



DOCUMENT TYPE:

ENGINEERING SPECIFICATION

**TECHNICAL SPECIFICATION,
FOD PVNT, ENG TEST &
WIND TUNNEL FAC**

Prepared	Dated	Approved	Dated	Approved	Dated
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			NO. 704823-001		
			Sheet 1 of 14		REV E

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RECORDS OF REVISION

ECO NO.	REV.	PAGE	ISSUE DATE	BY	DESCRIPTION
Release	A	All	2010-Oct-28	JB/GM	New Release
14166	B	All	2016-Nov-08	JB	Updated logo throughout document
14278	C	All	2017-Aug-09	AWB	Remove reference to training presentation 704822-001
14363	D	14	2018-Sep-06	AWB	Revise section IV to add clarity to who supplies FOD prevention plan for approval and who shall maintain an auditable plan.
14377	E	5	2018-Oct-16	AWB	Revise section 1.04 to resolve ambiguity about collecting documentation for specialty contractors.



ENGINE TEST FACILITY AND WIND TUNNEL FACILITY FOD PREVENTION SPECIFICATION

PART I: GENERAL

1.01 Summary

- A. FOD is an abbreviation for Foreign Object Debris which is any object or substance, large or small, that when introduced into a system can cause that particular system to be damaged and malfunction. In the case of engine test and wind tunnel facilities, FOD is any object or substance that if permitted to become airborne can cause injury to personnel, damage to test components, and damage to test equipment and surrounding facility components.
- B. To prevent FOD from becoming airborne and causing damage, it is essential that engine test facilities and wind tunnels be free of FOD. To be free of FOD, the following are required:
 - 1. Facilities and all installed equipment and components must be properly designed for all environmental and operating conditions.
 - 2. Facility equipment and components must be properly fabricated and installed.
 - 3. Facility construction must be of high quality.
 - 4. Facility construction and equipment installation clean-up must be complete and thorough and must be conducted by individuals who have a complete understanding of FOD and how to prevent it.
 - 5. Facility maintenance and operation must be conducted in a way to prevent the presence and generation of FOD.
- C. FOD prevention therefore requires that all personnel involved in the design, fabrication, construction, operation and maintenance of engine test and wind tunnel facilities and its equipment understand the nature and causes of FOD, and actively participate in practices necessary to prevent the presence and formation of FOD.
- D. The remainder of this specification further defines what FOD is, its sources, and how to prevent it from occurring. All general contractor and subcontractor personnel performing design, construction, fabrication and maintenance in engine test and wind tunnel facilities must become familiar with the body of this specification and conduct their work in strict accordance with this specification and its requirements.

1.02 FOD Material

- A. Construction and equipment installation debris including but not limited to: wire, bolts, nuts, washers, slugs, screws, nails, sand, gravel, concrete and masonry fragments, wood pieces, paper and packaging, welding stick ends, weld splatter and slag, drill shavings, wire mesh edges and cuttings, loose caulk and RTV, lost or misplaced tools, rags, brushes, applicators, plastic covers, consumable remnants, cable ties, etc.



- B. Equipment fabrication debris including but not limited to: wire, bolts, nuts, washers, screws, clips, weld splatter and slag, steel drill shavings, wire mesh edges, loose caulk and RTV, misplaced tools, consumable remnants, etc.
- C. Operating and Maintenance debris including but not limited to: wire, bolts, nuts, washers, screws, sand, gravel, concrete fragments, twigs, sticks, birds, rodents, pens, pencils, paper and packaging, plastic, rags, brushes, applicators, tools, loose caulk and RTV, paint chips, cable ties, security badges, personal articles, etc.

1.03 FOD Sources

- A. Exterior roof areas local to vertical inlets and exterior ground areas within 40 feet of horizontal inlets.
- B. Facility concrete floors, walls and ceilings that are insufficiently cleaned of debris or that are deteriorated, spalled or otherwise damaged and that are within an area where FOD could become airborne. The insufficiently cleaned or compromised condition of these components can lead to the presence of miscellaneous debris and/or loose concrete debris.
- C. Facility steel embedments and steel construction that is significantly oxidized, damaged or exhibiting loosened connections, loosened attachment hardware or improperly secured fastening hardware and that is within an area where FOD could become airborne.
- D. Installed facility equipment that is improperly designed, improperly installed, insufficiently cleaned of debris, deteriorated, damaged or not performing properly and that is within an area where FOD could become airborne. The list of equipment includes but is not limited to the following:
 - 1. Acoustic treatment and its supporting structure.
 - 2. Debris and flow conditioning screens and their supporting structure.
 - 3. Acoustic wall and ceiling panels.
 - 4. Acoustic main door and service doors.
 - 5. Access platforms and stairs.
 - 6. Test equipment supporting structure.
 - 7. Test equipment.
 - 8. Lift and work platforms
 - 9. Overhead supported engine handling systems.
 - 10. Interior utilities such as electrical, compressed air, fuel and fire protection systems.
 - 11. Control system cables, cabling trays, junction boxes and CCTV cameras including all supporting hardware and connectors.
- E. Abandoned, misplaced, dropped or forgotten tools, hardware or personal artifacts within an area where FOD could become airborne.



1.04 FOD Training

- A. The supplier in control of the site is the General Contractor (GC). All personnel performing work on site shall receive FOD training administered by the GC. The GC shall provide Calspan Aero Systems Engineering (ASE) the attendance roster and training documents. FOD training shall be part of the site induction and refresher courses shall be administered at least monthly. Site induction must occur prior to the start of work. Training must address all the elements of this specification and may utilize a localized version of ASE FOD document, drawing #704822 - Foreign Object Debris/Foreign Object Damage (FOD) Awareness and Prevention Training. This document is available upon request from ASE Global Sourcing.
- B. Other suppliers shall reference Part IV for training requirements outlined in the FOD Prevention Plan.

1.05 Regulatory Requirements

- A. Referenced requirements within this specification are to be construed as minimum requirements and shall be exceeded whenever good practices and engineering judgment should prevail.
- B. The installation of all materials shall comply with the 2006 international Building Code (IBC) and all applicable local and national building code provisions. In the event that there is a requirement conflict between the 2006 IBC and local codes, the local code requirement shall govern.
- C. In the event that there is a requirement conflict between the provisions of this specification and local codes, the more stringent of the two shall govern.

1.06 References

- A. NAS 412 (National Aerospace Standard for "Foreign Object Damage/ Foreign Object Debris (FOD) Prevention")
- B. Military Standard NASM 33540 (Safety Wiring, Safety Cabling, Cotter Pinning, General Practices For)
- C. NCATT: (Foreign Object Elimination Elements of Basic Awareness")
- D. ASE Manufacturing Specifications
 - 1. MS-173: "Lock Wiring"
 - 2. MS-215: "Thread Locking Adhesive"
 - 3. MS-198: "ASE Torque Chart"
- E. 2006 International Building Code
- F. American Welding Society Specification D1.1



PART II: FOD PREVENTION

2.01 Facility and Equipment Design

- A. Engine test and wind tunnel facilities foster hostile environments subject to high levels of air flow, vibration, temperature change and acoustic energy which can turn inappropriately or poorly designed facilities and equipment into direct sources of FOD. Therefore, all facility components and equipment shall be designed for all environmental, operating and accident loading conditions in strict accordance with all applicable design and local codes.
- B. All facility and equipment designs shall avoid features, conditions and configurations that increase the risk of FOD development and that can harbor elements of FOD in hard to inspect and clean locations.
- C. All equipment components and members including welds and fasteners shall be designed and sized with due consideration of high cycle fatigue to reduce the risk of cracking that can lead to FOD.
- D. All fasteners materials and coating systems shall be specified appropriate for the environment to prevent the formation of corrosion products which could later become FOD.
- E. All facility construction drawings, equipment design drawings and equipment fabrication drawings shall specify fastener installation torques and fastener retention systems. Fastener installation torques shall comply with ASE Specification MS-198 and fastener retention system requirements shall comply with ASE Specification MS-173 and Military Standard NASM 33540. Acceptable retention systems are a function of fastener size and include tack welding, deformed thread lock nuts, Loctite, safety wiring and application of RTV.
- F. Movable components within or attached to assemblies in the air-flow chamber shall, whenever possible, be attached to the structural elements of the assemblies with welded connections or fasteners welded in place, allowing only the bushings, hinges, cylinders, and similar components to move freely as intended.
- G. Piping, though typically welded or threaded, shall be installed with all drains and bleeder valves outside of the test chamber.
- H. Electrical raceways shall be in the form of cable trays with positive clamping mechanisms and without removable fasteners. Alternate raceway assemblies shall be of threaded connections without fasteners except at the junction with air-flow chamber equipment.

2.02 Construction and Equipment Installation

- A. Construction and equipment installation practices shall be configured to result in high quality finished products with a constant focus on the prevention of FOD.



- B. All facility interior surfaces within areas where FOD could become airborne shall be free of defects and loose or unsound concrete, brick, block, etc. Surfaces shall be periodically inspected to ensure they are mechanically sound. Mechanically unsound surfaces shall be reworked until acceptable to ASE.
- C. After completion of construction and equipment installation, all equipment and facility wall, ceiling and floor surface in areas where FOD could become airborne shall be properly inspected for FOD and cleaned. All construction equipment, tools, materials, debris, etc. shall be removed. Should the surfaces remain unfinished for more than two weeks, the procedure shall be repeated until the surfaces have been coated and/or finished.
- D. In addition to other contract specifications, concrete formwork used in construction of the air-flow chamber shall be maintained in excellent condition to prevent the formation of ribs at the form joints on the concrete surface that may be rubbed, bumped, or chipped off the finish surface to create FOD. Avoid form ties that do not break off cleanly at the surface without spalling significant amounts of concrete from the surface.
- E. Concrete materials shall be properly mixed and placed to ensure a monolithic surface appearance with only small voids less than 5mm in diameter and no spalling. Patching of non-compliant areas shall not be conducted without written approval by ASE.
- F. Unless specified to remain unfinished, structural steel and steel embedded in concrete exposed in the air-flow chamber shall be new material, free of rust and corrosion, and protected from deterioration with sufficient primer to prevent rusting during the construction phase, and until final painting has been completed. If rusting occurs before final painting can be accomplished, the material shall be ground smooth and primer shall be re-applied according to primer manufacturer's specification for field application.
- G. All metal components shall be handled in such a manner to prevent scraping, scratching and otherwise marring the surfaces which could result in shavings or burrs being dislodged in the facility.
- H. Welded assemblies, whether preassembled or welded on site, shall have the welds ground smooth to eliminate small pockets of moisture or paint buildup, when applied to the finish surface.
 - 1. Prior to welding connections in the field, all debris, dirt, primer, and corrosion shall be ground from the area to be welded.
 - 2. Where welding is used to attach materials to embedded plates, care is to be taken to weld intermittently to avoid warp stresses in the embedded plate and applying tension to the anchors.
 - 3. Welds shall be ground smooth free of pits and ridges greater than 2mm from the smooth contour.
 - 4. After welding, ferrous metals shall be primed with a highly effective field primer compatible with the manufacturer's instruction from the finish paint supplier.
 - 5. Finish painting shall be done under controlled temperatures meeting the manufacturer's specifications.



- I. Anchors in concrete shall be installed in strict conformance to manufacturer's requirements and the following:
 1. Drill holes with carbide or diamond tipped bits to the diameter recommended by the anchor supplier for the specified anchor diameter and to the minimum depth as indicated on the contract documents.
 2. Follow manufacturer's installation requirements including hole cleaning and installation of the adhesive and required cure time prior to applying load.
 3. Nuts and washers applied to chemical anchors shall be tack welded or secured as indicated on the contract documents.

2.03 Equipment Fabrication

- A. Equipment fabrication shall comply with all requirements as indicated on the equipment design drawings and all requirements indicated within this specification. In the event of a conflict between a requirement within this specification and a requirement on the design drawings, contact ASE to confirm which requirement should be applied.
- B. Unless specified to remain unfinished, equipment steel exposed in the air-flow chamber shall be new material, free of rust and corrosion, and protected from deterioration with sufficient primer to prevent rusting during the construction phase, and until final painting has been completed. If rusting occurs before final painting can be accomplished, the material shall be ground smooth and primer shall be re-applied according to primer manufacturer's specification for field application.
- C. All metal components shall be handled in such a manner to prevent scraping, scratching and otherwise marring the surfaces which could result in shavings or burrs being dislodged in the facility.
- D. Welded assemblies, whether preassembled or welded on site, shall have the welds ground smooth to eliminate small pockets of moisture or paint buildup, when applied to the finish surface.
 - a. Prior to welding, all debris, dirt, primer, and corrosion shall be ground from the area to be welded.
 - b. Welds shall be ground smooth free of pits and ridges greater than 2mm from the smooth contour.
 - c. After welding, ferrous metals shall be primed with a highly effective field primer compatible with the manufacturer's instruction from the finish paint supplier.
 - d. Finish painting shall be done under controlled temperatures meeting the manufacturer's specifications.
- E. At the completion of fabrication and prior to packaging for shipping, all equipment shall be properly inspected for FOD and thoroughly cleaned of unused materials, debris, weld slag, drill filings, tools and other items that could become in test facilities or wind tunnel facilities FOD.



2.04 Materials and Fastener Retention

- A. All materials shall comply with the requirements indicated on the contract documents. In the event that materials are not specified on the contract documents, contact ASE engineering to confirm required materials.
- B. All fasteners shall be secured from loosening per the requirements indicated on the contract documents. In the event that fastener retention is not specified on the contract documents, contact ASE engineering for the required method of fastener retention. Fastener retention methods include:
 - 1. Safety wiring per the requirements of MS-173 and NASM 33540 using stainless steel safety wire not less than 0.025 inches in diameter.
 - 2. Full height solid metal locknuts, deformed thread type such as FLEXLOC by SPS Industries, ESNA, or equivalent. All locknuts shall be torqued per the locknut manufacturer's written instructions.
 - 3. Tack welding fastener components to each other and/or to the base component after installation.
 - 4. Applying a suitable RTV by Loctite Corporation or equivalent to smaller bolts and screws where safety wiring the bolt or screw head is impractical.
- C. Bolts threaded into blind holes, tapped holes or into backside welded nuts shall be secured by tack welding or by safety wiring per the requirements of MS-173 and NASM 33540 after proper installation and torquing.
- D. Unless specified by ASE or specifically approved by ASE in writing for a specific application, the following fasteners and fastening techniques are not acceptable and shall not be used:
 - 1. Cable ties, plastic or metal.
 - 2. Locknuts with plastic inserts.
 - 3. Adhesives and sealants.
 - 4. Sheet metal screws.
 - 5. Rivets.
 - 6. Friction fit or expansion-type anchors.
- E. The following fastener hardware, retention methods and conditions are unacceptable and shall be removed and replaced to yield an acceptable fastener retention condition:
 - 1. Improper wiring.
 - 2. Spot or undersized tack welds.
 - 3. Locknuts not torqued to manufacturer's written instructions.
 - 4. Sheet metal screws that have less than 6 threads of sheet metal engagement.
 - 5. Fasteners and/or methods not compliant with contract documents.
 - 6. Taped, Velcro secured or other improvised methods.
 - 7. Jam nuts, shakeproof washers, spring washers, tab washers, helicoil inserts, taper thread and slotted nuts.
- F. Fastener system retention systems shall comply with the following requirements as appropriate:



1. Safety wire shall be installed where it will be free and clear of all moving parts that could damage the safety wire.
 2. Fastener components shall be drilled in a location where the fastener can tolerate being drilled while maintaining physical integrity and in a position from where the securing force via the wire shall be applied.
 3. Thread locking adhesives shall fully comply with ASE's Manufacturing Specification MS-215.
 4. All welded connections shall comply with the requirements of Section D1.1 of the American Welding Society (AWS).
 5. All welded connections shall be ground smooth, cleaned of slag and other welding by-products and wire brushed to remove loose materials.
- G. Tags and labels shall be kept to a minimum in the air flow chamber and should be secured by means of fasteners or an adhesive backing capable of withstanding the extremes of the facility environment including temperature, moisture and vibration. Where possible, labels shall wrap completely around the pipe or apparatus and should be secured to itself by overlap.

2.05 Construction Tools and Equipment

A. General Construction Tools

1. The GC shall coordinate and perform all facility construction without special requirements to maintain an inventory and control over the use of tools up to the point until facility equipment installation begins.
2. The GC shall coordinate and perform facility construction with special requirements to maintain an inventory and control over the use of tools in all areas where facility equipment installation has begun.
3. Immediately prior to the onset of facility equipment installation, the GC shall perform a complete cleaning of the facility in the area of equipment installation including the removal of all foreign objects that are not properly secured and attached according to this specification. Upon completion of the facility cleaning, the facility in the area of equipment installation shall then be inspected to ensure that no construction materials, tools, or cleaning equipment have been left in the facility.
4. If all facility construction has been completed prior to equipment installation then the GC shall perform a complete cleaning and inspection of the entire facility per 2.05 A. 3.

B. Equipment Installation Tools

1. The GC and all Specialty Contractors shall commence their equipment installation on-site work by making a complete inventory of the materials to be incorporate into the facility and an inventory of the installation tools required for that work. Records of each of those inventories shall be made and retained for inspection purposes.
2. Defective and surplus materials shall be retained and kept for a final inventory of the unused components. Workers are to justify that no material is logically missing that could have



remained in the test facility. Records of the inventory shall be made and retained for inspection purposes.

3. Upon completion of the installation, a complete inventory of the tools, gauges, and equipment used in the installation shall be gathered and an inventory taken to determine that all tools and surplus materials are accounted for. Records of the inventory shall be made and retained for inspection purposes.

C. Test Apparatus Installation Tools (When test apparatus installation is required as a part of the work.)

1. The test apparatus installation Specialty Contractor shall commence his installation work by making a complete inventory of all materials and tools required for the installation of the test apparatus. Records of this inventory shall be made and retained for inspection purposes.
2. Those items that do not remain in the chamber during the test shall be allowed into the test facility after they have been checked out to a responsible installer, who will return the item(s) to the location of the primary inventory and check the item(s) back into the inventory. On a weekly basis, the inventory of tools and installation equipment shall be verified that no inventory items have been left in the test facility. Records of the inventory shall be made and retained for inspection.
3. When the test apparatus has been completely installed and is ready for testing, the tools and materials shall be thoroughly removed and checked back into the inventory per item 2.05.C.2.
4. Each Test Apparatus remaining in the facility shall be checked to ensure that all fabrication materials, fasteners, and connections are secure according to this specification and ready for the test run.

2.06 *Cleaning*

- A. Prior to equipment installation and after completion of all wall, ceiling and floor construction including abrading and preparing the surfaces for subsequent coating system application, thoroughly clean all surfaces removing all loose materials by high pressure washing, vacuuming, compressed air or other effective means.
- B. Clean as you go. This is an on going process of removing work debris as it accumulates and keeping the work area clean while performing tasks in FOD sensitive areas. This process shall be applied during equipment installation and refurbishment work.
1. Clean the immediate area when work cannot continue.
 2. Clean the immediate area when work debris has the potential to migrate to an out-of-sight or inaccessible area where it could subsequently cause FOD damage.
 3. Inspect and clean all tools after job completion or end of shift.
 4. Clean the immediate area after work is completed and prior to inspection.
 5. Clean at the end of each shift.
 6. If you drop something or hear something drop, pick it up.
- C. As equipment installation work and cleaning proceed, all tools used shall be maintained, stored and formally tracked to assure accountability.



- D. After installation of facility equipment such as acoustic treatment, turning vanes, flow conditioning screens, material handling systems and test apparatus, thoroughly clean all facility wall, ceiling and floor surfaces and thoroughly clean all equipment surfaces by vacuuming, high pressure washing, compressed air or other effective means. Care should be taken to remove debris from all corners, trenches and sumps.
- E. High pressure washing and compressed air, if used, shall be used after an initial broom or vacuum cleaning that removes the majority of all debris since high pressure washing and compressed air have the potential to wedge or lodge FOD into crevices. Any wedged FOD, if not discovered, could in time become dislodged and become an active FOD hazard.
- F. In addition to performing a cleaning at the above stages of construction and equipment installation, the following minimum cleaning schedule shall apply:
 - 1. Once the building floor has been installed, and upon completion of the work of each trade constructing the facility structure, a broom clean condition shall remain.
 - 2. During the installation of equipment, a bi-weekly clean-up shall be conducted to broom clean conditions.
- G. Minimum cleaning requirements to prevent FOD are as follows:
 - 1. All surfaces shall be broom cleaned and then visually observed to determine that no objects have been left behind. Particular care must be taken to be certain that small objects do not remain in pockets of assemblies, pinched between components, or partially fastened to building or acoustical elements.
 - 2. All surfaces shall be additionally cleaned with the application of a strong air pressure spray applying no less than 3 psi (2100 Kg/m²) pressure or high pressure water if appropriate. Indentations and pockets that may capture or retain debris shall be investigated and brushed with wire brushes, if possible, then probed and scraped with a pointed pick type object to ensure any potentially loosened material has been removed. This includes, but is not limited to voids in the concrete surfaces, along the edges of steel embedded in concrete, and along weld features.
 - 3. Vacuum all surfaces to remove all loose and settled debris. Visually pre-inspect all surfaces to determine that a thorough cleaning has been conducted.
- H. Upon completion of the Final Clean-up, a representative from each of the contractors participating in the clean-up shall sign a statement that the work of clean-up has been properly executed as per the FOD prevention plan. This statement shall be turned over to ASE as a declaration that the facility is ready for the Final Inspection for FOD. ASE will then request the Final Inspection by the Owner.

2.07 Inspection/Cleaning Equipment

- A. Personnel protective equipment as necessary.
- B. Lifts, ladders and scaffolds as required for complete access for cleaning and inspecting.



- C. Lights for examining poorly lit areas and mirrors for looking behind equipment and structures where direct visual access is limited.
- D. All equipment as required to perform thorough cleaning and inspection including but not limited to:
 - 1. Fine and stiff brushes with a range of sizes from small to large.
 - 2. Picking tools for dislodging small items.
 - 3. Scrapers for removing surface debris.
 - 4. Hammers for sounding concrete for delaminations.
 - 5. Vacuums with appropriately sized nozzles, clean filters, hoses and extension cords as necessary to access all areas.
 - 6. Buckets and pouches for collecting debris.

PART III: FINAL INSPECTION AND REWORK

3.01 *Final Inspection*

- A. Upon receipt of the statement of Final Clean-up, the Owner will schedule and conduct the Final Inspection. The Owner shall have access to the GC personnel lift equipment in order to conduct the inspection. A representative of ASE and the GC will accompany the Owner's representative(s) during the inspection in the event that any items of FOD are found.
- B. In the event that an element of FOD is discovered, it shall be duly documented as to type and location. The Owner will incorporate the recorded location(s) of FOD, if any are discovered, in its inspection report. If the facility is found to be free of FOD, the Owner will approve the condition with certification that the work has passed the Final Inspection and is commissioned for service.
- C. Without exception, all FOD elements found during the Final Inspection shall be promptly removed by the contractors. At the Owner's discretion, those areas of the air-chamber where FOD was discovered, or the entire chamber, shall be re-cleaned and subjected to another Final Inspection. At the discretion of the Owner, this process may be repeated until a FOD free inspection results.
- D. In the event the Owner elects not to schedule and conduct the Final Inspection, ASE will perform the Final Inspection and act as the Owners representative as indicated in 3.01 A, 3.01 B and 3.01 C.

3.02 *Rework*

- A. The cost of any re-work, re-cleaning, or additional inspections as a result of failed inspections and rejected work shall be borne by the contractor responsible for that work.

PART IV: FOD PREVENTION PLAN & SUBMITTALS



All ASE Suppliers that impact FOD (either through design and supply of subcontracted items that could potentially be a FOD source or through direct construction site interaction) shall prepare and execute a FOD prevention plan. ASE may require an audit of the FOD prevention plan at any time during the course of the work, and successfully passing the audit is a condition of payment.

Supplier shall maintain the FOD prevention plan and all related logs for submission and inspection at all times. Key FOD plan and audit elements include, at minimum:

1. Implementation and oversight of the FOD prevention plan
2. Flow Down of the FOD plan to all of Supplier's Sub-Suppliers or other related personnel.
3. Training requirements and training logs.
4. Design criteria.
5. Cleaning procedures and Schedule.
6. Inspection procedures and Schedule.
7. Cleaning and Inspection submittal schedule.
8. Equipment check-in procedure. (Applies during equipment installation period.)
9. Documentation forms for FOD inspection. (Forms shall include documentation requirements and shall require detailed entries for all FOD recovered during inspection.)
10. Commissioning schedule.
11. Final Inspection Records

In addition to the requirements above, General Contractors must submit the FOD plan to ASE for review and approval and must receive ASE approval prior to commencing the Work. In their role, General Contractors must pay special attention to Flow Down of the FOD plan to all Sub-Suppliers and other related personnel, as the General Contractor bears responsibility for all site FOD until handover to ASE.

END OF SPECIFICATION