Heavily Edited from: CONSTRUCTION STANDARD SPECIFICATION

ULTRA HIGH PURITY GAS DISTRIBUTION SYSTEMS

The edit contains only sections applicable to field construction of the COUPP high purity fluid handling cart at FNAL. Project specific information added. (Editor: R. Rucinski)

1.0 WELDING

A. Welding Procedures: All welding procedures shall conform to ASME Code, Section IX. Welding equipment settings shall be pre-determined on tube samples using the same weld machine, head, and operator.

B. Electrodes in automatic tube welder shall be tungsten electrodes that are non-thoriated such as pure tungsten electrodes, Ceriated tungsten electrodes, or Lanthanated tungsten electrodes. Thoriated electrodes are not permitted.

C. Welder Qualification:

Operators working on ultra high purity gas distribution systems must be qualified to ASME Section IX. Operators shall be certified using the automatic orbital Tungsten Inert Gas (TIG) welding machine to be used during fabrication and assembly. The operator shall be certified for each tube size to be fabricated, and in each weld position.

2.0 TUBE AND FITTINGS

1. Seamless tubing , 316L stainless steel per ASTM A-269 and A-632, factory cleaned for ultra-high purity gas service to be used. Tubing, HP series 5 material with HPT-100 process specification from High Purity Technology Inc. has been procured for the COUPP high purity fluid handling system. Material certifications were provided.

2. Tubing has been electropolished and cleaned to the manufacturer's specification. Tubing shall be bright inside and out, without discoloration, free from all foreign oxides, oil, grease, lubricants, mill chips, and draw marks.

3. Tube and fittings interior roughness is no greater than 10 micro-inches Ra (Ave) or 15 micro-inches Ra (Max) as measured in accordance with ANSI/ASME B46.1.

4. Tube and fittings shall meet the following dimensional tolerances:

O.D. (inches)	Wall Thickness (+/- 5%)	Ovality (+/- in.)
1/4"	.035"	N/A
3/8"	.035"	N/A
1/2"	.049"	0.0018
3/4"	.065"	0.010

5. Finished tube I.D. shall match finished I.D. of any fittings used in system. Fittings which have heavier wall thickness than adjoining tubing shall have ends machined to equal the tube wall thickness.

6. All changes in direction shall be made with a fitting manufactured from seamless tube stock. Changes in direction in 1/4" through 1/2" tubing may be made with a field bend with a minimum bend radius of 8 times the tube diameter.

   0.25" OD tube needs minimum bend radius = 2.0"
   0.50" OD tube needs minimum bend radius = 4.0"

7. Threaded or compression type mechanical joint fittings are not acceptable for process lines downstream of the Liqui-Cel filters. Use Swagelok VCR type face seal fittings where servicing is required. Only unplated stainless steel gaskets shall be used. Gaskets shall be replaced each time fitting seal is broken.

8. All gas wetted surfaces of fittings and tubing shall be electropolished to a 10 micro-inch Ra (Ave) or 15 micro-inch Ra (Max) finish. Prior to electropolishing all gas wetted surfaces shall have a minimum 20 micro-inch Ra mill finish.

9. Each tube and fitting assemblies shall be flushed with deionized water with a minimum of 18 megohm resistivity (0.056 µS-cm conductivity) until the measured resistivity of the effluent water reaches 17.5 megohm or higher resistivity (or **0.06 µS-cm or less** conductivity). Ideally the conductivity of the output water will nearly match the conductivity of the input water. Measurements at this level require frequent refreshing of the sample as time exposure to air will raise conductivity values (lower resistivity values).

   The deionized water used for flushing tube and fittings shall come from the Millipore element point of use trigger source. Millipore claims to meet the following purity criteria.

a. Filtration - 0.2 micron at point of use
b. Bacteria - 10 per 100 ml. Maximum
c. Particles - < 100 per liter greater than 0.1 micron
d. Total Organic Content (TOC) - 100 ppb maximum

10. Particle testing shall be performed using a laser particle counter. Fixturing shall include filtration, flow metering device, cryogenic nitrogen or argon source, electropolished 316L stainless steel tubing and/or anti-static PFA (Teflon) tube from gas source to particle counter. Flow shall remain turbulent throughout the test period (Re > 4000). Acceptance criteria per 20 foot length of tube or individual fitting shall be as follows:

    0 particles $\geq$ 0.3 microns
    $\leq$ 5 particles $\geq$ 0.1 microns

    Data shall be presented in record form from a series of 1 minute samples at a sample rate of 1 scfm (Solair 3100 unit) or 10 minute samples at a sampling rate of 0.1 scfm (handheld Lighthouse 3016).

11. Moisture testing shall be performed on tube and fittings using a Meeco NEP-1 Bravo Moisture Analyzer (or equal). Fixturing shall include filtration, cryogenic nitrogen source, and anti-static PFA (Teflon) tubing from gas source to moisture analyzer. Flow shall remain turbulent throughout the test (Re > 4000). See table below. Acceptance criteria per 20 foot length of tube or individual fitting shall be less than 1 ppm moisture content. Each tubing assembly shall be accompanied by a certificate stating results of moisture testing.

    The table below lists minimum purge and drying flow to achieve Re>4000 in a tube. Equivalent air value is the value that a Dwyer flowmeter should read in scfh air units.

Tube Size	Argon (scfh)	Argon gas, equiv.Air (scfh)	Nitrogen or Air equiv. (scfh)
.250	25	30	30
.375	42	50	50
.500	56	65	65
.750	86	100	100

12. Each tubing sub-assembly shall be documented to show that it verifies compliance with the rinsing requirement (conductivity < 0.06 µS-cm),

particle counting measurement ($\leq$ 5 particles $\geq$ 0.1 microns), and moisture measurement after drying (< 1 ppm).

The document should describe the tubing assembly boundary and a photograph of the assembly taken. An example description "Distillation line bounded by MV-401, MV-405, MV-402, inlets of MV-104 and MV-204, and high tap tee." Each tube and fitting assembly shall be marked to identify certification.

13. All work shall be performed in cleanroom B, a Class 10,000 cleanroom. No tubes or vessels of valves should be left open to the environment except during assembly work.

14. Individual tube assemblies not being immediately installed shall receive a positive nitrogen or argon purge with 0.05 micron filtered nitrogen (Balston DX filter is acceptable) and then the tube ends shall be covered by clean polyethylene plastic. A second cover or piece of plastic is also applied to provide a second seal against contamination. Any tape shall be at least 3" from any area of welding. Any residue from tabing shall be removed promptly after the tape is removed.

PART 3 - EXECUTION

3.01 CLEANING

A. Each piece of tubing and fitting that is used shall be inspected in the following manner:

Every length of tubing shall be inspected inside and out to verify compliance with Section 2.01 - Tube and Fittings. Tube and fittings shall be bright and clean inside and out, with tube interior exhibiting a mirror finish. There shall be no stains, oxides, oils, mill chips or other visible impurities. There shall be no uncapped, split or otherwise damaged end caps. If any of these characteristics is noted, the tube shall be permanently marked, removed from the job site.

B. All tube and fitting assemblies to be installed in field weld fabricated systems shall be inspected and conditioned before installation. This inspection and conditioning may be made as a final step after welding is completed. Inspection shall be carried out under the following conditions:

1. Inspection shall be performed in the Lab 3 Class 10,000 cleanroom environment.

2. Area shall be adequately ventilated and provided with air moving devices to meet OSHA requirements for fume removal, but is not required to have humidity control; tubing should not be exposed to excessive moisture once end caps have been removed.

3. Personnel handling, inspecting and cleaning tubing shall wear a minimum of disposable cleanroom garments, including hair covering and non powdered nitrile or latex gloves to maintain a contamination free environment.

4. Inspect and condition each tubing assembly as described below prior to installation on the fluid handling skid:

   a. Flush with 18 megohm (0.056 µS-cm conductivity) deionized water for a minimum of three minutes. DI water flow rate shall be controlled to maintain a minimum velocity within the tube of 5 feet per second (FPS). The table below lists the required water flow rate to achieve 5 FPS. The lab 3 house water before the Millipore unit should be able to supply up to 3 gpm = 11.3 lpm. The Millipore unit can only supply about 1.3 lpm so it can not be used for this flushing.

Tube Size	Flow (gpm)	Flow (lpm)
0.250	0.4	1.5
.375	1.1	4.1
.500	2.0	7.5
.750	4.8	1.8

   b. Upon completion of DI water flushing each tube shall rinsed per step 9 of section 2.0, then blown dry per step 10 of section 2.0 using nitrogen or argon from a cryogenic source filtered to a minimum of 0.01 microns. Flow shall continue until moisture level in the tube is less than 1 ppm above the measured level of the purge gas. A particle measurement per step 11 of section 2.0 must also be performed. All measurements shall be documented per step 12 of section 2.0.

   c. At the end of the final purge cycle, the tube assembly may be immediately installed. If not immediately installed, the tube ends shall be covered with a polyethylene bag over a 1.75 mil polyamide (nylon) film. The bag shall be sealed with polyethylene tape at least three inches from the tube end. The bag is followed by a hard plastic cap and another polyethylene bag on the outside of the cap. The entire length of each tube will then be heat sealed in polyethylene bags in an inert nitrogen atmosphere.

5. Each length of tubing accepted after inspection shall be stored in the Lab 3 cleanroom B.

C. The following is a minimum tube recleaning procedure for tubes requiring field cutting.

1. Welders, fitters, and apprentices required to install the ultra high purity process piping shall wear cleanroom garments (to include gown, hair and beard covers and foot covers) while inside cleanroom. Nitrile or Latex, non-powdered gloves shall be worn at all times while handling any component of the UHP system, whether inside or outside cleanroom.

2. All cutting, facing, deburring and cleaning operations shall be done in a separate area at least five feet away from the assembly area. No openings to the process system tubes shall be within 10 feet of the material removal operation.

3. All tools used within a cleanroom environment for UHP cleaning and installation shall be kept separate from other tools, and shall be used exclusively for UHP systems. They shall be cleaned prior to initial use with a solution of 25% isopropyl alcohol (IPA) and 75% 18 megohm deionized water, and blown dry with 0.01 micron filtered nitrogen or argon from a cryogenic source.

4. Once tube is cut and squared, fill the tube with a solution of 25% IPA and 75% 18 megohm deionized water, drain, and blow dry with 0.01 micron filtered nitrogen or argon from a cryogenic source. Visually inspect the interior surface for cleanliness.

5. Cleaning solutions and nitrogen or argon shall be used only once.

6. Final cleaning of tubing, spool pieces or system sub-assemblies as described in section B above shall be performed under the Class 100 laminar flow station if possible.

7. All cleaned components shall be protected against contamination as follows:

a. Small parts shall be placed in clean polyethylene bags and heat sealed.

b. Tube ends shall be sealed under a positive 0.01 micron filtered nitrogen purge with polyethylene bags, sealed and covered with plastic caps.

c. All tubing and fittings cut in the field and not immediately installed shall be stored in in the cleanroom environment.

8. Ends of systems and components shall not be left open to ambient conditions when unattended or when work has been delayed.

D. Valve preparation shall be per the following procedures:

1. Valves to be purchased precleaned and bagged for ultra high purity service as detailed in Section 2.02 - Valves.

2. Valves contaminated during construction or fabrication of subsystems shall be recleaned under the laminar flow hood and re-bagged if not immediately used.

E. All submicron filters used in the execution of this section shall be membrane type.

F. Use only the ACS grade isopropyl alcohol for use in all cleaning solutions detailed in this section. Presaturated (isopropyl alcohol and DI water) technical wipes for use in the class 100 cleanroom may also be used.

G. Material Data Safety Sheets (MSDS) for all solvents, chemicals and cleaning solutions used in the execution of this specification are on file in the right to know binders.

3.02 WORKMANSHIP

A. Tube Preparation

1. To cut tube, scribe with wheel type tube cutter, and complete cut with wheel cutter. Deburr and rinse with the ACS grade isopropyl alcohol, and bag ends.

2. For butt welds, ends must be squared with a squaring tool such as Tri-Tool, rinsed with isopropyl alcohol and bagged. Face tolerances of all butt weld ends shall be no greater than 0.008 inches from a plane perpendicular to centerline of tube or fitting.

B. Welding

1. Welding Procedure

a. Systems shall be welded with an automatic orbital TIG welding machine with a fully enclosed weld head. Welding process shall utilize Gas Tungsten Arc (GTA). Tungsten electrodes (see section 1.0, paragraph B) shall be replaced to the following schedule. Field profiling of tungsten shall not be permitted.

Tube Size	No. of Welds
1/4" - 3/8"	30
1/2" - 3/4"	25
1" - 1-1/2"	15
2" and up	10

The schedule of welds above lists only the maximum number of welds allowed before replacing the tungsten electrode. The tungsten electrode may also be replaced at any time if it is determined by the SDR that the tungsten is showing sufficient wear as to produce faulty welds.

b. Voltage at the power source for the welding machine shall be measured and recorded in the daily log before any welds may be performed.

c. An argon back purge is required inside the tubing during welding. This purge shall be performed as follows:

(1) Grade 5.0 (99.9995% pure) high purity argon gas shall be used. Additional 0.01 micron filtering is required. The purge gas should be measured to verify < 100 ppb moisture, <100 ppb oxygen, and 100 ppb total hydrocarbons (TOC).

(3) For continuous runs of tubing, welding shall begin at the purge port area and continue through the system. The purge connection shall not be changed. Use purge restrictor at the end of tubing runs. Stainless steel compression fittings with nylon ferrules can be used for temporary restriction on tees and tube ends.

(4) While welding, the minimum purge rate shall be 15 scfh for 1/4" tubing, and 25 scfh for all tubing 3/8" and larger.

(5) Do not begin welding until oxygen and moisture content in the tubing has been measured at less than 1 ppm. Allow a minimum of 5 minutes purge time per 20 feet of tubing.

(6) Continue purge after completion of weld until joint is cool to touch.

(7) Minimum purge extension of 12 inches is required for all joints.

d. At the completion of each work day, the Contractor shall continue the argon purge in any uncompleted tubing runs, or cap and seal the tubing runs using stainless steel compression fittings with nylon ferrules. Any tubing run which has been bedded down using this procedure shall be re-purged until the oxygen and moisture content have been measured at less than 1 ppm before the resumption of work on the system. The results of all oxygen and moisture analyses shall be recorded in the daily log.

e. If contaminants (oxides, etc.) are discovered at any time inside tubing, the contaminated sections shall be removed or a remediation plan discussed with and approved by the engineer. All cut tubing ends must be squared, deburred, faced and cleaned as described in Section 3.02A - Tube Preparation.

f. An argon purge is required around the weld head during the welding process. This purge shall be performed as follows:

(1) The purge gas need not be of the same quality used to purge the inside of the tubing. Stockroom grade argon gas or argon gas from cryogenic boil off is acceptable.

(2) Purge rates shall be per the welding machine manufacturer's recommendations.

(3) The pre-weld purge shall be of a duration as recommended by the welding machine manufacturer.

(4) The post-weld purge shall be maintained for a minimum period of thirty (30) seconds after completion of the weld.

g. Maintain alignment of tube and fittings during welding. No misalignment is acceptable. Tack welds may be made provided that purge and welding requirements are met.

h. All welds shall be exposed on installed tubing. Do not cover welds with saddle, jacket, pad or supports.

i. All welding operations shall be performed in the cleanroom.

2. Welder Requirements:

   a. A qualification test for both the welding machine and the welder operator shall be conducted prior to assembly of any work.

   b. Each welder operator shall be certified and identified per ASME Section IX and the welding machine manufacturer's instructions.

   d. A sample weld from each welder operator, for each size of tubing diameter required, for vertical and horizontal positions shall be required, and given to the weld shop for testing.

3. Each weld shall be given a number, and recorded in the daily log. The weld shall be described with reference to the project drawing or flow schematic. The welding machine schedule used, and the welder operators' identifying mark or symbol shall be stated.

Edited: Russ Rucinski
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COUPP High Purity Fluid Handling Cart

QUALITY CONTROL DOCUMENT

Assembly / Sub-Assembly name:_____

Filled out by (name): _____ Date: _____

Make a sketch of the assembly below. Show each component, weld joint and connection. Label components by component tag number. Label tubing sizes. If assembly is set up for welding, designate the purge gas inlet and outlet. Number each weld in the sequence (work from purge port inlet towards outlet).

Preparation checklist:

- ☐ Tubing ends square to better than 0.008"?
- ☐ Tubing clean and dry inside and out?
- ☐ Remnants of tape residue, foreign matter, marker marks > 3" away?

Pre-welding checklist:

- ☐ Voltage at welder power source:_____
- ☐ Interior purge flow rate:_____
  (minimum 15 scfh for ¼" tubing, 25 scfh for larger tubing)
- ☐ Interior purge flowing for more than 1 minute per 4 feet of tubing?
- ☐ Electrode: No. of welds < 25 for ¾" & ½" tube, < 30 for ¼" tube?
- ☐ Oxygen and Moisture < 1 ppm?
- ☐ Weld head purge gas on?

COUPP High Purity Fluid Handling Cart

QUALITY CONTROL DOCUMENT

Assembly / Sub-Assembly name:_____

Filled out by (name): _____ Date: _____

Welding information

Welder:

Name: _____

Identifying mark or symbol: _____

WPS used:_____

WQR number: _____

Weld machine being used:_____

Weld number (from sketch)	# of prior welds made by this Electrode	Comments

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COUPP High Purity Fluid Handling Cart

QUALITY CONTROL DOCUMENT

Assembly / Sub-Assembly name:_____

Filled out by (name): _____ Date: _____

Pre-Installation Conditioning

Water flushing (conductivity ≤ 0.06 µS-cm?) Meter used:_____

Millipore water upstream of assembly: effluent water:

Particle counting measurement (0 particles ≥ 0.3 microns & ≤ 5 particles ≥ 0.1 microns?)

Handheld Lighthouse 3016 – Use 10 minute x 0.1 cfm record.
Record # _____ Date & Time stamp: _____

0.3 micron counts:

0.5 micron counts:

0.7 micron counts:

1.0 micron counts:

2.0 micron counts:

5.0 micron counts:

Solair 3100 unit – Use 1 minute x 1.0 cfm record.
Record # _____ Date & Time stamp: _____

0.3 micron counts:

0.5 micron counts:

1.0 micron counts:

3.0 micron counts:

5.0 micron counts:

10.0 micron counts:

Moisture measurement after drying (< 1 ppm?) Meter used: _____

Moisture measured : _____

3.03 PRESSURE TEST PROCEDURE

A. System Protection

1. Remove or disconnect from system all:

   a. instruments and equipment which are not rated for test pressure
   b. filters which are not rated for test pressure
   c. any other items subject to damage by test pressure as designated by the SDR

2. Provide all necessary fittings and spool pieces required to maintain system integrity during pressure test

3. Protect tubing and equipment against over pressure

4. Do not subject closed valves left in system to pressures greater than their pressure rating

B. Engineer to provide test pressure permits and approvals.

3.04 QUALITY CONTROL

A.

I. Perform a helium leak test on all welded and mechanical joints, and miscellaneous components upon completion of the pressure test performed as detailed in Section 3.02 - Pressure Test Procedure. The test shall be performed as follows:

1. Using the turbo molecular pump on the helium leak detector, the system shall be evacuated to a maximum pressure of 1×10^{-4} mbar.

2. The background level of the leak detector shall be measured and recorded at less than 1×10^{-8} atmos cc/sec prior to beginning testing.

3. Each weld, fitting, valve, and miscellaneous component shall be flooded with helium gas. Allow a minimum of 1 minute per 100 feet of tubing from the helium leak detector for leak detection. The joint, fitting, or component shall be considered passed if there is no single leak greater than 1×10^{-8} atmos cc/sec above the recorded background level. All joints, fittings, or components not passing the helium leak test shall be repaired or replaced at the Contractor's expense, and a second test performed.

4. The entire system shall be considered passed if the sum of all recorded leak rates at individual joints, fittings, and miscellaneous components does not exceed 3×10^{-8} atmos cc/sec.

J. Sandia shall perform a particulate analysis on all UHP gas lines installed under this specification. All particulate testing shall be performed in the following manner:

1. A background count shall be determined by connecting the particle counter inlet to a 0.1 micron absolute filter and observing the number of counts per volume. Background counting shall begin at least 8 hours prior to beginning particulate analysis.

2. Samples shall be withdrawn from each valved outlet in the system, as well as the end point of all UHP gas lines. Samples shall be taken by connecting the particle counter to the system using a Cajon VCR type face seal fitting. Sample gas flow rate shall be sufficient to produce and maintain turbulent flow (Re > 4000).

3. Particle counts shall not exceed the following limits:

0.01 micron	< 50 per scf
0.1 micron	< 10 per scf
0.2 micron	< 5 per scf
0.3 micron	0
0.4 micron	0
0.5 micron	0
1.0 micron	0

4. The duration of each individual test shall be such that a total of 10 scf of effluent is sampled by counter per test point, or effluent is sampled for a 10 minute period per point, whichever is greater. Each test shall be terminated upon conformance to the specification and approval by the SDR. A test shall be considered failed if the gas sample does not meet specification within a 30 scf sample or a 30 minute period, whichever is greater. Failed lines shall be turned over to the installing Contractor for purging before a retest is begun. All additional purging required for retesting shall be at the Contractor's expense.

5. Each system shall be documented as acceptable and certified as such in accordance with specification at each outlet.

K. Sandia shall perform a residual impurity analysis on the UHP system to detect residual moisture, oxygen, and total hydrocarbon content (THC) which may have been physisorbed or chemisorbed by the interior walls of the distribution piping or miscellaneous components. The tests shall be done

with nitrogen from a cryogenic source filtered to 0.01 microns. The cryogenic source gas shall be certified by the supplier as having no impurities in excess of 100 ppb. All residual testing shall be performed in the following manner:

1. For comparative analysis, the nitrogen purge source shall be tested before trace gas analysis of the systems. If the nitrogen purge source is from dewars, these tests shall be repeated daily during the use of the dewar to detect possible changes in contaminant levels. Nitrogen shall be used as the purge gas for all tests unless otherwise specified in writing by the SDR.

2. Sample gas shall flow continuously throughout the sampling period at a rate no greater than 10 scfh to eliminate any dilution of sample contamination due to excess flow.

3. The system shall be certified as acceptable and documented as such if in accordance with specification, the delta increase from source to sample point of each impurity does not exceed the following levels:

Oxygen	< 10 ppb
Moisture	< 10 ppb
Total hydrocarbon content	< 10 ppb

4. A test shall be considered failed if the sample gas does not meet specification within one hour. Failed lines will be turned over to the installing Contractor for cycle purging before a retest is begun.

L. Instrument calibration certification for all test equipment shall be submitted in writing to the SDR for approval prior to beginning any testing.

M. All tests shall be witnessed and documented by the SDR. Upon completion of testing, all test documents shall be submitted to the SDR for approval.

N. At completion of testing, all systems and components shall be restored to normal operating conditions. All mechanical joints and fittings shall be marked in a manner which will provide a tamper-proof indicator that the joint or fitting has been checked and certified as helium leak tight. The method for marking joints shall be approved in writing by the SDR prior to the start of testing.

O. The Contractor shall incorporate the following minimum quality control provisions:

1. Workers shall check in daily with signature

2. Provide a clean, controlled material authorization point

3. Maintain a daily log reflecting work performed and personnel assigned to each task

P. The Contractor is responsible for any and all retesting, recleaning, or replacement required to meet leak, particle, and residual gas testing.

3.05 INSPECTION

A. Sandia may retain an independent inspector to monitor the installation of the UHP systems. His responsibilities and observation shall include:

1. Select samples of tubing joints which may be removed from installed systems or fabricated samples 6" in length for quality check;

2. A duplication master plan shall be maintained by the special inspector and Contractor which identifies daily work progress, welds accomplished, and name of welding machine operator;

3. Verify and document purge gas pressure and purity at source and run outs;

4. Verify and document that only approved materials are used;

5. Verify and document that installation methods and technologies conform to manufacturer's installation instructions;

6. Assure cleanliness of conditions of work area;

7. Document workers daily attitude.

B. The special inspector shall be authorized to stop work when non-conforming work is observed or results of tests indicate improper execution of the installation. Additional samples, testing procedures, or modifications required to restore the system to specified requirements shall be at the installing Contractor's expense.

END OF SECTION