ANVILOY® PRODUCTS

WELDSTONE
TUNGSTEN COMPONENTS

RADIATION ATTENUATION OR RADIATION SHIELDING FROM IONIZING RADIATION

IBG GROUP

Shielding of ionizing radiation

The shielding of ionizing radiation is one of the most important uses of ANVILOY® tungsten alloys (also called heavy metal alloy) because of the following characteristics:

- Good mechanical properties or durability with a yield strength comparable to quenched and tempered steels.
- High thermal conductivity for efficient dissipation of decay heat from highly active sources
- High attenuation of photonic radiation for a given mass or thickness (specific attenuation)
- Minimal susceptibility to photonuclear reactions
- Low toxicity, chemical reactivity, and susceptibility to corrosion
- Easy machining

ANVILOY® tungsten alloys are particularly suitable for shielding high-energy photonic radiation emanating from radioisotope sources such as Co60, from reactor operation and from high-voltage X-ray generators. Crucial for attenuation of high-energy photonic radiation, is the atomic mass as well as the density of the shielding material. ANVILOY® tungsten alloys offer many advantages over the widely used lead alloys. These include higher strength, higher thermal conductivity, better thermal stability, greatly reduced toxicity, and better shielding efficiency (up to 36% lower thickness for Co60 radiation).

ANVILOY® tungsten alloys are not needed for shielding alpha or other charged particle radiation, since much cheaper material solutions with lower atomic mass, such as plastics or Al alloys, are sufficient for this purpose. ANVILOY® tungsten alloys are also not used for attenuation (shielding) of beta radiation. Due to its high braking effect on beta radiation due to the high atomic number (Z) of tungsten, this could even be counterproductive, as the resulting high-energy X-rays could pose a much greater shielding problem than the original beta radiation.

These and other advantages of ANVILOY® shielding over other materials can be seen in the table. ANVILOY® tungsten alloys offer linear attenuation close to that of pure tungsten, which in turn is only slightly lower than that of depleted uranium (DU). ANVILOY® tungsten alloys offer distinct advantages over both DU and Pb because they are not subject to OSHA, EPA, NRC or other regulations governing sale, handling and/or use.

Comparison of metallic gamma shielding materials in order of attenuation efficiency

Element/ alloy	μ (cm^{-1}) for 1.25 MeV*	Z	Density (g/cm^3)	Melting temp. or Solidus start (°C)	Thermal conductivity (W/mK)	Thermal expansion coefficient. ($10^{-6}/K$)	Strength (MPa)
Stainless steel (Fe-19Cr-9Ni)	0,428	mixed	8	1400	16	17	515
Cu	0,471	29	8,96	1083	390	17	<365
Lead	0,667	82	11,35	328	33	29	~21
THA	0,953 -1,04	mixed	17 - 18,5	~1450	~70 – 100	~5,8 – 4,8	870
W	1,076	74	19,3	3420	160	4,2	980
U	1,217	92	19,1	11,32	27	19	400

* Calculated with the NIST XCOM photon scattering program.

Whenever shielding is exposed to elevated temperature, e.g., decay heat from very active sources, at which lead alloys would deform or melt, tungsten alloys should be used because of their high thermal conductivity and solidus temperature.

Cobalt cannot be used as an alloy component for radiation shielding of particle radiation or photonic radiation >10 MeV because of its possible activation.

Their gamma shielding power for the respective photon energy is described by the linear attenuation coefficient (μ) of different materials. The radiation transmission (T) through a plate-shaped shielding is given by

$$T = e^{-(\mu \cdot x)}$$

where μ is in cm^{-1} and the shielding thickness x is in cm. It may be that this simple estimate of the shielding effectiveness of a given material, for certain source, shielding, and sensor geometries, understates the actual thickness of shielding required for a given level of protection.
The shielding of an average Co_{60} beam source with a gamma energy of 1.25 MeV using a typical class 1 tungsten alloy (with a $\mu = 0.953\ cm^{-1}$) to one tenth (tenth-value thickness TVT or 10% transmittance) would be calculated as follows:

$$\ln(0{,}1) = -0{,}953 \cdot x$$

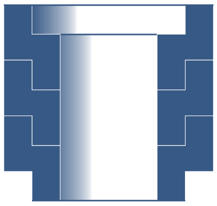
$$x = 2{,}42\ cm$$

The table below contains the approximate tenth-value thicknesses of various Anviloy® tungsten alloys for the major photon energies. The addition of the tenth-value thicknesses corresponds to a multiplication of the attenuation. Accordingly, a 10^4: 1 ratio of incident radiation attenuation would require a shielding of 4 tenth value thicknesses.

Calculated tenth thickness (cm) at different photon energies. (Thickness of a radiated material at which the electromagnetic radiation is reduced in its radiation intensity to one tenth.)												
Energy (MeV)	Anviloy® 170C	Anviloy® 175C	Anviloy® 180C	Anviloy® 185C	Anviloy® 170F	Anviloy® 175F	Anviloy® 180F	Anviloy® 185F	W ref.	Pb ref.	U ref.	Anviloy® 180F / Lead
μ (cm^{-1})	0,951	0,980	1,010	1,037	0,955	0,984	1,010	1,037	1,076	0,665	1,206	
0.12	0,053	0,051	0,048	0,046	0,053	0,050	0,048	0,046	0,043	0,058	0,028	0,79
0.14 ^{99m}Tc	0,078	0,074	0,071	0,068	0,079	0,074	0,071	0,068	0,064	0,085	0,040	0,80
0.20	0,186	0,178	0,169	0,163	0,186	0,178	0,169	0,163	0,153	0,204	0,094	0,80
0.36 ^{131}I	0,619	0,591	0,566	0,549	0,618	0,589	0,565	0,549	0,519	0,722	0,340	0,76
0.47 ^{192}Ir	0,933	0,893	0,863	0,838	0,933	0,893	0,861	0,838	0,795	1,140	0,509	0,74
0.51 from β+	1,050	1,010	0,960	0,933	1,040	0,993	0,960	0,933	0,890	1,300	0,637	0,72
0.66 ^{137}Cs	1,410	1,360	1,310	1,280	1,400	1,350	1,310	1,280	1,220	1,830	1,540	0,70
1.00	2,100	1,990	1,920	1,880	2,040	1,980	1,920	1,880	1,800	2,860	1,540	0,66
1.25 ^{60}Co	2,420	2,350	2,280	2,220	2,410	2,340	2,280	2,220	2,140	3,460	1,910	0,64
2.22 H(n,γ)	3,130	3,050	2,950	2,880	3,120	3,040	2,950	2,880	2,780	4,540	2,580	0,63
6.00	3,270	3,160	3,050	2,960	3,270	3,150	3,050	2,960	2,840	4,630	2,660	0,64
10.0	2,930	2,820	2,720	2,640	2,920	2,820	2,710	2,640	2,520	4,090	2,340	0,65
20.0	2,390	2,280	2,200	2,140	2,380	2,280	2,200	2,140	2,020	3,270	1,880	0,65

ANVILOY® tungsten alloys expand very minimally with temperature increase and thus offer good dimensional stability. In shielding constructions made of several materials, the internal tungsten component expands less than a surrounding stainless-steel construction at the same temperature change. Lead shields encounter risk of permanent deformation due to their greater thermal expansion. ANVILOY® tungsten alloys dissipate heat 4-6 times better than austenitic stainless steel. These improved properties alloy the heat from the interior to be quickly distributed over larger heat dissipation surfaces. This has a very positive effect on heat management. The offset of the radiation joints should be as large as possible.

If large shields are required, they can be assembled from individual smaller components. In this case, offsets or radiation interruptions should always be used. In this way, any straight-line radiation from the interior is prevented. Cylindrical shields could be composed of stacked rings with an axial offset (male and female stages). The offset of the radiation joints should be as large as possible.

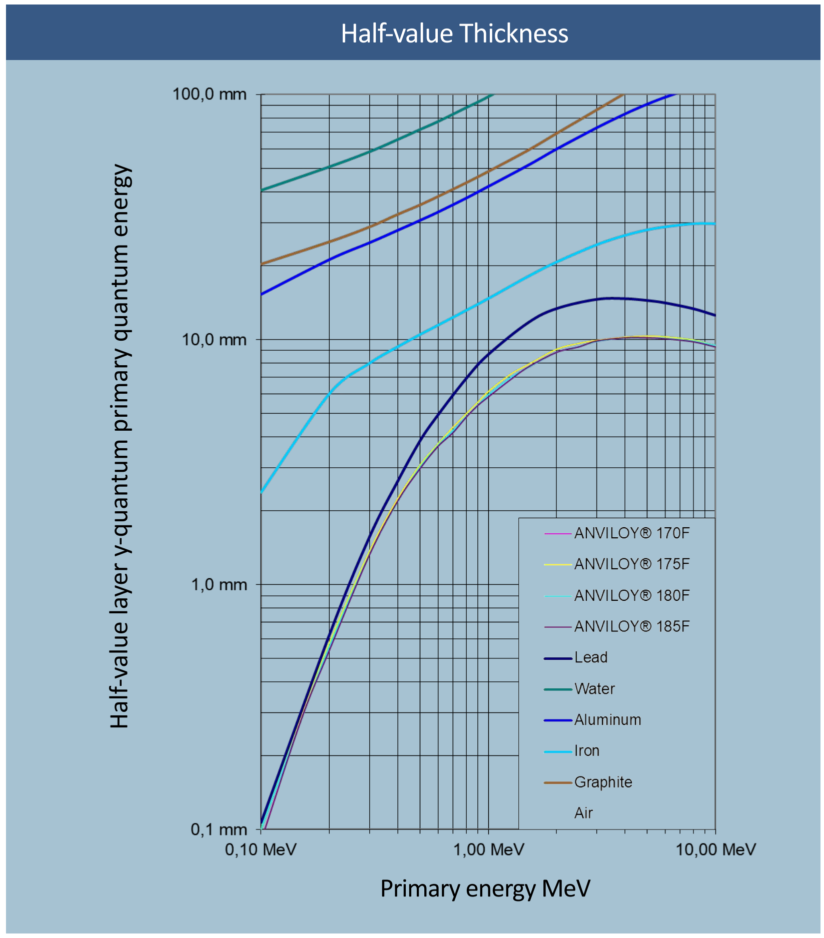


Neutron shielding is usually realized with water, hydrogen-rich polymers such as PE or materials such as boron concrete. However, in neutron shielding, ANVILOY® tungsten alloys are usually not exclusively used. Nevertheless, the high tungsten content provides better neutron absorption than many other metals (see table). Tungsten has a neutron capture cross section more than 100 times higher than lead and almost seven times higher than pure iron. Although ANVILOY® tungsten alloys have never been selected for use in a primary neutron shield because of its weight and cost, it can still play an important secondary shielding role in mixed radiation environments. A typical secondary shielding task would be the attenuation of 2.2 MeV gamma radiation from H-capture of neutrons in PE or similar H-rich primary shielding layers, in addition to an existing gamma flux.

The term "radiation shielding" is also used in the context of electromagnetic interference (EMI) or radio-frequency interference (RFI) shielding. However, ANVILOY® tungsten alloys are unsuitable for high-frequency radiation shielding due to cost, density, and low magnetic permeability.

Neutron absorption cross section of different materials

Element	Absorption cross section (10^{-28} m^2)
B	760
W	18
Ni	4.5
Fe	2.6
Al	0.23
Pb	0.172



Europe, Asia, Australia

Contact:
Andreas Endemann, Thomas Hoehn

Weldstone Components GmbH
Am Rübgarten 2
D-57299 Burbach

Tel.: +49 8031-94 13 99-0
+49 8031-94 13 99-02
Fax: +49 8031-94 13 99-09
Email: hello@weldstone.com
Internet: www.weldstone.com

China

Contact:
Ted Li, Kitty Cheng

Shandong Weldstone Tungsten Industry Co., Ltd
3001 Sichou Road, Zhoucun,
Zibo, Shandong, PRC

Tel: +86-533-6824658
Fax: +86-533-6823685
Email: hello@weldstone.cn
Internet: www.weldstone.cn