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Philosophy

• The ISS fluid systems are so complex that fluid system cleanliness cannot be verified at the assembly level.

• A “build clean / maintain clean” approach was used by all major fluid systems.
  – Verify cleanliness at the detail and subassembly level.
  – Maintain cleanliness during assembly.
Background

• Leakage in ISS ammonia system Quick Disconnect (QD) hardware led to the establishment of a “Clean Team”.
• Analysis of contaminants indicated multiple contamination sources.
• “Clean Team” was to identify and eliminate as many contamination sources as possible.
Background cont’d

Figure 1. Contaminated QD Seal
Clean Team visited the ISS hardware manufacturing sites and reviewed all procedures used to produce and maintain precision cleaned hardware.

Result was a set of recommendations or “best practices” to be used in the manufacture of precision cleaned hardware.
Documentation

- ISS-PI-044, Maintenance of Fluid Systems Cleanliness
- SSP 30573, Space Station Program Fluid Procurement and Use Control Specification
Training

• All personnel working around precision cleaned hardware in the ISS program are required to attend TR001484, ISS, Maintenance of Fluid Systems Cleanliness training course
• Clean rooms are enclosed, environmentally controlled areas for the performance of work on contamination sensitive hardware or assemblies. Consists of Class 100,000 or cleaner.

• Precision cleanliness shall be maintained to program requirements (e.g. SN-C-0005 Level 200)
  – SN-C-0005 Level 200 states that there should not be any particles of a size greater than 200 microns present in a 100 milliliter sample of fluid from the system
Welding Practices

- All welding of assemblies for precision cleaned hardware will be performed in a dedicated class 100,000 Clean Work Area (CWA)
- Temporary tents and local monitors may be required to maintain the 100k environment
Welding Practices cont’d

- Accurate monitoring of local contamination is required
- Portable particle counters shall be located as close to the work area as possible during tube preparation and welding
Welding Practices cont’d

- A proven method of contamination prevention such as tube plugs is required
- Installation and removal of such plugs shall be tracked and independently verified by Quality Assurance
- Prior to plug removal, the tube ID shall be cleaned with a swab and approved solvent
- Positive back pressure shall be maintained as the plug is removed
Figure 2. Damage from not removing a plug
Welding Practices cont’d

Figure 3. More damage from not removing a plug
After each tube preparation and prior to welding, a high-velocity gas blow down shall be performed.

Gas velocity target shall be the maximum attainable using a 90 psig purge gas source.

CAUTION, use only approved purge gases per SSP 30573.
Welding Practices cont’d

- Tube cutters shall use a sharp blade, changed frequently
- Cutting shall be performed with minimal cutting pressure to prevent particle generation
Tube Facing Practices

- Vacuum shall be used during tube facing operations.
- Whenever possible, facing operations shall be performed away from the weld assembly area.
- Tube facing shall be accomplished without the use of cutting oils, lubricants or coolants.
- Abrasives, such as sandpaper or abrasive pads shall not be used inside tubes or when unprotected internal surfaces are exposed.
Tool Preparation

• Inspection tools (e.g., borescopes) that may be exposed to precision cleaned systems hardware shall be visibly cleaned and maintained clean.

• Tools used in weld preparation and welding, such as cutters, weld heads and files, shall be visibly cleaned and maintained clean (e.g. bagged when not in use).
Tool Preparation cont’d

- Purge caps, mating QDs and vent tools shall be precision cleaned to at least the level of the associated system and bagged after use
Purge Gas Practices

- Purge gas used during facing and welding shall meet the hydrocarbon and particulate controls per SSP 30573
- Purge gas used during facing and welding shall be supplied through precision cleaned low NVR/particulate tubing such as polyethylene, nylon, Teflon, or ethyl vinyl acetate
- Standard grade Tygon is not suitable
Ground Support Equipment

- Ground Support Equipment (GSE) that interfaces with precision cleaned flight fluid systems shall incorporate interface filters per SSP 30573
- These filters shall be located as close to the interface as possible
- Outlet lines require filters if it is determined that reverse flow could occur during the servicing or deservicing operation
Ground Support Equipment cont’d

- GSE that interfaces with precision cleaned flight fluid systems shall be cleaned to at least the level of cleanliness of the flight hardware
- GSE fluid hardware, such as hoses and servicing units shall be handled with the same cleanliness procedures as flight hardware
Cleaning Convoluted Flex Hoses

- Cleaning Convoluted Flex hoses requires special attention
- Detail flex hoses shall be cleaned and verified precision clean in a vertical orientation:

  Vertical Orientation

  Horizontal Orientation
Cleaning Convoluted Flex Hoses cont’d

- Cleanliness is verified by sampling the rinse fluids. The sample must meet the flex hose engineering cleanliness requirement.
- For flex hoses that are one inch or greater in diameter
  - Rinse fluid is applied to all internal surfaces with a high pressure nozzle.
Cleaning Convoluted Flex Hoses cont’d

- For flex hoses that are less than one inch diameter
  - Use of high pressure nozzles is preferred, but cleaning by flushing the rinse fluid though the length of the hose with agitation is acceptable
Maintenance of System Cleanliness

• All precision cleaned open tubes and lines must be protected, i.e. wrapped or bagged with approved materials, as soon as possible after fabrication
• Tubes and lines must remain wrapped until final installation
Oxygen Systems

- Regulators used during purging operations shall have O₂ compatible grease
- Purge tubing must be O₂ compatible
- Bagging materials used to store O₂ components shall be cleaned to the same level of cleanliness as the O₂ hardware, and must be O₂ compatible
Sampling for Residual Solvent

- Liquid solvents become trapped in crevices or absorbed into soft goods.
- Some fluid systems are quite sensitive to these contaminants.
- ISS uses a 24-hour “lock up”, to ensure gas sampling accurately reflects residual solvent concentration.
General Practices

- Solvents such as IPA, reagent grade or better, shall be filtered to 10 microns or better prior to use.
- Precision cleaned hardware that has been welded shall remain properly capped during the x-ray operations to avoid potential contamination.
General Practices cont’d

- Hardware that has not been precision cleaned shall not be brought into the vicinity of unprotected precision cleaned flight hardware.
- Flight hardware must be wrapped in approved packaging material.
- All precision cleaning fluid systems configured for flight shall have integrity seals installed.
General Practices cont’d

- Precision cleaned hardware cannot be exposed to an uncontrolled environment. This includes flow benches providing 100,000 CWA or better during inspections.
- Bag hardware that must be transported outside the clean room.
- Clean room gloves are required when handling any precision cleaned flight hardware.
Summary

• Many of the “best practices” are simple and straightforward.
• However, the different heritage ISS organizations had different priorities for meeting the same end product requirements.
• The “Clean Team” has provided a common focus, and significantly reduced the incidents of contamination induced failures.
External Thermal Control System Schematic