Repair of the H^- ion source

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The H^- ion source has been providing high-intensity H^- and D^- ions to the K150 cyclotron since 2008. The H^- source is a magnetically filtered multicusp volume ion source [1] and operates in two stages. In the first stage, a hot filament of tantalum ionizes hydrogen gas into H^+ and e^-. The resulting plasma is confined by permanent magnets positioned around the ion source chamber (the "multicusp" field). In the second stage, near the exit of the ion source, but before the extraction region, there is a magnetic filter stage that also consists of permanent magnets. The magnetic filter serves two purposes. First, the field in the magnetic filter region is strong enough to prevent all energetic electrons from escaping the plasma chamber of the ion source in the first stage. Second, the magnetic filter captures low energy electrons which are capable of dissociating H_2 molecules in the following process:

$$e^- + H_2 \rightarrow H_2^- \rightarrow H^- + H$$

which is the main method of producing H^- (or D^-) ions in the ion source. The resulting negative ions are then extracted with a voltage of 8-10 kV and injected into the K150 cyclotron for acceleration.

In December 2014, a water leak was discovered in the H-minus ion source. The source of the water leak was a small hole in one of the water cooling lines that make up the magnetic filter part of the source mentioned above. A picture of the magnetic filter region of the ion source before the repair is shown in Fig. 1.

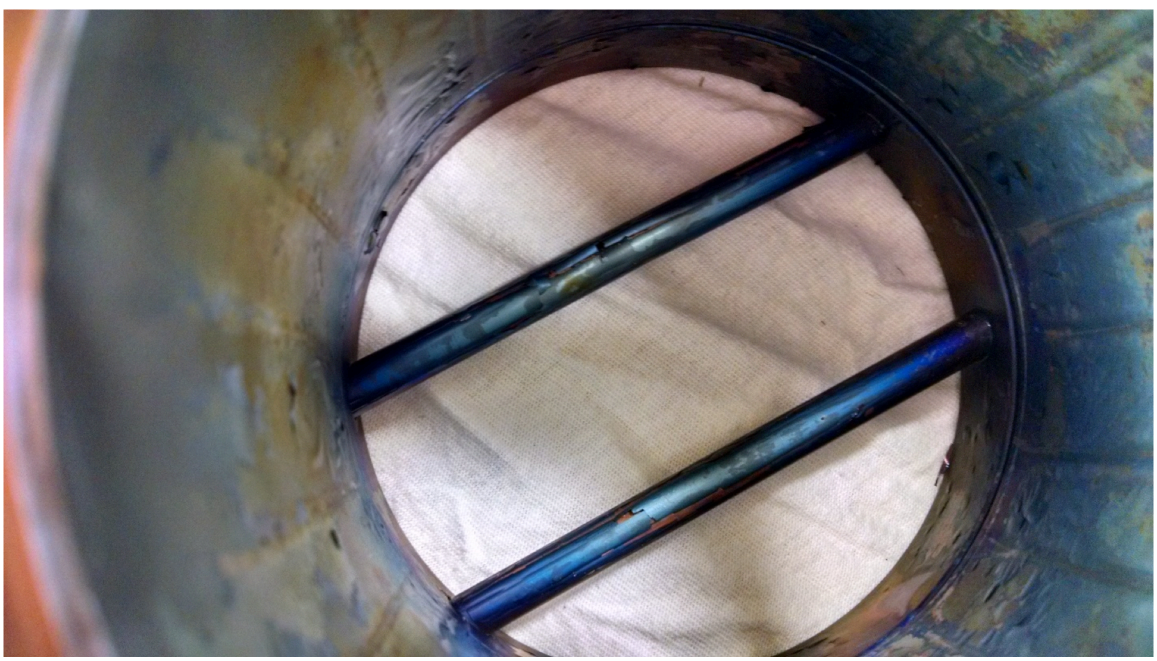

FIG. 1. Picture of the inside of H^- ion source plasma chamber with the tantalum filament removed. The magnetic filter region is formed by the field from small permanent magnets housed in the two copper water cooling lines that pass through the middle of the chamber near the source exit. The damaged water cooling line is the upper pipe in the picture.

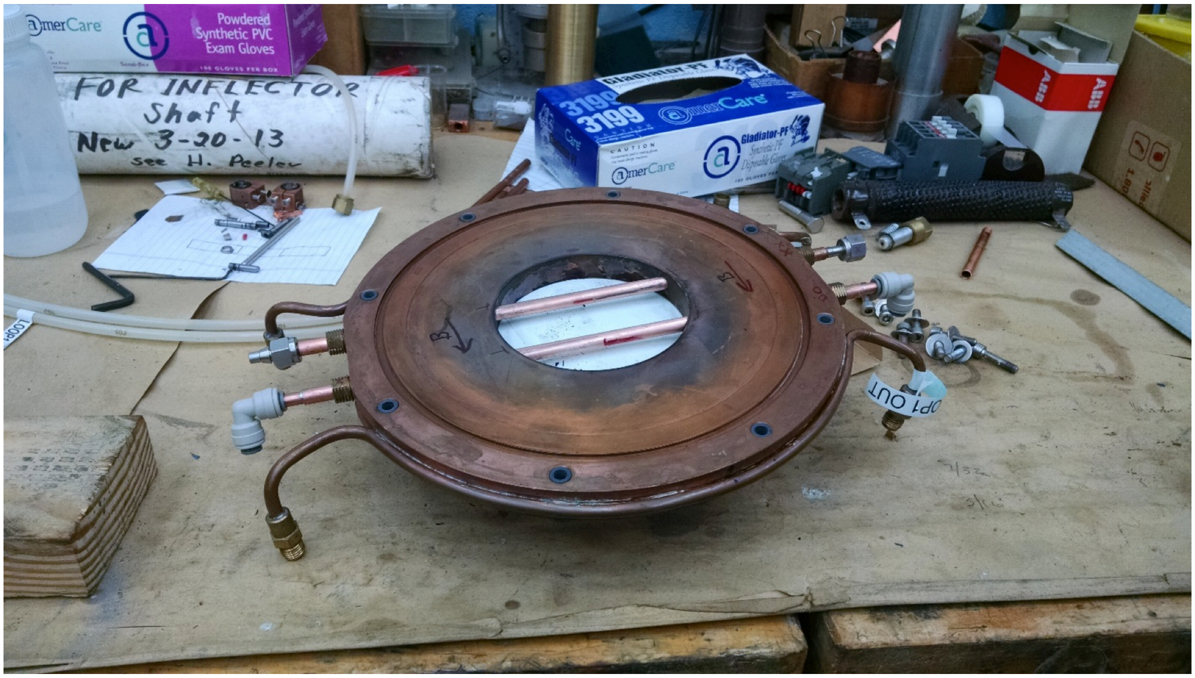

FIG. 2. The new cooling line installed in the magnetic filter region of the H^- source. The north poles of the permanent magnets are aligned perpendicular to the path of the extracted beam as shown above.

To repair the leak, the upper cooling line shown in the figure was removed. The first idea for the repair was to try to plug the hole with solder or similar material, but the heating process would likely damage the permanent magnet that was housed on the inside of the cooling line. Also, when the magnet was removed from the damaged copper line, it was found to be broken and severely corroded. In the end, it was decided to make a new cooling line with a new permanent magnet embedded in the middle. We found that we had purchased some replacement permanent magnets during the original installation of the ion source. The magnets are made of $SmCo_5$, and are held in place in the middle of the cooling line where they are kept cool with low-conductivity water. The new cooling line consists of two of the replacement $SmCo_5$ magnets super-glued together pole to pole on a thin rod of Inconel. The resulting rod was then mounted in the middle of the new copper cooling line and reinserted into the plasma chamber of the H^- ion source. Finally, the north poles of both of the magnetic filter permanent magnets were aligned in the same direction and perpendicular to the path of the extracted H^- beam. The new cooling line installed in the magnetic filter region of the source is shown in figure 2. When the ion source was reassembled, the inside of the plasma chamber was also thoroughly cleaned to remove the deposits that had built up on the walls.

As a result of the repair, the H^- ion source is again operational and is producing H^- ions with intensities similar to those observed previously. However, the extraction optics of the ion source have changed slightly now that the new permanent magnet has been installed. This slight change does not significantly affect the performance of the ion source.

[1] H. Zhang, Ion Sources, (Science Press, Beijing, 1999). Section 8.6.3, p. 364-368.