CPI™ Instrumentation Tube Fittings

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Parker CPI™ Instrumentation Tube Fittings Story

"In reducing the number of necessary sealing points (i.e., potential leak paths) in any containment system, you increase the system reliability."

General

The Parker Hannifin CPI™ Instrumentation fitting is a precision three piece high quality compression fitting for use in instrumentation and process systems.

The fitting was produced in 1966 and was designed to be fully interchangeable with the Swagelok® double ferrule fitting. The decision to design a fully interchangeable fitting was based on two factors. A market research study indicated a concern on the part of purchasing and maintenance personnel for:

(a) The cost in completely converting a plant from one fitting to another non-interchangeable fitting.

(b) The cost in lost time when a technician had to return to the stores area for another type of fitting because the one he had picked up was not interchangeable with the one used in the work area.

Is Parker CPI™ Really Interchangeable?

Yes. All threads, the seal seat angles and position, tube insertion depth, hex sizes and width, etc., are the same as Swagelok®. The fitting is totally the same as Swagelok® in all functional dimensions of the body and nut. The only basic difference between the two fittings is the fact that Swagelok® uses two ferrules while we use one. That a single ferrule is used should not cause concern as to the interchangeability with Swagelok®, because the single ferrule when made up in either the Swagelok® fitting body or the machined Parker CPI™ or A-LOK® body will be positioned the same to the Swagelok® ferrules in relation to the tube stop in the fitting bore and the seal seat in the body. Just as a made up tube assembly with the ferrules already swaged on the tube may be removed from one Swagelok® fitting body and connected to another Swagelok® body, the same tube assemble may be connected to the CPI™ fitting body which has the same high quality machining as the Swagelok®. The same logical facts would apply to the use of a CPI™ tube assembly and the Swagelok® body.

The best demonstration of interchange is given by a pair of sectioned fittings of the same size and shape side by side. Here it will be evident that both fittings are the same.

Holding Power and Sealing

In order to understand the function of the components of the CPI™ fitting we will first need to cover the following basics.

Sealing

Let us first concern ourselves with sealing ability. Metal parts with production surface finishes may well be capable of sealing one type of fluid (or media) while allowing another to leak. A good example of this is the air or helium filled common rubber balloon. Fill the balloon with air, tie a tight knot in the neck and it will stay inflated for a long period of time. Fill the same balloon with helium, tie the same knot and the next morning you will find only a limp hunk of rubber. Same balloon, same knot, different media. By the same token, a fitting system handling air may be "leak tight," but switch to a light gas like helium and you may have leaks all over the place.

It is the molecular structure of the contained fluid or media in relation to the "hole" or leak path size that determines the absolute sealing capability of the system. By molecular structure we mean that it is not only the molecular size but the molecular arrangement that determines whether the contained fluid will leak through a particular "leak path."

Imagine a one inch diameter ball or bead and a two inch diameter hole. The bead will pass freely through the hole. String a large number of the beads together, but still feed them through the hole one at a time and they will still pass through. But tie the string of beads into a knot and you will find that it will never go through that two inch hole. Here the single bead could be thought to be a simple molecular structure (such as a light gas) while the uncomplicated string of beads could have been a "thin chain" molecular structure (such as the heavier hydrocarbons.) Our large knot, however, would be a complex molecule (such as petroleum oils.)

If you imagine that the string we used to string our beads together was unbreakable you can see that there would be no way to force the "knot" through the hole. By now you may have discovered the above was a clue for our next statement.

A leak is only dependent on the molecular structure of the media to be contained. Pressure only determines the rate or speed of leakage.

As an example, imagine a bucket full of single beads one inch in diameter. The bucket has a hole in it which is slightly larger than the bead and we will shake the bucket to stimulate movement of the beads out of the hole or leak. If we can pour beads into the bucket faster than they can get out of the hole or leak path, we will cause the "pressure" in the bucket to increase. This increased pressure will cause the beads that are escaping to move through the leak at a faster rate. No amount of pressure, on the other hand, could force our knot of beads, or even one larger single bead to go through that hole.

As we mentioned before, surface finish on mating parts is what determines the size of the "hole" as mentioned above. The better the surface finish, the smaller the hole or potential leak path. However, even the best production surface finish when compared will show as a series of “hills and valleys” under microscopic inspection. This is because metal cutting processes are actually only microscopic tearing of the metal. It is these hills and valleys that form a leak path for small molecules.

To eliminate these leak paths caused by surface finish we may resort to three basic techniques:

- First we can apply enough stress through mechanical loading to roll the hills and valleys together and thus “coin” them out. This, however, can only be done if the parts we are forcing together are strong enough not to deflect away from the coining action.
- Another way to eliminate the hills and valleys is to use a sharp edge and bite through the surface layer into the dense metal. To use this technique you must insure that your sharp edge is harder than the metal you are biting into, and therefore you must concern yourself with hardening methods.
- The final method of eliminating the hills and valleys is to fill the low points with a softer material for a gasket effect. Here the gasket material must be hard enough to resist movement or “cold flow” caused by pressure, and yet it must be compatible with the media to be contained. One such “gasket material” process commonly used in both aerospace and instrumentation is a thin plating of silver or gold on the ferrule of the fitting. Here the material is hard enough to resist cold flow and yet soft enough to flow into the pockets in the base material surface. Gold or silver also has the advantage of being highly compatible with most media.

Mechanical Holding Power

Mechanical holding power, or the ability to mechanically restrain the tube against pressure blowout, is a function of the ratio of the system pressure and the area represented by the O.D. of the tube with an overall consideration for an operation safety factor. For example, a 1/4" O.D. tube has a representative area of 0.0491 square inches. When exposed to a pressure of 1000 psi we only have to grip the tube with a force strong enough to resist a 50 pound blowout force (1000 psi x 0.0491 in^2.) Even if we add a high safety factor, the holding force necessary is still somewhat low in comparison to the operation pressure.

There are many ways to achieve the mechanical holding power function. For example you can weld, thread, bite or swage the tube. The last two mentioned are most commonly used and they lend themselves to field assembly. Both methods, however, have limitations. The main fitting factor in both is tube “hoop strength.” Hoop strength is the ability of the tube to resist compressive or crushing action such as that exerted by a ferrule, and for any given material it is a function of a ratio between the wall thickness of the tube and the outside diameter.

Imagine a 1/2" diameter stainless steel rod. If we bore a very small hole in the rod lengthwise we end up with a “heavy wall tube.” This piece of “tubing” has maximum hoop strength. As we go back and re-drill our small hole to make it larger we decrease the hoop strength. When we have finally drilled out the hole until the tube wall is only a little thicker than tinfoil we will have reached a point where the hoop strength is almost zero.

In designing the fitting you must therefore consider the wall thickness range of the tubing that will be commonly used with the fitting. A compression or swaging type fitting, for example, will not work on heavy wall tubing because the tube simply will not compress or swage because of its high hoop strength. An unlimited bite type fitting, on the other hand, such as that used on hydraulic service will not work on thin wall tubing because the tube will simply collapse because it does not have sufficient hoop strength to resist the high contact stress caused by the gripping ferrule.

Designing the Parker CPI™ Instrumentation Tube Fitting

In designing the CPI™ fitting we were basically controlled by two goals:

- To design a fitting that was fully interchangeable with Swagelok®, and
- To design a fitting that was further advanced in customer desired features than Swagelok®.

Our first design goal limited us to using the same body and nut configuration as Swagelok®, for this was the only way to achieve full interchange. This action was further made necessary by the fact that several other interchange fittings were being marketed by other manufacturers which were not fully interchangeable. This fact of not being fully interchangeable had caused a creditability gap whenever the word "interchange" was used, and therefore we had to be above reproach in our design.

Our second design goal was achieved by the use of a single ferrule approach. Here the advanced technology that was not available when the Swagelok® fitting was designed in 1947 was applied to the design of a single ferrule. This allowed us to eliminate the necessity of using two ferrules, thus eliminating the problems that are part of a two ferrule design. These problems eliminated were:

1. Ferrule mix-up
2. Ferrule loss
3. Vibration sensitivity
4. Multiple sealing points

A second reason for wanting to use a single ferrule was the fact that all industrial and military specifications such as the SAE specifications require the use of a single ferrule.

In the early stages of design we, just as Swagelok® had, utilized pure compression to achieve both the holding power and sealing functions. This proved to be an excellent design in the small sizes (3/8" O.D. and below) because the tube, even in the thin wall has enough hoop strength to resist collapse. Here the first method of sealing, as mentioned in the section on sealing, was applied. The ferrule acting on the tube and fitting body through pure compression where the strength of the tube and fitting body is high enough to resist unwanted deformation and thus allows enough stress to be imparted into the mating surfaces to mash or iron out the hills and valleys surface irregularities. While tube deformation is small, enough is present to achieve the necessary holding power.

In larger sizes (1/2" O.D. tube and larger) we, just as Swagelok® had, developed problems caused by the low hoop strength in thin wall stainless steel tubing. In this case the ferrule force necessary to iron out the tube surface irregularities was often greater than the hoop strength of the tube and tube collapse would occur. As this was a borderline area, we had to go back to the drawing board (and computer) to find a new solution. Finally, through a redesigned ferrule configuration tied in with proprietary hardening of the ferrule, there evolved a ferrule that worked with a combination of a light grip and compression. In this ferrule enough compressive action is achieved to create, through the coining action of surface irregularities, the seal between the ferrule and the body of the fitting while an additional amount of compression is imparted to the tube, thus achieving a slight swage which serves as a part of the necessary holding power. The real sealing and holding power action between the ferrule and the tube is achieved by the light grip of the hardened ferrule. Here the hard, sharp edge at the front of the ferrule penetrates the tube surface, thus cutting through any draw marks or surface abrasion caused by handling, and a gas tight seal is achieved. This same light grip serves a holding power function in that the tube is held in shear and therefore a blowout cannot occur. This is because a light layer of material from the location of the grip to the front end of the tube would have to shear off. The grip principle, which is the same as that used in all flareless hydraulic fittings, is applied lightly enough to eliminate any danger of thin wall tubing collapse.

The Parker CPI™ Single Ferrule

There are many obvious reasons why a single ferrule is better than multiple ferrules:

- Fewer pieces to handle.
- One right way and one wrong way to assemble as compared to one right way and over ten wrong ways for a multiple ferrule unit.
- One larger ferrule is less likely to get lost than two smaller ferrules.

Of course it could be argued that you do not have to take the fitting apart to use it. But it should be remembered that it will always be an inexperienced technician who will take it apart just "to see how it works." And this same inexperienced person will be just the one most likely to reassemble it incorrectly.

Beyond the obvious advantages, however, let us consider how the single ferrule fills the bill in functional areas of its design.

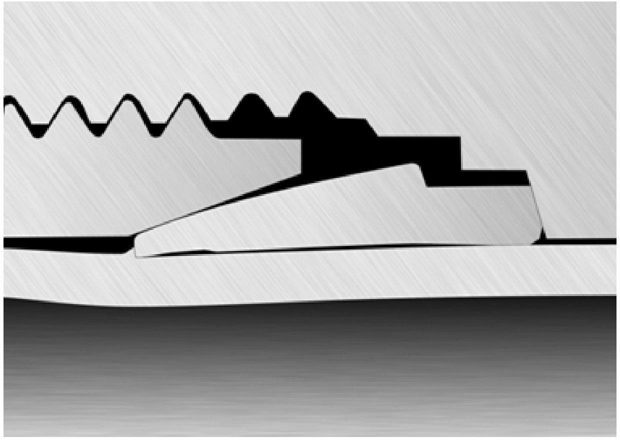
Sealing

We have already covered how we can get the sealing action. Now let us cover where we get this action with the single ferrule and how it compares to the old multiple ferrule approach.

The key point in sealing is not how many sealing points you have (the number of sealing points being used as a sales advantage by many fitting manufacturers), but how many sealing points do you need to have? Each extra sealing point you must have in a single ferrule increases the odds that you may not get every one of the necessary seals and therefore end up with a leak. As an example, the military resisted acceptance of any flareless fitting over a flared fitting for use in a flight vehicle because flareless fittings must have at least two sealing points, these two necessary sealing points being between the ferrule and the tube. The fact that there were more needed sealing points resulted in a feeling that there would be greater probability of leakage. In contrast, flared fittings have only the one sealing point, this being between the male nose on the body of the fitting and the female cone of the flare on the tube.

Points A and B, are the two necessary sealing points. These sealing points are the outside of the ferrule and the body of the fitting (compression seal point A), and the seal between the front inner edge of the ferrule and the tube (combination compression and light grip seal point B.) While this arrangement is not as simple as the single sealing point on a modern three piece 37° flared fitting, it is much simpler than the three necessary sealing points on a multiple ferrule fitting.

Vibration



In the design on the tube fitting, two considerations must be made for the effects of vibration. The first concerns itself with the fitting nut shaking itself loose and allowing the fitting to uncouple. To compensate for this action you may incorporate lockwires, ratchet nuts or other means from a host of expensive methods which lock the nut in place. In a production fitting such as those used in instrumentation, however, you will find that the fitting design incorporates "component loading" for a lockwasher effect. Here the parts (nut, ferrules and body), are designed to become "sprung" like a spring under compression during make-up. In this "loaded" condition the energy stored in the sprung components exerts enough stress on the components to hold them together by contact area friction.

While a multiple ferrule system has some ability to become sprung or loaded, its energy storing ability is much lower than that of a single ferrule system where in the ferrule is actually designed to spring or bow like a Belleville washer[1].

No less important is the effect of vibration on any stress risers that may be present in the fitting design. A stress riser is defined as an abrupt change in section about which stress may concentrate. Glass cutting is a good example of how stress concentration is used. Here a small scratch line is made on the surface of the glass with a cutter and the glass is broken along this line. The stress riser is the line made with the cutter and the clean break is achieved by concentration of the stress at the stress riser.

Another example of a stress riser situation is the common wire coat hanger which is often pressed into service around the house as a source for wire to repair some broken item. If you can remember the last time you used a coat hanger for this purpose you can probably remember how you cut the wire length, especially as you did not have a pair of wire cutters. You probably used one of the following methods to cut the coat hanger. First, you may have held it between both hands and bent it back and forth for a few years until it finally work hardened and broke. If you used this method, however, you did not know at exactly what point it would finally break. If, on the other hand, you are a precision "do it yourself" addict, you probably put a nick in the hanger at the point where you wanted it to break,

1 A Belleville washer is a form of a spring shaped like a conical or flared flat washer. Its capability of developing a high amount of stored energy under a minimum amount of deflection is among the highest of all spring types.

and then with a few bending strokes caused it to fail at the nicked point. If you did use this method you used a stress riser (the nick), and stress concentration (all of the work input on the bending concentrated at the nicked point), to cause repair failure.

As you can see from the above, a tube fitting that puts a nick or grip into the tube could hardly be considered a “standard” unless some provision is made to isolate the input stress caused by vibration from the grip or stress riser area. This isolation is one of the strongest points of a single ferrule fitting when it is compared to a multiple ferrule design. The grip in a single ferrule fitting is at the front of the ferrule and is isolated from incoming vibration by the grip made on the tube at the back of the ferrule. The incoming vibration stress is routed in to the fitting system via the ferrule to the nut and onward to the body and therefore never sees the grip area. This grip is achieved by the action of the nut upon the ferrule which causes it to bow and came downward upon the tube. Note that the ferrule in its gripping action never penetrated the surface of the tube and therefore does not cause a stress riser to appear at this point. This shows where the ferrule has gripped the tube.

Thermal Shock

Thermal shock is the stress induced into a fitting system through a rapid change in temperature. Unfortunately, most concern with thermal shock problems is given to assuring that all parts are of the same material so that the expansion/concentration rate will be identical.

All too often, however, the mass of each unit component and the thermal conductivity of the system as a whole are forgotten factors. The relative mass of each component is important because a larger part will gain or lose heat over a different time span from a smaller part. In a fitting having parts with a larger mass difference, part interaction or movement will occur before temperature saturation of the whole unit is reached. The more parts that are present with a large mass difference, the more pronounced the part interaction. This interaction results in “nipping” at all seal points, causing grip to dig in deeper and mating compression sealing points to move in relation to each other. This nipping action can be compensated for by loading the parts to move in or out under almost the same component load as that given by the original make-up. But once this spring load compensation ability has been used up, a leak will occur.

Naturally, if you can store up more spring action in the loaded components, you can expect more adjustment to thermal cycling over a longer period of time. This is the strong point of the single ferrule in relating to thermal shock. Not only is it just one part having a mass relatively closer to that of the whole fitting system, but the single ferrule also has an extremely high “spring” loaded factor which allows it to compensate for thermal stress.

In the single ferrule CPI™ system, there are only four points to offer resistance to heat conductivity. These are at the contact points between the:

1. Ferrule & Body
2. Ferrule & Nut
3. Front of the ferrule & tube
4. Rear of the ferrule & tube

With a multiple ferrule system you have one more resistance point – this being between the front and rear ferrule.

Summing up, the larger single ferrule has:

1. One less thermal contact point.
2. Heavier mass and less pieces, which means one less problem caused by mass difference.
3. The ability to absorb through its superior springing action any movement caused by thermal shock.

CPI™ Fittings – Other Advantages

On top of being completely interchangeable and having the superior single ferrule approach, the CPI™ fitting offers quite a few other benefits over all other available instrumentation fittings.

Lubricating

The most important benefit in lubrication is seen in the CPI™ stainless steel fittings. This is because it is the only stainless steel instrumentation fitting with pre-lubricated components.

The lubricant used is a baked on, multiple coating, dry film lubricant manufactured under the trade name of Everlube 620 and consists of molybdenum disulfide in suspension in an organic resin base. It is dark gray in color and applied to all surfaces of the CPI™ stainless nut.

As a lubricant or anti-galling device it is twice as effective as the common internally silver plated nut used in other fittings of this type. For example, the average make-up torque for a CPI™ tube fitting ("moly" coated nut) is roughly half that of a silver plated nut. This is because the moly is a lubricant while the silver plate only provides a differential metal bearing surface which still requires lubricant.

The advantages of the molybdenum disulfide are readily seen in the above because a technician will not consistently achieve the full 50 to 60 pound pull necessary on the average 10 inch wrench in order to make-up the plated nut fitting while the 30-32 pound force needed with the moly coated fitting is quite readily achieved. On the other hand, because of the easy pull required it should be noted that it is very important that technicians using the moly coated nut are informed as to proper make-up techniques so that they do not overmake the fitting and thus lose the ability to achieve a reasonable number of remakes.

It was mentioned above that silver plated nuts require a lubricant because the plating exists only as a bearing surface and not a lubricant. This silver plate may be compared to a connecting rod bearing used in the common automobile engine. Here a thin insert bearing of a dissimilar material is used to isolate the steel of the crank from the steel of the connecting rod, but the engine still needs oil for lubrication. This is why a product called "goop" is offered by one of the multiple ferrule fittings manufacturers.

In cases where the appearance of the final assembly is more important than functional remakes, Parker Hannifin CPI™ fittings are available with the internally silver plated bright external finish stainless steel nuts. These nuts have a 99% pure silver plate with no copper content as is found in other such nuts. This high level of purity is maintained in order to avoid a copper-silver alloy situation which can "braze" the fitting together at elevated temperatures.

Silver Plated Ferrules

Silver plated ferrules are available for use in the lower range of CPI™ sizes for use in extremely critical applications.

The need for the plated ferrules is caused by the lack of deflection strength in the small size fittings. As you will recall, we have determined that the compression seal between the ferrule and the body seat was achieved by coining out the hills and valleys in the surface finish for a gas tight seal. We also mentioned a limitation caused by the fact that this coining action depended upon the parts being strong enough not to deflect away from the coining action. Unfortunately, the smaller Swagelok® body, and therefore the CPI™ body, is not strong enough to stand this coining action and the fittings have more noticeable leak rate as a result. While this normal leak rate accounts for only 27 cubic inches of helium yearly it can be drastically reduced by at least a one hundred factor by the silver plating process.

The extremely low leak rate of the small silver plated ferrules will prove highly interesting to those persons in fields such as gas chromatography who have learned to live with the higher leak rate of the multiple ferrules. Because of the small size of the helium molecule there is really no “screw together” type of fitting that will give a leak tight seal. It can only be hoped to reduce the leakage to an acceptable level. This is because it allows a lower leak rate connection that imparts less stress into the fitting body, therefore giving longer component life. It should be noted that field objections may arise to the incompatibility of silver to some media. Those objecting should first be cautioned that we are concerned with the plating as applied to stainless steel, and that the media which will react with the silver will more often react more violently with the stainless base material. All in all, the silver plate approach provides an excellent solution to leakage problems when concerned with part per million or billion analysis.

CPI™ Nuts

Where high usage makes it economically possible, all CPI™ nuts are manufactured by a high quality heading process. Here the nut is not cut from straight grained bar stock, but cold formed in five steps from heading “wire,” (actually 3/4" to 1" diameter coiled rod) dropping off of the header complete except for threading.

The advantage of a headed nut is in its strength which often will run 30% higher than a normally processed nut. This is because the grain of the material is forced to conform, similar to a rolled thread, to the nuts contour while the cut part process cuts through the grain of the material.

Parker SuparcaseTM

The Parker Suparcase ferrule is a new breakthrough as a result of technology transfer from extensive research into super-corrosion resistant austenitic stainless steel by Parker’s Research and Development Group. The Suparcase ferrule has been developed to greatly enhance the corrosion resistance and hardness of ASTM type 316 stainless steel. Due to the Suparcase ferrule’s unique set of physical characteristics, it is ideal for instrumentation fitting ferrules which must seal and grip on commercial stainless steel tubing.

The Parker Suparcase ferrule has the following features, advantages and benefits to the user:

1. Superior or equal to ASTM type 316 stainless steel in a broad range of corrosive applications.
2. Not affected by the standard working temperatures of ASTM type 316 stainless steel.
3. Superior resistance to pitting compared to ASTM 316.
4. Superior to ASTM 316 in stress corrosion tests.
5. A high surface hardness that prevents galling and increases remakes.
6. Proven in field applications throughout the world.

Typical Sample of Corrosion Resistance Corrosion Environment Suparcase Ferrule compared to Untreated ASTM 316 Acetic Acid Superior Boiling Nitric Acid Equivalent Hydrochloric Acid Equivalent ASTM Salt Spray Test #B117 Equivalent Sulfuric Acid Superior SO2 Atmosphere Equivalent 34% MgCL2 Stress Corrosion Test Superior Elevated Temperature Test The upper temperature limit for the use of ASTM 316 stainless steel in tube fittings is established by the potential formation of carbide precipitates. The Suparcase ferrules are fully functional at these temperatures.

Stress Corrosion Stress corrosion tests confirming the superiority of the Suparcase ferrule have been carried out in 34% Magnesium Chloride solution under pure bending conditions with constant load. The Tensile stress in the specimens is 29,000 lbs. in 2 that are about 80% of the 0.2% yield stress.

The first tests were carried out with ground specimens of ASTM 316 at a temperature of 158 degrees F. The results are shown in the following table. Time to rupture in hours of ground ASTM 316 specimen is shown below. Temperature of 158 Degrees F Untreated ASTM 316 Suparcase Ferrule Failure at 262 hrs. No failure at 3,000+ hrs. Failure at 339 hrs. No failure at 3,000+hrs. Failure at 333 hrs. No failure at 3,000+ hrs. Failure at 304 hrs. No failure at 3,000+ hrs.

Surface Hardness The Suparcase ferrule has a surface hardness greater than a ferrule produced from untreated ASTM 316. This means that the Suparcase ferrule will seal on welded and redrawn as well as seamless ASTM stainless steel tubing and hold it to its burst pressure.

Infusion into the Surface of the Ferrule The hard surface of the Suparcase ferrule, because of the complete infusion into the surface, creates no dimensional changes. The Suparcase ferrule integrity is unaffected by initial or repeated remakes.

That we have met our design goals is evident. We have produced an interchangeable fitting; and by virtue of its single ferrule and further features as covered above, we have assured the customer of a more modern, up-to-date instrumentation product.

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