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November 2013

COLD WELDING DUCTILE METAL TUBULATION

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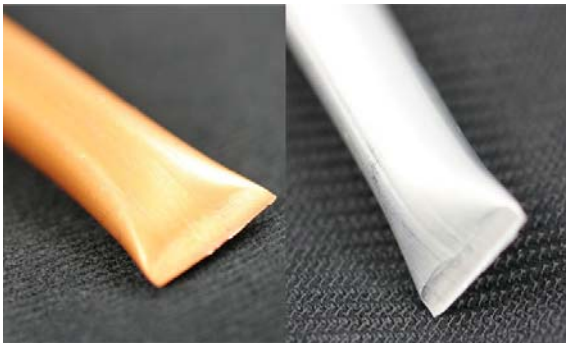
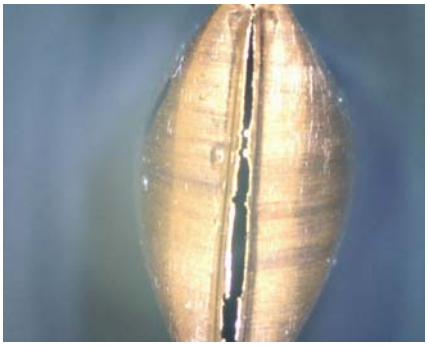
Within a wide variety of industries, the requirement to pinch-off and hermetically seal ductile metal tubulation (tubing) is a critical and necessary process when separating a device from a vacuum pumping station. Tools that can reliably perform the pinch-off (cold weld) function will produce a reliable seal that can withstand bake-out temperatures up to 600^{o} C and eliminates the necessity of using expensive valves to perform the same process. The tube pinch-off and resulting cold welded (hermetically sealed) joint is accomplished in a single step using these effective tools. Although this pinch-off process is most commonly used in vacuum applications, they are equally effective with applications involving high or low pressure. Without question, the most important factor in achieving this cold welded joint is the tubing itself. Select the wrong tubing and the results will be very disappointing indeed. Tube selection is critical and well worth discussing in more detail.

SELECTING THE PROPER TUBULATION MATERIAL

Achieving a dependable, repeatable cold welded joint when using mechanical pinch-off tools requires the proper tubing material and tube preparation. All conditions must be met to yield a hermetically sealed joint. Without question, the tubing material and heat treat is the most critical factor in this entire process.



OFHC Copper and Aluminum tubing properly pinched off and sealed.



Example of tubing that was too hard and separated prematurely during the pinch-off process.

The tubing most commonly used for mechanical pinch-offs is OFHC (Oxygen Free High Conductivity) Copper. The specifications, chemistry and state of ductility for billet certified (99.9% pure) Copper is detailed in ASTM specs B68-83, B75-84, B133-33 and B170-82. Other approved and commonly used materials include: High purity Nickel (“A” Nickel, NI 270, NI 200 or 99.4% pure Nickel ASTM-B161), Aluminum (annealed 3003 H14, 98% classified non-heat treatable), pure Iron, Gold, Platinum, Silver, and Columbium.

OFHC Copper Tubing

When you consider that the pinch-off process will deform and elongate the tubing by 350% or more, and the cold welded area will work-harden during the pinch-off process producing an elongated grain structure in the tube, it's important that the tubing is processed properly before attempting a mechanical pinch-off. OFHC Copper is annealed at 650^{o} - 850^{o} C for 30 minutes in a dry hydrogen atmosphere. The end result is a malleable tubing material that will pinch-off properly with the tool and will not separate prematurely. Tubing that is too hard will fatigue and separate before the pinch-off tool can complete its cycle, thereby resulting in a compromised cold welded joint and a leaking or questionable seal. On the other hand, tubing can also be annealed too soft which will result in the tube failing to separate, leaving a very fine web of material that requires the technician to physically "wiggle" the excess material to achieve separation. Neither of these scenarios are acceptable and emphasizes the necessity of selecting tubing that has been processed properly and within the specifications discussed above.

It should also be noted that classifying a Copper tube as OFHC does not necessarily guarantee that it will pinch-off properly with a mechanical tool. It has been my experience that tubing originating in many countries around the world are providing and marketing OFHC Copper tubing that may be produced using a different or modified process. Typically, tubing tested from these sources will be harder and less malleable than OFHC tubing processed in the U.S. To avoid pinch-off related issues, regardless of your vendor, you should provide the pinch-off tool vendor with samples for testing prior to specifying a particular tubing source for your application. This important step will pre-qualify your tube selection as either being acceptable, or not, for a cold welding process.

Nickel Tubing

High purity Nickel offers several advantages for the cold welding process: (1) Minimal outgassing during bake-out and pinch-off , (2) Minimal oxidation and, (3) Higher bake out temperatures. For the purposes of performing a mechanical cold welded joint with a mechanical pinch-off tool, the nickel must be fully annealed at 1150^{o} C for 30 minutes to achieve the correct tube hardness.

Additional Tube Selection Factors

Another tubing factor that can affect the quality and consistency of the pinch-off is wall thickness. Typically, OFHC Copper and Nickel tubing is supplied with a fairly thin wall. For example, 1/8" diameter tubing will usually have a wall thickness of approximately 0.030 - 0.035", while 1/2" diameter tubing will be approximately 0.040 - 0.045". Heavy wall tubing that may also exceed the proper hardness specification will require more tool pressure to compress and pinch-off or separate the tubing. As all tubing will work-harden during the pinch-off process, any variation in tube hardness or wall thickness will directly affect the quality and reliability of the pinched-off tube. Having your tubing evaluated by CPS is a very important step in the process and should not be avoided. All of the factors discussed above need to be addressed carefully before you finalize your tube or the model of the pinch-off tool to be used. Applications involving a cold welded tube pinch-off are almost always critical applications that rely heavily upon the quality and reliability of the cold welded joint. Tube seal failure often results in sizeable losses from both a financial and product performance perspective.

Preparing the Tube for Pinch-Off

Regardless of the tube material selected for your application, proper tube preparation is a critical step in the process. Tubulation I.D. must be totally free of any contamination at the pinch-off point. Sonic or mechanical cleaning methods are much preferred over chemical cleaning prior to pump down, as that produces the most consistent cold welded joints. Tubulation O.D. should be polished to remove any oxidation, as these oxide crystals will be harder than the tubing and may compromise the cold welded joint.

The tools offered by CPS for producing a tubulation pinch-off are equipped with a set of precision carbide rollers that compress the tubing to produce the cold welded joint. Prior to performing the pinch-off, these

rollers should be lubricated with a light weight oil to reduce friction during the compression stage. Between each pinch-off cycle, residual metal from the tubing will often remain on the carbide rollers and this contamination should be removed by lightly wiping the carbide rollers with a soft towel wetted with a light weight machine oil so the surface is clean and ready for the next pinch-off cycle.

During the pinch-off process, constant and even pressure must be applied to the tube until it severs suddenly. As mentioned earlier, all tubing will work-harden during the tube compression stage, so any interruption in that cycle will likely yield incomplete or unsatisfactory tube separation.

Trouble-shooting a Bad Pinch-off

Problem:
Tool compresses the tubing, but the tube will not separate.

Suggested procedure:

1. Increase jaw closure force on the tool (adjust pump settings), but do not exceed maximum safe pump pressure levels as recommended by CPS.
2. The tubing may be too hard. If the tool is at the maximum safe pressure setting and the tubing still fails to separate, the specifications of the tubing should be reviewed. Materials such as Copper can actually get harder just sitting on the shelf for extended periods. Secure fresh tubing from your supplier and try the pinch-off again.
3. The tubing may be contaminated, either inside or outside. Clean tubing and try the pinch-off again.
4. If all suggestions listed fail to resolve the issue, contact CPS to assist with further testing and evaluations.

Problem:
Tubing separates successfully, but will not hold pressure or vacuum

Suggested procedure:

1. In most cases, this is due to a tube hardness issue or tube cleanliness issue. Start by cleaning the tube thoroughly and test again. If the tube still leaks, see suggestion 2.
2. Secure a sample of tubing from a different batch and test again. If the tube still leaks, see suggestion 3.
3. Contact your tubing vendor and secure fresh samples. Be sure to advise the vendor that you are performing a pinch-off, cold weld process with this tubing.
4. Check the carbide pinch-off rollers on your tool for any signs of chipping or excess wear. These rollers must remain perfectly round. Any flat spots or chipping may contribute to the poor results. Replace the rollers if any chipping or wear is detected. Contact CPS with any other questions or issues that you may have regarding the pinch-off process.

Problem:
Tubing compresses completely, but will not separate, leaving a very fine web of material that requires the technician to "wiggle" the excess tubing in order to achieve full separation.

Suggested procedure:

1. In nearly every case, this symptom is caused by tubing that is too "soft". The tubing has likely been annealed improperly for use in a cold weld application. When tubing is in this condition, more pinching force from the tool will not solve the problem. Manually wiggling the excess tubing is never recommended, as this could alter the tubulation grain structure in the cold welded joint, resulting in a leak. Secure the correct tubing from your vendor. There are no adjustments required for the tool in this situation.

After Pinch-off

Testing procedures will vary depending upon the application for the tubing being sealed. Typically, tubes that are sustaining a vacuum will be subjected to a helium leak test or examination under a microscope for comparative analysis purposes. For high or low pressure applications, testing procedures will often involve a leak-down test in some form. Whichever testing procedure is used, the process procedures should be duplicated exactly so any tube failure issues can be traced.

Once the tubulation has been successfully pinched-off and a hermetic seal has been confirmed, the processed end of the tube should be protected with a plastic cap, epoxy or sealant as the edge is very sharp and the sealed end is susceptible to damage if bumped or bent. Soldering or brazing the cold welded end of the tubulation is NEVER recommended, as the grain structure can be compromised, thus resulting in a leak.

Pinch-off Tool Selection

Selecting the proper tool to perform the cold weld pinch-off process will depend on many factors. Some of those factors include:

1. Tubulation material (OFHC Copper, Nickel, Aluminum, etc.)
2. Tube O.D.
3. Tube I.D.
4. Clearance issues accessing the tool to the tubing being pinched-off.
5. Tool angle required to access the tubulation being processed. This will determine the style, profile and angle of the pinch-off jaw required. The standard jaw angle on the scissor style tools will usually be 45^{o}. Special jaw angles and profiles may be required to meet your requirements.
6. How many tubes will be pinched-off and processed in a day, week, month, etc.?
7. Has the tubing been exposed to any processes involving heat (braze, solder, bake-out) or severe cold prior to the pinch-off process?

The most effective tools for performing the pinch-off process are powered via hydraulic pumps. The pinch-off jaw closure force required to successfully pinch-off and cold weld approved tubing will be in excess of 5000 psi. In addition, the carbide pinch-off rollers that make contact with the tubing must be precision ground to insure the pinch surface is consistent and resists wear. Although there are a few hand held mechanical pinch-off tools available, the pinch-off produced by these tools are inconsistent and not dependable or repeatable. Hand tools simply can't generate enough closure force to yield a hermetic seal on a consistent basis for highly critical applications.

Scissor-style handset & jaws with hydraulic / pneumatic pump and remote footswitch.

Handset with scissor style, 45° angled jaw for use on 3/8 -1/2" diameter tubing.

C-style handset with parallel action jaw set. Teamed with hydraulic pump (not shown).

Hydraulic pinch-off tools are available in a variety of sizes and styles, configured with a variety of hydraulic pumps, depending upon the application.

Handsets and pinch jaw models are available for tubes ranging from 1/16 - 1" diameter. Hydraulic pumps are available in either pneumatic or electric models and can be further modified for low or high volume applications. It's important to match the correct handset and pump combinations to the job being performed.

HYDRAULIC PUMPS

ELECTRIC HYDRAULIC PUMP
WITH FOOTSWITCH

STANDARD HYDRAULIC/PNEUMATIC PUMP

FOOTSWITCH CONTROL HYDRUALIC/PNEUMATIC PUMP

HYDRAULIC HAND SETS WITH STANDARD 45° ANGLE JAWS
(Custom angled jaws available)

Summary

Applications that involve the necessity to cold weld and hermetically seal tubulation are typically critical by nature. In other words, these tubes must be hermetically sealed and remain in that condition indefinitely, under a wide range of temperatures and environmental conditions. As a result, it's imperative that both the tubing and the tool selected for the application be matched properly. When done correctly, the end result will be a cold welded joint that will remain hermetically sealed for the life of the product being produced.

Contact Custom Products & Services, Inc. for more information, or visit our website to download catalogs and data sheets pertaining to the hydraulic pinch-off tools. www.custom-products.com