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2/10/2006

Assembly
Of an Electrostatic
Quadrupole

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Background

In the ISOLDE hall there are several quadrupoles mounted in the beamlines; these are essential equipment used for beam transport by the Machine Supervisor when he sets up beam for various experiments. The quadrupoles are used to correct the focusing and position of the produced ion beam.

This document will try to explain a little bit about the function of a quadrupole and also show the various parts needed to build one of the types that we use at ISOLDE.
It will also show some problems that you can run into during the assembly, what you need to take extra care about and how I solved the problems that I ran into when putting my quadrupole together.

What is a QP?

Quadrupoles are designed to create an electric field whose magnitude grows linearly with the radial distance from its longitudinal axis, which is usually centered on and parallel to the main motion of the charged particles.

The net result of these fields is a focusing force in one plane and a defocusing in the opposite plane. In a quadrupole there are four pole tips: two opposing positively charged and two opposing negatively charged ones. The pole tips create the electric field by a large electric current being applied to them.

In a particle accelerator, the quadrupoles are required for steering and focusing of the beam. The quadrupoles are of two types: 'F quadrupoles' (which are horizontally focusing but vertically defocusing) and 'D quadrupoles' (which are vertically focusing but horizontally defocusing). This situation is due to the laws of electromagnetism (the Maxwell equations which show that it is impossible for a quadrupole to focus in both planes at the same time.)

If an F quadrupole and a D quadrupole are placed immediately next to each other, their fields completely cancel out. But if there is a space between them (and the length of this has been correctly chosen), the overall effect is focusing in both horizontal and vertical planes.

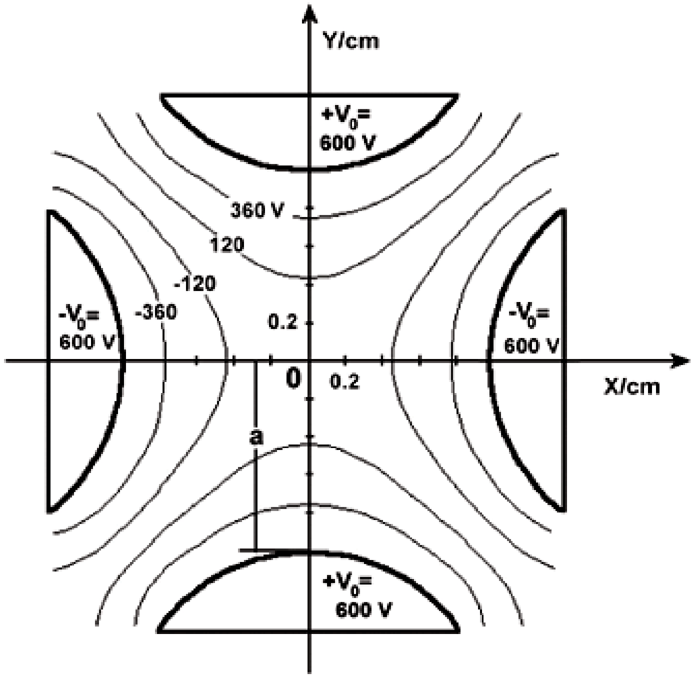

Figure 1. Electrodes and equipotential lines in an electrostatic quadrupole.

Getting started

The first thing to do is to make sure you have all the parts needed and to try to get an understanding about how they are supposed to be assembled.
Detailed drawings are of course of much help since they will provide all information of which parts that are needed and how they fit together.
In my case I had some drawings from a "similar" quadrupole that helped me out but if you have never built a quadrupole before I would recommend that you try it out by hand, the pieces more or less tell you how to be mounted by themselves once you have them in front of you.
Beware though, some parts are quite heavy while others are fragile (ceramic insulators) and could easily be damaged if handled without care.

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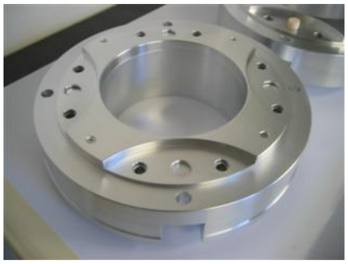
I will now show some of the parts that build up the quadrupole:

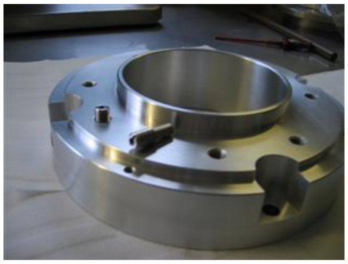

Pic.1

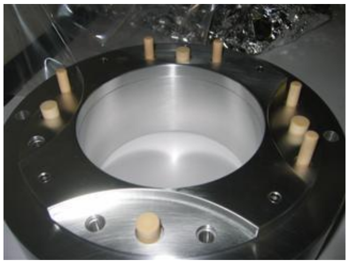

Pic.2


Pic.3

These first three pictures show two parts that are essential for the QP-interior; they are screwed together by 4 small screws of stainless steel (Pic.3).
There is two of each of these “end pieces” and they will both be aligning the four pole tips.


Pic.4


Pic.5


Pic.6

In the Pic.4 we have a couple of special screws that will act as supports for the ceramic insulators seen in Pic.4, these screws are made of stainless steel and you will need 16 of them (8 in each of the two “pole tip holders”).
The screws are screwed from the back side as seen in Pic.5, fine adjustments will be made possible with them later on in the mounting process.

In Pic.6 we can see the ceramic insulators that will shield the 4 pole tips from the rest of the quadrupole. On each end piece you will need 8+4pcs of insulators and those are simply inserted in their holes (Pic.2&6).
The two outer holes are deeper than the one in the middle and tolerances are very small which can sometimes make it a bit difficult to fit the ceramic parts. Take extra care when handling these parts as they are a bit fragile.


Pic.7

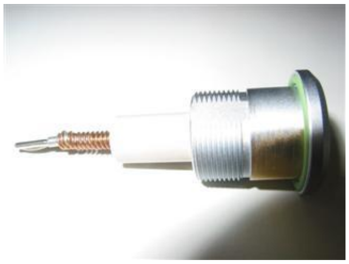

Pic.8


Pic.9

Pic.8 and 9 show the pole tips and on each end of them is a small aluminum plate attached and fixed in place with 3 screws. The plates keep the middle insulator in place. When looking carefully on the flat side on the pole tip one can see a few holes, one of them will have direct contact with the High Voltage-Fischer connector once in place.


Pic.10


Pic.11


Pic.12

The Fischer-connectors used are specially designed to work under vacuum-environments and electrically insulated for use with high voltages.

Pic.10 shows what will be seen from the outside of the quadrupole once in place, this is the connector for the HV-cables that will electrify the 4 pole tips.

Pic.11 shows the Fischer connector up front as it looks when shipped from the manufacturer (the steel ring in the middle of the connector is not needed and should be removed). In the behind (left) you can to the left see an aluminum-ring that will be screwed onto the quadrupole casing and that will keep the connector in place, once fitted it will also make sure that the pressure is sufficient for the green O-ring to keep the connectors vacuum-tight. Behind (right), you also have a custom made part that consists of a cupper-spring and the ‘pin’ that will go into the hole on the pole tip.

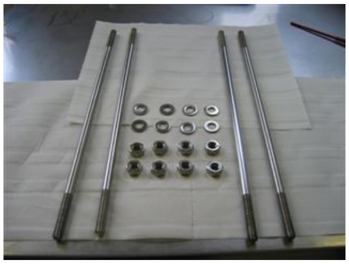
Pic.12 shows the Fischer-connector ready to be put in place. Take notice that the cupper-spring has been reduced in its length to make a better fit in the QP.
The length should be somewhere around 10-12mm.


Pic.13

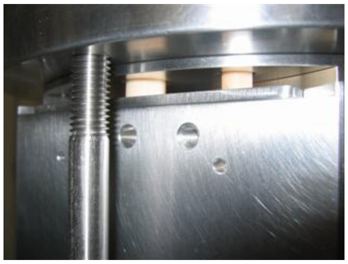

Pic.14

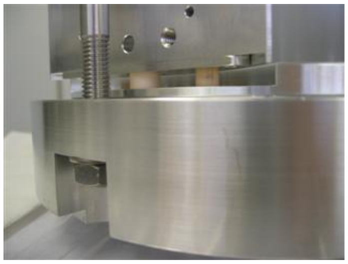
Pic.13 & 14 display the four points where the connectors slide in and then are fixed with the ring mentioned in Pic.11. As you can see you will need 16 screws (4 on each holder) for this operation.
Once the connectors are in place they will provide high tension for the 4 pole tips but the rest of the quadrupole will be electrically shielded.


Pic.15


Pic.16

To provide extra stability to the quadrupole, four stainless steel rods (Pic.16) will be holding the two end pieces together. This is helping to lessen the stress on the ceramic insulators as well. Take extra care here as well when you tighten the screws, un-necessary force should be avoided at all times. A firm tightening is all that is needed.
Pic.15 shows the 8 nuts (size M10) and washers that should be used, two of each on each of the rods.


Pic.17


Pic.18


Pic.19

Pic.17-19 show how the rods are holding everything together and also how the pole tips are shielded from the rest of the quadrupole.

Pic.18 clearly shows the hole (uppermost one), where the connector-pin will enter.

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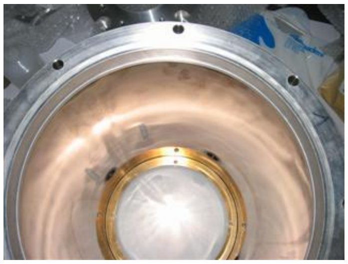
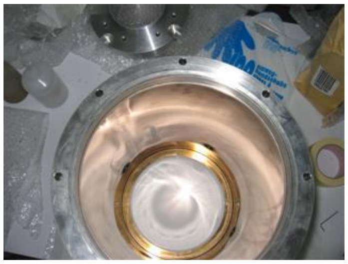
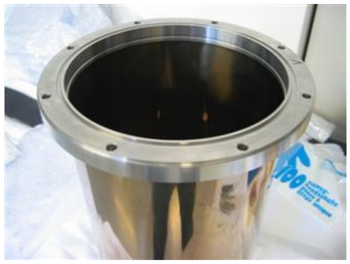

Pic.20

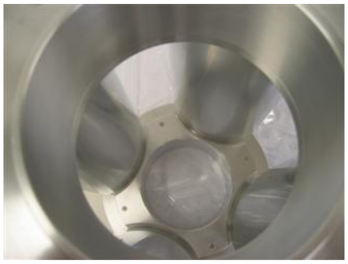

Pic.21


Pic.22

Pic.20 and 21 show the ‘tank’ or ‘casing’ in which the QP-interiors will be housed. Notice the four small holes that are to be found on the golden-colored ring in the bottom, once interiors are in place, these holes will be used together with 4 screws to hold the interior part firmly against that end. Screws are obviously tightened from the outside.

Also take notice in the small ‘track’ that is edged into the top plate about 10mm in from the 8 holes (easily spotted in Pic.22). This track will be where a large rubber O-ring will be placed to keep it vacuum tight, on the other side of the tank this ‘track’ is NOT present.


Pic.23


Pic.24

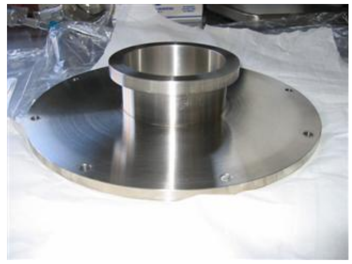

Pic.25

In Pic.23 you have an overview of how the interior parts of the quadrupole looks.

In Pic.24 we look from above, here you’ll see the 4 convex pole tips that are very well aligned facing each other.

Pic.25 is a overview of the tank in which the interiors (Pic.23) will be lowered into and attached.

Pic.26



Pic.27

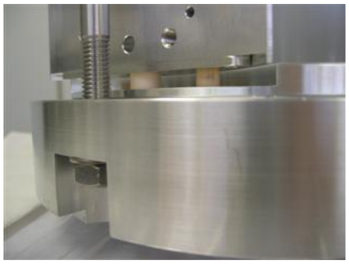
Pic.26 and 27 show the 2 end plates that will be fitted on each side of the tank (Pic.25). They are screwed together using the 8 holes (i.e. Pic.22).

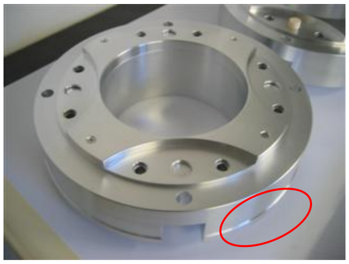
Cleaning of the parts

Since a quadrupole is working under vacuum and high currents are used it is essential that they are absolutely clean from any oxides, grease or other contaminants.
It is also of high importance that the pole tips are completely smooth; because of this every part should be absolutely clean.
To clean the parts one can first use gasoline together with a special tissue to rub all parts respectively and then followed up with alcohol to degrease the surfaces.
During cleaning (and assembly) it is very easy to get unwanted grease on various parts; one should therefore use plastic gloves and make it as a habit to change them very frequently.
Although this cleaning is good for a start it is not enough so to have every part completely pure one should contact a service here at CERN that remove oxides and perform a deeper cleaning by washing the parts in acid baths.

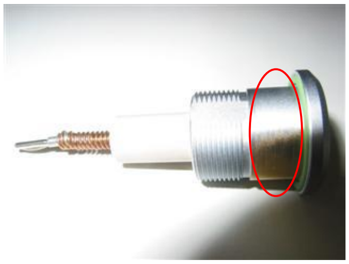
Assembly problems

During the assembly I ran into a couple of problems.
If you take a look at the interior end pieces (Pic.28 and 29) you will notice that the one on Pic.29 has a small raised edge. The tolerance between this edge and the tank was so small that when you lowered the assembled interiors into the tank you would easily get in a situation where the two parts got stuck and risking the ceramic parts to be damaged.
To remedy this situation I had a CERN workshop to take of 1/10th of a mm of the edge's diameter.


Pic.28


Pic.29

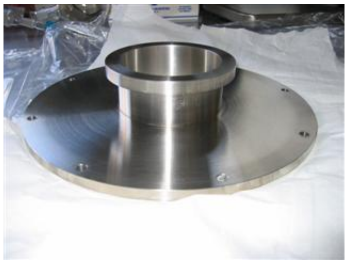
Another problem that showed up was that one of the holes where the Fisher-connector would be located had a bad fit, I tried several connectors but none would fit in that hole. Unfortunately the tank had been at the cleaning service and the interiors had already been inserted so a physical modification of the tank, risking it to be dirty or having metallic dust inside was out of the question.
The solution was simply to have the Fischer-connector diameter reduced a little.
(See Pic.30)


Pic.30

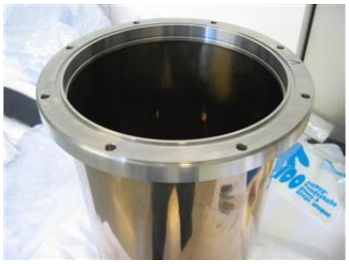

Pic.31

The last major modification that needed to be done was due to the fact that I had two end plates that were both intended to fit on the opposite side of what you can see in Pic.34. As both end plates already had the O-ring ‘track’ edged into them and I needed a completely flat end plate or I would have two O-rings on top of each other.
So one end plate was mounted in a machine and turned flat.

Pic.32



Pic.33



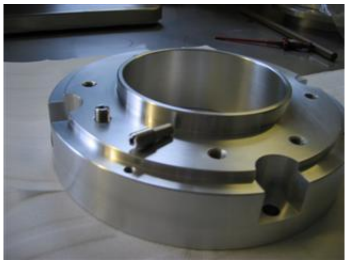
Pic.34

General Tips

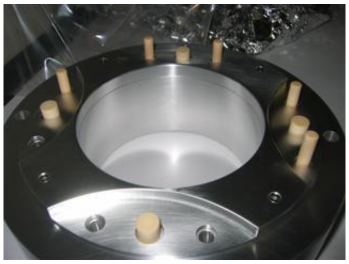
A thing to notice and that I learned during the assembly is how much more difficult everything gets when you need absolute clean parts. Not only is it hard to do the assembly by itself without getting grease or other unwanted dirt on the pieces. Once the parts are absolutely clean their surfaces have lost their ‘normal’ lubrication and what seemed to be easy before, like screwing one of the screws in Pic.35&36 could be a real treat. The parts stick together and you could end up damaging them if you start using to much force. A simple but very effective solution to this was to use special vacuum grease and to apply a minimal layer on the screw threads.

The ceramics had the same problem but here a tiny bit of alcohol on the parts would do the same job (Pic.37).

Pic.35



Pic.36



Pic.37

When parts are clean and during the whole assembly it is imperative that one use plastic gloves and make it a habit of changing them often, every five minutes or at any indication of contamination is a good rule to follow.

Testing

'Metrologie'

When the quadrupole has been assembled there are a couple of tests that it should pass. The first one is not really needed for its function but rather to see how well aligned the interior parts are. There is a service here at CERN called 'Metrologie service' at this place they mount the quadrupole in a high precision measurement equipment which can determine the parts alignment in the X,Y & Z-axis's from this measurement you will get an idea of what to expect from it. I learned that in order for the metrologie to make these measurements the interiors of the QP must not be assembled with the tank; their equipment will not be able to do the measurements otherwise.

Vacuum

After this test the quadrupole must also be tested to see weather it is vacuum tight or not. For this test a vacuum specialist should be contacted, they will have the possibility to test this QP in an offline vacuum-test system.

In my case I got the following result:

Pressure: 2.10-7 mbar
Sensitivity Helium: 5.10-10 mbar.l.s-1

In other words, the quadrupole was vacuum tight!

Electrical

One should also test the electrical features to see that:

1. The four pole tips are shielded from the rest of the exteriors.
2. The Fischer connectors have contact with each of the four pole tips.

This test should be done by a specialist in high tension since he will test the quadrupole to see that it can withstand voltages up to around 6kV. The tests should be done offline and in atmosphere conditions.

This test was also successful in my case!