Operating Instructions for the HEPA Filter Disassembly Station

Introduction:

The purpose of this manual is to describe the correct procedure for disassembling a nuclear grade HEPA filter inside of a hot-cell environment with the Filter Disassembly Station. This manual is intended to be followed step by step in the order that it is presented. Deviation from these steps can result in mechanical failure of the disassembly station or of the slave manipulators. A description of the filter as well as the disassembly station has been provided to help the user understand how the device works. Refer to the description section to understand the terminology used throughout the manual. Also be aware of additional comments added below certain steps in the process. These notes are there to help better describe the process and eliminate any confusion. Make sure to read these because they have important information on the disassembly process.

Description of HEPA Filter:

The disassembly station has been designed with a certain HEPA filter in mind. The particular filter that we have focused on is a 24” x 24” x 11”, type 304 stainless steel, gasket seal, nuclear grade HEPA filter (See Figure 1). These are the largest filters made by Flanders Corp. The model number for this particular filter is T-007-C-43-05-NE-00-GGF.

![Figure 1: 3D View of HEPA Filter](image)

The frame consists of 4 pieces of stainless steel that are bolted and adhered together. There are two different types of frame pieces, but they have similar characteristics. The main distinguishing characteristic is that one frame piece is longer than the other. They are similar in that they both have a 14 gauge thickness, and a C shaped cross section.

Between the filter frame is the filter media. The filter media consists of fiberglass paper and thin aluminum separators. The fiberglass paper is folded over and over in an accordion-like fashion and the aluminum separators fit between the folds in the fiberglass. The filter media is attached to the two longer sides of the frame with a very strong and durable adhesive.
A metal wire grid covers the open sides of the frame to protect the filter media from foreign objects. A rectangular metal overhang is welded around the perimeter of the frame with the wire grid underneath. The wire grid is not actually welded to the frame. The wire grid is just wedged between the metal overhang and the frame.

Description of Filter Disassembly Station:

Filter Disassembly Station is composed of two main systems (See Figure 2):
1. Turntable Mechanism
2. 3D Motion Mechanism

Figure 2: 3D View of Disassembly Station

Turntable Mechanism:

The turntable is composed of many complex parts but the operator should only be concerned with the following (See Figure 3):
1. Turntable Locking Pin
2. Hinge Lever
3. Locking Lever Hand Crank
4. Locking Levers
5. Round Plate
These are the parts that the operator will be using during the course of disassembling a filter.
The turntable mechanism is a locking platform that can reorient the position of the filter. This mechanism allows the operator to lock a filter in place while still allowing for complete accessibility to any side on the filter. Each side of the filter must be accessible in order for the slave manipulator operator to completely disassemble the filter. This has been accomplished by designing a locking platform with the freedom to rotate about two separate axes.

The filter is locked into place on top of a locking platform. The locking platform consists of a number of structural pieces, two locking levers, and a dual-threaded lead screw assembly that drives the locking levers (See Figure 3). The locking levers are opened or closed with a hand crank located on the end of the hinged platform. This mechanism can then be rotated about a horizontal or vertical axis to obtain the correct filter position for a given operation.

Rotation about the horizontal axis is provided by a hinge mechanism that is controlled by a lever. The locking platform is attached directly to the hinge mechanism, which allows the filter to be rotated 90° about the horizontal axis. This allows the operator to flip the filter from a vertical position to a horizontal position. The hinge lever faces the operator in the hot cell, so that it can be easily accessed by the slave manipulator arms.

Rotation about the vertical axis is provided by the large turntable which is mounted underneath the round plate. This turntable provides 360° of rotation in any direction about the vertical axis. The hinged locking platform is mounted above the round plate and offset to one side. A small locking pin allows the operator to lock the turntable into one of four positions. These slots are positioned 90° apart from each other,
which allows for four different filter orientations. The locking pin must be pulled out of the slot with the slave manipulators before the round plate can be rotated (See Figure 4). The locking pin is spring activated and the pin locks into place when it lines up with one of four slots in the round plate.

The combination of the two axes of rotation allows the operator to access all sides of the filter with the 3D Motion device. The front, back, left and right sides can be accessed by rotating the turntable, while the top and bottom sides can be accessed by rotating the hinge plate.

3D Motion Device:

The 3D motion device is the most complex device in the disassembly station (See Figure 5).

Figure 4: Locking Pin Assembly

Figure 5: 3D Motion Assembly
The operator should be concerned with only a few parts.
1. X-Dir Hand Wheel
2. Y-Dir Hand Wheel
3. Z-Dir Hand Wheel
4. Interchangeable Tool Mechanism

The 3D motion device is a three-degree-of-freedom linear motion system. A sliding block in the middle acts as a tool mount. The tool mount is interchangeable, allowing for the attachment of multiple tools. These tools can be moved within a space 26” x 28” x 30” in the x, y and z directions respectively. This range of motion allows for an operator to maneuver a tool anywhere necessary during the disassembly of the HEPA filter. The motion is driven by two types of mechanisms: 1) Lead Screw and 2) Rack and Pinion.

Lead screw driven linear motion mechanisms drive the tool mount in both the x and y directions. The lead screws are driven from hand wheels, which are positioned so they face toward the hot cell window. These hand wheels can be easily cranked by a slave manipulator. Unfortunately, it takes ten turns to travel only one inch. This means it can take around 250 turns of the crank to travel from one end of the motion device to the other. A large metal frame provides the structure for the x and y direction linear motion devices.

The rack and pinion mechanism allows the operator to move the mechanism back and forth in the z direction. The x and y linear motion system has a set of rollers on each side which roll along a C-Channel rail system. A shaft with a set of gears on each side goes through the x and y motion device. These gears line up with a rack that is directly mounted to the C-Channel. Cranking on the handle turns the gears, which moves the system along the rails in the direction that the hand wheel is turned.

The last mechanism that the operator needs to understand is the interchangeable tool mechanism (See Figure 6).

**Figure 6: Interchangeable Tool Mechanism**

<table>
<thead>
<tr>
<th>Locked</th>
<th>Unlocked</th>
</tr>
</thead>
</table>

This is where the tool is attached to the 3D motion device. The purple block is the motion block on the 3D motion device. The groove on the bottom is where the tool plate is slid into place. A tool will be permanently attached to the tool plate by a set of custom made tool collars (See Figure 7).
Once the tool plate is slid into place, a pin is dropped through the two pieces which locks them together. This pin keeps the tool plate from falling off of the motion block. The operator should become accustomed to using this mechanism because it will be used frequently during the disassembly process.

**Step by Step Instructions:**

Disassembling a HEPA filter with the disassembly station consists of 6 main operations:

1.) Placing the Filter on the Disassembly Station

2.) Removing the Metal Wire Grid from the Filter

3.) Removing the Top Side of the Filter

4.) Separating the Filter Media from the Filter Frame

5.) Removing Aluminum Separators/Resizing Filter Media

6.) Dismantling the Remaining Sides of the Filter Frame

Each one of these processes is described in detail in the following section.
Operation 1: Placing the Filter on the Disassembly Station

Steps:
1. Pick up the filter with the hot cell crane. Make sure to grab one of the shorter sides of the frame (See Figure 8).

![Figure 8: 3D View of HEPA Filter](image)

2. Move the filter with the crane so that it is above the turntable locking platform.

3. Lower the filter until it comes to rest on top of the locking lever assembly.

4. Use the slave manipulators to make minor positioning adjustments so that the filter is oriented correctly on the locking platform.

5. Crank the handle on the turntable until the locking levers are engaged with the sides of the filter (See Figure 3).
Operation 2: Removing the Metal Wire Grid

Steps:
1. Attach the grinder tool to the 3-D motion system (See Figures 6 and 7).
   a. Slide the grinder mounting plate into the groove on the sliding block.
   b. Drop the tool locking pin through the hole in the top of the sliding block to lock the tool in place.

2. Pull the turntable locking pin out of the round plate to unlock the turntable.

3. Rotate the round plate until the front side of the filter is facing the 3D motion device (See Figure 9).

   Figure 9: Front View of Disassembly Station

4. Maneuver the grinder to the top left corner of the filter with the x, y and z direction hand cranks on the 3D motion device.

5. Make one horizontal cut across the top of the filter where the wire grid is connected to the frame (See Figure 10).
6. Inspect the cut to make sure that it went completely through the wire grid and metal overhang on either side.

7. Continue grinding if necessary.

8. Maneuver the grinder over to the middle left corner of the filter with the x, y and z direction hand cranks on the 3D motion device.

9. Repeat steps 5 – 7 for the middle of the filter.

10. Maneuver the grinder over to the bottom left corner of the filter with the x, y and z direction hand cranks on the 3D motion device.

11. Repeat steps 5 – 7 for the bottom of the filter.

12. Pull the turntable locking pin out of the round plate to unlock the turntable.

13. Rotate the turntable 90° so that the cut side of the filter faces the hot cell window.

14. Pull the wire grid up and out through the horizontal cuts with the slave manipulators and place the pieces in the metal waste bin.

15. Pull the turntable locking pin out of the slot in the round plate to unlock the turntable.

16. Rotate the round plate 180° so that the back side of the filter faces the 3D motion device and let the turntable locking pin lock into place.

17. Repeat steps 4 - 14 for the back side of the filter.
Operation 3: Removing the Top Side of the Filter

Steps:
1. Pull the turntable locking pin out of the round plate to unlock the turntable.

2. Rotate the round plate 90° so that the bolts are facing the hot cell window (See Figure 11).

   Figure 11: View of Disassembly Station during Bolt Removal

   Remove the Top Row of Bolts (4x)

   Note
   This is the same orientation used in the grinding process.

3. Pick up the pneumatic wrench with the slave manipulators.

   Note
   The air wrench is operated with the slave manipulators, not with the 3D Motion Device.

4. Put the 7/16” short socket on the air wrench if it is not already connected.

5. Place the socket over the head of one of the bolts on the top of the side facing the hot cell window (See Figure 12).
6. Hold onto the nut behind the bolt with a regular 7/16” wrench.

7. Turn the air wrench on in reverse to unscrew the bolt.
8. Pick up the nut and bolt with the slave manipulators and place them in the metal scrap bin.

9. Repeat steps 5 - 8 for the remaining 3 bolts on the top of the frame (See Figure 12).

**Note**

*Remove the bolts on the TOP side of the frame only. The bolts on the bottom will be removed at the end of the disassembly process.*

10. Pull the turntable locking pin out of the round plate to unlock the turntable.

11. Rotate the round plate 180° so that the opposite side faces the hot cell window (See Figure 13).
12. Repeat steps 3 – 9 as shown above until the last 4 bolts on the top piece of the frame are removed.

13. Pull the turntable locking pin out of the round plate to unlock the turntable.

14. Rotate the round plate 90° in either direction and make sure that the locking pin engages (See Figure 14).

**Figure 14: Filter Orientation for the Spreading Operation**

15. Pick up the spreader device with the manipulator arms.

16. Grab a ratchet with a 5/16” socket with the manipulator arms.

17. Loosen the lead screw with the ratchet so that the spreader arms are fully retracted.

18. Place the spreader arms inside the frame of the filter and slide them apart until they fit against the inside of the frame.

19. Tighten the nut on the spreader device to begin spreading the filter apart (See Figure 15).
20. Keep cranking on the spreader device until the force from the spreader mechanism breaks the bonds of the adhesive.

21. If the travel on the spreader mechanism runs out before the top comes off, take the spreader out and repeat steps 15 - 18 as many times as needed.

\begin{center}
\textbf{Note}
\end{center}

\textit{Prying or hammering the frame may help to knock it loose.}

22. Grab the top piece of the frame with the slave manipulators and lift it off of the filter.

23. Tear off any fiberglass paper adhered to the top piece of the frame with the manipulator arms.

24. Place the piece of the frame in the metal waste bin.
Operation 5: Separating the Filter Media from the Filter Frame

Steps:
1. Remove the grinder tool from the interchangeable tool mechanism (See Figures 6 and 7).
   a. Pull out the tool locking pin.
   b. Slide the grinder plate out of the tool mount.

2. Attach the reciprocating saw to the interchangeable tool mechanism (See Figures 6 and 7).
   a. Slide the saw plate into the tool mount.
   b. Drop the tool locking pin through the hole and make sure that it locks the saw plate in place.

3. Pull the turntable locking pin out of the round plate to unlock the turntable as explained previously.

4. Rotate the round plate 90° until the locking pin engages with the round plate (See Figure 16).

5. Maneuver the saw into the cutting position above the top right side of the filter with the x, y and z direction hand cranks on the 3D motion device.

6. Make a full depth vertical cut (y-dir) along the right side of the filter media.

Note
A full depth cut with the saw only goes slightly over halfway through the filter media. Also make sure to not cut into the adhesive because if it gets mixed with the fiberglass it will affect post processing of the material. It is also not very good for the saw blade.
7. Pull the saw out of the filter (z-dir) and reposition it above the top left side of the filter.

8. Make a vertical cut (y-dir) down the left side of the filter media.

9. Pull the saw out of the filter (z-dir).

10. Pull the turntable locking pin out of the round plate to unlock the turntable.

11. Rotate the filter 180° so that the back side of the filter is facing the 3D Motion device (See Figure17).

![Figure 17: Second Filter Orientation for the Sawing Operation](image)

12. Release the turntable locking pin to lock the filter in this position.

13. Repeat steps 5 - 9 for the back side of the filter.

14. Double check to see if the cuts go completely through the filter and make additional cuts if necessary.
Operation 6: Removing Aluminum Separators/Resizing Filter Media

Steps:
1. Pull the turntable locking pin out of the round plate to unlock the turntable.

2. Rotate the filter so that it faces the hot cell window (See Figure 18).

![Figure 18: Filter Orientation for Removing Aluminum Separators](image)

3. Grab the fiberglass paper with the slave manipulators and pull the paper up.

4. Allow the aluminum separators to fall to the table as the fiberglass paper is pulled out of the filter (See Figure 19).

![Figure 19: Aluminum Separation](image)

5. Dump the fiberglass paper into a waste bin or shredder.

6. Pick up the aluminum separators with the slave manipulators and place them in the metal waste barrel.
Operation 7: Dismantling the Remaining Sides of the Filter Frame

Steps:
1. Place the filter support blocks in position to support the filter in the horizontal position.

2. Pull down on the hinge lever with the manipulators to flip the filter into a horizontal position (See Figure 20).

Figure 20: Front View of Flipping the Filter from a Vertical to a Horizontal Position

<table>
<thead>
<tr>
<th>Vertical Position</th>
<th>Horizontal Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hinge Lever</td>
<td>Filter Supports</td>
</tr>
</tbody>
</table>

3. Pull the turntable locking pin out of the round plate to unlock the turntable.

4. Rotate the round plate 180° clockwise so that the bottom of the filter is facing the hot cell window (See Figure 21).

Figure 21: Front View after Rotating Filter 180 Degrees

Remove the Bottom Row of Bolts on each side (8x Total)
5. Make sure that the locking pin is locked in the round plate.

6. Pick up the pneumatic wrench with the slave manipulators.

7. Put the 7/16” long socket on the air wrench if it is not already connected.

8. Place the socket over the head of one of the bolts.

9. Hold onto the nut behind the bolt with a regular 7/16” wrench.

10. Turn the wrench on in reverse to unscrew the bolt.

11. Pick up the nut and bolt and place them in the metal scrap bin.

12. Repeat steps 7 – 11 for the remaining 7 bolts on the filter.

13. Pull the turntable locking pin out of the round plate to unlock the turntable.

14. Rotate the round plate 180° counterclockwise so that the hinge lever is within reach of the manipulator arms.

15. Make sure that the turntable locking pin is engaged in the round plate.

16. Pull up on the hinge lever with the slave manipulators to flip the filter back into a vertical position.

17. Push the vertical sides of the filter inward one at a time with the slave manipulators to collapse the frame (See Figure 22).

Figure 22: Collapsing the Filter Frame Pieces

18. Pick up the two side pieces of the frame and place them in the metal waste bin.
19. Pull the turntable locking pin out of the round plate to unlock the turntable.

20. Rotate the round plate 90° so that the locking lever hand crank is within reach of the manipulator arms (See Figure 23).

![Figure 23: Front View of Final Filter Orientation](image)

21. Make sure that the turntable locking pin locks in place.

22. Crank the locking lever hand crank counterclockwise to disengage the locking levers from the bottom piece of the frame.

23. Pick up the last piece of the frame with the slave manipulators and place it in the metal waste bin.

You have now completely disassembled the HEPA filter.