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Precision Attenuator for Hard X-Rays

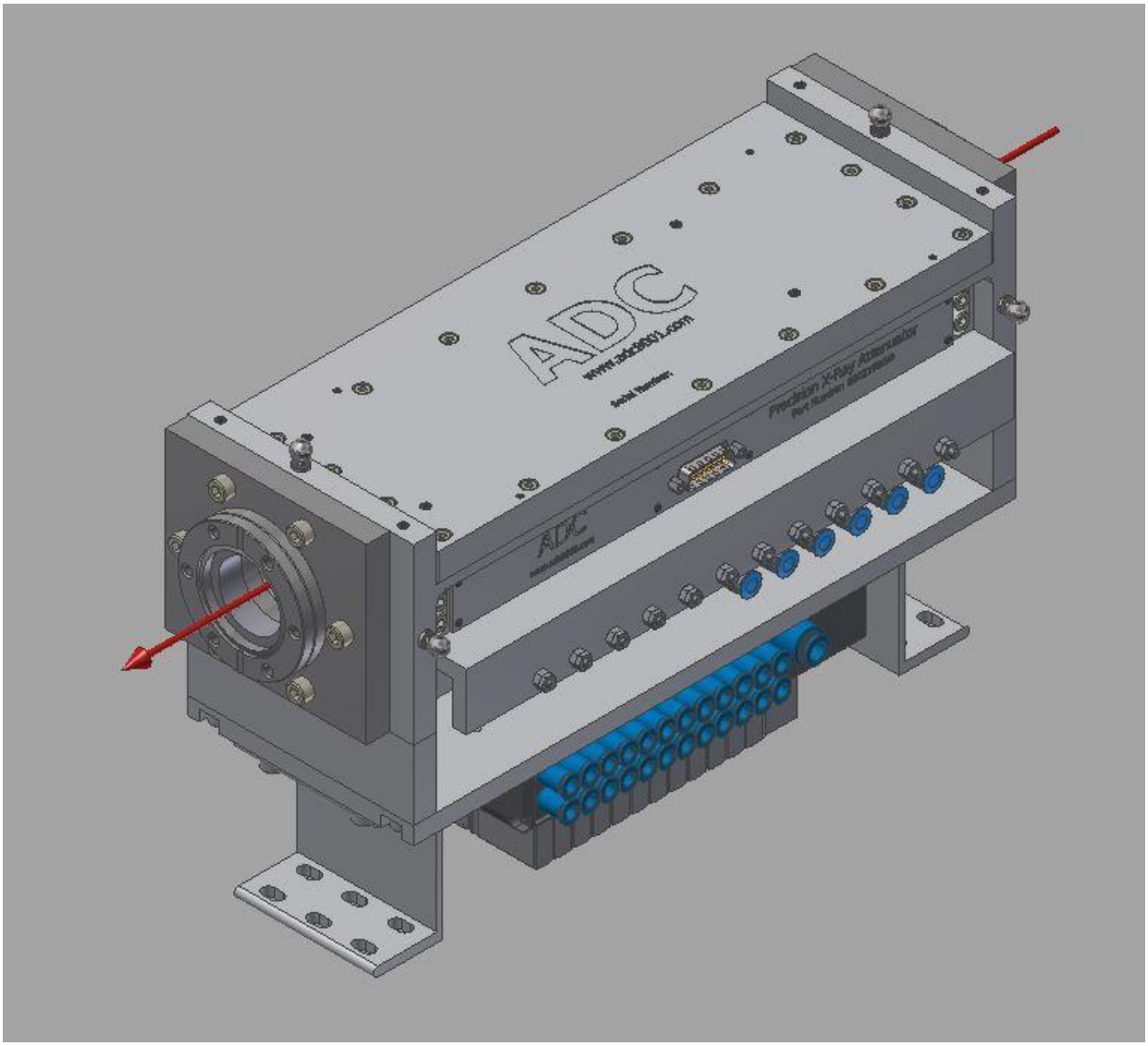

Figure 1 – Overview of the system with pneumatic hoses omitted for clearer viewing, shown with the DN40 flange option – the red arrow shows the beam path.

OVERVIEW

ADC has licensed and is offering a Precision Attenuator for Hard X-Rays (ABS-300) that was developed over many years at the synchrotron radiation source PETRA III at DESY. This system will provide the ability for scientists to reduce the incident x-ray flux to any desired value.

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For many applications at hard x-ray beamlines at lab sources and synchrotron radiation sources the detected intensity spans more than six orders of magnitude. An integrated flux of more than one million counts per second is far too much for most of the detectors in use, which can even be severely damaged on saturation. For this reason, x-ray beamlines are equipped with so-called attenuators (or absorbers) which reduce the beam load on the detector by blocking the beam with a (for x-rays) semi-transparent material (called filter or foil).

ABS-300 FEATURES:

- 12 Foil carriers, 2.1cm x 2.1cm square aperture (20 mm x 15 mm effective aperture)
- Foil carriers can be loaded with other items of similar size such as photodiodes
- Foils can easily be exchanged for others of different metal and thickness, including calibration foils
- Low power electrically controlled
- Easy filter/absorber changes (using pressurized air: 3 – 8 bar), speed is adjustable through screws on the pneumatic actuators
- Usable in a wide energy range (Type 1: 5-30 keV; Type 2: 2.5-20 keV)
- High-Vacuum Capability (1e-7 mbar)
- No vacuum feed-through used
- Stiff structure and minimal vibration
- Reliable detection of the actual position of the slides (in or out of the beam)
- The ABS-300 precision attenuator is controlled using a Beckhoff BC9000 Bus Controller, but could be operated with other controllers. The BC9000 Bus Terminal Controllers are Bus Couplers with integrated PLC functionality and have a fieldbus interface for Ethernet.
- Can manually move the slides from the outside without venting or feedthroughs
- At 3rd generation synchrotron radiation sources the beam can be micrometer sized. As the foils are not made fully homogeneous it is mandatory for an absorber that it stand still and that the same spot is always illuminated. Our product does this well.
- NW40 or DN40 flanges, or adapters for Blake Industries beam tube available to meet customer needs
- Most similar products contain only 4 foils, requiring three stacked together to provide functionality through such a wide energy range
- Experimental Physics and Industrial Control System (EPICS) compatible

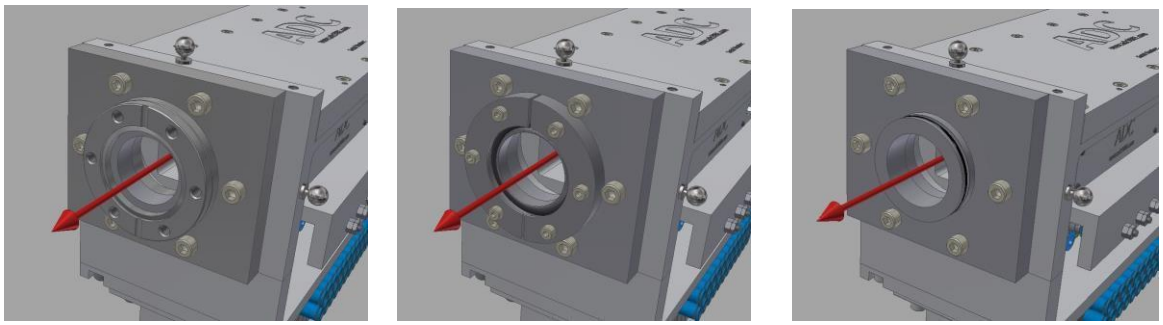

Figure 2 – End views showing flange options: DN40 on the left, NW40 in the center, and Blake Industries beam tube on the right.

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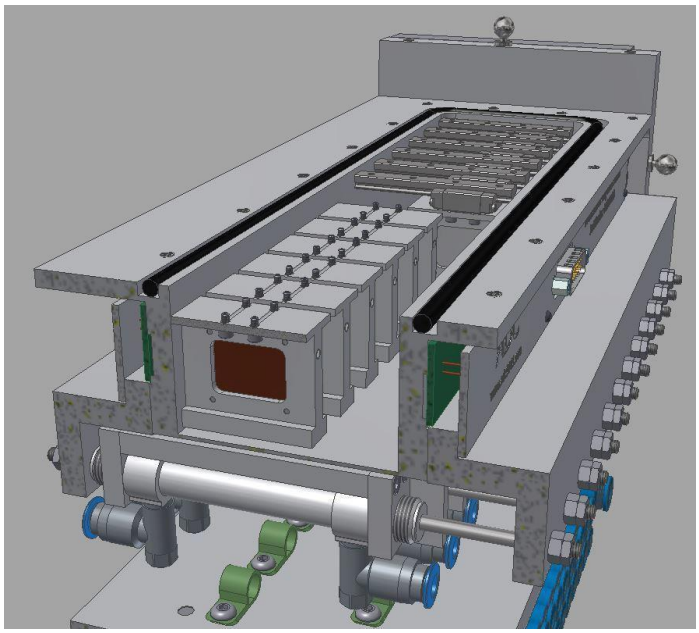

Figure 3 – Cutaway view showing filter frames and pneumatic cylinders.
Top cover, some slide rails, and pneumatic hoses omitted for ease of viewing.

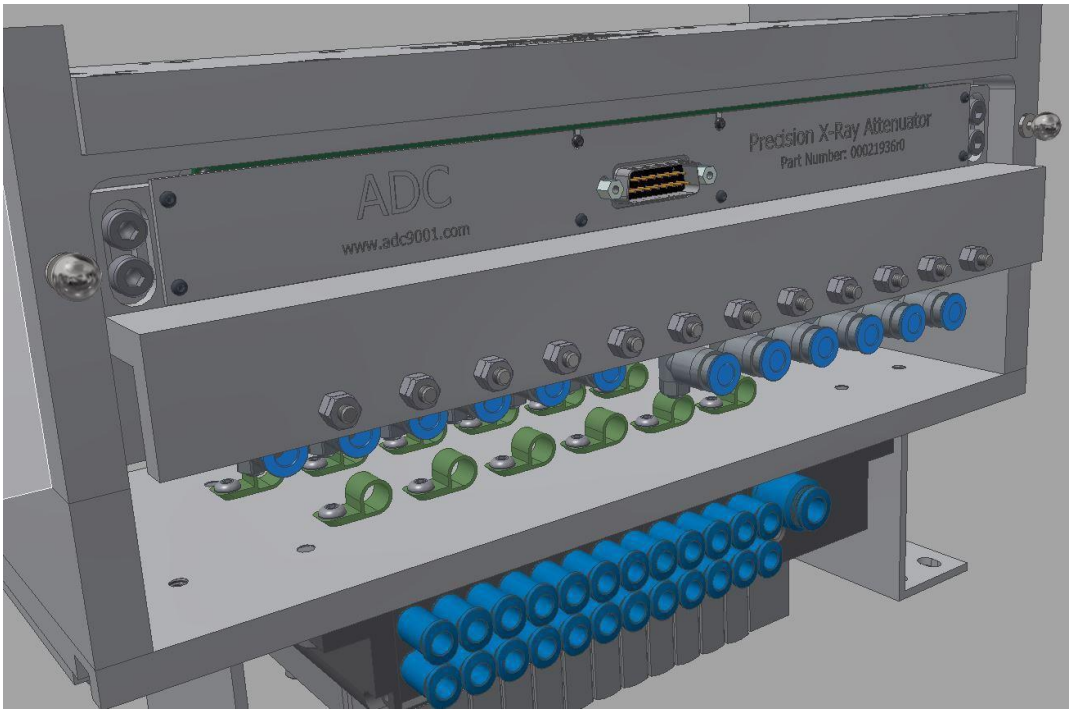

Figure 4 – Pneumatic and electrical connectors: 6 mm quick-connect for pneumatics and DB-15 for electrical signal from the reed switches. Pneumatic hoses again omitted.

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ABS-300 CONTROLLER:

The ABS-300 precision attenuator is controlled using a Productivity 3000 Programmable Automation Controller (Fig.5 & Fig.6), but could be operated with other controllers. The Productivity 3000 acts as a slave to the PC and use the MODBUS protocol to interface over the Ethernet port. The Productivity 3000 is a modular system. This particular application uses two relay inputs and one relay output. Each relay module has a total of sixteen terminals. The user PC will act as the master and can communicate using the MODBUS ports or the software which is freely sent with the ABS-300 Controller.

Figure 5 – ABS-CR-01 controller for pneumatic actuators.

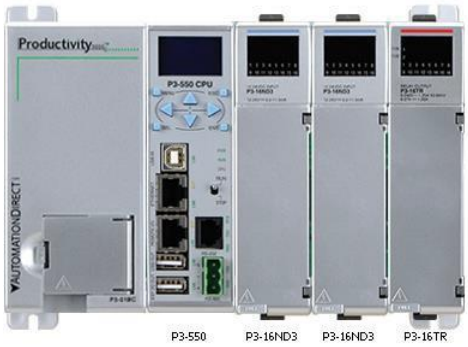

Figure 6 – Productivity 3000 PLC inside brains of the ABS-CR-01.

The ABS-300 precision attenuator is of the filter bank rather than wheel type. It is an economical and robust absorber system which can be used in a wide energy range, depending on the choice of filters. The provided filters may easily be swapped for filters of other thicknesses and metals as needed by the researcher. It is high-vacuum capable to 1e-7 bar. The filters are moved by means of pneumatic actuators which are located on the outside and are coupled magnetically to the filters inside the vacuum. This means that no vacuum feed- through has been used for this design and that the absorber moves promptly and quickly.

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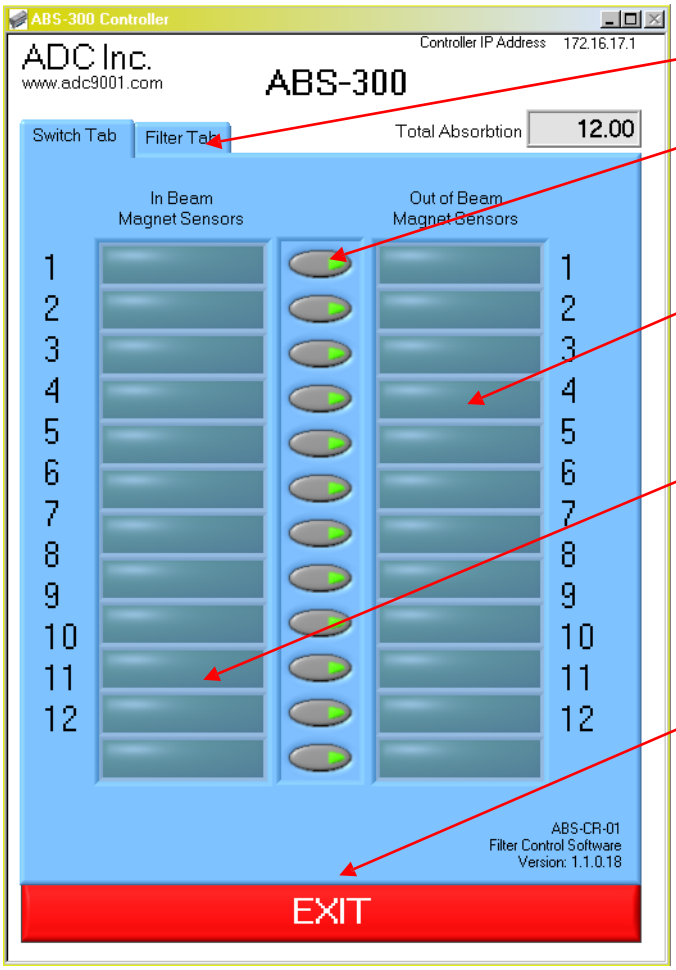
In the presented setup 12 different filters (made from ultrapure aluminum, titanium and copper) can be moved into the beam and small reed-sensors detect success of the movement. The communication with external control systems is in the presented setup done by a stand-alone Productivity 3000 controller. However, any external 24V-toggle signal can be used to drive the single pneumatic actuators, and the reed-sensors are simple switches which can be read by TTL- logics.

ABS-300 SOFTWARE

The ABS-CR-01Controller will come with control software on a CD. This should automatically install on the user's PC. The ABS-300 software is a simple but effective way to move the filters in and out of the beam. Below is a summary layout.



Filter Tab

Move filter button

Magnet sensor on the 'out of beam' side

Magnet sensor on the 'in beam' side

Exit the program

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ABSORBER FILTERS

In terms of the filters, it has been taken care that, beginning from the thinnest filter, every other absorbs twice as much as the former (in the linear configuration) so that the filter bank can be accounted as a bit-number. By proper bit-combinations any absorption factor can be approximated in a photon energy range from 5-30 keV. Another nonlinear filter is offered which spans 2.5-20 keV.

Table 1 – Absorber Configuration 1 (Linear Increase in absorption)

Absorber 5-30keV (type 1)

Thicknesses *t* of the foils

	theoretical	theoretical	theoretical	actual combination
number	*t* Al (µm)	*t* Ti (µm)	*t* Cu (µm)	all figures given in µm
1	25			Al25
2	50			Al50
3	100			Al100
4	200			2 x Al100
5	400			Al250 & Al100 & Al25
6	800			Al500 & Al250 & Al50
7	1600	234.1		Ti125 & 2 x Ti50 & Al50 & Al10
8	3200	468.2		3 x Ti125 & Ti50 & Al250 & Al50
9	6400	936.4		7 x Ti125 & Al250 & Al50 & Al25
10	12800	1873	403.4	4 x Cu100 & Al100
11	25600	3746	806.8	2 x Cu250 & 3 x Cu100 & 2 x Al100
12	51200	7491	1614	Cu1000 & 2 x Cu250 & Cu100 & Al250 & 2 x Al100

Table 2 – Absorber Configuration 2 (Non-linear increase in absorption)

Absorber 2.5-20keV (type 2, nonlinear)

Thicknesses *t* of the foils

	theoritical	theoritical	theoritical	actual combination (purity of Al6 : 99.0%)
number	*t* Al (µm)	*t* Ti (µm)	*t* Cu (µm)	all figures given in µm
1	6			Al6
2	12			2 x Al6
3	24			Al25
4	48			Al50
5	106			Al100 & Al6
6	230			2 x Al100 & Al25 & Al6
7	500			Al500
8	1070			2 x Al500 & Al50 & Al25
9	2300	327.6		2 x Ti125 & Al250 & Al50 & Al25
10	5000	712.1		4 x Ti125 & Ti50 & Al250
11	10700	1524	341.8	3 x Cu100 & Cu25 & 2 x Al250 & Al25
12	23500	3347	750.7	3 x Cu250

Standard devices for this are wheels with a number of different foils or filter banks. These simple devices have several disadvantages:

- Mostly they are not in vacuum and are therefore not appropriate for photon energies below 5keV. If they are in-vacuum devices they are extremely expensive.
- Especially wheels are restricted to a quite narrow photon energy range due to a lack of sufficient number of different foils.

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For further flexibility the system has several possible mounting configurations. It can be placed entirely upside-down (Fig. 7) and the pneumatic manifold can be removed and placed separately or placed on top of the chamber unit. Note that more tubing will be required for other manifold mounting locations. The lower leg and manifold assembly is held in place using just four bolts, so that reconfiguration is easy.

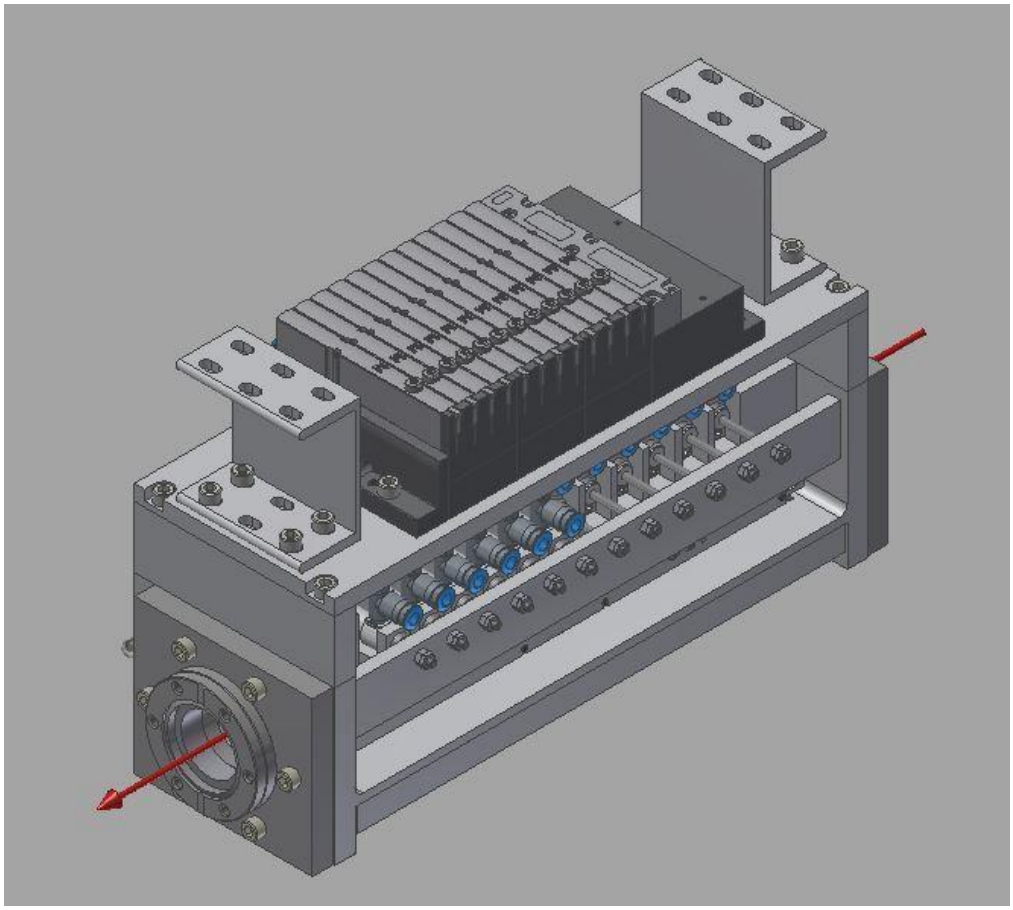

Figure 7 – System shown upside-down.

In summary, the Precision Attenuator is vacuum compatible, robust, ready to use and easy to control. When using appropriate foils, the attenuation factor can be tuned with high precision in a wide photon energy range.

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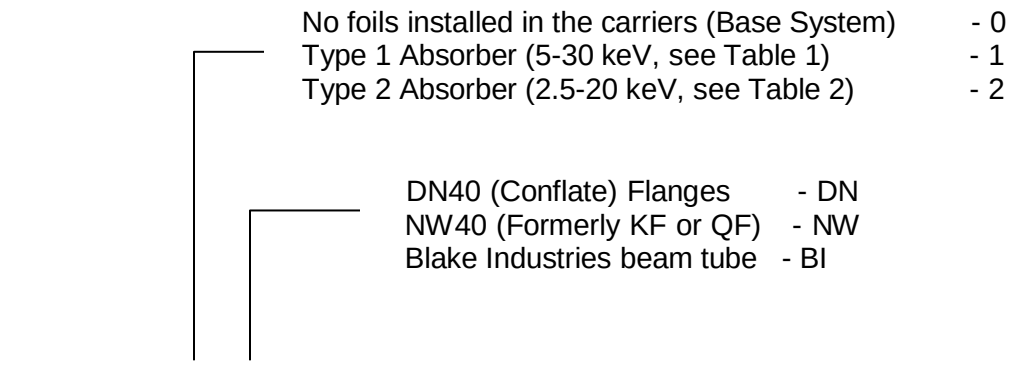
ORDERING INFORMATION:

The attenuator can be ordered with different foil configurations, please use the codes provided below when ordering. Please call or e-mail to ask about customization if your application requires it.



For example, a chamber configured for 5-30 keV with DN40 flanges would be denoted by:
ABS-300-12-1-DN