Evaluating Reduced Weld, Prefabricated Pulled Tee/Valve Manifolds for Ultrahigh Purity Gas System Distribution

By Ralph M. Cohen, P.E.

Abstract

An evaluation program was required to successfully market a new, more cost effective design for ultra high purity gas manifolds to the semiconductor industry. The new design has fewer welds, smaller diameter welds or both, but has slightly longer branch dead leg length. This article presents the results, comparing performance of the new product utilizing pulled tees and discrete valves to the current manifold design that combines tees and valves into 316L stainless steel, machined blocks.

Each manifold was evaluated based on the oxygen removal rate with a purified nitrogen purge after first saturating the manifolds with 100% oxygen.

Background

As discussed in a prior article[1] high purity gases are distributed in several factory types in long (~ 120 feet +) manifolds fabricated from stainless steel tubing (electropolished, 316L) with periodic branches and valves. Manifolds are typically one inch diameter or larger and branches are, typically, ½ inch or ¾ inch. Prior to ~ 1990, the branches in manifolds (aka laterals) were made by welding a tee between two straight tubing lengths. This created a long "dead-leg" or entrapment area between the branch, valve, and the branch end cap whenever a branch valve was not flowing gas, increasing the time between construction and process gas qualification due to the slow migration of argon and other welding contaminants out of the deadleg. This deficiency was eliminated with the integrated tee/valve development that gave very short dead-legs (< 1 inch). But as the laterals (as they are called in the semiconductor industry) increased in diameter, the cost and size of the integrated tee/valve as well as the large diameter weld quantities justified examining an alternate approach—the pulled tee branch requiring only a small outlet valve (½" or ¾") welded to that branch. The referenced article stated that, dependent on valve configuration, up to ⅔ weld reduction and 20% cost reduction (highly dependent on local labor cost) is possible. Acceptance was impeded because the dead-leg, dependent on pull length and branch valve type, increased to 1.61 or 2.13 inches, which is a 66% or 120% increase.

Tests were conducted to determine the impact on the time required to eliminate residual purge gas due to the longer branch dead-leg.

Experiment Hypothesis

Purging laterals with proposed 1.61 inch long branches with purified nitrogen initially containing 100% oxygen would require 22% more purge gas (volume) as compared to the lateral with 0.97 inch long branches using integrated tee/valves. Stated differently, the oxygen concentration decrease rate in ppb/min. for the longer branched lateral would be 22% less than the shorter branched lateral.

The basis for the 22% value is a theoretical oxygen displacement by nitrogen calculation using cycle purges, assuming complete oxygen and nitrogen mixing after each purge cycle and a 1.3% increased volume for the lateral with longer branches. The ½ inch lateral represents the worst case volumetric increase. As lateral diameters increase, the theoretical increase in purge gas reduces to 1.1% and 0.4 % for 2 inch and 3 inch, respectively. Proving the hypothesis would imply that the model is valid and that the difference in purge volume for the larger laterals would be, in fact, inconsequential and acceptable for actual factory installations.

While potential customers are most interested in eliminating residual weld argon after introducing process gas, measuring argon concentration isn't easily accomplished. Since oxygen density and viscosity are

Figure 1. Three laterals connected to the test manifold

Figure 3. Test lateral downstream end and purge/ analyzer interconnects

similar to argon, oxygen was substituted as its concentration could be easily measured.

Test Methodology

The test program was developed by the author incorporating three, parallel, 25 feet long x ½ inch diameter laterals with five branches, each. One lateral had branch lengths equal to a 0.97 inch "state of the art" value , the second with 1.61 inch (pulled tee welded to a bottom inlet valve), and the third with 2.13 inch (pulled tee welded to side inlet valve).

Figure 1 shows the three valves attached to the three test laterals (photo by Evans Components Inc.)

An oxygen cylinder was used to completely fill the test laterals after which a nitrogen dewar with purifier was used to purge the oxygen from the laterals in a timed test. The oxygen concentration was monitored with two Delta F analyzers—an analog unit (0-1000 ppm) and a Nanotrace E (0-10 ppm) at the testing manifold outlet. Moisture was monitored during initial test manifold dry-down and for the Protocol E tests (explained below) with a Meeco Tracer analyzer (0 – 2 ppm).

The testing manifold schematic is shown in Figure 2 and in the photo in Figure 3 (downstream portion only).

Ten preliminary tests were used to refine the final test protocols D and E. Test protocol D consists of the following steps. :

1. Load each lateral with 100% O_2 using 20 cycle purges from 20 psig to 100 psig.
2. Purge laterals with purified N_2 (60 scfh) for exactly 3 min. to reduce O_2 concentration within the analyzer range.

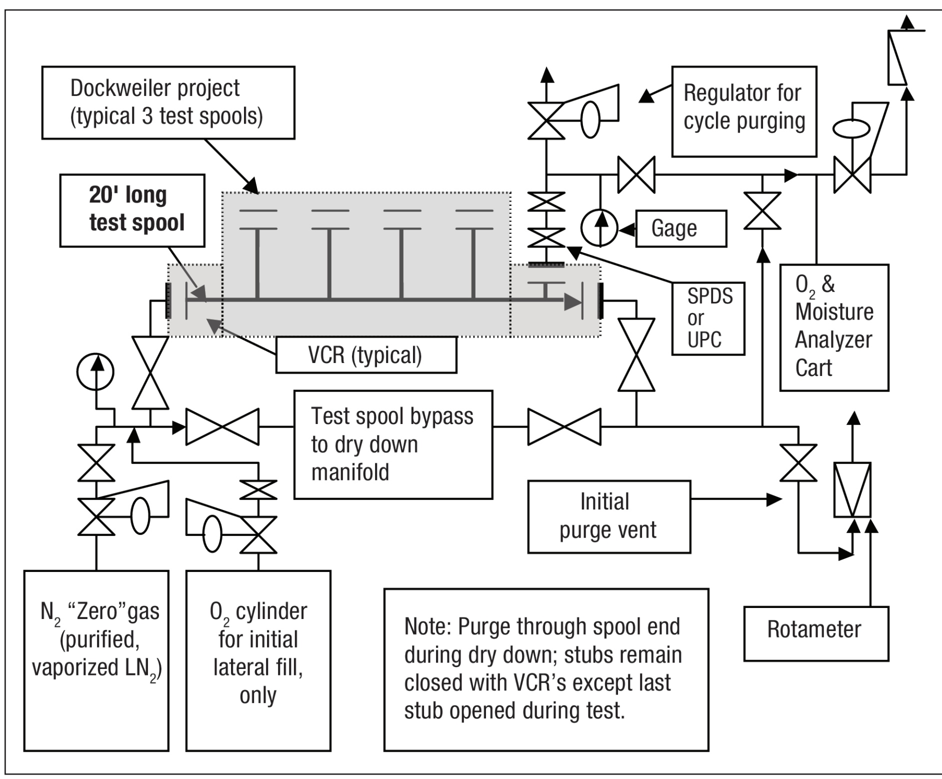


Figure 2. Test manifold schematic: Legend: VCR is a face seal fitting; a spool is a section of tube with fittings between the ends of the tube (manifold); SPDS is a model of valve by Carten Controls and attached to the pulled Ts; for the pulled T manifolds, we attached SPDS valves to the pulled tees; a UPC valve is a "uniplex transition" valve that combines a tee and a diaphram valve into one assembly.

3. Isolate lateral under test and purge remainder of test manifold to reduce O_2 in dead legs to low ppb baseline.
4. Flow pure N_2 through lateral under test at 5 or 10 scfh directed to the analyzers and analyzer bypass; record ppb O_2concentration (from lateral end) vs. time until concentration is at or close to baseline.

Test protocol E was developed after connecting a permeation tube (PFA tubing length) between the purified nitrogen supply and the common inlet to the three laterals. It was used to introduce a controlled oxygen and moisture concentration and proved to be easier to conduct tests and hence provided more consistent data. Steps 3 and 4 were unchanged from protocol D except that the purge was 7.5 scfh during testing

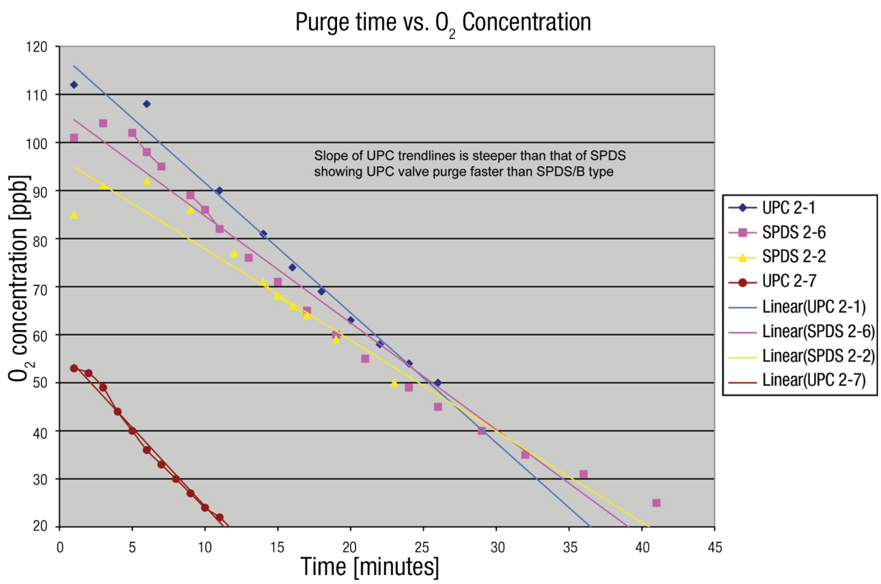


Figure 4. O_2 decline with N_2 purge comparison between UPC (integrated tee/valve) branches and pulled T branches using Protocol D

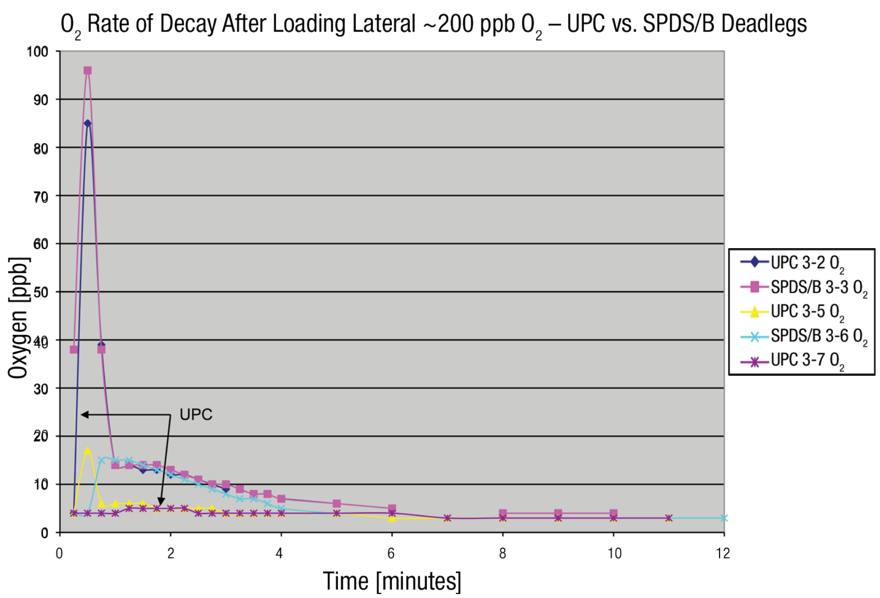


Figure 5. O_2 decline with N_2 purge comparison between UPC (integrated tee/valve) branches and pulled T branches using protocol E

Data

The protocol D and E testing results are summarized in Figures 4 through 7.

Discussion

The Protocol D tests showed that the O_2 concentration declined 18% quicker for the UPC valves after reaching 0 ppm on the 0-1000 ppm O_2 instrument and then timing the decline from a range of starting points (53 – 112 ppb O_2)

Tests UPC 2-1, 2-7	2.8 ppb/minute, average
Tests SPDS/B 2-2, 2-6	2.3 ppb/minute, average

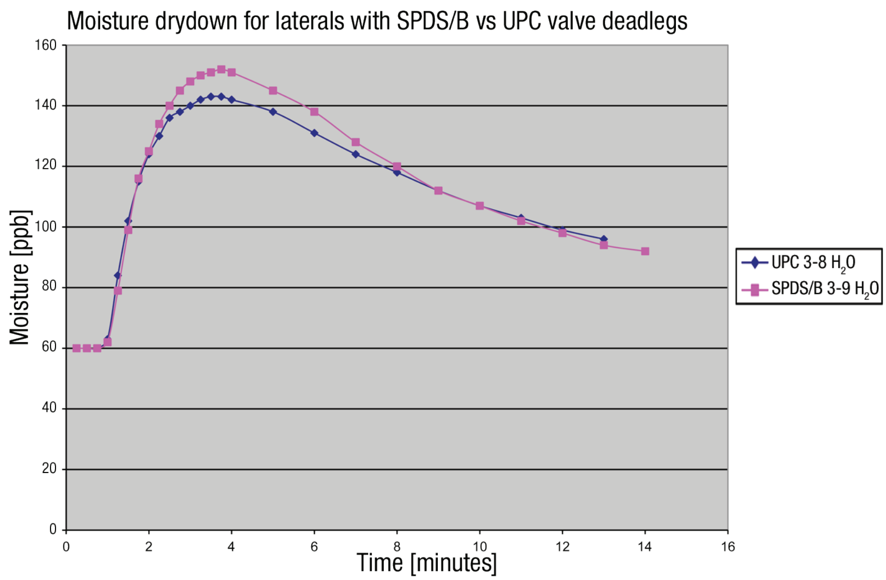
Later Protocol E tests showed that the O_2 concentration declined 28% quicker for the UPC valves from higher initial O_2 concentration of 174 – 366 ppb; the graphs in figure 5 only shows the concentration measured from the start of the data collection period.

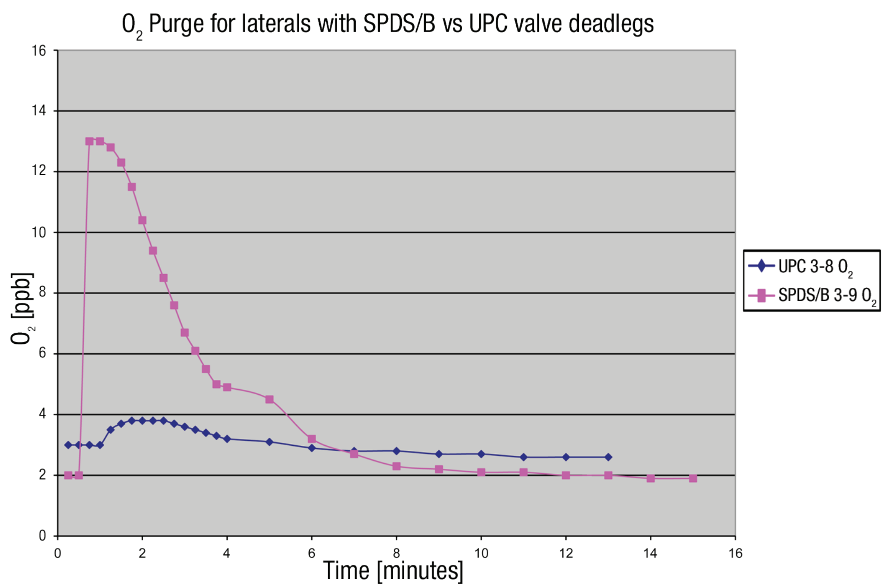
Tests UPC 3-2, 3-5	67 ppb/minute, average
Tests SPDS/B 3-3, 3-6	48 ppb/minute, average

Final tests UPC 3-8 and SPDS/B 3-9 that started with identical O_2 and moisture concentrations showed there were O_2 and moisture spikes for the laterals with longer dead-legs as would be expected because the length increased. However, both O_2 and moisture concentrations for the two configurations approached each other within a relatively short time (~ 6-8 minutes).

Conclusions

The 10 tests showed that the pulled T/valve configurations purged at a rate close to the predicted rate (18% to 28% slower vs. 22% theoretical) for the ½ inch diameter lateral. The tests also showed that either branch valve configuration would purge back to the 5 ppb O_2 baseline level within 5-12 minutes (8–15 minutes including the initial 3 minute purge used to reduce the concentration from pure O_2 in the lateral to the analyzer range). Similarly, the 40 ppb H_2O baseline would be reached in 9-14 minutes (12-17 minutes including





Figures 6 and 7. O_2 and H_2O decline with N_2 purge; identical 370 ppb O_2 and 1000 ppb H_2O initial loading

initial 3 minute purge) for either branch/valve configuration.

Based on the author's theoretical model, large lateral purge performance—the new fabrication method target—would be significantly better as can be seen in Table 1. With typical laterals being 1 inch and larger, the time to purge weld argon from systems will be only negligibly longer (~5% or less).

More tests with the final Protocol E would have been desirable but the program was time constrained.

Acknowledgements

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References

1. "Reducing Welds with Prefabricated Assemblies and Weld Free Couplings and Fittings" by Ralph Cohen, Gases and Instrumentation, (Jan/Feb 2011), pp 20-23, www.gasesmag.com

Diameter [inch]	Increased volume	Increased purge
0.5	1.3%	22%
0.75	0.55%	9%
1.0	0.28%	4.8%
1.5	0.12%	2.1%
2.0	0.06%	1.1%
3.0	0.03%	0.4%

Table 1. Diameter effect on theoretical purge volume

RALPH COHEN, P.E. retired from Intel in 2005, completing 20+ years. While at Intel he was engaged in facility design, construction, startup, failure analysis, engineering team management, and recruiting. Design work focused on mechanical systems for wafer fabs, assembly-test plants, and data centers world-wide, with specialties in HVAC, bulk gas systems, and energy conservation. He also worked closely with suppliers in the development and qualification of new products. In 2006, he established Ralph M Cohen Consultancy providing engineering services. He may be reached at +1 503-292-5633, or by email at rmoc999@q.com