
User's Manual
PF4 Filter Set
&
PF2S2 Filter-Shutter Set

S/N 9x-00nn

XIA

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Section I: Warranty and Registration Card

I.A. Our Guarantee Policy

Both PF4 filter sets and PF2S2 filter-shutter sets are guaranteed against failure under normal operating conditions for 1 year from time of purchase. Should one of these products fail, it will be repaired or replaced in as expeditious a manner as possible to minimize disruption to its owner's experiments. In such an event please call us immediately to arrange for free repair service. Be sure to register your instrument.

I.B. Our Repair Service

In line with XIA's goal of making your experimental life easier, we also have a repair service which will attempt to repair, at a reasonable cost, any XIA instrument that fails, whether it is in warranty or not. The components of this service, which can be selected as your needs require, include:

- 1: **Timely repairs:** Our goal is to complete normal repairs in 2 working days or less.
- 2: **Complete testing** and checkout before return to assure that the repaired instrument will continue to perform reliably.
- 3: **Loaners:** to keep your experiment running if we expect a delay in obtaining necessary replacement parts.
- 4: **Expedited handling:** by 2nd day, overnight or even same day rush delivery to get you going again in critical situations.

I.C. Warranty Card

In order to register your instrument for our guarantee policy, please fill out and return the warranty card at the bottom of the Warranty Information sheet.

Section II: General Product Description

I.A. Description

The Model PF4 is an instrument for reproducibly attenuating an x-ray beam under remote control by the insertion of four filter foils. It is physically compatible with Blake Industries' line of beampath components and can be operated either evacuated or He filled if desired. The foils are moved by miniature pneumatic cylinders which are controlled by electrically actuated valves. O-rings provide vacuum seals on the cylinder shafts as they pass through the instrument wall. As a result of careful design the entire instrument is very compact.

In the Model PF2S2, two of the filters are replaced by thicker absorber blades to create a focal plane shutter. This design allows for a much more uniform spatial exposure than is possible with single bladed shutters which open and then close. Further, by adjusting the time between the opening of one blade and the closing of the other, it is possible to obtain exposures which are shorter than the motion time of either blade. Attainable exposure times vary with the mass of the blades and pneumatic supply pressure, but times less than 0.1 sec are not difficult to produce. Either instrument can be retrofitted as the other.

I.B. Technical Specifications

Physical Size	100 mm in line, 62 mm wide, 200 mm high
Through beam size	20 mm H by 20 mm W for PF4 8 mm H by 20 mm W for PF2S2
Foil size	1" (25 mm) square; up to 3 mm thick
Pneumatic connection	Accepts 6 mm or 1/4" diameter polyethylene, polyurethane or similar
Pneumatic medium	Compressed air or non-reactive gas, 5 mm filtered, unlubricated
Required pressure	50 to 100 psi (3.5 to 7.0 bar)
Electrical Connection	Subminiature 9 pin D Plug [male] (AMP 745203), accepts connections via 9 pin D Receptacle [female] (AMP: 745201, ITT: DE111813, DuPont: 66168-009, Cinch: 008-04108-9 {ref TE-9STS}, or other equivalent)
Electrical Supply	24 V DC (+10%, -15%), 0.55 W per activated valve.

I.C. Applications

1: The Model PF4 was originally designed to match single photon counting detectors to synchrotron radiation experiments where the detected x-ray intensity varied over several orders of magnitude. The experiment is optimized for acceptable counting rates with the

weakest signals and then the attenuators are inserted to maintain detector linearity in the presence of strong signals. Examples include surface reflection studies, Huang scattering near diffraction peaks, samples with both normal and "forbidden" peaks, etc. With a proper choice of foil thicknesses and computer actuation of the PF4 valves, these experiments can be completely automated.

2: With either manual or computer controls the PF4 also offers a convenient way to match sample scattering strength to the detector's linear range even for samples whose scattering intensity does not vary widely. This creates a very simple way to "tune" the spectrometer to the sample in a standardized and reliable manner.

3: With a properly graded series of filters the PF4 also provides a simple way to adjust x-ray "exposure" in those experiments requiring a particular x-ray dose (e.g. topographic photographs). This capability is further enhanced in the Model PF2S2, which allows x-ray exposures to be timed as well.

4: For radiation sensitive samples, using the PF4 with a heavy absorber replacing one of foils is a convenient way to implement a beam stopper to minimize sample damage by restricting exposure to only those times when data is actually being collected.

Section III. Installation

Installation consists of the following four steps: mechanically installing the body of the instrument, making electrical connections, making pneumatic connection, and installing filters (or shutters) in the filter carrier assemblies. These topics are treated in further detail below. Except for explicit differences relating to shutter blade installation, which are treated in Sect. III.D, all references to the PF4 apply to the PF2S2 as well.

III.A. Mechanical Installation

The PF4 is designed to be supported by an optical rail and make vacuum tight connections with its neighboring beampath components. To this end it has an O-ring socket on one end and an O-ring plug on the other. Both are sized to be compatible with the Blake Industries' line of beampath components. Their dimensions are shown on the drawing in Section VI.C if it is desirable to mate them to locally produced parts.

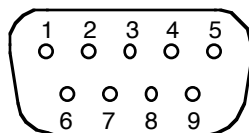
The PF4 can either be attached to its supporting optical rail or left simply supported against gravity and held in line by its neighboring components as may be desirable. Attachments can be made either by clamping or bolting it in place. Because potential mounting arrangements vary so widely, no bolt holes have been provided. The body of the PF4 is aluminum and such holes are easily added, although the obvious precautions against drilling into the vacuum path should be taken.

III.B. Electrical Connections

Each valve requires 24 V DC (+10%, -15%) at 0.5 W (approximately 20 mA) to operate. These control signals may be supplied by manual switches, CAMAC modules, or electronically using any of a variety of driver devices. Quad driver packages with this capability are now readily available commercially. A **point to remember** in choosing or designing control circuitry is that the valves are inductors and the control electronics should be protected (by bypass diodes) against the voltage surges which will arise when the valves are switched off.

Wiring to the PF4's 9 pin D connector is shown below. Each valve has an LED indicator to show when it is energized, so it is important to observe the indicated polarity. The valves are numbered sequentially, with Valve 1 closest to the D connector. This is also shown in the assembly drawing, Sect. VI.C.

9 Pin D Connector



Pinning Chart

Valve	1	2	3	4
V+	6	7	8	9
V-	1	2	4	5

III.C. Pneumatic Connection

Connecting the pneumatic gas supply to the PF4 is very easily done via the supplied push-pull Qwik-connect fitting. This fitting accepts either 6.0 mm or 1/4" high pressure plastic

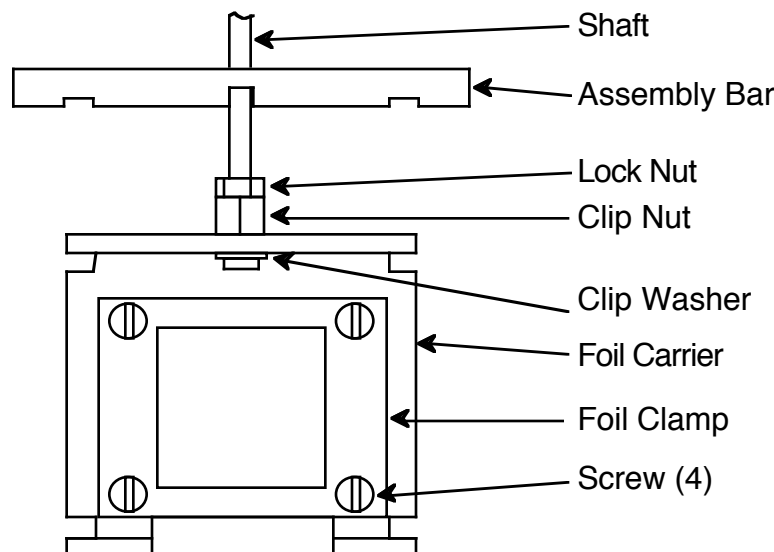
gas line tubing. Polyethylene, polyurethane or similar tubing materials are acceptable. Simply insert the gas supply line into the fitting until it bottoms and then pull up the red Qwik-connect sleeve to lock the gas line in place. A **point to remember** in this procedure is that there is an O-ring seal in the bottom of the Qwik-connect that will produce resistance as you insert the gas line. Be sure the gas line is inserted completely through the O-ring to the bottom of the fitting. If the connection fails to seal properly and leaks, this is the most likely cause. **Also notice** that the Qwik-connect fitting rotates about its connection to the valve block and may be positioned at any convenient angle.

The pressurized gas supply can be air or any non-reactive gas. It must be non-lubricated and, for longest cylinder life, be filtered through a 5 μm filter. Bottled gas can be used. Pressures between 50 and 100 psi (3.5 to 7.0 Pa) are appropriate. If the pressure is too low the cylinders will not move reliably, particularly after a period of disuse. You should check your pressure setting by installing the foils you will actually use and activating the valves to and observing whether the carriers operate smoothly.

III.D. Installing Filters or Shutters

Due to the close distances between the foil carriers, the most convenient way to install foils (or shutter blades) is to first remove all the carriers from their cylinder shafts, load the foils into the carriers, and then reinstall the carriers on the shafts. This process is described in detail below, referring to the following figure.

Foil Carrier Assembly Drawing



III.D.1. Installing Filter Foils

1: Filter Foils:

Filter foils can be made of any convenient material. Foil thickness is primarily limited by the requirement that neighboring foil carrier assemblies do not interfere. Very thick "foils" will act as beam stoppers, of course, and this is one of the modes in which the PF4 is useful. Because of their greater mass, thicker foils will actuate

somewhat more slowly. Also, longer screws will be required to accommodate foils thicker than about 1 mm.

Foil size (nominal): 1" x 1" (25 mm x 25 mm)

Screws (supplied): 4-40 Fillister Head x 3/16"

2: Removing Foil Carriers From Shafts:

- a:** Remove the upper half of the instrument by removing the 4 socket head screws that attach it to the lower half. These are M5 x 0.8 SS Socket Head screws, 30 mm long, so a **4 mm hex key** or driver is required. Position the head so the carriers are facing up, as in the drawing above.
- b:** Starting with the uppermost carrier, draw it out to the fully extended position by hand and slide the assembly bar over the shaft between the lock nut and the upper half body, as shown. The assembly bar will now hold the foil carrier in an extended position while you work on it.
- c:** Supporting the foil carrier with one hand, use a pair of fine needle nose pliers to remove the clip washer from the clip nut to free the foil carrier. Remove the foil carrier from the clip nut.
- d:** By hand, pull on the clip nut to release pressure on the assembly bar. Remove the assembly bar and return the shaft to its retracted position.
- e:** Repeat this operation for each of the remaining three foil carriers to remove it from its shaft.

3: Installing the Foils:

Remove the foil clamp from the carrier by loosening the 4 screws. Place the foil so it completely covers the hole in the foil carrier. Replace the foil clamp and screws. Be certain the foil is still completely covering the hole and tighten the screws.

4: Replacing the Foil Carriers:

Reverse the steps in Section 2 above, starting with the lowest foil carrier. That is, pull out the shaft and catch it with the assembly bar. Slide the foil carrier onto its guide rods and onto the clip nut. Replace the clip washer and remove the assembly bar to allow the foil carrier to retract. Test that the carrier operates smoothly. After all the carriers have been reinstalled, replace the upper half assembly into the lower half assembly and reattach it with the 4 screws.

III.D.2. Installing Shutter Blades

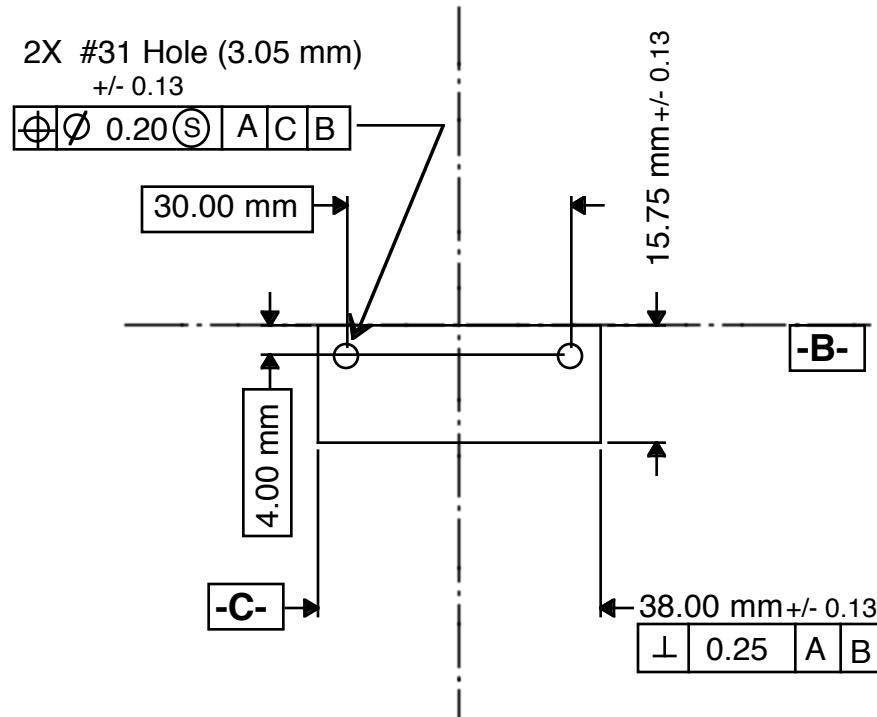
1: Installation Procedure:

The general procedure for installing shutter blades is the same as for installing filter foils with the following two exceptions:

- a:** No foil clamp is used. The shutter blade is attached directly to the foil carrier by two 4-40 screws.
- b:** Two shutter blades are installed, **one per foil carrier**, in complementary positions as described below.

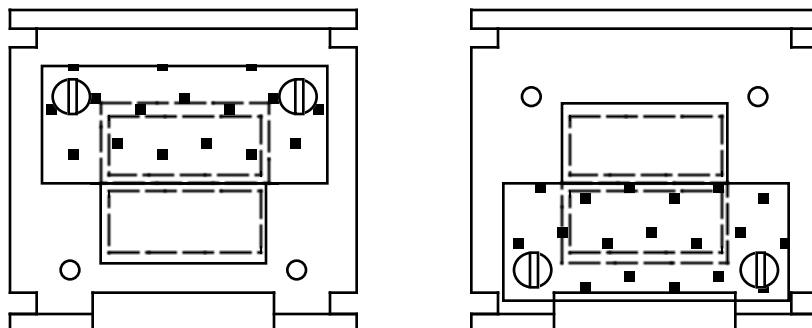
2: Shutter Blade Design:

The shutter blades normally provided are made of 1/8" (3.2 mm) stainless steel, which gives an absorption factor of over 10^{12} at x-ray energies up to 25 keV. Replacement blades in other materials or thicknesses can be readily made according to the drawing below.



3: Positioning the Shutter Blades:

Each shutter blade should be positioned so that its edge exactly bisects the opening in the foil carrier as shown in the figure below. The foil carrier openings are 21.0 mm high, so the unblocked openings should be 10.5 mm high. If the blades have been properly made this is where they should fall, within the limits of the hole clearances, but it is always wise to check. Notice that it is unimportant which carrier has the upper blade and which the lower, except insofar as it is important for the operator to know which is which in order to correctly program the shutter's operation.



Section IV: Operation

IV.A. Normal Filter Set Operation

From an operational point of view the PF4 is a very straightforward device: when a valve is activated a filter drops into the x-ray beam. The attenuation of multiple filters is simply the product of their individual attenuations. It is worth emphasizing that the absorptivity of a particular filter is an energy dependent function. In particular, if the x-ray beam is polychromatic or has harmonics of some fundamental energy (as is often the case in synchrotron research), each energy will be absorbed differently. This means that the potential exists to change the harmonic content of the beam as a function of attenuation and, if this could be important it should be carefully considered.

IV.B. Selecting Filter Parameters

The choice of filters may vary widely with application. There are two basic questions to be answered: 1: what material should be used; and 2: in what thickness. The answers to these questions will also depend upon whether one foil carrier will be employed as a stopper, since this reduces the number of available foil carriers. Multiple PF4's or a PF4 and a PF2S2 can obviously be used in conjunction when necessary.

1: Choice of material:

The first criterion in material choice is that its absorption be such that the thinnest foil is not too thin to handle and the thickest foil is not too thick to fit on the foil carriers. Thus it is not typically appropriate to use Al filters at 50 keV nor W filters at 4 keV. Secondly, it is also important to use materials which can be obtained in uniform, accurate thicknesses so that each foil will have a uniform spatial response. Third, cheap strong materials are obviously preferable to fragile expensive one. Beyond these fairly obvious criteria lie opportunities to be clever. For example, if the x-ray beam has an undesirably strong 2nd harmonic content, it may be possible to choose a filter material whose K edge lies just below the harmonic, differentially attenuating it.

2: Foil thickness:

The answer to this question depends upon both what attenuation step is desired and what maximum attenuation may be required. Thus if a foil should reduce the x-ray beam intensity to A of its former value ($0 < A < 1$), and a maximum attenuation of 10^M is required, then the number N of foils which will produce this maximum attenuation is $N = M / \log A$. If the foils are then arranged in thickness ratios 1, 2, 4, 8, 16, etc, which uses the least number of carriers to generate any intermediate thickness, then the number of required carriers C can be found from $C = (\log N / \log 2) - 1$. Of course C has to be an integer, so a little juggling of M and A will be required. Once A is known then the foil thickness can be computed, given the foil material and the x-ray beam energy.

Inversely, one can start with a given value of C (e.g. 4) and work back to either A or M . Thus, for example, if $C = 4$, $M = -6$ is desired, then N will be $2^5 = 16$, which will require an A value of $A = 10^{(M/N)} = 0.42$. All of these calculations will have to be further adjusted depending upon the availability of arbitrary foil thicknesses.

IV.C. Multiple Foil Carrier Sets

Because the choice filters will clearly vary both with experiment and with x-ray beam energy, the typical laboratory may require several sets of filter foils to accommodate its typical experiments. Constant shuffling of foils in and out of a single set of carriers rapidly becomes tedious and carries an ongoing risk of error in mounting the correct sequence of foils or of foil damage. We recommend instead that multiple sets of foil carriers be purchased and loaded with the most common foils. These need only be calibrated once and then are easily mounted and dismounted as required.

IV.D. Shutter Operation

The design of the focal plane shutters is based on the following analysis. Because the shutter blade is driven by a pneumatic cylinder, it accelerates in a non-linear manner and therefore has a nonuniform velocity profile which is difficult to characterize. In the present design, however, both blades, their carriers and mounting hardware have all been made as identical as possible. Therefore, to the extent that the cylinders are also identical, the velocity profiles of the two blades will also be identical, whatever they are. As a result, if both blades start at the same position in space (set by the centerline of the carrier) then, if blade #1 is triggered at time 0 and blade #2 is triggered at time Δt later, both blades will continue to pass all subsequent positions in space still separated by the same interval Δt . As a result the exposure at all locations is a constant Δt .

The design of a program to control the shutters is therefore quite simple. The algorithm is as follows:

- 1: Energize blade #1, which is initially blocking the x-ray beam.
- 2: Energize blade #2, which blocks the beam again, the desired exposure time Δt later.
- 3: Pause long enough for both blades to finish moving.
- 4: Deenergize blade #1 and wait for it to return to its initial position. Both blades are now blocking the beam.
- 5: Deenergize blade #2 and wait for it to return to its initial position. The shutter is now ready for another exposure and has been moved into this position without passing any additional x-rays.

Section V: Maintenance and Service

V.A. Maintenance

The only normal maintenance which is required beyond keeping the instrument clean is to grease the shafts of the pneumatic cylinders from time to time to maintain lubrication of their O-ring seals. This is most easily done during foil changes when the shafts are readily accessible. Any light, vacuum compatible O-ring grease may be used for this purpose. Original assembly was with Parker O Lube. Simply pull out a shaft, smear a very light coating of grease onto it, and exercise it a few times to distribute the grease onto the O-ring.

V.B. Service

All parts may be readily replaced if they fail after extended service. Replacement parts may be obtained either from XIA, from Festo (in the case of pneumatic parts), or locally (in the case of O-rings or screws). Specific parts are discussed below.

1: Valves:

Replacing valves is straightforward. The only trick to removing them is to squeeze the tops of the electrical connectors to release them from the body of the valves. If the valve block hold-down screws are removed, the socket bracket can be slid from one side to the other to facilitate access to these connectors.

2: O-rings or Cylinders:

Access to the O-rings is obtained by removing the clip nut and lock nut from the shaft and then unscrewing the cylinder. Either the O-ring or cylinder may then be replaced. Be sure to pack the O-ring with Parker O Lube or equivalent grease before replacing it. Also, a few drops of LockTite should be applied to the cylinder thread before it is reinstalled. Be careful not to tighten the cylinder too much, as this will cause the shaft to bind. The best procedure is to tighten it until jamming does occur and then back off until the shaft moves freely.

3: Replacing the Clip Nut and Lock Nut:

In order to assure that the O-ring always rides on a smooth section of the shaft, the lock nut must be positioned so that the shaft is prevented from fully retracting by about 0.5 mm. In the case of the clip nuts used with the foil carriers this condition is guaranteed by making sure the shaft end is flush with the end of the clip nut and then tightening the lock nut. In the case of the longer clip nuts used with the shutters, the lock nut should be screwed up on the shaft until it just touched the base of its cavity and then rotated exactly one more turn (the thread is 0.5 mm pitch) and the clip nut tightened against it. Take care in this process not to use tools or techniques which might damage the shaft surface as this is the sealing surface with the O-ring.

Section VI: Construction and Parts List

The following list gives all the parts of the PF4 and PF2S2 instruments, showing their XIA part number, their name and description, and material of fabrication. Their locations on the instrument may be found by reference to the assembly drawings in Sections III.D (for the foil carriers) or VI.B below for the overall instrument. Parts are grouped by functional subassembly.

VI.A. Parts List:

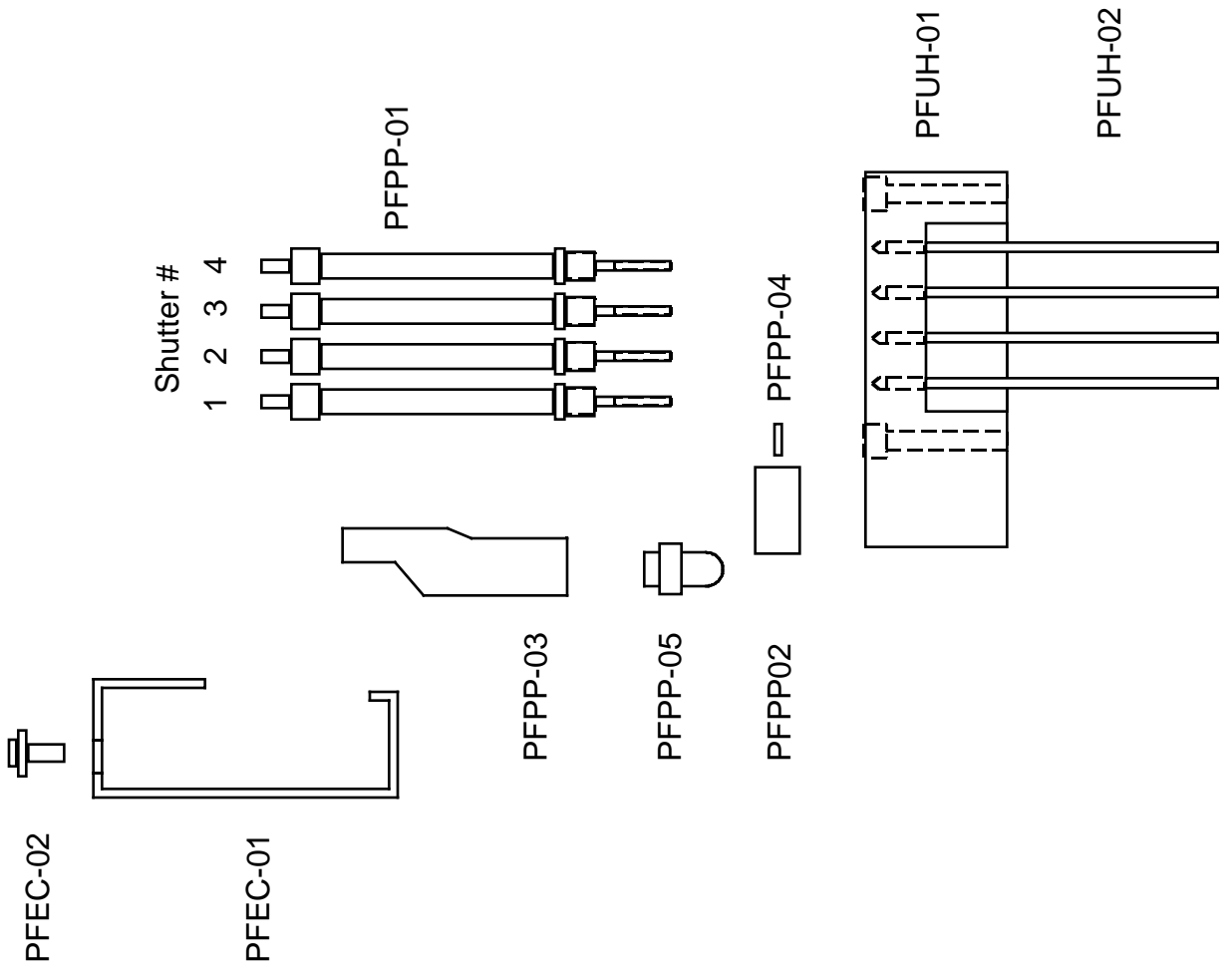
XIA Part Name	Specification
<u>VI.A.1 Lower Half Parts</u>	
PFLH-01 Lower half body	Black anodized aluminum
PFLH-02 O-ring, joint seal	Buna N-135, 3/32"W, 1-15/16" ID
PFLH-03 O-ring, flange seal	Buna N-038, 1/16"W, 2-5/8" ID
PFLH-04 Screw, flange seal	M5 x 0.8 30mm SS Socket Hd
<u>VI.A.2 Upper Half Parts</u>	
PFUH-01 Upper half body	Black anodized aluminum
PFUH-02 Guide Rod	Stainless Steel
PFUH-03 Clamp, O-ring	Nylon Washer
PFUH-04 O-ring, Actuator seal	Buna N-006, 1/16"W, 1/8" ID
PFUH-05 Screw, valve mounting	M3 x 0.5 SS Screw, Fillister Hd, 20 mm long
<u>VI.A.3 Electrical connector</u>	
PFEC-01 Plug bracket	Black anodized aluminum
PFEC-02 Plug	AMP IDC Connector 745203-2
PFEC-03 Plug mounting hardware	AMP hardware kit 205817-1
<u>VI.A.4 Foil Carrier & Shutter Parts</u>	
PFFC-01 Foil carrier	Aluminum
PFFC-02 Foil clamp	Aluminum
PFFC-03 Screw, clamp-to-carrier	4-40 SS Screw, Fillister Hd, 3/16" long
PFFC-04 Foil clip nut	Stainless steel
PFFC-05 Shutter clip nut	Stainless steel
PFFC-06 Lock nut	SS M3 X 0.5 nut
PFFC-07 Clip washer	Truarc 5133-18
PFFC-08 Shutter Blade	Stainless steel
PFFC-09 Screw, blade-to-carrier	4-40 SS Screw, Fillister Hd, 1/4" long

VI.A.5 Pneumatic Parts

PFPP-01	Pneumatic actuator cylinder	FESTO Part Name EG-6-25-PK-3 Part # 15875
PFPP-02	Manifold base for valve	FESTO Part Name PRMZ-3-M3-4 Part # 30226
PFPP-03	Pneumatic Valve	FESTO Part Name MZH-3-0.4-LED Part # 30217
PFPP-04	Hose barb	FESTO Part Name CH-M3-PK3 Part # 15872
PFPP-05	Kwik Connect	FESTO Part Name LCS-M5-PK-4 Part # 13688
PFPP-06	Hole Plug	FESTO Part Name BM5 Part # 3843
PFPP-07	3 mm Blue Connecting Tube	FESTO Tubing Name PU-3 Tubing Part # 5732

VI.B. Assembly Drawing:

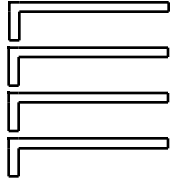
See following 2 pages.



VI.B. PF4 Assembly Drawing

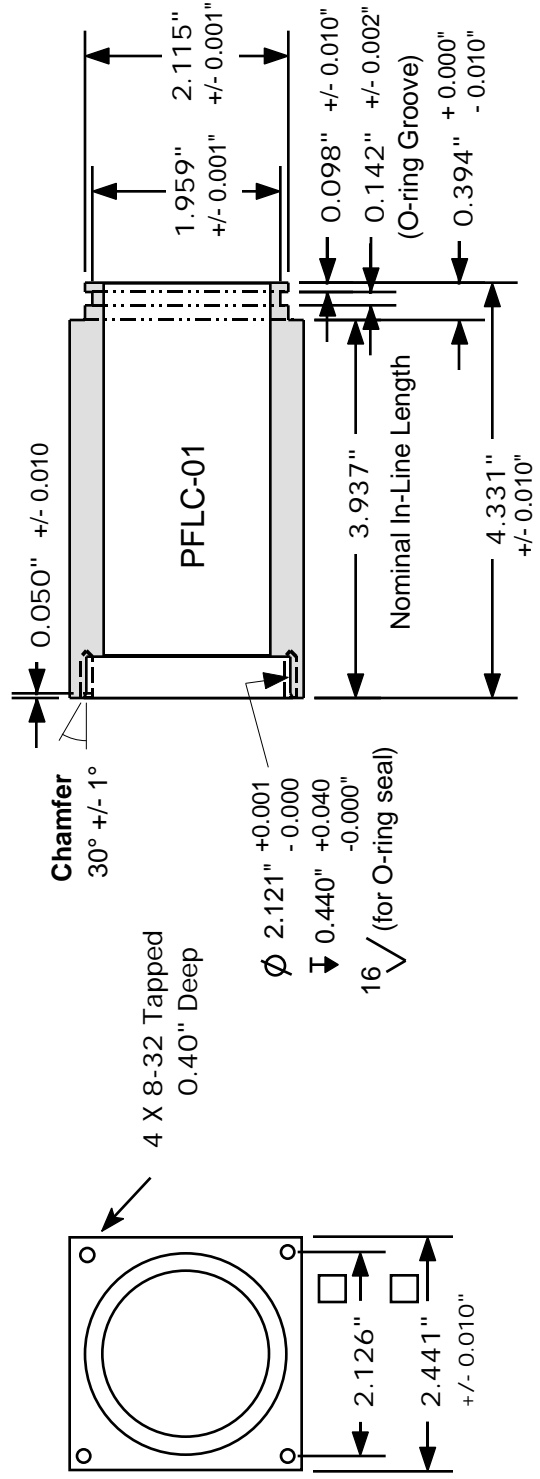
Note: The following parts are not shown:

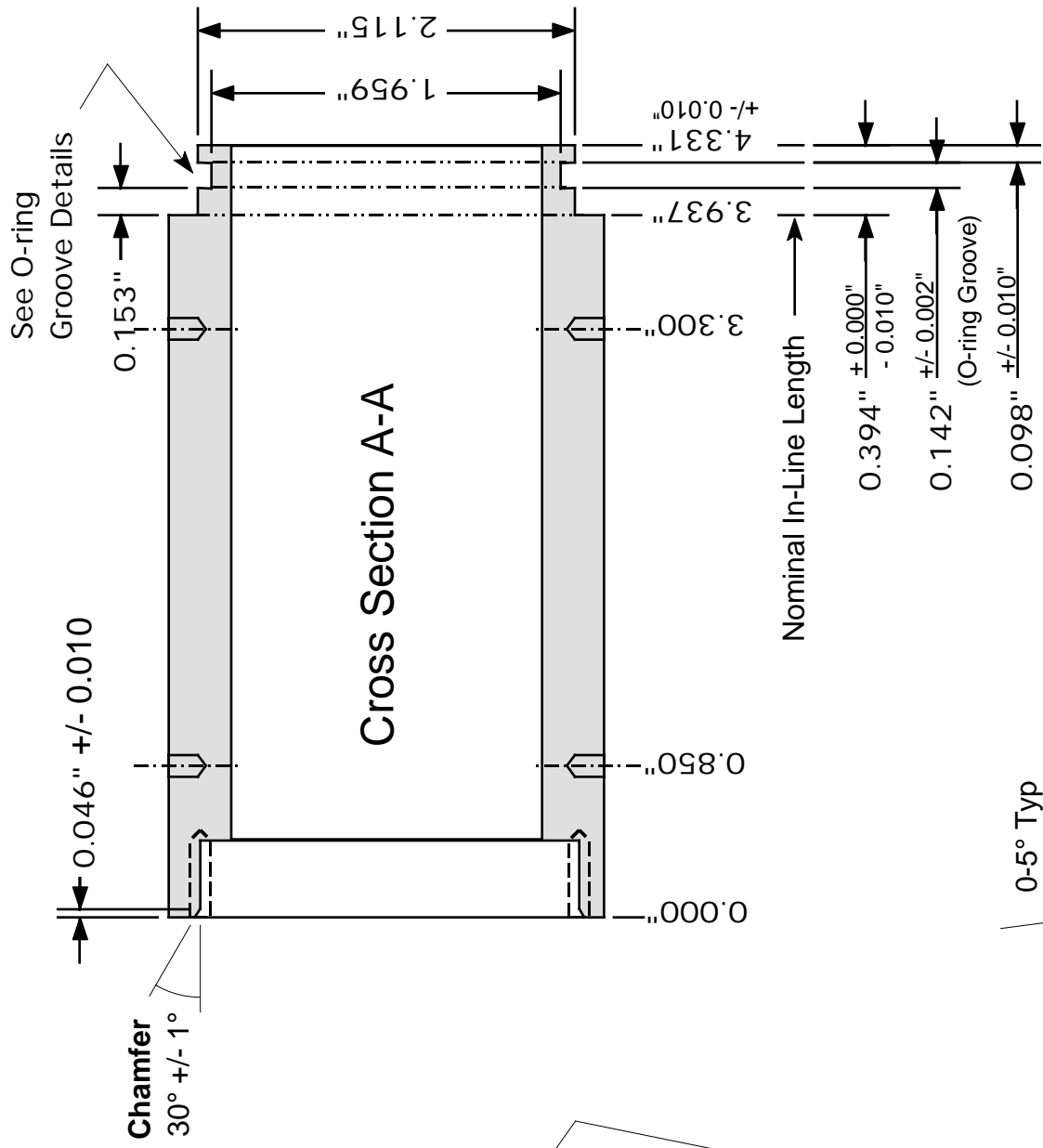
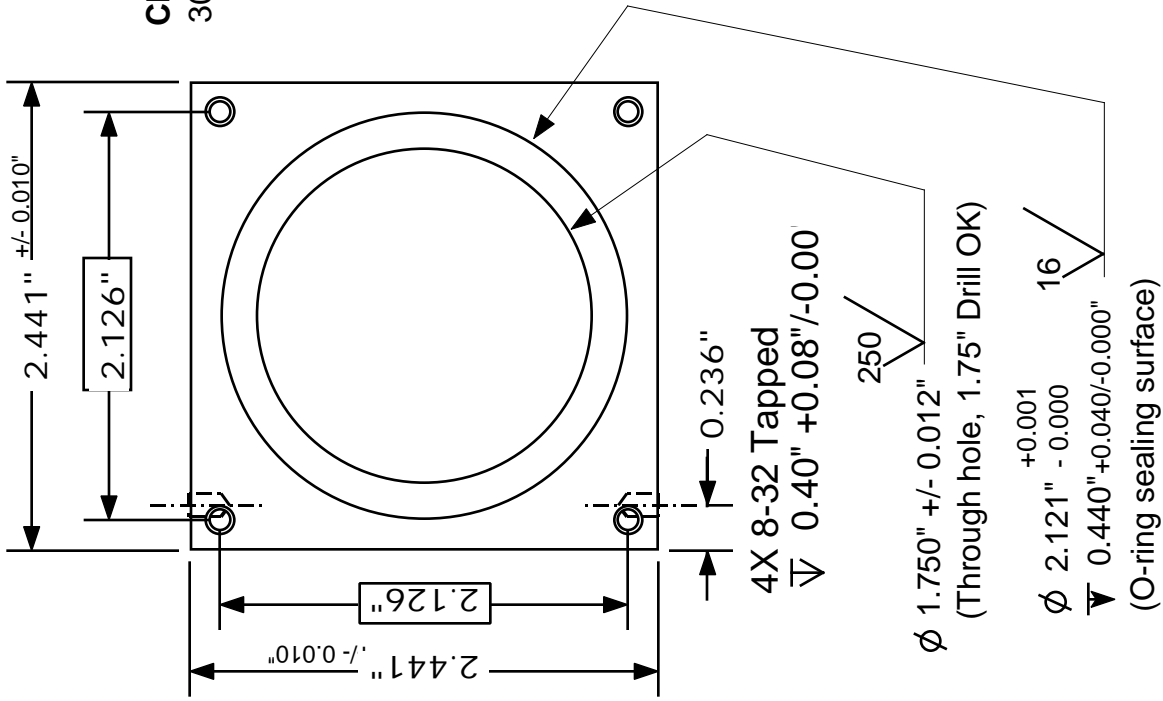
- 1: All screws
- 2: All O-rings
- 3: PFUH-03, brass clamp which rides on the actuator shaft above O-ring PFUH-04.
- 4: PFPP-06, hole plug which is in PFPP-02 on the other end from PFPP-05
- 5: PFPP-07, connecting tubes between PFPP-04 and PFPP-01.



PFFC Parts: See Section III.D.

Mating Part Dimensions

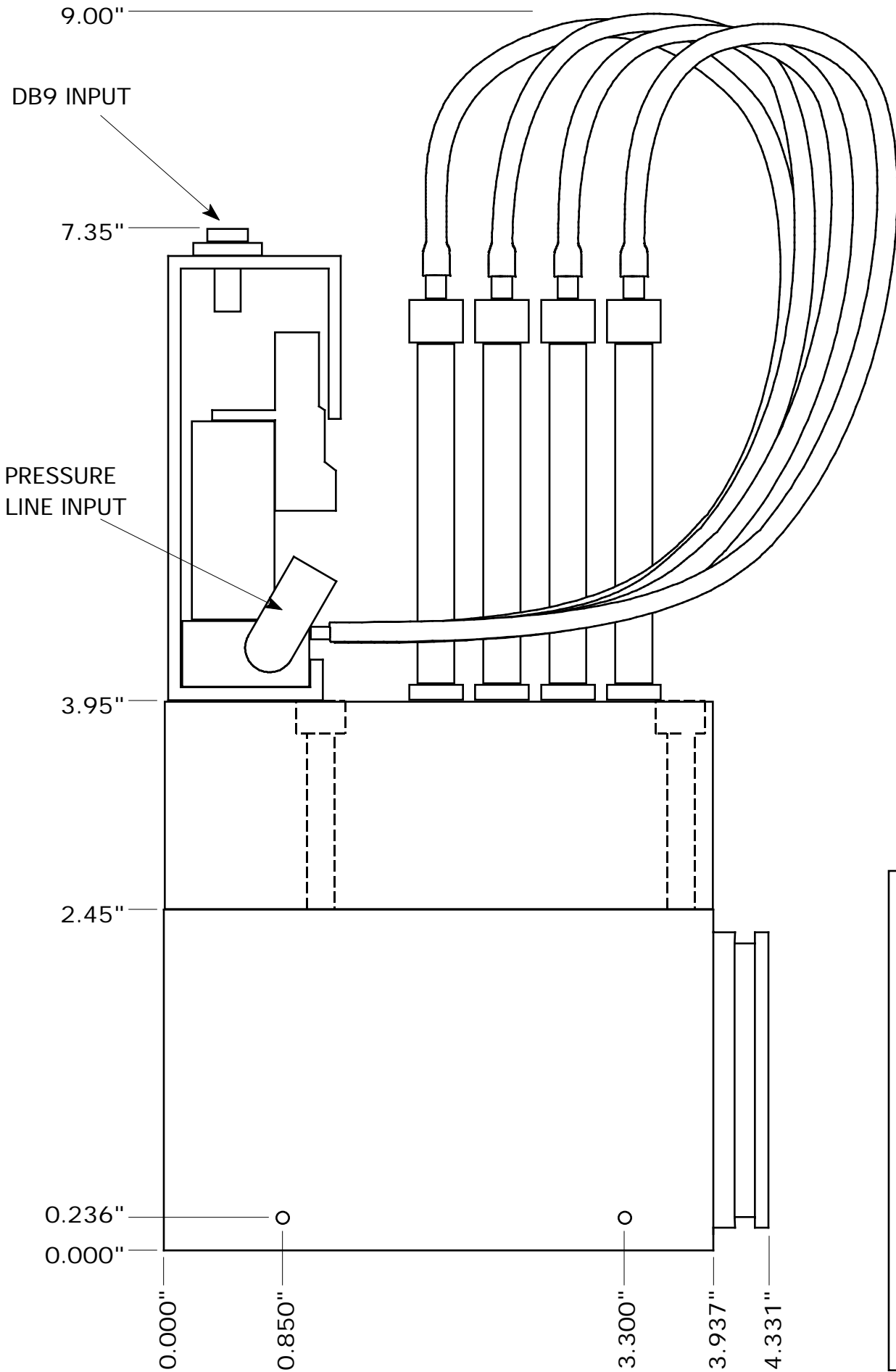




Body Mating Details

By: William K. Warburton
 X-ray Instrumentation Associates
 File: Body Mating Details 010913

O-Ring Groove Details



PF4 Installation Dwg
By: William K. Warburton
X-ray Instrumentation Associates
File: Installation Dwg 010913