

Reducing Welds with Prefabricated Assemblies and Weld-Free Couplings and Fittings

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A look at existing products that can reduce welds up to 75% and significantly reduce labor costs by the use of prefabricated manifolds, and crimped couplings and fittings

Abstract

The challenge facing facility designers is to continually reduce construction costs without adversely affecting operating reliability, maintainability, or system quality parameters.

This article will discuss two ideas being implemented for gas distribution systems in semi-conductor and photovoltaic (PV) manufacturing facilities: 20-foot (6 m) long "laterals" with "pulled" branches and the inter-connection of laterals and equipment tubing with an O-ring sealed, crimped connector. Implications of changing from 316L to 304L stainless steel for specific applications will also be discussed.

Background

Laterals refer to lines of stainless steel tubing (either 304L or 316L, electropolished or cleaned for oxygen service) with periodic branches and valves used to supply gas to and locally isolate process equipment. Gas lateral sizes commonly range from ½ inch to 2 inch diameter and branches are typically ½ inch to 1 inch. Historically, the branches in laterals were accomplished either by welding a tee between two straight lengths of tubing or by using a machined body, integrated valve that combines a tee with a branch valve. The drawback of welded tees is the number of welds required per tee—at least three per branch. And using integrated valves does not always result in a net cost savings compared to a tee and a valve (or a cross and two valves).

Pulled Branches

A viable alternative to either of the current lateral fabri-

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cation practices is to pre-fabricate laterals in 20-foot long sections by first pulling the tees¹ and then welding the valve to the pulled tee or to a short tee extension. In this way, 50% to 75% of the welds at each valve branch are



Figure 1. Ball valve attached to pulled tee (photo by Evans Components Inc.)



Figure 2. Pulled tee (foreground) and diaphragm seal UHP valve attached to pulled tee (photo by Dockweiler AG)

eliminated. See Figures 1 and 2 that show examples of pulled tees and attached valves.

Specialist suppliers have the expertise and experience to form the tees uniformly and consistently, electropolish the lateral and tee or only clean for oxygen service, weld the valve to the pulled tee, then helium leak check and particle count certify the entire assembly prior to packaging and shipping to the job-site. Prefabricated laterals with pulled tees may be used for any gas from utility grade nitrogen to ultra-high-purity hydrogen by changing tube and valve specifications, tube treatment, and QA protocols. Viability can be evaluated using established cost models that factor in site vs. factory labor rates, numbers of welds saved, weld costs, site QA costs, etc.

Table 1 shows the savings in contractor site welds where pulled tee laterals were proposed rather than welding tubes and tees—in this case, a 66% reduction since only one weld would be made for each of the 3075 valved branches while an additional 6150 site welds would be made if tubes and tees were used. Note that ≤ 1 " conventional tube/tee welds include branches and lateral-run welds.

Argument in Favor of 304L Stainless Steel for Lower Purity Gases

The industry has evolved from using copper to using 316L stainless steel for non-corrosive gas systems. This decision should be examined in light of 304L stainless steel tubing compo-

Lateral Size (inch)	Pulled Tee Manifolds			On Site Manifolds with tubes/tees		
	Total shop welds			Total shop welds		
	≤ 0.5 "	0.75"	Total	≤ 1 "	1.5" - 3"	Total
2.0	0	0	0	0	0	0
1.5	135	0	135	135	270	405
1.0	0	930	930	2790	0	2790
0.75	0	1470	1470	4410	0	4410
0.5	540	0	540	1620	0	1620
Total	675	2400	3075	8955	270	9225

Table 1. 6150 welds eliminated in a typical project: 66% reduction

nents and systems that are tailored by several suppliers to meet the relaxed specifications for semi-conductor grade compressed air and utility nitrogen, as well as PV medium purity requirements. Relaxed specifications for PV industry gases are highlighted in the recently approved SEMI guidelines and include nitrogen, argon, oxygen, and hydrogen—ppm impurity levels rather than the ppb impurity levels for UHP semi-conductor applications. An example of a 304L tubing product is the Dockweiler AG "Solar TCC" line that has been approved for use with the Evans PLHT Series "Victaulic Pressfit"™ system discussed below.

Stainless 304L is alloyed with 2% less molybdenum, 2-3% less nickel, and 2% more chromium. Results from several samples that were either electropolished (316L) or annealed/pickled in HF/HNO₃ (304L) are shown in Table 2.

Based on Table 2, one could summarize the difference between annealed/pickled 304L should and electropolished 316L, by saying that the chromium enriched layer of annealed/pickled 304L is similar but 50% thinner than electropolished 316L; surface cleanliness is similar, and although annealed/pickled 304L surface defects are much greater than electropolished 316L, it

is acceptable for lower purity, non-corrosive gases. Raw tubing prices for 304L are 12% - 45% lower than 316L in the size range of 1/2 - 2 inch diameter with further savings from pickling vs. electropolishing processes.

Weld-free Tube Joining

Using pulled tee, prefabricated laterals still require welding the 20-foot long sections together in the field to form the entire lateral, often 100 feet long or greater. And, tubing runs from the branch valves to the equipment use either welds or compression fittings to join the tube and components together (valves, regulators, filters, gages, etc.).

An O-ring sealed/mechanically crimped connector manufactured by Victaulic Company as part of a fire protection and industrial fluids piping system has been adapted for use in the semi-conductor and PV industry. It is used in high reliability cooling systems and is well suited to semiconductor CFOS/low-purity (utility nitrogen, argon, exhaust, and compressed air) applications, and to PV low-medium purity (nitrogen, argon, and compressed air) gas applications. This connector offers the key advantage of rapid installation with minimal training and eliminates weld-

	Cr:Fe ratio	CrOx:FeO	CrOx layer	Carbon layer	SEM defects
316L	1.7	3.2	25 °A	4 °A	10/15 per field
304L	1.5	3.0	11 °A	4 °A	Too numerous to count

Table 2. Comparing several properties between 316L and 304L tubing (Table courtesy of Dockweiler AG)

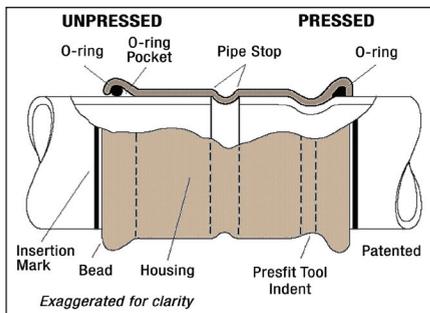


Figure 3. An O-ring sealed/mechanically crimped connector (Drawing from Victaulic catalog)



Figure 4. Examples of fittings, valves, manifold, and battery powered pressing/ crimping tool. (Shown are Evans PLHT Series Pressfit fittings. Photo by Evans Components Inc.)

ing, associated purge gases, and welding QA. Figure 3 shows the “unpressed” and “pressed” coupling and the O-ring seal. Figure 4 shows several examples of products using the Evans PLHT Series Pressfit joining method.

Third party testing utilizing SAES Puregas CollectTorr™ sampling and GC-MS analysis of test spools consisting of 14 Pressfit connections each in 1 and 2 inch sizes at two temperatures determined the concentration of contaminants that may be present in the O-ring, lubricant, and on the stainless 304L surface of the connector. While the original Victaulic fitting is manufactured in pipe size dimensioning, the Pressfit gas fitting system is offered in O.D. tube sizing from ½ inch through 2 inch diameter. The SAES Puregas report² indicated that the principal contaminants were organic—primarily alpha-methyl-styrene (used in the manufacture of plasticizers, resins and polymers). Volatile aromatics (ethyl-benzene and xylene), and oxygen containing organic compounds (aceto-phenone, a compound when combined with other compounds is used to make polymeric resins) were also detected

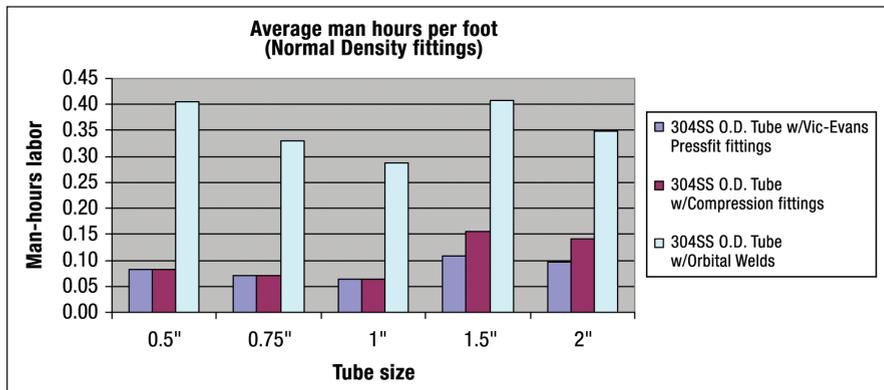


Figure 5. Installation time comparison between three joining methods Note: “Normal Density” refers to a mix of tube and fittings representative of typical lateral configurations.)

at lower concentrations. No acidic or basic contaminants were found. The total hydrocarbon concentration was in the low ppb range. Results are summarized in Table 3.

Using a simple dilution model, the author concluded that in a 2 inch diameter system

SIZE:	2 inch	1 inch
TEMPERATURE:	Total Hydrocarbon concentration for 14 connections per test spool	
68°F	4 ppb	0.081 ppb
104°F	12.7 ppb	0.43 ppb

Table 3. Results of outgas testing conducted on Pressfit connections

with 200 Pressfit connections and flowing 20 ft³/min of gas, the outgassing contribution from connector contaminants would be approximately 0.4 ppb total hydrocarbons (as methane). This is well below the allowable level for semi-conductor non-process gases

and PV gases (argon, nitrogen, oxygen).

Third party helium leak testing showed that leak rates per joint are ~ 4 x 10⁻⁸ atm-cc/sec or better (inboard or outboard) for 1, 1-1/2, or 2 inch diameters. Some particles are generated during mechanical crimping but in third party tests, particle counts were reduced from ~ 100 – 300 particles/ft³ (@ 0.1 micron) to 0 within 10 minutes when gas flowed through the fittings at a velocity of 20 ft/sec.

Installation time for a typical system using only Pressfit tees and connectors (not pulled tees), compared to welding and compression fittings are shown in Figure 5. Pressfit is best in 1.5 and 2 inch size but comparable to compression fitting in smaller sizes; both are more time efficient than welding.

Typical cost savings are shown in Figure 6, comparing welded and compression fittings. Lowest cost is achieved with Pressfit in 1.5 and 2 inch sizes. An hourly labor rate of \$55 was assumed.

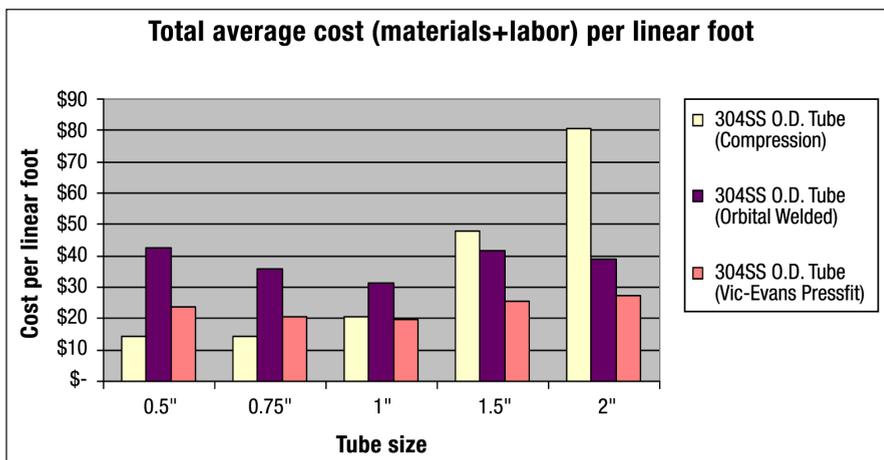


Figure 6. Installation cost comparison between three joining methods

Lithographic (Stepper) Compressed Air Systems

In order to determine if it is necessary to use UHP (electropolished) tubing components including diaphragm sealed valves to supply compressed air to steppers, third party testing using SAES Puregas CollecTORR analysis was used to quantify contaminant levels from laterals fabricated from both Dockweiler AG's TCC.1 anodically cleaned 316L tubing and Evans Components ECC.1 cleaned 304 stainless steel ball valves. Such analysis has shown both to be suitable.

Using pulled tee, prefabricated laterals still require field welding 20-foot long sections.

The worst contamination was approximately 50 ppt per valve in one test. Results of a second test for a 20-foot length of 2 inch diameter tubing with three ball valve branches were non-detectable. The detected contaminants were primarily 2-propanone, 1-methoxy with a small amount of alpha-methylstyrene. With the much higher flow rate expected in an operating system, THC [total hydrocarbons] contaminant levels would likely be < 100 ppt compared to a THC specification level < 20 ppb.³

Summary/Conclusions

Pulled tee laterals reduce total system welds by 50% to 75%. This could result in significant cost savings, dependent primarily on a site labor costs. There are other advantages including reduced site work force and congestion, quality control, just-in-time delivery, and single point responsibility. Pulled tee laterals may be applied to both CFOS and UHP gas systems (utility grade to high purity).

Pressfit fittings, adapted by Victaulic, Evans Components, and Dockweiler AG to 304L stainless tubing-sized components offer a labor saving option compared to welding for low and medium purity gas systems in PV and

semi-conductor applications ~70% in 1.5 inch and 2 inch tube size. It is cost effective where site labor costs are high.

A tubing/valve system using anodically cleaned 316L stainless tubing and similarly cleaned 304 ball valves is suitable for "state-of-the-art" lithographic stepper compressed air supply systems.

Third party tests, including outgassing and leak rates, show that the proposed components and methods are expected to meet the purity requirements of the applications discussed.



References:

1. A pulled tee is a tee that is formed at a location along the run of a tube by milling a hole, then inserting a mandrel into the hole, followed by drawing the mandrel back out of the hole while resisting the force with a die such that some of the tube is drawn into a collar that then machined level forming a very short branch tee.
2. "Evans PLHT Series Pressfit Microcontamination Tests, 304L CFOS Stainless Tube Pressfit System", Evans Components Inc., Portland, OR, (July 2009).
3. "Evans ECC.1 cleaned ball valve / Dockweiler TCC.1 tube Out-Gassing Test," Evans Components Inc., Portland, OR (May 25, 2010).

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