calibration.	X		X			A volume within the cryostat has been allocated for the cryogenic blackbody
	R1.3	The SPIRE instrument must be mounted with the baseplate horizontal (I.E., +Y direction down) so that the instrument mechanisms do not work against gravity.	X		X			
	R1.4	The distance from the Cryostat outer window to the SPIRE image plane must be no greater than 759mm to ensure correct alignment to the telescope simulator.	X		X			The optical model for the telescope simulator has been incorporated into the cryostat design.
	R1.5	All materials used for the cryostat and equipment contained in the vacuum environment must be suitable for vacuum and low temperature use.	X	X			X	Standard vacuum and low-temperature materials and processes will be used.
	R1.6	The instrument must be mounted in such a way as to allow ease of access and minimum effort during integration.	X		X			
Cryostat Thermal	R1.8	The cryostat must be able to simulate the thermal environment provided by the FIRST cryostat. The main interface temperatures are 9-15K, 4.2K and 1.7K.	X			X	X	
	R1.9	At operating temperatures, the temperature of the SPIRE FPU should drift by no-more than 1 Khr-1 at 4.2K	X			X	X	
	R1.10	The cryostat should enable the SPIRE instrument and electronics to attain operating temperature within 24 hours, at a maximum rate of 20Khr$^{-1.}$	X			X	X	This is probably an optimistic estimate at present and may be revised pending the results of the instrument thermal analysis
	R1.11	The cryostat should allow a cryogen hold time of at least three days when the instrument is fully cooled. This will eliminate the need for an automatic liquid He delivery system, therefore reducing overall costs. The helium exhaust will not be recovered for future use.	X			X	X	This should allow at least one full operating cycle of the ^{3}He cooler.
	R1.12	The cryostat design should allow the instrument to be heated to TBDK before allowing the He shrouds to warm up to prevent contamination of the instrument optics.	X			X	X	
	R1.13	Heat leaks must be kept to a minimum by anchoring the thermometer wires to the refrigerant tanks, and/or using low thermal conductivity wire.	X		X	X		
	R1.14	Temperatures of the thermal environment must be measured during the tests. The location and accuracy of the thermometers will be defined in the thermal test plan.	X				X	Temperature sensors to be calibrated in accordance with the RAL SSTD ISO-9000 procedures
	R1.15	The support structure and optical bench simulator shall not impart any forces (lateral or twisting) on the SPIRE instrument during cool-down or warm-up.	X			X		

Section	Ref.	Requirement	Verification					Comments
			Design	Demo	Insp.	Analysis	Test	
Cryostat Vacuum	R1.16	The vacuum system must be able to pump the chamber to 10--6mbar (TBD) within 24 hours before filling the cryogen tanks to ensure that the inside of the instrument is at least 10-4mbar (TBC).				X	X	Vacuum system suppliers have provided models showing pump-down times to be within specification. Tests to be performed with cryostat prior to delivery to RAL
	R1.17	The maximum pumping rate shall be 50mBar min-1- (TBC) to protect the instrument filters. These rates also apply for letting up to air.	X				X	A butterfly valve in the roughing system will be used to restrict the flow during initial pump-down.
	R1.18	The pumping system must be mechanically isolated from the chamber to prevent vibrations being transmitted to the instrument optics.	X					Turbo-pump will not be operating once cryogen tanks are cold.
	R1.19	The pumping system must be oil free if possible to prevent contamination of the optical surfaces.	X					A completely dry system will be used.
	R1.20	A gate valve will be installed between the pumping system and cryostat. The valve must be closed before filling the cryogen tanks in order to prevent backflow of any lubricants into the main chamber. The gate valve must automatically close in the event of a failure of the pumping system.	X				X	The gate valve is controlled from the turbo-pump drive unit.
	R1.21	A burst valve must be installed to prevent the chamber exceeding atmospheric pressure either during controlled let-up-to-air, or a sudden loss of vacuum.	X					In accordance with standard RAL safety procedures. Vacuum vessel will be pressure tested to BS5500
	R1.22	The cleanliness of the inside of the tank must be better than class 1000. Mountings for TBD witness mirrors shall be provided in the calibration rig.	X	X			X	
	R1.23	The vacuum pressure must be measured during pumpdown. The pressure range is expected to be 1bar to 10-8mbar. After high vacuum has been reached the pressure gauges will be switched off.	X	X			X	
	R1.24	A Residual Gas Analyser (range 1-200 AMU) is required to monitor partial pressures of contaminants in the chamber during commissioning. This is not required for the actual calibration tests.		X			X	The gas analyser will be tested and calibrated in accordance with RAL-SSTD ISO-9000 procedures
Cryostat Optical	R1.25	The support structure must ensure that the optical alignment is maintained to TBD" when the instrument is cold.	X			X	X	
	R1.26	Optical filters will be mounted at each of the cryostat interfaces between the instrument aperture and telescope simulator. The filtering scheme should ensure that the radiative load on the instrument to simulate the load from the HERSCHEL telescope as closely as possible.	X			X	X	To be provided by Cardiff University
	R1.27	A flip mirror will be mounted to allow the instrument to view the full area of the cold blackbody source.	X		X		X	To be provided by Cardiff University
	R1.28	The cryostat design should allow the optical alignment to be verified with the instrument cold (STM only).	X		X		X	
Cryostat Electrical	R1.29	Electrical feedthroughs between the air and vacuum sides of the chamber will be provided for the instrument electronics, thermometry and cold calibration target(s).	X		X			
	R1.30	It must be demonstrated that there is no electrical interference to the supplies of the SPIRE instrument and EGSE.	X				X	
Control and Monitoring	R1.31	The cryostat temperatures will be measured and logged	X				X	Part of test facility control system

Section	Ref.	Requirement	Verification					Comments
			Design	Demo	Insp.	Analysis	Test	
	R1.32	The liquid nitrogen level shall be monitored throughout the tests. The output from this monitor will feed back to an automatic LN2 dispenser to ensure that the level remains above TBD cm. If the level drops below TBD cm an alarm will sound.	X				X	Part of test facility control system
	R1.33	The 4K helium level will be monitored throughout the tests. An alarm will sound when the level falls below TBD cm. There will be no automatic dispensation of He.	X				X	Part of test facility control system
	R1.34	The cryostat must be automatically monitored from the TFCS. The cryostat monitoring software should interface to the facility control software in accordance with an agreed interface specification (see R5-17).	X				X	Part of test facility control system
	R1.35	No command instructions are required for the cryostat monitor.	X					
	R1.36	The monitoring software will send the cryostat temperatures, cryogen levels and status of alarm flags to the TFCS-TEI to be compiled in telemetry packets for transfer to the SPIRE EGSE.	X				X	Part of test facility control system
	R1.37	A software interface specification will be produced.		X				
	R1.38	The cryostat monitor will save all data to an archive.	X				X	Part of test facility control system
Cryoharness	R2.1	The heat load from the harness into the level 1 interfaces must be less than 5mW.	X			X		Cryoharness to be defined by SPIRE systems engineer
	R2.2	The total impedance of the conductors must be less than the limits specified in the SPIRE IIDB (AD 5)	X			X	X	
	R2.3	The harness routing must not obstruct the instrument’s field of view.	X		X			

Section	Ref.	Requirement	Verification					Comments
			Design	Demo	Insp.	Analysis	Test	
Cryolab Cleanliness	R3.1	The area immediately surrounding the cryostat, where instrument optics will be exposed, will be class 1000.	X	X			X	As per RAL-SSTD ISO9000 clean room procedures.
	R3.2	All other areas in the clean room will be class 10,000 or better.	X	X			X	As per RAL-SSTD ISO9000 clean room procedures.
	R3.3	Cleanliness will be monitored throughout the SPIRE calibration period		X			X	Monitoring equipment to be calibrated in accordance with RAL-SSTD ISO9000 clean room procedures.
Cryolab Electrical	R3.4	Two clean 28V power supplies must be provided for the SPIRE instrument.		X			X	Power supplies to be calibrated in accordance with RAL-SSTD ISO9000 procedures.
	R3.5	There shall be adequate mains power points for the SPIRE EGSE, test equipment and vacuum system. The mains supply must be uninterruptible and surge protected.	X		X		X	
	R3.6	The electrical design of the facility must ensure that there are no ground loops that could pose an EMI problem.		X		X		
	R3.7	All electrical connections in the facility must be fully documented and readily accessible.		X		X		
	R3.8	ESD protective equipment (mats, wristbands) must be used during instrument integration.		X	X		X	These will be provided as required and tested in accordance with RAL-SSTD ISO9000 procedures.
Cryolab - Access	R3.9	The entrance to the clean room must be wide enough to allow the instrument and MGSE to pass through.	X	X				
	R3.10	Due to limited space and to maintain cleanliness, access to the clean room will be restricted to a few authorised personnel. To prevent unauthorised access, a card key system will be installed.		X			X	This has already been implemented. Access to the clean room is via the control room that can only be entered using a card key. Entry to the room is automatically logged.
Cryolab - Safety	R3.11	Oxygen monitors will be installed in the clean room that should sound a clear alarm in the event of O2 going below safe levels.		X			X	In accordance with RAL SSTD safety plan.
	R3.12	Escape from the room in the event of an emergency must be unrestricted.		X			X	In accordance with RAL SSTD safety plan.
	R3.13	A full risk assessment must be carried out and emergency procedures must be ready before the facility is used for cryogenic work.		X	X			In accordance with RAL SSTD safety plan.
	R3.14	Laser warning signs and eye goggles will be provided in accordance with RAL site regulations.		X	X			In accordance with RAL SSTD safety plan.
	R3.15	A full risk assessment must be carried out and emergency procedures must be ready before using laser equipment.		X	X			In accordance with RAL SSTD safety plan.
Cryolab - other	R3.16	The clean room should be light tight to allow use as a dark room.		X			X	Blinds will be installed on all windows.
	R3.17	The temperature within the clean room must be maintained at TBD°C± °C.		X			X	An air conditioning unit has been installed to maintain the laboratory at constant temperature
	R3.18	The humidity within the clean room must be maintained at TBD		X			X	Humidity will be monitored

Section	Ref.	Requirement	Verification					Comments
			Design	Demo	Insp.	Analysis	Test	
Control Room	R4.1	There must be adequate space for the SPIRE EGSE, TFCS, vacuum equipment and at least 4-5 people.	X	X				
	R4.2	Access to the control room will be restricted by a card key system provided by the RAL AIV facility.		X			X	A card key system has already been installed
	R4.3	The entrance to the clean room will have changing facilities.	X	X	X			Already in place
	R4.4	There will be sufficient mains power supplies for the EGSE and support equipment. The mains supply must be uninterruptible and surge protected.		X			X	
	R4.5	The control room will have a telephone.		X				
	R4.6	Connection points will be provided to allow connection to the internet, and fax machines.		X				Connection points are in place,
	R4.7	The control room must be air-conditioned.		X			X	

Section	Ref.	Requirement	Verification					Comments
			Design	Demo	Insp.	Analysis	Test	
Telescope Simulator	R5-1	Optical beam		X				
	R5-2	Field-of-view.		X				
	R5-3	Spectral range.	X					Determined by filters
	R5-4	Sources.		X				
	R5-5	Instrument line-of-sight.						
	R5-6	The Telescope Simulator excluding the source will occupy an area no larger than 1500 mm x 2500mm.	X					
	R5-7	The simulator is required to have sufficient working distance to access the SPIRE input focal surface (FP) as situated inside the tank.	X					
	R5-8	The optical axis height is defined by the cryostat design.						
	R5-9	Out-of-focus ghost beams are to be eliminated by tilting the filters & wedging the window such that these reflections all fall on the instrument at positions outside of the entrance aperture.	X					To include filter angle uncertainities
	R5-10	It shall be possible to verify the alignment and focus of the simulated beam.					X	Separate beam-split visible path is used
	R5-11	The position of the moving mirrors will be remotely controlled and monitored by the TFCS.	X					
	R5-12	The scanning system must synthesise the curved FIRST focal surface, again by means of co-ordinated control of elements in accordance with specified control laws.					X	Verification path and camera are used
	R5-13	The pupil must be sized so that the central obscuration is > 20 times longest wavelength. For use at oblique incidence it must have size & shape such that its effect on the clipped beam is to impose a pupil pattern equivalent to that of Herschel.	X					
	R5-14	Spatial uniformity of optics	X					Visual inspection of optics
	R5-15	Spectral uniformity of optics	X					Determined by unit level data
	R5-16	Stability of beam < 0.05 pixel size of shortest wavelength.					X	Against vibration, image capture noise and drift
	R5-17	Simulator alignment verification					X	
	R5-18	The telescope simulator should have the ability to scan a point source beyond the instrument's field of view in both axes.	X					
	R5-19	The telescope simulator must be automatically controlled from the TFCS. The telescope simulator control software should interface to the facility control software in accordance with an agreed interface specification.	X					
	R5-20	The telescope simulator control software must be able to receive instructions/commands from an external application.	X					
	R5-21	The telescope simulator control software will send the mirror positions to the TFCS-TEI to be compiled in telemetry packets for transfer to the SPIRE EGSE.	X					
	R5-22	A software interface specification will be produced. The specification should define	X					
	R5-23	The telescope control software shall be synchronised to the SPIRE EGSE.	X					
	R5-24	The control software shall allow continuous scanning of the telescope simulator.	X					

Section	Ref.	Requirement	Verification					Comments
			Design	Demo	Insp.	Analysis	Test	
FTS	R6-1	The FTS shall have a resolving power of >1000 at 200μm.	X					
	R6-3	The output beam from the FTS must match the input to the telescope simulator.					X	
	R6-4	The modulation efficiency shall be >TBD.					X	Using laser as source
	R6-5	The source output shall be stable to TBD% over the scanning period.	X					
	R6-6	The FTS must be automatically controlled from the TFCS. The FTS control software should interface to the facility control software in accordance with an agreed interface specification.	X					
	R6-7	The FTS control software must be able to receive instructions/commands from an external application.	X					
	R6-8	The FTS control software will record the positions of the moving mirror as a function of time.	X					
	R6-9	The FTS will autonomously find the zero path difference.		X				
	R6-10	A software interface specification will be produced.	X					
	R6-11	The FTS control software shall be synchronised to the SPIRE EGSE.	X					
FIR Laser	R7-1	Deleted						
	R7-2	The stability required is to meet SNR requirement of R5-4. The laser has a power monitor & readings from this are used to correct the measurement for effects of instability.					X	Laser also has stabiliser
	R7-3	The laser itself is not single-moded, but approximates to the fully spatially coherent (i.e. point-like) source required. A single longitudinal mode of the laser cavity will be selected using a Fabry-Perot filter. A single transverse mode of the laser (normally the lowest order mode which is a Gaussian beam) will be selected by a spatial filter.					X	
	R7.4	A beam expander will be required to match the output of the laser to the input of the telescope simulator. In order to produce a near-uniform top hat profile from the Gaussian beam of R7-3, it will be necessary to over-expand it with respect to the simulator pupil mask.	X					Trade off in power (SNR) vs beam shape
	R7-5	The laser is linearly polarised, with orientation horizontal or vertical depending on the particular line used. This polarisation must be made switchable to provide both options at each wavelength; this can be done using rotatable wire grids or rooftop retro-reflector.	X					Rooftop reflectors used (switchable)

Section	Ref.	Requirement	Verification					Comments
			Design	Demo	Insp.	Analysis	Test	
Cryogenic Blackbody	R8-1	The cold blackbody source must be able to operate at any temperature between 4K and 40K.	X				X	
	R8-2	The temperature of the cold blackbody must be stable to ±TBDK over a TBD minute period during calibration	X				X	
	R8-3	The temperatures of the cold blackbody source must be measured by three separate temperature sensors calibrated to an accuracy of TBDK traceable to ITS-90 (RD 7).	X				X	
	R8-4	The radiance errors of the blackbody must be less than an equivalent temperature of TBDK.	X			X	X	
	R8-5	The cold blackbody will be mounted in the calibration cryostat. The target will be cooled to 4K by a thermal strap from the cryostat. The target must be thermally isolated from the cryostat when operating at temperatures > 4K.	X		X			
	R8-6	The instrument will view by the cold blackbody source via a flip mirror. This mirror must be moved out of the instrument's field of view when the blackbody source is not in use.	X		X		X	
	R8-7	The blackbody should completely fill the SPIRE field of view.	X			X		
	R8-8	The cold blackbody must be automatically controlled and monitored from the TFCS (see §4.7). The control software should interface to the facility control software in accordance with an agreed interface specification (see R8-11).	X				X	Part of test facility control system
	R8-9	The cold blackbody control software must be able to receive instructions/commands from an external application.	X				X	Part of test facility control system
	R8-10	The cold-blackbody control software will record the position of the shutter/mirror, the blackbody temperature(s), the heater power and the position of heat switch. The data will be sent to the TFCS-TEI to be compiled in telemetry packets for transfer to the SPIRE EGSE.	X				X	Part of test facility control system
	R8-11	A software interface specification will be produced.		X				
	R8-12	The cold-blackbody control software shall be synchronised to the SPIRE EGSE.	X				X	Part of test facility control system

Section	Ref.	Requirement	Verification					Comments
			Design	Demo	Insp.	Analysis	Test	
Reference Detector	R9-1	The reference detector is located in the cryostat & is to have a wide field of view. It may therefore be a 'bare' detector, i.e. without feedhorn. Its location & view is TBD in the design but the aim is for it to view possible stray radiance affecting the instrument. It is to be mounted on the 4K structure (TBC).		X			X	
	R9-2	The detector is to be capable of detecting radiance from a 20K source, and so should have sensitivity to ~200um wavelength.		X			X	
Hot Source	R10-1	The output of the hot-source shall be strong enough to produce a TBDnW signal		X			X	
	R10-2	The optical geometry of the source output must be matched to the input of the FTS or telescope simulator.	X				X	
	R10-3	The source output must not drift by more than TBD over TBDs.		X			X	
Beam Monitor	R11-1	The input signal from the telescope simulator will be chopped using a variable 1-25Hz chopper.	X					
	R11-2	The output of the telescope simulator will be picked off before the cryostat window using a broadband beamsplitter. This may be switchable into the path.	X				X	
	R11-3	The detector used to measure the beam output must be stable to TBD.		X			X	
	R11-4	The beam monitor output must be automatically monitored and logged by the TFCS (see §4.7). The data will be sent to the TFCS-TEI to be compiled in telemetry packets for transfer to the SPIRE EGSE. The software application should interface to the facility control software in accordance with an agreed interface specification (see R11-5).	X				X	Part of test facility control system
	R11-5	A software interface specification will be produced.		X				
	R11-6	The chopper frequency will be logged by the TFCS	X				X	Part of test facility control system

Section	Ref.	Requirement	Verification					Comments
			Design	Demo	Insp.	Analysis	Test	
Test Facility Control and Monitoring	R12-1	The TFCS will be used to provide central control for the test equipment, log temperatures and other test data (e.g. source levels).	X				X	
	R12-2	The TFCS will monitor the temperatures and fluid levels of the calibration cryostat.	X				X	
	R12-3	The TFCS will control and monitor the telescope simulator.	X				X	
	R12-4	The TFCS will control and monitor the cold blackbody source.	X				X	
	R12-5	The TFCS will control and monitor the FTS	X				X	
	R12-6	The TFCS will monitor the signal from the beam pickoff monitor.	X				X	
	R12-7	The TFCS will provide control of a Fabry Perot for laser line selection.	X				X	
	R12-8	There will be a TCP/IP network to allow transfer of data between the TFCS and the SPIRE EGSE.	X				X	
	R12-9	The TFCS will be assigned its own application ID.	X				X	
	R12-10	The TFCS will be able to receive command packets from the SPIRE EGSE	X				X	
	R12-11	The TFCS will transmit telemetry packets to the SPIRE EGSE	X				X	
	R12-12	The TFCS clock will be synchronised to the SPIRE EGSE to allow accurate matching of data.	X				X	
	R12-13	The TFCS will be able to run in a stand-alone mode.	X				X	
	R12-14	The TFCS will log all cryostat and cold blackbody temperatures.	X				X	
	R12-15	The TFCS will record the chopper frequency	X				X	

Section	Ref.	Requirement	Verification					Comments
			Design	Demo	Insp.	Analysis	Test	
Assembly Clean Rooms	R13-1	The area where instrument optics will be exposed, will be class 100.		X			X	As per RAL-SSTD ISO9000 clean room procedures.
	R13-2	All other areas in the clean room will be class 10,000 or better.		X			X	As per RAL-SSTD ISO9000 clean room procedures.
	R13-3	Cleanliness will be monitored throughout the SPIRE integration period.		X			X	As per RAL-SSTD ISO9000 clean room procedures.
	R13-4	When transporting SPIRE between clean areas, the instrument and MGSE will be sealed in an airtight bag.		X				As per RAL-SSTD ISO9000 clean room procedures.
	R13-5	Two clean 28V power supplies must be provided for the SPIRE instrument.		X			X	Power supplies to be calibrated in accordance with RAL-SSTD ISO9000 procedures.
	R13-6	There shall be adequate uninterruptable mains power points for the SPIRE EGSE, test equipment and vacuum system.		X				
	R13-7	The electrical design of the facility must ensure that there are no ground loops that could pose an EMI problem.		X				
	R13-8	All electrical connections in the facility must be fully documented and readily accessible.		X				As per RAL-SSTD ISO9000 clean room procedures.
	R13-9	The entrance to the clean room must be wide enough to allow the instrument and MGSE to pass through.		X				
	R13-10	There must be adequate space to perform the integration activities and store tools, test equipment and flight hardware.		X				
	R13-11	To maintain cleanliness, access to the clean room will be restricted to a few authorised personnel. To prevent unauthorised access, a card key system will be installed.		X			X	As per RAL-SSTD ISO9000 clean room procedures.
	R13-12	Clean room facilities shall be available for the whole SPIRE AIV period until the launch of Herschel.		X				
Vibration Facility	R14-1	The vibration facility will allow testing to be performed at temperatures between 4K and 300K		X			X	Use ESA common facility at CSL
	R14-2	The maximum force rating required is TBD kN		X			X	
	R14-3	Maximum accelerations required		X			X	
	R14-4	The maximum velocity required is TBD ms--1		X			X	
	R14-5	The frequency range required is 5 – 100Hz		X			X	
	R14-9	There shall be TBD accelerometer channels		X			X	Accelerometers to be calibrated by accredited laboratory
	R14-6	The area where instrument optics will be exposed, will be class 100.		X			X	
	R14-7	All other areas in the clean room will be class 10,000 or better.		X			X	
	R14-8	Cleanliness will be monitored throughout the SPIRE test period.		X			X	
Inspection Facility	R15-1	The mechanical inspection facility must be capable of measuring the positions of the mirror interfaces in 3 axes to a precision of < 10µm.		X				SPIRE will use RAL inspection facility.
	R15-2	The area where instrument optics will be exposed, will be class 100.		X				A clean tent may be required for this
	R15-3	All other areas in the clean room will be class 10,000 or better.		X				A clean tent may be required for this
	R15-4	Cleanliness will be monitored throughout the SPIRE test period.		X			X	As per RAL-SSTD ISO9000 clean room procedures