What Are Tungsten Alloy Shielding Cans

中钨智造科技有限公司

CTIA GROUP LTD

CTIA GROUP LTD

Global Leader in Intelligent Manufacturing for Tungsten, Molybdenum, and Rare Earth Industries

INTRODUCTION TO CTIA GROUP

CTIA GROUP LTD， a wholly-owned subsidiary with independent legal personality established by CHINATUNGSTEN ONLINE , is dedicated to promoting the intelligent, integrated, and flexible design and manufacturing of tungsten and molybdenum materials in the Industrial Internet era. CHINATUNGSTEN ONLINE, founded in 1997 with www.chinatungsten.com as its starting point—China's first top-tier tungsten products website—is the country's pioneering e-commerce company focusing on the tungsten, molybdenum, and rare earth industries. Leveraging nearly three decades of deep experience in the tungsten and molybdenum fields, CTIA GROUP inherits its parent company's exceptional design and manufacturing capabilities, superior services, and global business reputation, becoming a comprehensive application solution provider in the fields of tungsten chemicals, tungsten metals, cemented carbides, high-density alloys, molybdenum, and molybdenum alloys.

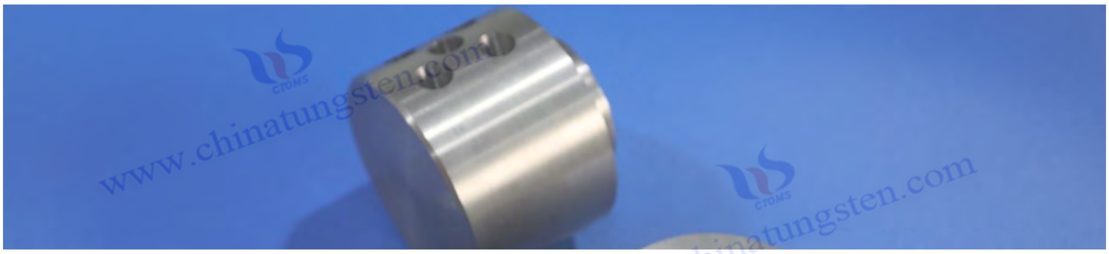
Over the past 30 years, CHINATUNGSTEN ONLINE has established more than 200 multilingual tungsten and molybdenum professional websites covering more than 20 languages, with over one million pages of news, prices, and market analysis related to tungsten, molybdenum, and rare earths. Since 2013, its WeChat official account "CHINATUNGSTEN ONLINE" has published over 40,000 pieces of information, serving nearly 100,000 followers and providing free information daily to hundreds of thousands of industry professionals worldwide. With cumulative visits to its website cluster and official account reaching billions of times, it has become a recognized global and authoritative information hub for the tungsten, molybdenum, and rare earth industries, providing 24/7 multilingual news, product performance, market prices, and market trend services.

Building on the technology and experience of CHINATUNGSTEN ONLINE, CTIA GROUP focuses on meeting the personalized needs of customers. Utilizing AI technology, it collaboratively designs and produces tungsten and molybdenum products with specific chemical compositions and physical properties (such as particle size, density, hardness, strength, dimensions, and tolerances) with customers. It offers full-process integrated services ranging from mold opening, trial production, to finishing, packaging, and logistics. Over the past 30 years, CHINATUNGSTEN ONLINE has provided R&D, design, and production services for over 500,000 types of tungsten and molybdenum products to more than 130,000 customers worldwide, laying the foundation for customized, flexible, and intelligent manufacturing. Relying on this foundation, CTIA GROUP further deepens the intelligent manufacturing and integrated innovation of tungsten and molybdenum materials in the Industrial Internet era.

Dr. Hanns and his team at CTIA GROUP, based on their more than 30 years of industry experience, have also written and publicly released knowledge, technology, tungsten price and market trend analysis related to tungsten, molybdenum, and rare earths, freely sharing it with the tungsten industry. Dr. Han, with over 30 years of experience since the 1990s in the e-commerce and international trade of tungsten and molybdenum products, as well as the design and manufacturing of cemented carbides and high-density alloys, is a renowned expert in tungsten and molybdenum products both domestically and internationally. Adhering to the principle of providing professional and high-quality information to the industry, CTIA GROUP's team continuously writes technical research papers, articles, and industry reports based on production practice and market customer needs, winning widespread praise in the industry. These achievements provide solid support for CTIA GROUP's technological innovation, product promotion, and industry exchanges, propelling it to become a leader in global tungsten and molybdenum product manufacturing and information services.

Table of Contents

Appendices:



CTIA GROUP LTD Tungsten Alloy Shielding Can

CTIA GROUP LTD
High-Density Tungsten Alloy Customization Service

CTIA GROUP LTD, a customization expert in high-density tungsten alloy design and production with 30 years of experience.

Core advantages: 30 years of experience: deeply familiar with tungsten alloy production, mature technology.
Precision customization: support high density (17-19 g/cm³), special performance, complex structure, super large and very small parts design and production.
Quality cost: optimized design, optimal mold and processing mode, excellent cost performance.
Advanced capabilities: advanced production equipment, RMI, ISO 9001 certification.

100,000+ customers

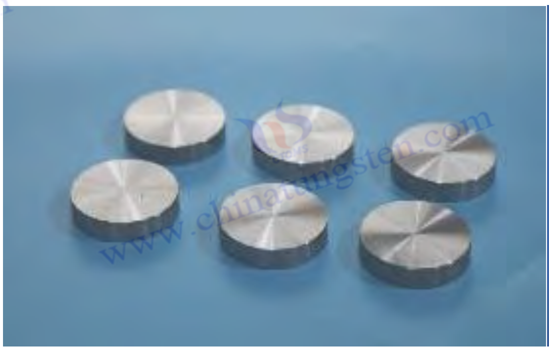
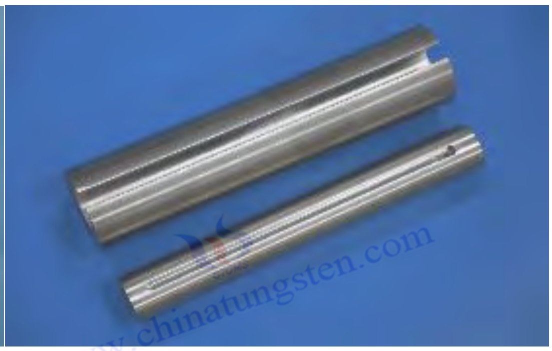
Widely involved, covering aerospace, military industry, medical equipment, energy industry, sports and entertainment and other fields.

Service commitment

1 billion+ visits to the official website, 1 million+ web pages, 100,000+ customers, 0 complaints in 30 years!

Contact us
Email: sales@chinatungsten.com
Tel: +86 592 5129696
Official website: www.tungsten-alloy.com



Chapter 1 Entering the World of Tungsten Alloy Shielding Cans

1.1 Concept of Tungsten Alloy Shielding Can

Tungsten alloy shielding containers are functional containers designed and manufactured specifically for containing and shielding radioactive materials, using tungsten-based high-density alloys as the main material in modern radiation protection engineering . They fully utilize the significantly higher bulk density of tungsten alloys compared to lead, iron, or concrete, as well as their superior attenuation capabilities for gamma rays, X-rays, and neutron fluxes, achieving highly efficient radiation shielding within a very limited space. Simultaneously, they possess sufficient structural strength, thermal stability, chemical inertness, and long-term containment reliability. Compared to traditional shielding methods, tungsten alloy shielding containers completely break the inherent contradiction of "better protection, larger volume, and heavier weight," significantly reducing the overall volume and mass for the same level of protection, thereby improving the space utilization, operational flexibility, and personnel accessibility of the facility.

In practical applications, tungsten alloy shielding containers serve as both the first physical containment barrier for radioactive sources or radioactive waste and a core engineering barrier for radiation dose control. They are widely used around nuclear medicine imaging equipment, isotope production hot chambers, industrial X-ray inspection darkrooms, irradiation channels in research reactors, high-energy physics experimental terminals, and in the temporary storage and transfer of radioactive waste, becoming a key physical component for achieving the principles of "optimal protection" and "minimized dose." As radiation applications evolve towards higher activity, compactness, and mobility, tungsten alloy shielding containers have gradually replaced traditional lead containers, lead glass containers, and heavy concrete containers, becoming the recognized representative of high-end, green, and long-life shielding solutions in the field of radiation protection today.

1.1.1 Definition of Tungsten Alloy Shielded Can

A tungsten alloy shielding container is strictly defined as a composite engineering container made of tungsten-nickel-iron, tungsten-nickel-copper, or tungsten-nickel-iron-copper high-density alloys with a tungsten content of not less than 90%, manufactured through near-net-shape forming sintering, forging, or precision machining processes, possessing both radioactive material containment and radiation shielding functions. Its design must simultaneously meet the mechanical and thermal requirements of the International Atomic Energy Agency for radioactive material transport containers, the type approval conditions of national nuclear safety regulatory authorities for storage and handling containers, and the most stringent surface dose rate limits for medical and industrial radiation protection.

From a materials science perspective, it represents a typical structural-functional integrated application of high-density alloys in radiation protection; from a systems engineering perspective, it is a core node in an inclusive shielding system; and from a regulatory and standards perspective, it is one of the specific implementations of Type A, Type B, or Type C radioactive material transport containers, industrial source

电话/TEL：0086 592 512 9696
CTIAQCD-MA-E/P 2018-2024V
sales@chinatungsten.com

containers, medical source containers, or waste containers. It is precisely this high degree of integration of multiple attributes that makes tungsten alloy shielding containers irreplaceable in the modern radiation safety system.

1.1.2 Basic Components of Tungsten Alloy Shielded Cans

typical tungsten alloy shielding tank consists of a tank body, a top cover or end cover, a sealing and locking system, a lifting and handling interface, a surface functional coating, an inner cavity cleaning lining, and various auxiliary functional interfaces. The tank body is usually made of integral sintered blank or multi-segment forged ring welding process to ensure continuous shielding layer thickness and no splicing gaps; the top cover mostly adopts an embedded or convex structure, and achieves micron - level fit through precision grinding .

The sealing system generally employs a double-safety design with a multi-stage labyrinth seal and radiation-resistant elastic sealing rings or corrugated metal sealing rings. This design prevents the leakage of radioactive aerosols while maintaining detachability after high-temperature irradiation. Locking mechanisms primarily utilize quick-lock clamps , multi-threaded joints, or hydraulic locking rings , balancing rapid operation with long-term anti-loosening requirements. Lifting and handling interfaces include integral forged lifting lugs on the top, forklift slots on the sides, or standardized pallets on the bottom, meeting the full-process operational needs of shielded transport vehicles, gantry cranes, or robotic arms.

The surface is often coated with electroless nickel plating, black oxide oxidation, or a special decontamination coating to improve corrosion resistance and decontamination efficiency. The product also integrates a lead glass observation window, a dose rate monitoring probe interface, a pressure balancing valve, a built-in source operating mechanism, or a replaceable liner, transforming a single container into an integrated shielded system with multiple functions including monitoring, operation, and transportation. These elements were designed from the outset following the system principles of containment, shielding, operability, and decontamination capability, ultimately forming a highly coordinated and safety-redundant overall structure.

1.1.3 Basic characteristics of tungsten alloy shielding containers

The most significant features of tungsten alloy shielding containers are their high shielding effectiveness and small size and weight. Under the same radiation energy and protection requirements, their wall thickness is much lower than that of lead containers, yet they can achieve the same or even better dose attenuation effect, thereby greatly freeing up valuable thermal chamber space and building load. Secondly, they possess excellent comprehensive mechanical properties and high-temperature stability. Long-term irradiation and temperature cycling will not cause creep softening of lead or micro-cracks and leakage in concrete, ensuring the permanent reliability of the structure and seal.

Third, it boasts excellent corrosion resistance and easy cleaning properties. The tungsten-nickel-copper

电话/TEL：0086 592 512 9696
CTIAQCD-MA-E/P 2018-2024V
sales@chinatungsten.com

system is stable in humid, acidic, alkaline, or saline environments. Combined with a mirror-finished inner cavity, it makes repeated cleaning operations simple and efficient, significantly reducing the volume of secondary waste. Fourth, it is completely non-toxic and lead-free, fundamentally eliminating the environmental and health hazards of traditional lead containers and meeting the most stringent requirements for the final disposal of radioactive waste and green radiation protection. Finally, it offers extremely high design freedom and manufacturing precision. The wall thickness, cavity shape, and interface type can be deeply customized according to the specific energy spectrum, activity, chemical form, and application scenario of the radioactive source, achieving full-spectrum coverage from miniature medical source containers to large waste transfer containers.

Because of these interconnected and outstanding advantages, tungsten alloy shielding canisters have not only significantly improved the economy and ease of operation of radiation protection, but also promoted the deep evolution of nuclear medicine, isotope production, industrial flaw detection and scientific irradiation facilities towards miniaturization, modularization and greening, becoming one of the most technologically advanced and representative shielding components in contemporary radiation safety engineering.

1.2 Material Selection Logic for Tungsten Alloy Shielding Cans

tungsten alloys have stood out among numerous candidate shielding materials and become the preferred structural material for high-end shielding tanks lies in their optimal balance across multiple dimensions, including radiation attenuation capability, mechanical properties, thermal stability, chemical inertness, processability, and environmental compatibility. Traditional shielding designs have long relied on lead, concrete, boronized polyethylene, or ordinary steel, but each of these materials has insurmountable shortcomings: lead, although dense, is toxic and suffers from severe high-temperature creep; concrete has low shielding efficiency and is immovable; boronized polyethylene is only effective against neutrons and almost powerless against gamma rays; and ordinary steel can only barely meet the requirements with extremely thick walls. The underlying logic of material selection has always revolved around the core objective of "achieving maximum radiation attenuation, longest service life, lowest maintenance cost, and highest environmental compatibility within a limited space and weight budget." Tungsten alloys, with their near-theoretical density microstructure, high-quality gamma-ray attenuation coefficient, moderate neutron moderation capability, and excellent comprehensive mechanical properties, perfectly meet this objective. Especially in scenarios where space is extremely sensitive and decontamination requirements are stringent, such as nuclear medicine hot chambers, isotope production lines, industrial flaw detection anechoic chambers, and high-energy physics experimental terminals, tungsten alloy shielding containers have become almost the only realistic solution that simultaneously meets the constraints of regulations, engineering, and economy.

1.2.1 Performance Comparison of Tungsten Alloys and Mainstream Shielding Materials

Compared to lead, tungsten alloys offer equal or even higher gamma-ray shielding capabilities while completely eliminating the high toxicity , creep softening, and secondary contamination risks associated with lead . Lead containers are highly susceptible to irreversible deformation after prolonged irradiation and elevated temperatures, leading to seal failure and increased surface dose rate. In contrast, tungsten alloy containers maintain their geometric precision and structural strength even under high-temperature irradiation, completely avoiding these risks. Furthermore, the non-toxic nature of tungsten alloys makes them a regulatory favorite in the medical and isotope production fields; after decontamination, they can be directly disposed of as ordinary metal waste, while lead containers often require special environmentally friendly disposal procedures.

Compared to ordinary steel and stainless steel, tungsten alloys have a much higher bulk density, allowing for significantly thinner walls to achieve the same shielding effect. This results in a more reasonable overall weight distribution, making them particularly suitable for applications requiring frequent lifting or where installation space is limited. While stainless steel offers excellent corrosion resistance, it requires several times the thickness of tungsten alloys to achieve the same attenuation under high-energy gamma rays, leading to excessive container weight and excessive hot chamber load. Tungsten alloys, on the other hand, can achieve the required dose rate with a thinner wall, reducing civil engineering costs and lifting equipment requirements.

Compared to engineering ceramics and ultra-hard, brittle materials like sapphire, tungsten alloys maintain extremely high hardness while possessing metallic toughness, avoiding the catastrophic cracking seen in ceramic materials under impact or thermal shock . While ceramic shielding components offer high attenuation efficiency for certain energies of radiation, they are difficult to manufacture, costly, and cannot be repaired; once a microcrack appears, the component is rendered unusable. In contrast, tungsten alloy shielding containers allow for laser remelting repair after localized damage, significantly improving overall lifecycle economics.

Compared to boron-containing polyethylene and other neutron shielding materials, tungsten alloys, while less effective at moderating thermal neutrons than hydrogen-containing materials, offer far superior combined shielding against gamma rays and fast neutrons. More importantly, tungsten alloys can achieve combined gamma-neutron shielding within the same container by locally embedding boron-containing or hydrogen-containing layers , whereas plastic materials are prone to aging and deformation at high temperatures, making them unsuitable for structural applications.

Compared to depleted uranium shielding materials, tungsten alloys completely avoid the problems of radioactivity and regulatory restrictions, while having superior mechanical properties and machinability, thus gaining unimpeded access in civilian nuclear medicine, industrial flaw detection, and scientific research facilities.

1.2.2 Core Advantages of Tungsten Alloy Shielding Cans in Shielding Performance

tungsten alloy shielding containers in shielding performance lies primarily in their extremely high volumetric attenuation capability for gamma rays and X-rays. Due to tungsten 's high atomic number and large electron cloud density, the combined cross-section of the photoelectric effect, Compton scattering, and electron-pair effect far exceeds that of conventional metals such as lead and iron. This allows the same mass of shielding layer to block more high-energy photons, resulting in significantly reduced wall thickness at the same dose rate control level, a more compact container shape, and a substantial increase in usable internal volume. For space-constrained locations such as nuclear medicine hot cells, isotope dispensing rooms, and PET-CT rooms, this means more functional equipment can be installed or the thickness of the shielding walls can be significantly reduced, leading to a qualitative leap in overall engineering economics.

Secondly, tungsten alloys also exhibit excellent slowing and absorption capabilities for fast neutrons. Especially in the tungsten-nickel-iron system, the high inelastic scattering cross-section of iron and the high-density elastic scattering of tungsten work synergistically to effectively reduce neutron energy. Combined with an outer or inner hydrogen- or boron-containing slow-release layer, gamma-neutron composite shielding can be achieved without the need for additional layers of heterogeneous materials as required by lead containers. This ability to achieve broad-spectrum shielding with a single material significantly simplifies container structural design and eliminates the risk of interlayer interface failure.

More importantly, the shielding performance of tungsten alloys hardly decreases with increasing temperature, and even under high-temperature irradiation, they can maintain their complete microstructure and macro geometry. In contrast, lead exhibits significant creep at higher temperatures, concrete develops microcracks due to water loss, and boronized polyethylene softens and ages. The low coefficient of thermal expansion and high recrystallization temperature of tungsten alloys allow the shielding canister to maintain its designed shielding thickness even in fire accidents or long-term high-temperature irradiation scenarios, ensuring that the dose rate does not exceed the limit and buying valuable time for emergency response.

Finally, tungsten alloy surfaces can form a dense and stable oxide film through polishing, plating, or chemical passivation, exhibiting extremely low adsorption of secondary radionuclides, a high decontamination coefficient, and the ability to recover to background levels even after repeated contamination. In contrast, lead surfaces are porous and prone to irreversible contamination, while concrete, due to its roughness and porosity, becomes a long-term carrier of radioactive dust. Considering these characteristics, tungsten alloy shielding containers achieve multi-dimensional leadership in shielding efficiency, spectral adaptability, environmental robustness, and long-term decontamination capability, making them the preferred shielding medium for modern high-end radiation protection facilities.

1.2.3 Selection Logic of Tungsten Alloy Shielding Cans under Scenario Adaptation

In practical engineering, the selection of tungsten alloy shielding containers follows a systematic logic integrating "source, scenario, regulations, lifespan, and cost." First, the required shielding thickness and material system are determined based on the type, energy spectrum, and activity of the radioactive source: tungsten -nickel-iron system is preferred for high-energy gamma sources to also provide neutron shielding; non-magnetic tungsten-nickel-copper system is selected for pure gamma sources in medical environments sensitive to magnetic fields; when dealing with fluoride-containing or strongly acidic radioactive waste liquids, an inner corrosion-resistant lining layer needs to be added or a tungsten-nickel-copper alloy with stronger pitting corrosion resistance should be selected.

Secondly, the wall thickness distribution and structural form are determined based on the space and weight constraints of the usage scenario: hot chamber fixed large tanks pursue uniform wall thickness and overall rigidity, and adopt integral sintering or multi-layer sleeve structure; mobile transport containers emphasize optimal weight and drop resistance, and often adopt an outer thin and inner thick gradient design and supplemented by shock-absorbing base; glove box built-in small source tanks pay more attention to the ease of operation, and use quick-opening lids and lightweight lifting lugs.

Furthermore, strict compliance with regulatory requirements is essential: medical waste transfer tanks must comply with dual registration by the National Medical Products Administration and the National Nuclear Safety Administration, and surface dose rate, decontamination factor, and biocompatibility must all pass type tests; industrial waste transfer tanks must meet the Type A or Type B transport container standards, and drop, stacking, and fire tests are indispensable; and tanks used for scientific research experiments focus more on interface diversity and the ability to be quickly modified.

Finally, considering the total life cycle cost and maintenance strategy: although the initial purchase cost of tungsten alloy is higher than that of lead, its maintenance-free, zero-lead-contamination , repairability and ultra-long service life result in a total cost of ownership that is far lower than that of traditional materials. Especially in nuclear medicine and isotope production lines that require frequent opening, dispensing and decontamination, tungsten alloy shielding containers can often recover the investment within three years by saving labor, reducing waste volume and avoiding downtime losses.

Because of the tight closed loop of the above logic, the selection of tungsten alloy shielding tanks has evolved from the early "performance priority" to today's "scenario-driven, regulation-guided, and life-cycle-economic" system engineering practice, ensuring that every shielding tank leaving the factory is not only a solid barrier for radiation safety, but also the optimal carrier for facility operation efficiency and green compliance .

1.3 Development History and Industrial Value of Tungsten Alloy Shielding Cans

tungsten alloy shielding containers is the result of the coupling of three factors: high-density alloy materials science, the needs of radiation protection engineering, and the rapid rise of the nuclear medicine and isotope industries. From its initial role as a "high-end alternative" to lead containers, to its current status as a standard component of nuclear medicine hot chambers and isotope production lines, and its gradual penetration into the entire chain of industrial flaw detection, scientific irradiation facilities, and radioactive waste management, tungsten alloy shielding containers have undergone a remarkable transformation from "optional" to "essential." Behind this transformation lies continuous breakthroughs in tungsten alloy metallurgy and processing technology, the mandatory requirements of global radiation safety regulations for lead-free, long-life, and decontamination-resistant materials, and the pressing reality of increasingly expensive space resources and strict limitations on personnel doses. Its industrial value lies not only in significantly improving the safety level and operational efficiency of facilities, but also in driving the structural upgrade of the entire radiation application industry towards compactness, greening, and intelligence.

1.3.1 Technological Evolution Stages of Tungsten Alloy Shielding Cans

The first phase (before the 1990s) was a period of proof-of-concept and small-scale trial use. At that time, tungsten alloys were mainly used in the form of simple blocks or plates for localized radiation collimators, and shielding containers were still mainly made of lead casting or lead brick masonry. A few research institutions and high-end medical centers attempted to machine tungsten alloys into small medical source containers or syringe protective sleeves, but due to the immaturity of near-net-shape forming technology for tungsten alloys , high costs, and insufficient performance data after irradiation, the application scope was extremely narrow, remaining only at the laboratory customization level.

The second phase (late 1990s to early 21st century) saw a breakthrough. With the industrialization of vacuum sintering and hot isostatic pressing processes, the size and density of tungsten alloy blanks increased significantly, making near-net-shape forming of complex, irregularly shaped containers possible in a single operation. Simultaneously, the rapid popularization of nuclear medicine PET-CT and cyclotrons brought to the forefront the problems of hot chamber space constraints and lead contamination, leading to the expansion of tungsten alloy shielding containers from small-batch medical source containers to medium-sized transport containers and hot chamber fixation containers. The maturity of the non-magnetic tungsten -nickel-copper system further removed obstacles to its application in MRI-compatible environments, establishing tungsten alloy shielding containers as a "high-end alternative material" in the market during this period.

The third stage (the first decade of the 21st century) entered the stage of standardization and large-scale production. The International Atomic Energy Agency and nuclear safety regulatory agencies in various countries successively incorporated "lead-free" into their recommended guidelines for the transport and storage of radioactive materials, and tungsten alloy shielded containers were officially included in the list of optional materials for Type A and Type B transport containers for the first time. At the same time, large isotope production companies began to purchase tungsten alloy hot chamber shielding components as complete sets, which led to the maturity of tungsten alloy large billet forging, deep hole machining, and multi-layer composite welding technologies. The weight of a single container jumped from a few kilograms to several tons, and the product range achieved full coverage from micro to giant.

The fourth stage (from the second decade of the 21st century to the present) is a period of comprehensive leapfrog development in integration, intelligence, and green technology. Tungsten alloy shielding containers are no longer simply "metal containers," but have evolved into intelligent shielding systems integrating dose monitoring, automatic source relocation, pressure balancing, remote opening and closing, and self-diagnosis. Key supporting technologies such as surface functional coatings, radiation-resistant sealing materials, and built-in lead glass observation windows have all been domestically produced or are independently controllable, resulting in a significant reduction in costs. At the same time, a closed-loop system for the recycling and reuse of waste tungsten alloy shielding containers has been established, giving them true green full life-cycle attributes. Today, tungsten alloy shielding containers have completely transformed from their initial status as "expensive luxury items" into standard "infrastructure-level" components in nuclear medicine centers, isotope factories, and industrial flaw detection workshops , marking the completion of this technology's evolution from the laboratory to the main battlefield of industry.

1.3.2 Technological Breakthroughs in the Application of Tungsten Alloys in Shielding Cans

Tungsten alloy shielding containers have undergone several decisive technological breakthroughs, evolving from a laboratory concept to a standard component of nuclear medicine, isotope production, and industrial irradiation facilities . These breakthroughs have not only significantly reduced manufacturing difficulty and costs but also fundamentally expanded their application boundaries in terms of space, weight, lifespan, and regulatory compliance , ultimately transforming them from a "high-end alternative" into the "only legal option."

The first key milestone was the maturity of near-net-shape forming technology for large and complex blanks . Early tungsten alloy shielding containers were limited by the size and shape of the blanks, requiring modular machining and brazing assembly, resulting in seams becoming weak points in shielding and dead zones for cleaning. With breakthroughs in cold isostatic pressing, hot isostatic pressing, and ultra-large mold technologies, the weight and complexity of integrated sintered blanks increased significantly. One-piece forming of the entire container body and irregularly shaped internal cavities became a reality, completely eliminating seams and simultaneously improving shielding continuity and structural strength. This breakthrough directly spurred the development of a full-spectrum product line, from miniature medical source containers to large waste transfer containers.

The second milestone is the engineering of a non-magnetic, corrosion-resistant tungsten-nickel-copper (TTC-CCP) system. While traditional TTC- nickel-iron alloys offer high strength, they generate unacceptable magnetic interference in MRI-compatible nuclear medicine environments and exhibit relatively insufficient corrosion resistance. The TTC -CCP system, through precise control of copper content and sintering processes, achieves complete non-magnetism while exhibiting near-chemical inertness in humid environments, chlorine-containing detergents, and acidic waste liquids. This breakthrough has enabled tungsten alloy shielding containers to be used on a large scale for the first time in PET-CT rooms, cyclotron hot chambers, and high-activity dispensing lines, completely removing obstacles to their application in mainstream medical scenarios.

The third key breakthrough was in mastering the machining of deep blind holes and the integral forming technology for ultra-thick walls. Shielding tanks often require extremely deep internal cavities and locally ultra-thick shielding areas, where traditional drilling methods are inefficient and have high scrap rates. Gun drilling, deep hole honing, ultrasonic-assisted electrolytic machining, and improved forgeability of tungsten alloy billets with large aspect ratios have collectively solved the challenge of one-time forming of blind holes with aspect ratios exceeding 20. This has made achieving mirror-level surface finish inside the tank a common practice, significantly improving decontamination efficiency and reducing the volume of secondary waste.

The fourth milestone is the systemic breakthrough in functional coatings and integrated design. Early tungsten alloy shielding containers only had simple polishing on their surfaces, resulting in limited scratch and contamination resistance. The standardization of functional modules such as electroless nickel plating, radiation-resistant cleaning coatings, high-temperature $MoSi_2$ anti-oxidation layers, and built-in lead glass observation windows, dose monitoring interfaces, and pressure balancing valves has transformed shielding containers from simple containment and shielding containers into intelligent systems with multiple functions including monitoring, operation, and transportation, significantly improving overall ease of use and safety redundancy.

The fifth step is establishing a closed-loop system for the complete recycling and reuse of waste tungsten alloy shielding containers. The completely non-toxic nature of tungsten alloy, along with its ability to be repeatedly melted and pulverized, allows waste shielding containers to re-enter the production chain with a near 100% recycling rate, truly achieving a green full lifecycle. This breakthrough completely eliminates customers' concerns about heavy metal accumulation and final disposal, and also grants tungsten alloy shielding containers a permanent exemption under the strictest radioactive waste management regulations, making them a truly "green shielding material."

The successive breakthroughs in these five key areas, progressing step by step and mutually coupled, ultimately propelled tungsten alloy shielding containers to the forefront of radiation protection engineering. Together, they constitute a complete technological chain from materials, forming, processing, surface treatment to recycling, enabling tungsten alloy shielding containers to not only surpass lead containers and concrete containers in performance but also establish insurmountable comprehensive advantages in economic efficiency, regulatory compliance , and environmental friendliness, becoming one of the most typical and successful material substitution cases in the contemporary field of radiation safety.

1.3.3 The Core Supporting Value of Tungsten Alloy Shielding Cans in the Industrial Sector

Tungsten alloy shielding containers has long transcended the level of a single component. Instead, it has profoundly reshaped and continuously supported the operational efficiency, safety level, and sustainable development capabilities of the entire radioactive isotope and radiation application industry chain in a three-in-one form of "key enabling technologies + systematic cost reduction platform + green compliance infrastructure".

First, it is the true driving force behind the spatial and cost revolution in the nuclear medicine and isotope industry. Traditional lead shielding systems necessitate thick, heavy hot chamber walls, huge footprints, and high civil engineering and lifting costs. In contrast, tungsten alloy shielding tanks achieve the same or even better dose control with wall thicknesses far less than lead, resulting in a 30-50% reduction in the hot chamber area of newly built PET-CT centers, cyclotron pharmaceutical plants, and high-activity dispensing lines . This has led to a significant decrease in both building and shielding investment. More importantly, the compact design allows for greater flexibility in equipment layout, enabling more production lines or accelerators to be housed in a single building. This multiplies the output efficiency per unit area, directly supporting the exponential expansion of global nuclear medicine imaging and radiopharmaceutical production capacity over the past fifteen years .

Secondly, it is the only realistic path for the green transformation of the industrial chain under increasingly stringent regulations . Globally, "lead-free" has risen from a recommendation to a mandatory requirement. The procurement, use, decontamination, and final disposal of lead containers are facing increasingly higher environmental thresholds and economic penalties. Tungsten alloy shielding tanks, however, inherently meet the strictest regulations and can be directly exempted without additional compliance modifications . This not only saves manufacturing companies huge sums of money on lead pollution control but also avoids the risk of project environmental impact assessment obstruction or production shutdowns due to lead containers , becoming a standard "compliance pass" for new isotope plants and the renovation of existing plants .

Third, its zero secondary pollution throughout its entire life cycle and near 100% recyclability completely end the vicious cycle of traditional shielding materials being "expensive when in use and even more expensive when discarded." Discarded tungsten alloy shielding cans can be directly returned to the smelting furnace as high-quality raw materials, while lead cans must enter the hazardous waste disposal process, with disposal costs often several times higher than the purchase cost. This closed-loop attribute of tungsten alloy shielding cans makes its total cost of ownership significantly lower than that of lead cans after eight to ten years of service, becoming a decisive variable in the long-term economic viability of the industry chain.

Fourth, its high reliability and long lifespan significantly reduce the intensity of operation and maintenance and the risk of unplanned downtime. A high-quality tungsten alloy shielded tank can easily exceed twenty years of service life under normal use, with almost no maintenance required during this period, and no need for regular lining replacement or welding repairs. In contrast, lead tanks often show creep, cracking, and irreversible contamination after about five years. This means that for the same production capacity, the tungsten alloy shielding system requires fewer spare tanks , has a lower frequency of opening the hot chamber, and results in a lower radiation dose for personnel. Its overall operating efficiency and occupational health level are significantly higher than those of traditional systems.Finally, as one of the highest value-added end products in the tungsten industry chain , tungsten alloy shielding cans have driven technological upgrades and capacity expansion across the entire upstream chain, including tungsten powder, billets, deep processing, and surface treatment, creating a significant positive feedback effect. It is the continuous stream of high-end shielding can orders that has supported the ongoing iteration of a series of strategic processes such as large-scale hot isostatic pressing, ultra-deep blind hole processing, and functional coatings, enabling China's tungsten industry to maintain a strong position at both the upstream and downstream ends of the global value chain.

Chapter 2 Shielding Mechanism and Performance Indicators of Tungsten Alloy Shielding Cans

2.1 Basic Principles of Radiation Shielding in Tungsten Alloy Shielding Cans

Tungsten alloy shielding containers is based on the composite attenuation mechanism of ionizing radiation by high-density alloys. Its core lies in achieving rapid energy deposition and exponential attenuation of gamma rays, X-rays, and neutron fluxes through the material's extremely high electron density and atomic number. Simultaneously, it integrates containment shielding, ease of operation, and decontamination friendliness through a structure-function integrated design. Unlike traditional lead shielding, which relies solely on the photoelectric effect, or concrete, which relies on stereotactic slowing, tungsten alloy shielding forms a broad-spectrum, highly efficient shielding system based on the photoelectric effect, Compton scattering, electron pair generation, and the synergistic effects of inelastic and elastic neutron scattering. This makes it the only technological approach in nuclear medicine, isotope production, industrial flaw detection, and scientific irradiation facilities that can simultaneously meet dose rate control, optimized protection, and regulatory compliance within limited space and weight budgets.

2.1.1 Analysis of the Propagation Characteristics of Ionizing Radiation in Tungsten Alloy Shielding Cans

Tungsten alloy shielding cans actually deal with mainly includes gamma rays, X-rays, fast neutrons, thermal neutrons, and associated secondary radiation. Their propagation characteristics and energy spectrum distribution determine the underlying logic of the shielding material and structural design.

Gamma rays and high-energy X-rays are indirect ionizing radiation with strong penetrating power. They lose energy in matter primarily through three mechanisms: the photoelectric effect, Compton scattering, and electron-electron pair production. Tungsten alloys, due to their high atomic number and large electron cloud density, maintain an extremely high mass decay coefficient across a wide energy range. Especially in the characteristic gamma-ray energy range produced by cobalt-60 and cesium-137 commonly used in nuclear medicine, as well as in medical linear accelerators and cyclotrons, the photoelectric effect and electron-electron pair production dominate, making their energy deposition efficiency far superior to lead, iron, or concrete. Simultaneously, the high density of tungsten alloys results in a shorter mean free path for the same mass of shielding layer. The rays undergo more interactions within the container wall, leading to faster exponential decay and an order-of-magnitude decrease in the external surface dose rate.

Fast neutrons and thermal neutrons are mainly found in research reactor irradiation channels, boron neutron capture therapy devices, and some isotope production processes. Fast neutrons rapidly lose energy through inelastic and elastic scattering; tungsten alloys, due to their extremely high nucleon density, are excellent fast neutron moderators. Thermal neutrons, on the other hand, are mainly captured and produce secondary gamma rays. The addition of iron and trace amounts of rare earth elements in the tungsten-nickel-iron system can significantly improve the thermal neutron absorption cross-section, while the tungsten-nickel-copper system achieves the same effect through outer or inner boride layers. Practical shielding containers often employ a hybrid design of "tungsten alloy body + local composite neutron-absorbing layer" to maintain structural strength while achieving combined gamma-neutron shielding.

Secondary radiation includes Compton scattered photons, annihilation photons, characteristic X-rays, bremsstrahlung radiation, and neutron-captured gamma rays. While these secondary radiations typically have lower energies than primary radiation, their location closer to the outer surface of the canister makes them a critical bottleneck for dose control. Tungsten alloy shielded canisters, through precise wall thickness gradient design and a low-Z lining on the inner surface, ensure that secondary radiation is reabsorbed or scattered before it escapes, completely eliminating the "secondary radiation leakage" problem common in traditional lead canisters .

Furthermore, tungsten alloys exhibit highly stable microstructures under long-term irradiation, producing almost no activation products or gas swelling, resulting in minimal degradation of shielding performance over time. In contrast, materials such as lead, concrete, and boron-containing plastics all show varying degrees of performance degradation under the same radiation dose. It is precisely this profound understanding and systematic approach to the aforementioned propagation characteristics and interaction mechanisms that enables tungsten alloy shielding containers to achieve truly "broad-spectrum, efficient, and long-life" shielding in complex mixed radiation fields, making it the most scientifically sound and engineering-grade shielding solution in contemporary radiation protection engineering.

2.1.2 Shielding mechanism of tungsten alloy shielding cans (absorption and attenuation)

Tungsten alloy shielding cans is essentially a process of energy deposition and intensity exponential decay caused by multiple interactions between high-energy photons and neutrons in high-density composite materials, rather than a simple geometric blockage. Its decay mechanism exhibits significant stage-specific characteristics depending on the type and energy of the incident particles, yet it always maintains extremely high overall efficiency, thereby achieving a dramatic dose drop from a high-activity radioactive source to the background level at the outer surface within a finite wall thickness.

For gamma rays and high-energy X-rays, tungsten alloys exhibit photoelectric effect dominance in the low-energy range. K, L, and M shell electrons of tungsten atoms are directly ejected, with almost all energy converted into photoelectron kinetic energy and characteristic X-rays. These characteristic X-rays are then photoelectrically absorbed again by surrounding atoms, resulting in rapid local energy deposition. In the mid-energy range , Compton scattering becomes dominant. Incident photons undergo inelastic collisions with outer-shell electrons, randomizing the energy and direction of scattered photons. Repeated scattering eventually leads to a gradual decrease in photon energy until photoelectric absorption. In the high-energy range, electron pair formation becomes dominant. Incident photons are converted into electron-positron pairs in the strong electric field of atomic nuclei. These pairs then continue to lose energy through ionization and bremsstrahlung until all energy is deposited. These three mechanisms highly overlap within the tungsten alloy due to its extremely short mean free path, resulting in a strictly exponential decay of X-ray intensity and a much smaller half-value layer than lead or steel.

For fast neutrons, the tungsten alloy first induces a violent collision between the neutron and the tungsten nucleus through inelastic scattering, instantly transferring a large amount of kinetic energy and generating secondary neutrons and gamma rays. Subsequently, multiple elastic scattering processes further reduce the neutron energy, ultimately allowing it to enter the thermal neutron region where it is efficiently captured by iron, rare earth elements, or an external boron layer . This entire process is completed extremely rapidly in high nucleon density materials, significantly weakening the penetrating power of fast neutrons. The instantaneous gamma rays generated after thermal neutron capture have low energy and are subsequently photoelectrically absorbed or Compton scattered by the tungsten alloy itself, achieving closed-loop shielding.

The control of secondary radiation is a key advantage of tungsten alloy shielding containers compared to traditional materials. Lead produces high-energy characteristic X-rays after photoelectric absorption, which are prone to escape, while tungsten produces lower-energy characteristic X-rays that are more easily absorbed again by its thick walls. Simultaneously, the extremely high electron density of tungsten alloys causes bremsstrahlung radiation and annihilation photons to be generated closer to the inner surface, resulting in a very low escape probability. This localized characteristic of "generation and absorption" means that the outer surface of the tungsten alloy shielding container is almost devoid of the secondary radiation "hot spots" common in traditional lead containers , resulting in an extremely uniform dose distribution.

It is precisely these system characteristics of multi-mechanism synergy, local energy deposition, and secondary radiation self-consumption that enable tungsten alloy shielding containers to achieve truly broad-spectrum and efficient attenuation in complex mixed radiation fields, making them the most reliable dose control barrier in nuclear medicine hot cells, isotope production lines, and industrial irradiation facilities.

2.1.2.1 Correlation between tungsten atomic structure and the shielding performance of tungsten alloy shielding cans

Tungsten atoms, with their unique electronic configuration and nuclear characteristics, lay the microscopic foundation for the superior shielding performance of tungsten alloy shielding containers. Tungsten atoms have high atomic numbers, and their outer electron configuration exhibits a complete inner-shell structure. The binding energies of the K, L, and M shells increase sequentially and are highly matched with the energies of gamma rays commonly used in nuclear medicine and industrial flaw detection. This causes a significant jump in the photoelectric absorption cross-section at these characteristic energies, forming a natural "absorption window." When the incident photon energy is slightly higher than a certain shell binding energy, the probability of the photoelectric effect surges, with almost all energy transferred to photoelectrons in a single burst. The resulting characteristic X-rays, due to their lower energy, are then rapidly reabsorbed by neighboring atoms. This cascade absorption process is exceptionally efficient in high-tungsten alloys due to the extremely small interatomic spacing.

电话/TEL：0086 592 512 9696

sales@chinatungsten.com

The heavy nuclear mass and strong Coulomb field of tungsten atoms make the threshold effect of high-energy photons generating electron pairs near the nucleus more significant, resulting in a conversion efficiency far exceeding that of low-Z elements. Simultaneously, the strong binding of the outer electrons in the tungsten nucleus gives Compton scattering electrons greater back impulse energy, making it easier for them to escape atomic orbitals and trigger secondary ionization chains, ultimately leading to more thorough energy deposition. The small atomic radius and high packing density of tungsten allow for more interaction targets per unit volume, significantly shortening the mean free path, macroscopically manifested as multi-order-of-magnitude decay even with extremely thin walls.

In neutron shielding, the high mass and abundant isotopes of tungsten nuclei endow them with excellent inelastic scattering capabilities, enabling them to remove a large amount of kinetic energy from neutrons in a single collision. Meanwhile, the extremely high nucleon density of tungsten atoms causes frequent elastic scattering, forming a rapid slowing channel. Tungsten's low neutron activation cross-section ensures that it will not become a new radiation source after long-term irradiation, which is crucial for the long-term containment capacity of the shielding container.

Tungsten atoms in the alloy allows the aforementioned microscopic advantages to be fully transferred to the macroscopic scale. The binder phase only serves to connect and toughen the structure without weakening the dominant position of tungsten atoms. Ultimately, this enables the tungsten alloy shielding canister to exhibit highly efficient attenuation characteristics without significant weak windows across the entire spectrum, from low-energy X-rays to high-energy gamma rays and from fast neutrons to thermal neutrons. This rigorous causal chain of "atomic structure → microscopic mechanism → macroscopic performance" is the fundamental reason why tungsten alloy shielding canisters can achieve the same or even better protective effect with a wall thickness much smaller than that of traditional materials, making it the most perfect example of structure-function integration in contemporary radiation shielding materials science.

2.1.2.2 The interaction process of tungsten alloy shielding containers with different types of radiation

The tungsten alloy shielding tank exhibits clear stages and synergy in its interaction with different types of radiation in actual mixed radiation fields, forming a complete energy deposition chain from high-energy incident radiation to background output.

High-energy gamma rays are initially generated near the inner wall of the container primarily through the photoelectric effect or electron-electron pairing. Their energy is converted into photoelectrons, positrons, and annihilation photons, either in a single step or in stages. These charged particles rapidly transfer kinetic energy to the crystal lattice within the high-electron-density material through ionization and bremsstrahlung, with an extremely short thermal distance on the order of micrometers. The generated secondary photons, having significantly reduced energy, are then subjected to Compton scattering or further photoelectric absorption in the outer layers, forming a typical gradient decay mode of "hard absorption in the inner layer and soft scattering in the outer layer." Ultimately, almost no high-energy

电话/TEL：0086 592 512 9696
CTIAQCD-MA-E/P 2018-2024V
sales@chinatungsten.com

photons escape from the outer surface.

Medium-energy X-rays and medical diagnostic-grade X-rays are dominated by Compton scattering. Incident photons undergo multiple directional randomizations and energy reductions within the container wall. Reflected photons and recoil electrons have extremely short mean free paths in the high-density medium and are quickly scattered or absorbed again by subsequent atoms, ultimately being converted into uniformly distributed low-energy scattered photons and thermal energy. This multiple scattering process causes the X-ray intensity to decay exponentially , and scattered photons are unlikely to leak in a directional manner.

lose most of their kinetic energy through inelastic scattering with tungsten nuclei in the outer layer of the container , producing secondary neutrons and gamma rays. Subsequently, in the inner layers, they are further slowed down into the thermal neutron region through elastic scattering with tungsten and iron nuclei. Thermal neutrons are efficiently captured by iron, trace rare earth elements, or an added boron layer . The captured gamma rays have relatively low energy and are then photoelectrically absorbed again by the tungsten alloy itself. The entire process results in almost no leakage of high-energy secondary radiation.

Thermal neutrons and low-energy gamma rays are primarily captured directly or absorbed photoelectrically in tungsten alloys, resulting in highly localized energy deposition and virtually no escape-prone secondary particles. The extremely low activation cross-section and high recrystallization temperature of tungsten alloys ensure that they do not become new radiation sources after long-term irradiation, and their shielding performance remains constant over time.

It is this process of "layering, mechanism, and gradual depletion" of different energies and particles that enables tungsten alloy shielding cans to achieve true "zero leakage" broadband shielding in complex mixed fields, completely surpassing the natural weak windows of traditional materials such as lead and concrete in a certain energy range.

2.1.2.3 The Optimizing Effect of Alloy Composition on the Shielding Mechanism of Tungsten Alloy Shielding Cans

Precise control of alloy composition is the key to transforming the shielding mechanism of tungsten alloy shielding cans from "the natural advantage of tungsten dominance" to "the optimal solution for scenario customization". Through systematic optimization of the type, proportion and trace elements of the binder phase, deep adaptation to specific radiation types, chemical environments and service life can be achieved.

Nickel, as the core binder phase, ensures the formation of a continuous framework for tungsten particles while providing sufficient toughness to prevent brittle fracture of pure tungsten. It also increases the density of the liquid-phase sintering, bringing the macroscopic shielding performance close to the theoretical limit. The addition of iron significantly enhances neutron inelastic scattering and thermal neutron trapping capabilities, while improving high-temperature strength and resistance to radiation swelling, making the tungsten-nickel-iron system the preferred choice for γ-neutron mixing fields and high-temperature irradiation scenarios. The introduction of copper completely eliminates magnetism and significantly improves resistance to pitting and uniform corrosion in acidic detergents, chlorine-containing waste liquids, and humid environments, making the tungsten-nickel-copper system the only choice for MRI-compatible nuclear medicine hot cells and liquid waste containers.

The targeted addition of trace rare earth elements (such as lanthanum and yttrium) or boron and gadolinium further optimizes the thermal neutron trapping cross section and resistance to radiation hole swelling, while refining grains, suppressing grain boundary slip, and improving geometric stability during long-term service. The proportion of the binder phase directly controls the strength-toughness balance of the alloy: high-tungsten, low-binder-phase systems have higher strength and better shielding efficiency, but are more difficult to process and are suitable for fixed, thick-walled tanks; moderately increasing the binder phase significantly improves cold and hot workability and impact resistance, making it suitable for transport containers and hot-chamber tanks with frequent opening.

The composition optimization ultimately resulted in a four-dimensional matching grade system encompassing "scenario-radiation spectrum-chemical environment-lifetime": pure gamma-ray high-activity medical source tanks utilize high-tungsten, tungsten -nickel-copper, non-magnetic, and corrosion-resistant grades; research reactor irradiation channel tanks utilize tungsten -nickel-iron + trace gadolinium strong neutron absorption grades; waste liquid storage tanks utilize high-copper, high-nickel, and ultra- corrosion-resistant grades; and high-temperature hot chamber tanks utilize low-binder-phase, high-strength grades. This composition-driven optimization mechanism has transformed tungsten alloy shielding tanks from a single , general-purpose material into a precisely tailored "set of shielding solutions," truly achieving seamless integration of shielding performance with actual engineering needs.

2.1.3 Analysis of Factors Affecting the Shielding Effect of Tungsten Alloy Shielding Cans

Tungsten alloy shielding canisters is not a simple linear mapping of the material's theoretical properties, but rather a systematic result of the coupled effects of multiple factors, including the material's intrinsic properties, structural geometry design, manufacturing process level, surface condition, and service environment conditions. Even a slight deviation in any of these factors can cause the external surface dose rate to rise from the background level to an unacceptable degree. Therefore, in engineering practice, all influencing factors must be incorporated into a closed-loop control system throughout the entire process to ensure that each shielding canister maintains sufficient safety margin even under the most severe operating conditions.

2.1.3.1 Intrinsic Properties of Tungsten Alloy Materials

The inherent properties of tungsten alloy materials are the fundamental internal factors that determine the shielding effect, mainly including five key dimensions: tungsten content and density, type and uniformity of binder phase, microstructure, impurity control level, and irradiation stability.

Tungsten content and density directly determine macroscopic volumetric density and atomic number density, which are the primary determinants of shielding efficiency. Higher tungsten content and denser sintering result in more interaction targets per unit thickness, a shorter mean free path, and faster exponential decay. Any pores, inclusions, or undissolved tungsten particles will become localized low-density weak areas, forming a potential X-ray "tunneling effect" and significantly weakening the overall shielding capability.

The type and uniformity of the binder phase, while ensuring high density, profoundly affect secondary radiation control and long-term performance. Nickel-iron binders can enhance neutron moderation and thermal neutron capture capabilities, but uneven distribution can lead to higher-energy captured gamma rays in localized iron-rich regions. While nickel-copper binders are non-magnetic and have excellent corrosion resistance , excessive copper content can slightly dilute the tungsten atomic density, necessitating a balance between corrosion resistance and shielding. Segregation of the binder phase or liquid-phase residues can also create micron-scale low-density channels, becoming preferred escape paths for high-energy photons. The microstructure is crucial to dynamic shielding behavior and radiation resistance. Ideally, tungsten particles are small, round, and uniformly distributed, forming a continuous framework, while the binder phase fully fills the gaps. A microstructure that has undergone sufficient secondary plastic deformation can significantly improve resistance to radiation swelling and hole migration, allowing the shielding container to maintain geometric accuracy and shielding thickness even at extremely high cumulative doses. Conversely, coarse tungsten particles or recrystallized microstructures are prone to grain boundary cracking and density reduction under long-term irradiation, leading to a slow degradation of shielding effectiveness.

Impurity control levels are directly related to secondary radiation and activation products. Excessive levels of impurities such as oxygen, carbon, sulfur, and phosphorus can form brittle phases or pores during sintering. More seriously, they can generate long-lived radioactive nuclides under irradiation, becoming internal contamination sources for the shielding vessel itself . In particular, carbon impurities react with tungsten to form a brittle tungsten carbide layer, which not only reduces toughness but also generates additional neutrons and gamma rays under high-energy particle bombardment. Irradiation stability is the most easily overlooked yet most decisive factor in long-term shielding effectiveness among material properties. High-quality tungsten alloys exhibit almost no volume swelling, strength decay, or activation products under high-dose irradiation, while inferior alloys may experience grain boundary void accumulation, binder phase precipitation, or microcrack propagation, ultimately leading to effective wall thickness reduction and dose leakage. These five characteristics collectively constitute the "high and stable" shielding foundation of tungsten alloy shielding containers, and also determine their fundamental difference in life-cycle performance compared to traditional materials such as lead and concrete.

2.1.3.2 Shielding Structure Design Parameters

The design parameters of the shielding structure are the key bridge for tungsten alloy shielding tanks to transform "material advantages" into "system shielding effectiveness". They mainly include five core elements: wall thickness distribution, cavity geometry, joint and interface treatment, gradient layer design and built-in auxiliary shielding components.

The uniformity of wall thickness distribution and the minimum wall thickness directly determine the attenuation capability of the weakest link. Ideal design requires that the minimum penetration thickness of all ray paths be consistent to avoid local thin areas becoming dose leakage channels. In actual engineering, the principle of equal dose rate on the outer surface is often adopted. The wall thickness is locally thickened or thinned by finite element ray tracing, so that the dose field on the outer surface is highly uniform.

Cavity geometry significantly affects scattering and secondary radiation reabsorption . Cylindrical or spherical cavities maximize the average path length of rays within the walls, reducing direct leakage; rectangular cavities, however, are prone to scattering photon accumulation at corners, requiring compensation through rounded corners or local thickening. Deep blind hole structures ensure that the bottom wall thickness is not less than the calculated minimum; otherwise, a typical "ray chimney effect" will occur.

Seams, lid openings, and interfaces are the most common weak points of traditional shielded containers. Tungsten alloy shielded containers completely eliminate through-seales through integral molding, a labyrinthine stepped lid, embedded sealing rings, and metallurgical-grade welding or electron beam welding, making the attenuation capacity of the seam area equal to or even better than the main body. Functional openings such as observation windows, probe holes, and infusion tube interfaces use a stepped shielding structure of tungsten alloy nesting combined with lead glass or borosilicate polyethylene to ensure no direct light path in the opening direction.

The gradient layer and built-in auxiliary shielding further optimize broadband performance. The outer low-tungsten transition layer weakens the escape of high-energy secondary electrons, while the inner high-boron or high-hydrogen composite liner efficiently absorbs thermal neutrons and suppresses gamma-ray capture. The built-in tungsten alloy grid or collimator is used in medical source containers with highly concentrated source terms to achieve precise directional shielding. The fine coupling of these design parameters has enabled the tungsten alloy shielding container to truly evolve from a "uniform thick-walled container" to a third-generation shielding system with "functional partitioning and intelligent gradients".

2.1.3.3 Intrinsic characteristics of the radiation source

The energy spectrum, activity, geometry, chemical form, and temporal distribution characteristics of the radiation source directly challenge the actual shielding difficulty of the tungsten alloy shielding can, and also determine the design margin and selection strategy.

High-energy gamma sources (such as cobalt-60 and byproducts of medical linear accelerators) have extremely strong penetrating power and require the thickest wall thickness. At the same time, the proportion of secondary bremsstrahlung and annihilation photons is large, requiring thicker outer walls and more refined gradient designs. Low- and medium-energy gamma sources (such as iodine-125 and iridium-192) are dominated by the photoelectric effect, and the wall thickness requirement is significantly reduced for the same activity. However, they require higher material density and surface cleanliness to avoid the accumulation of low-energy scattered photons.

Activity level determines total dose rate and heat load. High activity sources require shielding canisters with extremely high single-pass attenuation capability, while significant heat deposition within the walls necessitates consideration of convection ventilation holes or thermally conductive linings; low activity sources, on the other hand, are more concerned with the difficulty of material activation and decontamination under long-term cumulative dose.

The source term affect the cavity design and corrosion margin. Point sources can achieve optimal geometric attenuation using a deep cavity and thick bottom structure; volumetric or liquid sources require larger cavities and corrosion-resistant linings, while preventing the deposition of radioactive aerosols in dead corners. Powdered or gaseous sources place higher demands on the sealing structure and pressure balancing valve.

The temporal distribution characteristics determine the dynamic shielding requirements. Short half-life sources (such as fluorine-18) have short service lifespans and can accept slightly higher initial dose rates; long half-life sources (such as cesium-137 and strontium-90) require the shielding canister to maintain geometric and performance constants over decades, making the material's irradiation stability a decisive factor.

It is precisely the ever-changing characteristics of the source term that have forced tungsten alloy shielding containers to shift from a single standard product to a "source term customization" model, ensuring that each type of radiation source can obtain the most economical and safest dedicated shielding solution.

2.1.3.4 Factors affecting the use of environmental conditions

The environmental conditions are the final "acceptance test" of the shielding effect of tungsten alloy shielding cans, including five aspects: temperature field, humidity and corrosive media, mechanical load, cumulative irradiation dose, and unexpected working conditions.

High-temperature environments can slightly reduce the density of tungsten alloys and accelerate the diffusion of the binder phase, but the performance degradation of high-quality tungsten alloys is negligible at the common temperatures in nuclear medicine hot cells. Extreme high temperatures (such as fire accidents) test the recrystallization temperature of the material and the integrity of the anti-oxidation coating. Once the coating fails, surface oxidation will lead to local density reduction and micro-dose leakage.Humidity, acid and alkali detergents, seawater splashes, or chlorine-containing waste liquids constitute the most common chemical threats. Tungsten -nickel-copper systems exhibit stable surface passivation films and are virtually corrosion-free in these environments; while tungsten -nickel-iron systems, although stronger, are prone to intergranular corrosion with long-term exposure and must be supplemented with nickel plating or specialized cleaning coatings. Once corrosion leads to surface peeling or pitting, it becomes a low-density channel for preferential radiation escape.

Mechanical loads include static loads (self-weight, waste stacking), dynamic loads (transportation vibration, drops), and thermal stress cycles. Tungsten alloys have excellent high-temperature strength and low coefficient of thermal expansion, resulting in minimal geometric deformation under these loads and a constant shielding thickness; while traditional lead cans are prone to creep under the same conditions, leading to an expansion of the wall thickness reduction zone.

Long-term high-dose irradiation can cause hole swelling, helium embrittlement, and the accumulation of activation products. High-quality tungsten alloys, through grain refinement, rare earth purification, and pre-deformed fiber structure, significantly suppress swelling and embrittlement, resulting in extremely low levels of activation products; while inferior alloys may experience microcrack propagation at higher cumulative doses, leading to a slow degradation of shielding effectiveness.

Unexpected conditions (such as fire, flood, earthquake, and drop) are the ultimate test of shielding effectiveness. The high melting point, non-combustibility, and high toughness of tungsten alloy enable it to maintain structural integrity in a fire, not shatter in a drop, and not overturn in an earthquake , completely avoiding catastrophic consequences such as lead tanks melting and flowing, and concrete tanks cracking and collapsing.

The combination of these stringent environmental factors compels the tungsten alloy shielding canister to incorporate multiphysics coupling simulation and over-design margin during the design phase. This ensures that the external surface dose rate can be firmly controlled at the background level even under the most unfavorable conditions, making it the ultimate and reliable barrier for containing and shielding radioactive materials.

2.1.3.5 Factors affecting manufacturing process precision control

Manufacturing precision is the final step in realizing the shielding effect of tungsten alloy shielding cans from "theoretical optimality," and it is also the most easily overlooked yet most fatal variable. Any minute geometric deviation, surface defect, or internal residual defect can directly translate into a radiation leakage channel or a secondary radiation hotspot, causing the actual shielding effectiveness of the entire can to be far lower than the design value.

Density and shape consistency are the starting point during the blank forming stage. Cold isostatic pressing, hot isostatic pressing, or large mold pressing must ensure uniform tungsten powder filling and pressure transmission without dead zones; otherwise, local low-density areas will form pores or uneven shrinkage during subsequent sintering, becoming areas with weak penetration. Small fluctuations in sintering process parameters (temperature profile, atmosphere purity, holding time) can lead to uneven tungsten particle growth or binder phase segregation, directly affecting the uniformity of micro-shielding.

The machining precision of deep blind holes and complex internal cavities determines the minimum wall thickness and surface condition. Drill deviation , honing roundness deviation, and residual stress concentration at the bottom of the hole can all cause the actual minimum wall thickness to be several percentage points lower than the design value, resulting in a measurable dose surge in a high-energy gamma field. The roughness and waviness of the inner surface must be controlled at the mirror level; otherwise, microscopic pits will become permanent adsorption points for radioactive dust and aerosols, increasing the difficulty of decontamination and forming localized sources of contamination after long-term accumulation.

the fit between the lid and the can , as well as the parallelism of the labyrinth gap and sealing surface, directly determine the shielding continuity of the joint area . Traditional lead cans often suffer from poor fit due to lid deformation, while tungsten alloy cans achieve a micron- level full fit between the lid and the can opening through high-precision CNC grinding and online optical measurement, completely eliminating through gaps. Microstructural control in the welding or electron beam fusion welding areas is equally crucial; recrystallized coarse grains or microcracks in the heat-affected zone will become unacceptable weak points.

Consistency between the surface functional coating and the final polishing process is the last line of defense against surface corrosion and secondary electron escape. Uneven electroless nickel plating thickness, insufficient adhesion of the cleaning coating, or residual scratches from polishing can all evolve into pitting corrosion initiation points or electron emission sources after long-term cleaning and irradiation. High-end tungsten alloy shielding canisters have incorporated all key dimensions and surface parameters into the entire process of SPC statistical control, supplemented by X-ray CT non-destructive testing, ultrasonic phased array, and helium mass spectrometry leak detection to ensure that the actual shielding performance of each canister leaving the factory is completely consistent with the theoretical calculation value.

2.2 Key Performance Index System of Tungsten Alloy Shielded Cans

Tungsten alloy shielding cans has been developed into a complete, rigorous, and quantifiable indicator system, covering five dimensions: shielding effectiveness, structural safety, service life, ease of operation, and regulatory compliance. These indicators are no longer isolated material parameters, but rather interconnected systemic requirements that together constitute a full-chain evaluation standard from design and manufacturing to acceptance.

Shielding effectiveness metrics are centered on equivalent wall thickness, external surface dose rate, radiation leakage angular distribution, and secondary radiation control level. They require that, under the most unfavorable source term and longest service life, the dose rate at any point on the external surface is less than a fraction of the regulatory limit , with no directional leakage. Structural safety metrics include drop resistance, resistance to stacking static loads, resistance to fire thermal shock, and resistance to seismic overturning, ensuring that containment is not lost under the most severe unexpected conditions. Service life metrics encompass zero failure due to irradiation aging, perpetual geometric accuracy, constant surface decontamination factor, and long-term reliability of the sealing system, typically requiring a maintenance-free period of at least twenty years.

Ease of operation indicators focus on rapid single-person opening and closing, robotic arm compatibility, reasonable weight distribution, and standardized interfaces to minimize operation time in the heated chamber or glove box and optimize personnel radiation dose. Regulatory compliance indicators cover non-toxic and lead-free exemptions, direct recyclability, transport container type approval, wipeable surface contamination, and zero burden of final disposal, thoroughly meeting the most stringent requirements of the International Atomic Energy Agency, the National Nuclear Safety Administration, and environmental protection departments.

The above five indicators have been verified through type testing, accelerated aging testing, drop-fire combined testing, and long-term physical tracking, forming a complete set of qualification criteria. Only tungsten alloy shielding containers that simultaneously meet all the standards are allowed to enter nuclear medicine hot cells, isotope production lines, or waste transfer stations, becoming a truly "lifetime reliable shielding solution." The establishment of this system marks the complete transformation of tungsten alloy shielding containers from early "material substitutes" into the most mature and reliable system-level products in radiation protection engineering.

2.2.2.1 Density index of tungsten alloy shielding tank

The most crucial and fundamental performance indicator of tungsten alloy shielding containers , directly determining the atomic number density and mean free path of radiation per unit thickness. It is the "primary parameter" of shielding effectiveness. High-end tungsten alloy shielding containers require a stable and extremely high volumetric density, with minimal density deviation across any part of the container. This ensures that radiation undergoes a completely consistent exponential decay process within the container wall, preventing dose leakage caused by localized low-density weak areas.

In practical engineering, density indicators are subdivided into four sub-requirements: theoretical density achievement rate, minimum local density, density uniformity, and long-term density stability. The theoretical density achievement rate requires the overall density of the sintered blank to be close to a very high ratio of the theoretical weighted average of tungsten and binder phase ; any pores, inclusions, or undissolved tungsten particles are considered fatal defects. Minimum local density is verified layer by layer using X-ray CT or gamma-ray transmission scanning to ensure that there are no obvious low-density zones in all areas, including the bottom of holes, corners, and weld heat-affected zones. Density uniformity requires that density fluctuations throughout the entire batch be controlled within an extremely narrow range to avoid X-ray scattering direction deflection and asymmetric escape of secondary radiation caused by density gradients . Long-term density stability is assessed through accelerated irradiation swelling tests and high-temperature vacuum aging tests, requiring almost zero density decay within the design life.

电话/TEL：0086 592 512 9696
sales@chinatungsten.com

Because density has a decisive impact on shielding effectiveness, tungsten alloy shielding containers have established a rigorous closed-loop control system for density throughout the entire process, from raw material acceptance, sintering, hot isostatic pressing, machining, and final inspection. This system has made them a recognized representative of a "density-first" culture in the industry. Only shielding containers that fully meet the density standards are qualified to enter nuclear medicine hot cells and high-activity isotope production lines.

2.2.2 Hardness index of tungsten alloy shielding tank

While hardness doesn't directly influence radiation attenuation like density, it plays an irreplaceable role in the overall reliability of tungsten alloy shielding canisters throughout their lifecycle. It comprehensively reflects resistance to scratches, abrasion, pitting, radiation-induced surface peeling, and ease of cleaning. High-end tungsten alloy shielding canisters require a systematic approach to hardness: "surface hardness, internal toughness, and durability." The surface hardness must be sufficiently high to resist repeated mechanical cleaning and accidental impacts; the core must maintain adequate toughness to prevent brittle cracking; and the overall hardness must remain virtually unchanged after long-term irradiation and thermal cycling. The hardness index is specifically divided into four aspects: matrix microhardness, surface reinforcement layer hardness, hardness uniformity, and long-term hardness stability. The matrix microhardness requires a tight bond between the tungsten particles and the binder phase interface, with no softening bands, ensuring that the tank does not develop microcracks under drop, vibration, or thermal shock. The surface reinforcement layer hardness is achieved through boronizing, ion nitriding, diamond-like carbon coating, or supersonic spraying of nanocrystalline layers , making the outermost layer much harder than the core, forming a "hard on the outside, tough on the inside" protective shell that resists both cleaning steel brushes and acid pickling, and inhibits radiation-induced surface sputtering and peeling.

The uniformity of hardness requires minimal hardness fluctuations across the entire tank's inner and outer surfaces, the bottom of holes, and weld areas to prevent localized soft spots from becoming the starting point for corrosion and contamination. Long-term hardness stability is verified through high-volume irradiation tests and accelerated aging under high temperature and humidity conditions, requiring extremely low surface hardness decay, no peeling of the reinforcing layer, and no softening of the substrate within the designed lifespan . The true value of hardness index lies in extending "shielding effectiveness" from simple radiation attenuation to a green, full life cycle of "repeated decontamination and zero secondary pollution". It is precisely because of its high surface hardness and large decontamination factor that tungsten alloy shielding cans can still return to their original clean state after dozens or even hundreds of high-activity operations, completely getting rid of the fate of lead cans "getting dirtier with use and eventually becoming unusable", and becoming a truly sustainable shielding platform.

2.2.3 Tensile strength index of tungsten alloy shielding tank

Core mechanical guarantee for tungsten alloy shielded tanks to maintain structural integrity and shielding geometry throughout their entire life cycle . It must not only meet the requirements of static load, stacking and thermal stress under normal working conditions, but also ensure that the tank body does not crack, deform or lose roundness in extreme accident scenarios such as drops, earthquakes, fires, and transportation bumps , thereby ensuring that the minimum shielding thickness never decreases and the sealing surface never warps.

High-end tungsten alloy shielded containers are embodied in a comprehensive system of "high strength at room temperature, no softening at high temperatures, no embrittlement under irradiation, and strong fatigue resistance." Room temperature tensile strength must far exceed that of conventional structural steel to withstand sudden tensile stresses during lifting, transportation, and installation. High-temperature tensile strength must maintain sufficient residual strength even under the high temperatures commonly encountered in nuclear medicine hot chambers or at fire accident temperatures to avoid creep collapse similar to lead containers. The tensile strength decay after irradiation must be almost zero to prevent irradiation embrittlement and strength loss caused by long-term high injection rates . Fatigue strength under cyclic loading must ensure no microcracks develop after tens of thousands of opening cycles, thermal cycles, and vibrations.

To achieve the above objectives, tungsten alloy shielding containers generally employ fiber-reinforced structures that have undergone secondary plastic processing with large deformation, using tungsten-nickel-iron or tungsten-nickel-copper systems. This results in highly oriented, elongated fibrous tungsten particles with a binder phase evenly distributed along the fiber gaps, forming a natural "reinforced concrete" composite reinforcement structure. This structure exhibits extremely high load-bearing capacity and crack propagation resistance in the tensile direction; even minor defects can be quickly passivated without unstable propagation. Actual performance evaluation includes room temperature tensile testing, specified high-temperature tensile testing, post-irradiation tensile testing , and a full suite of high-cycle and low-cycle fatigue tests—all are indispensable. Only batches that pass all tests are permitted for use in large waste transfer containers, transport containers, and permanently fixed hot-chamber containers, ensuring that the shielding geometry and containment function never fail under the most severe mechanical-thermal-irradiation coupling environments.

2.2.4 Sealing performance indicators of tungsten alloy shielded tanks

Sealing is one of the most critical functional indicators that distinguishes tungsten alloy shielded containers from ordinary structural containers. It directly determines whether radioactive dust, aerosols and volatile nuclides will leak into the operating environment in unacceptable amounts. It is the last barrier to achieving the regulatory goal of "zero leakage and minimal personnel exposure".

Tungsten alloy shielded containers are divided into three levels: static sealing, dynamic sealing, and emergency sealing. Static sealing requires that the helium mass spectrometry leak detection rate remain consistently at an extremely low level within the range of room temperature to the maximum service temperature and the upper limit of cumulative irradiation dose, eliminating any molecular-level leakage. Dynamic sealing requires that after tens of thousands of opening and closing cycles, thermal cycles, and minor vibrations, the sealing surface maintains its initial fit accuracy and elastic recovery capability, without permanent deformation or loosening. Emergency sealing requires that under conditions of specified height drop, high temperature fire, external impact, and even partial plastic deformation, the labyrinth + sealing ring composite structure can still maintain sufficient compression to ensure that containment is not lost.

In terms of implementation, tungsten alloy shielding containers generally adopt a "triple protection" design:

- The first step is a high-precision maturation of a hard-on-hard metal labyrinth stepped surface, which utilizes the extremely low coefficient of thermal expansion and high rigidity of tungsten alloy to achieve micron-level bonding.
- The second layer is a C-shaped/Ω-shaped sealing ring made of fluororubber, silicone rubber, or metal that is resistant to radiation, high temperature, and strong acids and alkalis, providing elastic compensation and molecular-level barrier.
- of pressure is provided by the weight of the can lid itself, plus a quick-lock clamp or multi-threaded clamp, ensuring that it will not loosen over a long period of time.

Meanwhile, the sealing surfaces are generally treated with mirror polishing and ion implantation or DLC coating, resulting in extremely high surface hardness and strong chemical inertness, making them both scratch-resistant and extremely slow to age. Before leaving the factory, each canister must undergo a step-by-step leak test involving vacuum, pressurization, and helium mass spectrometry, combined with more than ten years of accelerated thermal aging and irradiation aging tests to verify the lifespan of the seals. It is this almost obsessive system of sealing performance indicators that has enabled tungsten alloy shielded canisters to achieve a true "zero leakage" operating record in the world's most demanding nuclear medicine hot cells and high-activity waste temporary storage facilities, making them the absolute benchmark in the field of containment shielded containers.

2.2.5 Corrosion Resistance Indicators of Tungsten Alloy Shielded Tanks

Corrosion resistance is the fundamental guarantee for tungsten alloy shielding tanks to achieve "repeated cleaning, long-term maintenance-free operation, and zero secondary pollution." It directly determines whether the tank can maintain its surface integrity and geometric authenticity under long-term immersion in acidic detergents, alkaline cleaning solutions, chlorine-containing disinfectants, humid and hot air, or even liquid radioactive waste, thereby preventing pitting, intergranular corrosion, or uniform dissolution from becoming channels for radiation leakage and permanent attachment points for radioactive dust.

The corrosion resistance of high-end tungsten alloy shielded tanks has formed a dual-track system: a primary non-magnetic corrosion-resistant tungsten-nickel-copper system and a secondary tungsten-nickel-iron system with enhanced coating. The tungsten -nickel-copper system, thanks to the dense self-passivating film formed by copper in the binder phase, exhibits extremely high corrosion resistance, approaching chemical inertness, across a wide pH range of 1–14, in strong oxidizing detergents, and in seawater splash environments. The surface shows almost no visible corrosion marks, exhibits extremely high pitting potential, and remains mirror-smooth even after long-term immersion. While the tungsten - nickel-iron system has higher strength, it exhibits a slight tendency for intergranular corrosion in acidic and chlorine-containing media. Therefore, it must be supplemented with electroless nickel plating, PVD CrN , or multi-layer composite cleaning coatings to achieve surface corrosion resistance at or above the level of tungsten -nickel-copper.

The specific tests for corrosion resistance include salt spray aging, immersion in strong acids and alkalis, repeated scrubbing with detergents, electrochemical polarization curves, pitting corrosion induction tests, and long-term contact verification with real radioactive waste liquid. The requirements are that under the most severe decontamination cycles and waste liquid storage conditions, the surface corrosion depth is almost zero, the mass loss is negligible, the decontamination factor remains consistently above extremely high levels, and the surface roughness does not increase. It is precisely these almost stringent corrosion resistance indicators that allow the tungsten alloy shielded tank to be easily wiped clean to its original state even after decades of high-activity operation.

2.2.6 Shielding efficiency of tungsten alloy shielding cans

All the performance of tungsten alloy shielding cans . It is no longer a single half-value layer or tenth-value layer concept, but rather uses the dose rate at any point on the outer surface under the "most unfavorable source term, longest service life, and most severe environment" as the sole criterion. It covers the broad spectrum, long life, and all-round control capabilities against gamma rays, X-rays, neutrons, and all secondary radiation.

The true shielding efficiency index is composed of the following five sub-indicators:

- Maximum dose rate on the outer surface: must be consistently below a fraction of the regulatory limit at the designed source term full activity and the shortest source-canister distance , and there must be no hot spots in any direction;
- Radiation leakage angle distribution: requires uniform dose in all directions, with no directional leakage or "chimney effect";
- Secondary radiation control level: including bremsstrahlung, annihilation photons, characteristic X-rays and captured gamma rays, must all be absorbed locally by the tank wall, and no detectable secondary peaks shall appear on the outer surface;
- Long-term shielding effectiveness stability: Within the design life, after cumulative maximum flux irradiation, high temperature and high humidity aging, and repeated decontamination, the shielding efficiency must decrease to almost zero.
- Shielding integrity under the worst-case scenario: After the specified drop, fire, stacking, and earthquake combined tests, the dose rate on the outer surface must still not exceed the standard.

To achieve this ultimate goal, the tungsten alloy shielding canister employs Monte Carlo full-spectrum simulation and multiphysics coupling analysis during the design phase to accurately predict the dose distribution under the thinnest wall thickness, the most complex geometry, and the most unfavorable source term combination . During the manufacturing phase, gamma-ray imaging, cobalt-60 real source irradiation calibration, and hot chamber real source term verification are used to ensure that the actual shielding efficiency of each canister leaving the factory is completely consistent with the theoretical calculation.

Because of the extremely stringent shielding efficiency requirements, tungsten alloy shielding containers can maintain a stable external surface dose rate at background levels for a long time in the world's most demanding nuclear medicine centers, the highest activity isotope factories, and the most strictly regulated waste storage facilities. This truly achieves the ultimate protection goal of "locking the radioactive source in the container and completely liberating personnel and the environment," making it the undisputed pinnacle of contemporary radiation shielding engineering.

2.2.7 Ductility Indicators of Tungsten Alloy Shielded Cans

Ductility is the lifeline that allows tungsten alloy shielded cans to maintain their integrity and prevent brittle fracture under extreme and unexpected conditions. It determines whether the can body will shatter instantly like ceramic when subjected to drop impacts, earthquake rollovers, transportation bumps, or even localized overloads, or whether it will undergo controlled plastic deformation like high-quality steel to absorb energy and avoid catastrophic cracking. The ductility index of tungsten alloy shielded cans has long surpassed the inherent prejudice that "high strength inevitably leads to brittleness" in traditional refractory metals, achieving a high degree of unity between strength and toughness.

High-quality tungsten alloy shielding containers require sufficiently high room temperature elongation. Even in the thickest-walled, lowest-binder-phase high-strength grades, tensile specimens must exhibit significant necking rather than flush fracture; bending tests should achieve near-right angles without cracking; and Charpy impact energy should be significantly higher than pure tungsten and most high-temperature alloys. High-temperature ductility is equally crucial. At common temperatures in nuclear medicine hot cells and even fire accident temperatures, elongation and impact toughness can only decrease slowly, and a sudden drop into the brittle zone is absolutely unacceptable. Post-irradiation ductility retention is paramount. After the cumulative injection volume over the design life, the attenuation of elongation and impact energy must be negligible to eliminate the risk of delayed cracking due to irradiation-induced embrittlement.

The key to achieving this goal lies in the natural composite structure formed by the slender fibrous tungsten particles and the uniformly dispersed binder phase: the tungsten particles bear high strength, the binder phase provides a tough bridge, and once a crack initiates, it will be repeatedly passivated, deflected and bridged by the binder phase, eventually exhausting the propagation energy.

2.2.8 High-Temperature Resistance Indicators of Tungsten Alloy Shielded Cans

High-temperature resistance is the fundamental guarantee that tungsten alloy shielded containers can maintain shielding thickness, sealing integrity, and structural stability under fire accidents, high-temperature hot chambers, or long-term heat load conditions. It allows tungsten alloy shielded containers to completely get rid of the fatal defects of lead containers that melt and flow when exposed to fire and concrete containers that dehydrate and crack at high temperatures, making it the only shielded container that can continue to "stand and protect" under extreme high temperatures.

High-end tungsten alloy shielding containers are required to maintain almost no decrease in strength, hardness, ductility, and dimensional accuracy over time under the sustained high temperatures commonly found in the hot chambers of nuclear medicine cyclotrons. Under short-term fire temperatures, slight oxidation may occur on the container surface, but the internal structure and geometry remain intact, the shielding wall thickness does not decrease, the sealing surface does not warp, and the locking mechanism still functions normally. Key indicators include high-temperature instantaneous strength, near-zero high-temperature creep rate, resistance to thermal shock cracking, and the retention rate of shielding effectiveness after high-temperature oxidation.

Tungsten alloys inherently possess extremely high recrystallization temperatures and extremely low coefficients of thermal expansion. Combined with surface $MoSi_2$, Al_2O_3 diffusion coatings or electroless nickel plating with a high-temperature passivation layer, they can form only a thin, dense oxide film in short bursts of flame at thousands of degrees Celsius, while the core retains its original mechanical properties and density. Under prolonged high temperatures, the fine tungsten particles and dispersed binder phases effectively pin the grain boundaries, preventing recrystallization coarsening and creep slip, ensuring the can's dimensions remain true and the sealing surface remains flat. This extraordinary high-temperature resistance—"not softening when exposed to fire, not expanding when heated, and remaining hard after burning"—allows tungsten alloy shielded cans to buy precious time for emergency response even in the most terrifying fire scenarios, becoming the ultimate "firewall" for containing radioactive materials.

2.3 MSDS of Tungsten Alloy Shielded Can from CTIA GROUP LTD

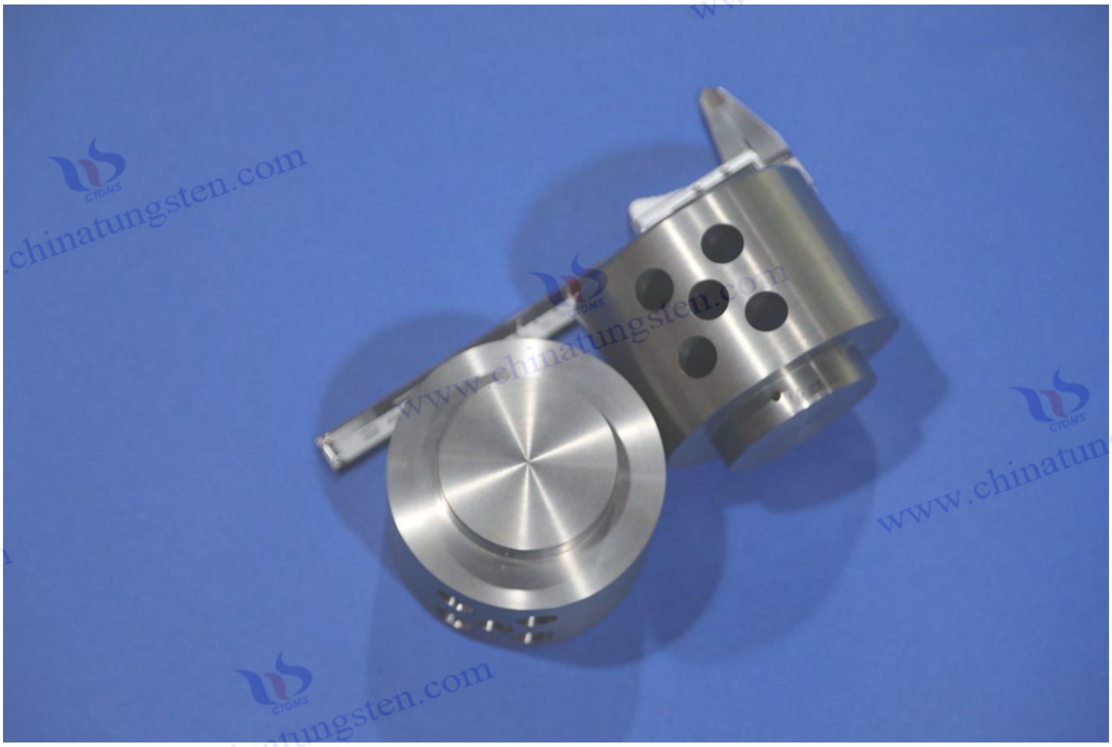
The Safety Data Sheet (MSDS) for tungsten alloy shielded containers manufactured by CTIA GROUP LTD Co., Ltd. is a standardized chemical safety document tailored for the company 's tungsten-based high-density shielded containers. It aims to provide comprehensive and reliable risk identification, protection guidance, and emergency response solutions throughout the entire lifecycle, from raw material procurement, manufacturing, transportation, and storage to on-site use, maintenance, decontamination, and final disposal. As a leading global supplier of tungsten materials , CTIA GROUP LTD 's MSDS strictly adheres to the requirements of the United Nations Globally Harmonized System of Classification and Labelling of Chemicals (GHS) and the Chinese National Standard GB/T 16483. It covers core modules such as basic substance information, potential hazard classification, first aid measures, fire and explosion risk response, spill response, operational exposure control and personal protective equipment, physicochemical properties, material stability and reactivity, toxicological information, ecotoxicological impacts, disposal guidelines, transportation information, and regulatory liability statement.

The basic information module first clarifies the chemical identity of the tungsten alloy shielding can: it is mainly composed of tungsten (CAS 7440-33-7), supplemented by nickel (CAS 7440-02-0), iron (CAS 7439-89-6) or copper (CAS 7440-50-8), and is in the form of a high-density metal composite with a typical appearance of a silver-gray metallic luster.

The potential hazard classification focuses on occupational exposure risks. Tungsten alloy shielding containers are inert metal products and exhibit no acute toxicity, carcinogenicity, or reproductive toxicity during normal containment and shielding use. The overall risk assessment classifies the shielding containers as "low-hazard solids."

The physicochemical properties section describes the tungsten alloy shielding container as a high-melting-point, high-temperature resistant metal composite that is insoluble in water. The material stability section indicates that the shielding container is highly stable at room temperature , but surface oxidation may occur at high temperatures. It is recommended to store it in a dry, well-ventilated place and avoid direct contact with strong acids and alkalis.

The transport information classifies tungsten alloy shielded containers as non-dangerous goods and allows them to be transported as ordinary metal products. Regulatory information lists REACH and RoHS compliance declarations , as well as compliance with Chinese GB 30000 series standards.



CTIA GROUP LTD Tungsten Alloy Shielding Can

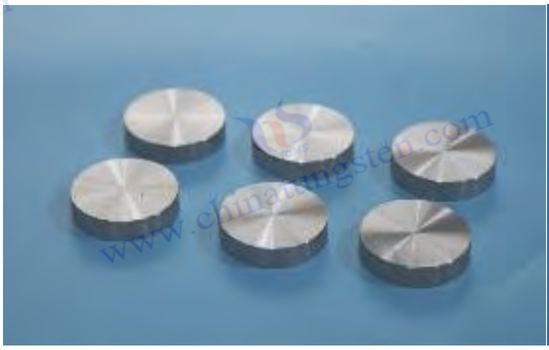
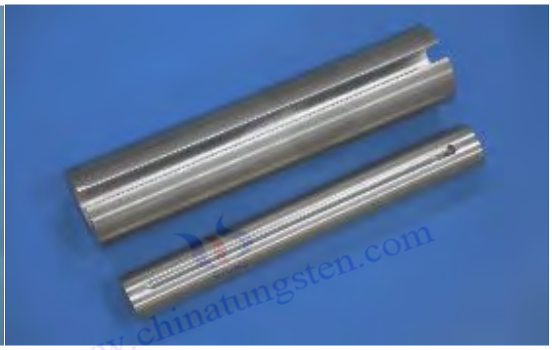
CTIA GROUP LTD
High-Density Tungsten Alloy Customization Service

CTIA GROUP LTD, a customization expert in high-density tungsten alloy design and production with 30 years of experience.

Core advantages: 30 years of experience: deeply familiar with tungsten alloy production, mature technology.
Precision customization: support high density (17-19 g/cm³), special performance, complex structure, super large and very small parts design and production.
Quality cost: optimized design, optimal mold and processing mode, excellent cost performance.
Advanced capabilities: advanced production equipment, RMI, ISO 9001 certification.
100,000+ customers
Widely involved, covering aerospace, military industry, medical equipment, energy industry, sports and entertainment and other fields.
Service commitment
1 billion+ visits to the official website, 1 million+ web pages, 100,000+ customers, 0 complaints in 30 years!

Contact us
Email: sales@chinatungsten.com
Tel: +86 592 5129696
Official website: www.tungsten-alloy.com



Chapter 3 Design Logic and Type Classification of Tungsten Alloy Shielding Cans

3.1 Structural Composition of Tungsten Alloy Shielding Can

Tungsten alloy shielded containers follows a five-in-one systems engineering principle of "enclosure-shielding-operation-decontamination-transportation." Each component is not isolated but deeply coupled with other components in terms of function, mechanics, thermodynamics, irradiation, and regulations, ultimately forming a highly redundant, safe, verifiable, and predictable-lifespan whole. Its design has long surpassed the simple stacking of traditional "metal cans + lead linings," maximizing the advantages of tungsten alloys in terms of high density, high strength, non-toxicity, and long lifespan, achieving full-spectrum coverage from micro-syringe protective sleeves to multi-ton waste transfer containers.

The main body of the tank is the core load-bearing and shielding unit of the entire structure. It is typically constructed from a single near-net-shape sintered billet or a large forged ring welded in sections, ensuring that the minimum wall thickness in any direction meets the attenuation requirements for the most unfavorable radiation. The internal cavity is precisely designed according to the shape of the radiation source, forming a cylindrical, rectangular, polygonal, or complex irregular cavity. All internal surfaces are mirror-polished to completely eliminate dead corners and contamination points. The external surface is equipped with integrated lifting lugs, forklift slots, or standardized pallet interfaces according to lifting requirements . It also has reserved dose rate monitoring holes, venting balance valves, and decontamination spray interfaces, upgrading the tank from a simple containment component into an integrated platform with monitoring and operation functions.

The can lid and sealing system are the last line of defense for containment and also the most frequently moving parts in daily operation. High-end designs generally use embedded stepped labyrinth lids, achieving a perfect fit between the lid and the can opening through high-precision CNC grinding. Combined with radiation-resistant fluororubber O-rings, metal C-rings, or double-safety composite seals, this ensures zero static leakage and zero dynamic leakage after tens of thousands of opening and closing cycles. Locking mechanisms often employ quick-lock clamps , rotary locking rings, or hydraulic quick-opening structures, ensuring that a single person can open and close the can in seconds from inside the glove box. Furthermore, it can still be manually opened after a fire or high-temperature event, buying time for emergency retrieval .

the user-friendly features that distinguish the tungsten alloy shielded container from traditional lead containers . The built-in lead glass observation window uses a tungsten alloy frame and a multi-layer gradient shielding design, which ensures that the operator can directly observe the source displacement process without sacrificing the overall shielding continuity. The dose rate monitoring port, vent valve, source operating rod channel, waste liquid inlet and outlet all adopt a labyrinth + tungsten alloy nested structure to ensure that there is no direct leakage in the opening direction.

The surface functional layer is the final guarantee for corrosion resistance and easy cleaning. Chemical nickel plating, radiation-resistant cleaning coatings, high-temperature antioxidant coatings, or composite

电话/TEL：0086 592 512 9696
CTIAQCD-MA-E/P 2018-2024V
sales@chinatungsten.com

multilayer systems ensure that the tank surface remains clean and new even after repeated acid washing, alkali washing, steam purging, and even strong oxidizing detergents, completely eliminating pitting and permanent contamination layers. The bottom and sidewalls are often equipped with replaceable sacrificial linings or inner stainless steel anti-corrosion linings, further extending the service life of the waste liquid storage tank.

The lifting and transportation interface seamlessly integrates structural safety with actual logistics. Integrated forged lifting lugs, side impact protection plates, bottom shock-absorbing pallets, and standardized container locks enable the shielded container to be precisely lifted by bridge cranes and maintain its containment and shielding integrity throughout road, rail, and sea transport.

All these components were optimized from the outset through multiphysics coupling simulation (radiation transport-thermal-mechanical-aging) and underwent a full range of verification tests in type testing, including drop, stacking, fire, immersion, and irradiation aging. Only when all components work together to meet the most stringent standards can the entire tungsten alloy shielding container truly be called the ultimate carrier of modern radiation protection, characterized by "reliable containment, high shielding efficiency, convenient operation, and ultra-long lifespan." It is no longer a simple metal container, but an industrial work of art that perfectly integrates materials science, precision manufacturing, radiation physics, and systems engineering.

3.1.1 Main shielding structure of the tungsten alloy shielding can (can body, can cover)

The can body and can lid together constitute the main shielding structure of the tungsten alloy shielding can, which is the core skeleton that determines the overall shielding continuity, minimum wall thickness, and geometric fidelity. Both are usually processed from high-density tungsten alloy blanks of the same batch and grade , ensuring that the material properties and shielding effectiveness are completely consistent, avoiding weak areas at the joints caused by the difference in materials between the lid and the can body in traditional lead cans .

The main body of the can adopts a near-net-shape forming process combined with precision machining of deep blind holes. First, a high-density, seamless blank is obtained through ultra-large cold or hot isostatic pressing. Then, the inner cavity with an extremely high depth-to-diameter ratio is completed in one go using gun drilling, multi-stage honing, and ultrasonic-assisted electrolysis, ensuring that the minimum wall thickness at any position on the bottom of the hole and the sidewall meets the attenuation requirements of the most unfavorable ray path. The outer contour is designed as a cylinder, square column, or irregular shape with gradient thinning, depending on the usage scenario, maximizing the usable internal volume and achieving optimal center of gravity distribution during hoisting and transportation. The can opening is formed by high-precision CNC grinding to create a multi-level stepped labyrinth surface, with flatness and roundness controlled at the micron level, providing a metal-grade sealing foundation for subsequent lid fitting.

The can lid is the most active and precise component in the structure, directly determining daily opening and closing efficiency and long-term sealing reliability. High-end designs generally employ an embedded self-centering structure: the outer diameter of the lid is slightly smaller than the inner diameter of the can opening, automatically aligning itself using gravity and guide ribs ; the bottom surface of the lid is machined with a multi-step labyrinth perfectly mirroring the can opening, forming a composite shielding band of several metal-to-metal hard contacts plus elastic sealing ring soft contacts after fitting. The top of the lid features an integrated forged lifting ring or quick-lock clamp interface, facilitating robotic gripping and maintaining operability even after high temperatures from fire. Some large waste containers even employ a double-lid design: the inner lid is a permanently sealed, one-time-use tungsten alloy welded lid, while the outer lid is a quick-opening lid that can be repeatedly opened and closed, achieving an optimal balance between containment and operability.

The connection area between the tank body and the lid is the most easily overlooked yet most critical link in the entire shielding structure. Tungsten alloy shielding tanks achieve metallurgical-grade bonding through integral forged ring welding and electron beam welding or vacuum brazing. The microstructure and properties of the heat-affected zone of the weld are completely restored to the level of the base material, thoroughly eliminating the risk of through-gap connections from traditional threaded connections or lead tank flange connections. Ultimately, the tank body and lid together form a complete tungsten alloy shielding shell without weaknesses or directional leakage , ensuring that radiation can only repeatedly collide within the high-density material until its energy is exhausted, without finding any escape route.

3.1.2 Auxiliary functional structures (lining, connectors) of tungsten alloy shielding tanks

Although auxiliary functional structures do not directly undertake the main shielding task, they play an irreplaceable role in corrosion resistance, ease of cleaning, convenient operation, and long-term durability. Like springs and washers in precision instruments, they may seem insignificant, but they determine whether the entire shielding container can truly achieve the ultimate goal of "a lifetime of use, a single wipe to make it look new."

The lining system serves as a dual protective layer against both chemical and radioactive contamination. Based on the application scenario, it is categorized into three types: replaceable sacrificial linings, fixed corrosion-resistant linings, and functional composite linings. Replaceable sacrificial linings are typically thin sheets of low-activation stainless steel or titanium alloy , fixed to the bottom and side walls of the inner cavity via clamps or magnetic attachment. They are specifically designed to collect liquid waste or powdery radioactive residues, and are removed and replaced entirely once saturated, ensuring the tungsten alloy body never directly contacts the contamination source. Fixed corrosion-resistant linings utilize PVD, thermal spraying, or diffusion processes to form a CrN , TiN , or diamond-like carbon film tens of micrometers thick on the tungsten alloy surface, making the tungsten alloy body undamaged even in strong acids, strong alkalis, and oxidizing detergents. Functional composite linings are commonly found in tanks with strong neutron shielding requirements. They incorporate boron-containing polyethylene or hydrogen-rich lithium layers on the inner surface of the tungsten alloy, absorbing thermal neutrons and suppressing gamma-ray capture, achieving optimal integration of gamma-neutron combined shielding.

The connectors and operating aids upgrade the shielding container from a static container to a dynamically interactive intelligent terminal. The quick-lock clamps are made of high-strength tungsten alloy or titanium alloy, and with the wedge self-locking principle, they can reliably tighten the ton-sized cover in seconds. The source operating lever channel uses a multi-stage tungsten alloy sleeve + bellows seal, allowing the robotic arm or remote control to move the radiation source deep inside the cavity while ensuring zero leakage in the channel direction. The venting pressure balancing valve has a built-in tungsten alloy filter element and radiation-resistant diaphragm, automatically balancing the slight pressure difference caused by temperature changes inside the container , while preventing any radioactive aerosol from escaping. The bottom waste liquid discharge valve uses a dual-valve series + tungsten alloy valve seat design to ensure that the discharge process does not compromise the overall containment.

All auxiliary functional structures are designed according to the principles of "removable, replaceable, inspectable, and traceable." Each lining plate, each sealing ring, and each operating lever has a unique identification code and lifespan record, facilitating rapid maintenance and compliance audits by users outside the thermal environment . Together with the main shielding structure, they form a highly modular and upgradeable system, ensuring that the tungsten alloy shielding tank not only delivers top-tier performance at the time of manufacture but also continues to thrive after twenty or thirty years of service by replacing auxiliary components . This truly embodies the meaning of "one-time investment, lifelong peace of mind."

3.1.3 Shielding Principle of Tungsten Alloy Shielding Can Structure

Tungsten alloy shielding containers lies not in how thick or hard a single component is, but in how all the structures—including the container body, lid, labyrinth, seals, lining, observation windows, and functional interfaces—work together like a symphony orchestra to block every possible escape path of radiation and eliminate every type of secondary radiation on-site, ultimately achieving a perfect shielding state of "complete silence outside the container and high order inside."

First, there is geometric synergy: the deep cavity of the tank body and the multi-step labyrinth of the lid form at least three continuous metal shielding bands, so that direct rays from any direction must pass through at least three times the wall thickness of the tungsten alloy to escape; at the same time, the rounded corners of the cavity, the self-centering of the lid, and the gradually thickening design at the bottom eliminate all geometric dead angles, so that scattered photons can only bounce repeatedly inside the tank wall until their energy is exhausted.

Secondly, there is material synergy: the main body uses high-tungsten, high-density grades to ensure primary attenuation, while local nested boron-, hydrogen-, or cadmium-containing layers precisely absorb thermal neutrons, and the surface functional coating or inner lining is specifically designed to deal with low-energy characteristic X-rays and secondary electrons, achieving broad-spectrum, blind-zone-free full-energy coverage .

Thirdly, there is the sealing synergy: the hard-on-hard metal labyrinth is responsible for geometric blocking and structural rigidity, the elastic sealing ring is responsible for molecular-level blocking, and the clamp or multi-thread provides continuous clamping force. The three work in layers to form a double insurance system that ensures that "even if the elastic ring ages, the metal surface will not leak; even if the metal surface is slightly deformed, the elastic ring can still compensate."

Fourthly, functional synergy: the lead glass observation window is completely enclosed by a tungsten alloy stepped frame, the dose monitoring port is equipped with a tungsten alloy screw plug and a labyrinth plug, and the waste liquid valve is equipped with a dual-valve series connection and a tungsten alloy valve seat, ensuring that each opening has its own independent shielding capability and does not rely on the thickness of the main body wall for compensation.

Finally, there is the synergy under unexpected operating conditions: when encountering a drop, the high-ductility tungsten alloy body absorbs the impact energy without shattering, and the labyrinth and sealing surface do not deform due to their high hardness; when encountering a fire, the high-melting-point tungsten alloy and anti-oxidation coating ensure that the tank does not melt or collapse, and although the sealing ring may be burned, the metal labyrinth can still maintain basic containment; after long-term irradiation, the material exhibits zero swelling, zero activation, and zero embrittlement, ensuring that all synergistic relationships remain effective for decades .

It is this interconnected, redundant, and mutually backup structural synergy that allows the tungsten alloy shielding canister to consistently maintain its external surface dose rate at the background level in the most complex mixed radiation fields, the most demanding operating environments, and the longest service cycles. It is no longer a simple assembly of parts, but a living, breathing, and self-protective shielding entity.

3.2 Main Types of Tungsten Alloy Shielding Cans Classified by Shielding Scenarios

Tungsten alloy shielding cans have long since broken free from the limitations of single standard products. They have formed a highly specialized and serialized series of types according to actual shielding scenarios. Each type has been deeply customized for specific source items, spaces, operating modes and regulatory requirements, yet they share the same material genes and design philosophy.

The medical source canister series is specifically designed for nuclear medicine PET-CT centers, cyclotron pharmaceutical plants, and Gamma Knife treatment rooms. Its features include small size, light weight, no magnetic interference, and extremely fast opening and closing. Typical products include syringe protective sleeves, molybdenum- technetium generator canisters, fluorine-18 transport canisters, and iodine-125 seed source storage canisters. They generally utilize non-magnetic, corrosion-resistant tungsten-nickel-copper alloys, with precise wall thickness gradients, quick-opening lids, and one-handed knobs. The surface features a super- mirror-finish coating, allowing direct access to MRI rooms and sterile operating rooms.

Our series of fixed hot chamber tanks are designed for high-activity isotope dispensing and target processing . They feature thick walls, deep cavities, high integration, and are maintenance-free for life. Common capacities range from tens of liters to several cubic meters. Made with high-strength tungsten -nickel-iron alloy, they are integrally molded in one piece and include an automatic source shifting mechanism, replaceable sacrificial lining, a large lead glass viewing window, and multiple robotic arm interfaces. They can operate continuously for over twenty years without requiring the hot chamber to be removed.

The transport container series is designed strictly according to the International Atomic Energy Agency's Type A and Type B standards, featuring drop resistance, fire resistance, immersion resistance, and global applicability. Its exterior conforms to ISO container standards, complete with corner fittings, latches, and shock-absorbing bases. The internal structure employs multi-layered nesting and cushioning padding, with a salt spray-resistant coating. It can withstand a nine-meter drop and a 30-minute flame at 800 degrees Celsius without leakage, making it the only legal carrier for the transnational and intercontinental transport of highly active radioactive materials and waste .

Our waste transfer and temporary storage tank series is designed for decommissioned irradiation facilities, centralized waste collection and storage, and temporary storage before geological disposal. Features include ultra-large capacity, ultra-long lifespan, and maximum redundancy. They often employ a double or even triple-lid structure, with a permanently welded inner tank , a quick-opening middle tank, and an anti-theft outer tank. Equipped with multiple monitoring interfaces and remotely readable status sensors, they can safely store waste in unattended warehouses for decades without any maintenance.

The industrial flaw detection and scientific research irradiation canister series emphasizes directional collimation and local windowing. Commonly used are cobalt-60 and iridium-192 flaw detection source canisters and reactor irradiation channel canisters. They adopt a directional conical window + rotatable tungsten alloy collimator to achieve precise delivery of the X-ray beam while providing strong shielding against non-target directions.

Each type of tungsten alloy shielding container is developed under a unified material platform and manufacturing system, with optimized structure, function, and ergonomics tailored to specific scenarios and pain points. It also allows for rapid transformation through modular interchange. This "platform-based design + scenario-based customization" classification model ensures that tungsten alloy shielding containers truly provide a one- stop solution for radiation protection, allowing customers to obtain the most suitable customized solutions regardless of whether they are in hospitals, factories, laboratories, or waste storage facilities.

3.2.1 Tungsten alloy shielding container for nuclear industry

The nuclear industry-specific tungsten alloy shielding container is a "heavy fortress" tailored for isotope production hot chambers, research reactor irradiation channels, radiochemical dispensing lines , and high-level waste temporary storage facilities. Its design goal is singular: to achieve absolute containment and permanent shielding in environments with the highest activity, the most complex mixed radiation fields, the longest service life, and the most unattended operation.

These canisters typically use high-strength tungsten -nickel-iron alloys with extremely high tungsten content and a wall thickness gradient (thinner on the outside, thicker on the inside) , easily resulting in a single canister weighing several tons. Structurally, they generally employ a near-net-shape integral forming process combined with deep blind hole precision machining to ensure that the minimum penetration thickness for any ray path meets the decay requirements of long-lived nuclides such as Cobalt-60, Cesium-137, and Strontium-90 throughout their full decay period. The canister lid system is often redundant with double or even triple lids: the inner lid uses electron beam full penetration welding for a permanent seal, the middle lid is a quick-opening hydraulic lock, and the outer lid is equipped with anti-theft and status monitoring sensors. The entire internal cavity is equipped with a replaceable sacrificial lining and a boron/lithium composite neutron absorption layer, achieving combined shielding of the entire γ-neutron-α spectrum.

Highly integrated functionality: It features a built-in automatic lifting mechanism, a remotely operable robotic arm interface, multi-point dose rate and temperature/pressure sensors, an automatic decontamination spray ring, and an online wastewater filtration and discharge system. The surface is coated with a high-temperature anti-oxidation and ultra-corrosion-resistant multi-layer composite coating, capable of withstanding steam purging, concentrated nitric acid immersion, and prolonged exposure to humid salt spray without losing its gloss. The transport interface is designed according to Type B(U) or Type C container standards, allowing direct loading into standard shielded transport vehicles or shipping containers.

3.2.2 Tungsten alloy shielding container for medical applications

The tungsten alloy shielded container for medical use is a product that truly embodies the concept of "people-oriented" in metal. It must simultaneously meet the requirements of non-magnetic interference, lightweight, ultra-fast opening and closing, easy-to-clean mirror surface, and compatibility with sterile rooms. It must also allow medical staff to complete the operation in a few seconds with one hand, even during the most tiring night shifts.

The material system almost exclusively uses tungsten -nickel-copper non-magnetic and corrosion-resistant grades, completely eliminating the risk of magnetic field distortion in the MRI room. The wall thickness employs a precise gradient design: while ensuring the dose rates of medical radionuclides such as molybdenum- technetium generators, fluorine-18, and iodine-131 meet standards, the weight is reduced to a fraction of that of lead containers , allowing nurses to easily lift them with one hand. The structure emphasizes extreme user-friendliness: the quick-opening lid uses a single-finger knob or foot-operated clamp, opening in three seconds and locking in one second; the lid features gravity self-centering and magnetic assisted positioning, allowing for one-time alignment even with three layers of gloves; the entire inner cavity has large rounded corners and a mirror-polished finish , allowing for a single wipe with special cleaning wipes to restore its original cleanliness.

Typical products include syringe protective sleeves, molybdenum -technetium generator containers, FDG dispensing containers, iodine-125 seed source implantation containers, and strontium-90 dressing storage containers. Their appearance is no longer the cold, industrial gray, but rather anodized or PVD gold/blue decorative coating, enhancing the aesthetics of the sterile environment and facilitating visual differentiation of different nuclides. The surfaces are also often permanently laser-etched with nuclide symbols, activity limits, and expiration dates, completely eliminating labeling errors caused by sticker peeling.

It is precisely because of these seemingly minor medical-specific details that tungsten alloy shielding canisters can be seamlessly integrated into the busiest PET-CT centers and the most stringent GMP pharmaceutical plants, allowing medical staff to focus all their energy on patients without worrying about shielding or contamination.

3.2.3 Tungsten alloy shielding container for industrial testing

The industrial inspection-specific tungsten alloy shielding canister is a "mobile fortress + precision window" combination tailored for non-destructive testing, pipeline weld inspection, casting endoscopy, and customs security inspection equipment. It must provide all-round high-strength shielding while also leaving a precise and controllable beam exit, so as to achieve "not a single photon leaks where it should be blocked, and not a millimeter is off where it should exit".

The materials used are mostly high-strength tungsten -nickel-iron grades, ensuring that the tank will never deform under conditions of field construction, frequent crane handling, or even accidental drops. The most distinctive structural feature is the directional collimation window design: the main body of the tank is fully enclosed by thick walls 360 degrees, with rotatable tungsten alloy collimators in the form of cones, fans, or slits on only one or more sides. The beam angle and beam width are precisely adjusted by an external handwheel or motor, enabling the X-rays to be accurately projected onto the weld or the workpiece being inspected, while providing superior shielding for operators and the environment.

Typical products include Iridium-192 flaw detection source canisters, Selenium-75 pipe crawler canisters, Cobalt-60 large workpiece irradiation canisters, and integrated shielding covers for X-ray machine heads. The canisters are often designed as integrated mobile platforms with wheeled chassis or forklift bays, allowing direct movement into flaw detection darkrooms or field work sites. The collimator uses multi-layer nested tungsten alloy plates and a stepper motor drive, achieving extremely high angular resolution without scattering. The surface is coated with an oil- and sand-resistant industrial-grade polyurea coating, suitable for the harshest environments such as oil fields, shipyards, and construction sites.

The sealing system emphasizes rapid source replacement capability : the cover uses quick-locking clamps and double O-rings, along with a special source replacement pig , allowing operators to complete source loading and removal outside the darkroom, with personnel exposure to near-zero radiation throughout the process.

电话/TEL：0086 592 512 9696
CTIAQCD-MA-E/P 2018-2024V
sales@chinatungsten.com

3.3 Common Types of Tungsten Alloy Shielding Cans Classified by Structural Form

In terms of structure and installation method, tungsten alloy shielding containers can be clearly divided into four major series: fixed, portable, transportable, and modular. The first two have the largest market share globally, covering almost 90% of actual needs.

3.3.1 Fixed Tungsten Alloy Shielded Canister

The fixed tungsten alloy shielding canister is the true "heart of the hot chamber." Once installed, it is almost never moved for its entire life. It pursues the ultimate shielding efficiency, extremely long maintenance-free life, and the highest level of integration, rather than any compromise on weight and volume.

These tanks are typically manufactured using a near-net-shape forming process, with single blanks weighing several tons or even tens of tons. Wall thicknesses range from tens of millimeters to two or three hundred millimeters, calculated entirely based on the worst-case scenario within the hot chamber. The tank body is rigidly connected to the foundation using pre-embedded tungsten alloy or high-strength steel anchor bolts, completely eliminating the risk of fretting wear and seal failure caused by long-term vibration. The tank cover system primarily uses hydraulic or pneumatic quick-opening covers, combined with hot chamber cranes and robotic arms to achieve fully automated opening and closing. Large hot chambers even employ double or triple cover structures: the innermost layer is a permanently welded tungsten alloy inner tank, the middle layer is a quick-opening cover for daily operation, and the outermost layer is a dustproof and accident-preventing safety cover.

The functional integration is unparalleled: the internal cavity features multi-layered replaceable sacrificial liners, an automatic source lifting platform, a waste liquid collection tank, and an online decontamination spray ring; the side walls are pre-embedded with large lead glass viewing windows, multi-channel robotic arm interfaces, and dose rate, temperature, and pressure sensors; the bottom directly connects to the hot chamber waste liquid system for automatic pumping and filtration. The entire surface is coated with a high-temperature anti-oxidation and ultra-corrosion-resistant multi-layer coating, capable of withstanding decades of steam purging and strong acid cleaning without losing its shine.

Fixed tungsten alloy shielded containers are generally designed to last over thirty years, during which time they require almost no maintenance, no spare parts, and no need for complete replacement. Like a miniature tungsten alloy building, it is firmly embedded in the center of the hot chamber, permanently locking the most dangerous radiation source in the safest position, allowing the entire hot chamber to operate for decades on this never-beating "tungsten heart".

3.3.2 Portable Tungsten Alloy Shielded Canister

Portable tungsten alloy shielding canisters are like "fortresses you can carry around in your hand." They compress most of the shielding capabilities of fixed canisters into a volume that a nurse, technician, or field operator can easily lift, push, or even carry on their back, representing a balance between lightweight and practicality in tungsten alloys.

Weight control is crucial for portability. The design team used precise Monte Carlo ray tracing and topology optimization to ensure every gram of tungsten alloy was used effectively: the thickest points are at the top and bottom of the source, with a streamlined gradient thinning around the perimeter. A thin tungsten or titanium alloy impact-resistant shell is then added to the outer surface, guaranteeing adequate dose rates in any direction while reducing the overall weight to a fraction of that of a lead canister. Typical medical portable canisters range in weight from a few kilograms to tens of kilograms, making them easy for technicians to lift with one hand, nurses to push on a trolley, and doctors to carry directly into the interventional operating room.

The design emphasizes minimalism and speed: the lid typically features a single-finger knob or magnetic quick-opening mechanism, opening in three seconds and locking in one second, ensuring a secure grip even when wearing three layers of gloves; the handle is integrally forged, ergonomically designed for comfortable long-term use; and the four corners of the bottom are often equipped with medical-grade casters and electromagnetic brakes, allowing for precise stopping at the injection table or bedside with a gentle push. The entire surface is mirror-polished and finished with medical-grade blue or gold anodizing, resulting in an aesthetically pleasing finish that is easy to clean, seamlessly integrating into a sterile environment.

Typical products include fluorine-18 injection protective containers, molybdenum -technetium generator transport containers, iodine-131 treatment containers, germanium-68 calibration source containers, and portable waste source collection containers. These often also feature built-in dose rate displays, residual activity reminders, and NFC identification, allowing direct integration with hospital HIS systems for end-to-end electronic tracking of the source.

Portable tungsten alloy shielded containers, with their minimal size, lightest weight, and fastest opening and closing, bring the sense of security of a fixed container's "tungsten fortress" to wards, operating tables, ambulances, and even patients' homes, ensuring that every second from the production to the administration of radiopharmaceuticals is under absolute control.

3.3.3 Sealed Tungsten Alloy Shielded Canister

Sealed tungsten alloy shielded containers represent the ultimate in containment and shielding. They adhere to the sole principle of "absolutely preventing any radioactive material from escaping the container in any form." They are suitable for all scenarios requiring zero leakage, long-term storage, transportation, or unattended operation, ranging from high-activity waste collection tanks to Type B containers for intercontinental transport.

Structurally, the sealed tank completely abandons any movable caps that could be repeatedly opened, instead adopting a minimalist design with one-time permanent closure or extremely reliable opening and closing with minimal usage. Typically, after source loading, the tank body and cap achieve a metallurgical-grade permanent seal through electron beam full penetration welding, vacuum brazing, or explosive welding. The weld seams are verified by both helium mass spectrometry leak detection and X-ray flaw detection to ensure a leakage rate so low that it is undetectable by instruments. Some models that require occasional source loading retain an extra-large diameter quick-opening cap, but the cap and tank opening employ a "triple-insurance" structure with a three-tiered or higher hard metal labyrinth, double radiation-resistant metal C-shaped sealing rings, and hydraulic clamp locking , ensuring zero leakage at the molecular level even with numerous opening and closing cycles .

The entire internal cavity is equipped with replaceable sacrificial liners and multi-stage filter elements. Radioactive aerosols, volatile iodine, and tritium vapors are physically adsorbed by the first layer, chemically captured by the second layer, and completely eliminated by the third layer of HEPA filtration. Multiple pressure, temperature, dose rate, and hydrogen concentration sensors are embedded in the tank sidewalls, transmitting data in real time via armored cables or wirelessly, allowing for remote monitoring even in deep underground storage facilities or shipping containers. The outer surface is coated with an ultra-thick, salt spray-resistant, and UV-resistant polyurea coating, ensuring it will not powder or blister for decades in marine climates.

3.3.4 Open-top tungsten alloy shielding container

The open-type tungsten alloy shielding canister goes against the grain entirely . It deliberately retains one or more permanently open windows, actively embracing the precise control philosophy of "the X-ray only goes where I want it to go." It is mainly used in industrial gamma-ray flaw detection, scientific research irradiation experiments, customs X-ray security inspection heads, and medical linear accelerator collimation systems.

The main body of the tank retains the high-density, thick-walled tungsten alloy structure, but tapered, fan-shaped, rectangular, or slit- shaped beam exit windows are precisely machined on one or more sides. Inside each window are multiple layers of independently rotatable or translatable tungsten alloy collimating blocks. The beam angle and beam width are infinitely adjustable via external lead screws, handwheels, or servo motors . Non- beam exit directions remain fully enclosed with ultra-thick walls to ensure that scattered and leaked rays are completely absorbed. Micrometer-level dovetail guides or ball-bearing linear guides are used between the collimating blocks to ensure that the gap does not increase and the positioning does not drift after long-term, frequent adjustments.

To ensure operational safety, open-top tanks are generally equipped with interlocking protective covers and multiple safety interlocks: the source can only be raised to the working position when the collimation window is completely closed or the protective cover is fully reset ; if the protective cover is accidentally opened, the source will automatically and urgently sink to the safety zone at the bottom of the tank. The surface treatment is also completely different from that of sealed tanks, with greater emphasis on resistance to oil stains, sand and dust , and mechanical scratches. Hard anodizing, supersonic flame spraying of tungsten carbide, or polyurea elastic coating are commonly used, which can maintain their

电话/TEL：0086 592 512 9696
CTIAQCD-MA-E/P 2018-2024V
sales@chinatungsten.com

color for ten years under the harsh conditions of field flaw detection vehicles, shipyard gantry cranes, or customs ports. Open-top tungsten alloy shielded tanks turn the extremely high density of tungsten alloy into a "controllable knife," allowing the X-rays to precisely cut welds, illuminate tumors, or see through luggage like a scalpel, while always maintaining the gentleness of the "back of the knife" for the operator and the environment.

3.3.5 Single-layer tungsten alloy shielding can

Single-layer tungsten alloy shielding containers represent the purest and most authentic expression of tungsten alloy shielding technology. They entrust all shielding responsibilities to the tungsten alloy body itself, a single material and wall thickness, without any composite lining, gradient transition layers, or external low-density materials. Everything is handled solely by the high density, high uniformity, and high stability of the tungsten alloy itself. This minimalism , seemingly crude, is actually a product of extreme confidence in the material's performance. Only when the density, compositional uniformity, fineness of the microstructure, and long-term irradiation stability of the tungsten alloy reach top-tier levels can such an uncompromising design be adopted.

The entire tank body, inside and out, is constructed from the same grade and batch of tungsten-nickel-iron or tungsten-nickel-copper alloy. The wall thickness is calculated conservatively during the design phase, taking into account the most conservative source terms and the longest service life, and is then manufactured strictly according to the "extra-thickness margin" principle. The inner surface is mirror-polished to a mirror finish, while the outer surface receives only a thin corrosion-resistant coating or cleaning coating, adding no extra weight and without compromising shielding capability. The lid and tank body feature a completely symmetrical, integrated design. The labyrinth, sealing surface, and locking mechanism are all directly machined from tungsten alloy, completely eliminating the potential risks of thermal expansion mismatch, irradiation swelling differences, or galvanic corrosion caused by dissimilar material interfaces.

The advantages of a single-layer structure are fully demonstrated in extreme scenarios: there is no risk of the low-melting-point lining melting and flowing during high-temperature fires; there is no possibility of delamination and cracking of the composite interface during long-term high-dose irradiation; and there is no embarrassing situation of the outer layer peeling off and exposing the low-density substrate when repeatedly decontaminated by strong acids and alkalis. Its shielding effectiveness will only slowly increase over time due to the decay of the radiation source itself, and will never decrease due to material aging.

The most common applications of this type of tank are those scenarios with almost obsessive reliability requirements: permanent waste tanks, temporary storage tanks before deep geological treatment, protective tanks for satellite-borne isotope heat sources, and certain high-end medical source tanks that require absolute non-magnetism and absolute corrosion resistance. They are often small in size, surprisingly heavy, and have an unadorned appearance, yet they achieve the ultimate long-term containment and shielding protection in the simplest form.

3.3.6 Multi-layer tungsten alloy shielding can

Multilayer tungsten alloy shielding tanks represent the pinnacle of systems engineering thinking in the field of shielding containers. Instead of using tungsten alloy as a single material, they break it down into multiple sub-layers with different tungsten contents, different binder phase systems, and different functional orientations. Through precise metallurgical composites, hot isostatic pressing cladding welding , or vacuum brazing, atomic-level bonding is achieved, constructing a "tungsten alloy sandwich" with clear functional partitions, continuous performance gradients, and a seamless overall structure.

The most classic structure, from the inside out, is as follows:

- The innermost layer uses an ultra-high density grade with ultra-high tungsten and low binder phase, which is specifically designed for hard absorption of main gamma rays;
- Adding trace amounts of rare earth elements or boron and cadmium to the middle layer enables efficient thermal neutron capture while maintaining sufficient strength;
- The outer layer is switched to a tungsten-nickel-copper non-magnetic corrosion-resistant system or a high-toughness tungsten -nickel-iron transition layer, which takes into account both surface corrosion resistance and impact resistance.
- The outermost layer can be an ultra-thin functional coating or a sacrificial decorative shell to satisfy both aesthetic and final cleaning needs.

Each layer of tungsten alloy is precisely differentiated in composition, sintering process, and secondary deformation, yet they achieve complete metallurgical bonding at the interface through a transition diffusion zone, without any macroscopic interfaces, microscopic voids, or abrupt performance changes. This multi-layered composite brings three revolutionary advantages: First, a significant improvement in shielding efficiency. The inner layer's hard absorption reduces the probability of high-energy photon escape, the middle layer precisely captures thermal neutrons and suppresses gamma trapping, and the outer layer further mitigates low-energy scattering. The entire system attenuates several orders of magnitude more than a single-layer can of the same weight . Second, optimization of weight and volume. The total weight can be significantly reduced while maintaining the same shielding capability, making it particularly suitable for transport containers and portable medical applications. Finally, a leap in lifespan and maintainability. The surface layer is highly corrosion-resistant and can be locally repaired, while the inner layer is high-purity and high-density, never aging. The entire can is like an onion, with each layer providing protection and being peelable.

multi-layer tungsten alloy shielding containers is extremely challenging, requiring precise control across the entire chain, from powder formulation, layer-by-layer powder spreading, gradient sintering, cladding welding to final machining. However, once successful, its comprehensive performance and wide range of applications cover almost all high-end needs, from miniature medical source containers to giant waste transport containers. It is no longer just a piece of tungsten alloy, but a meticulously choreographed tungsten alloy symphony, where each layer plays its strongest note in its own frequency band, and together they create the most perfect shielding chord.

3.3.7 Integrated Tungsten Alloy Shielding Can

The integrated tungsten alloy shielding tank represents the pinnacle of near-net-shape forming technology for tungsten alloys. Its core feature is that the tank body, the tank cover base, the lifting lugs, the labyrinth sealing surface, the embedded parts of the functional interfaces, and even some collimation structures are all formed and precisely machined from a single blank in one go, completely eliminating any form of welding, brazing, or mechanical assembly seams, and realizing a completely seamless tungsten alloy continuum from the inside out and from top to bottom.

The blank preparation typically employs ultra-large cold isostatic pressing combined with high-temperature vacuum-hydrogen two-step sintering, or direct hot isostatic pressing cladding process , resulting in single blanks weighing several tons or even more, achieving theoretical limits in density, compositional uniformity, and microstructure consistency. Subsequent deep blind holes are machined using a high-rigidity gun drill, multi-axis honing, and ultrasonic-assisted electrolytic composite machining to penetrate the extremely high depth-to-diameter ratio cavity in a single pass. The outer contour, lifting lugs, labyrinth steps, observation window frame, and pre-embedded threads for the dose monitoring holes are all completed using high-precision CNC wire EDM with five or more axes and mirror grinding. The final product macroscopically retains only one openable/closable cover joint surface; the remaining areas are completely free of interfaces, heat-affected zones, and residual stress concentration sources.

This thorough integrated design brings several significant engineering advantages:

- When the shielding continuity reaches its physical limit, the rays cannot find any low-density channels or interface scattering enhancement regions.
- The structural rigidity and impact resistance are greatly improved, and there will be no weld cracking or interface debonding even under extreme drop or seismic loads .
- The geometric fidelity is optimal under long-term irradiation, and there is no warping or sealing failure caused by differences in the swelling coefficient of different regions;
- It has the best surface cleaning performance, with no dead corners, gaps, or microscopic steps that can trap dirt and grime, and can maintain a mirror-like finish until it is scrapped.

Integrated tungsten alloy shielding containers are mainly used in scenarios with the highest reliability requirements and relatively relaxed weight and volume restrictions: core containers for large isotope production hot chambers, permanent insert containers for irradiation channels in research reactors, integrated protective containers for satellite isotope heat sources, and national strategic waste containers.

3.3.8 Modular Tungsten Alloy Shielding Can

Modular tungsten alloy shielding containers completely overturn the integrated philosophy, embracing a highly modular, scalable, and field-assembled upgradeable systems approach. They break down complex shielding tasks into a series of standard or semi-standard functional modules (main body section, top sealing assembly, bottom support assembly, neutron absorber, collimation window assembly, monitoring interface assembly, surface protective shell, etc.), achieving reliable connections through high-precision flanges, clamps, quick-locking pins , or vacuum brazing joints . This allows for flexible adjustments to the final configuration on-site based on changes in source parameters , space constraints, or regulatory upgrades.

The core of modular design lies in the standardization and interchangeability of interfaces: all cylindrical sections have completely uniform outer diameter, inner diameter, wall thickness gradient, labyrinth pattern, and sealing surface roughness, allowing seamless connection between any two sections; functional plug-ins adopt a drawer-type or radial insertion structure, enabling the addition or removal of neutron absorption layers, replacement of collimation windows, and upgrading of monitoring probes without production stoppage outside the heat exchange area; the outer protective shell and shock-absorbing tray are also modular, allowing for rapid switching according to road, rail, sea, or air transport requirements. Connection points generally employ a triple-safety system of double O-rings + metal bellows + helium mass spectrometer leak detection ports , ensuring that the overall leakage rate after assembly is completely equivalent to that of an integrated tank.

This modular architecture brings unprecedented engineering flexibility and lifecycle economics:

- Initial investment can be implemented in stages, starting with the core shielding cylinder section, and then gradually adding functional modules as production capacity increases.
- upgrading a source item , only some plugins need to be replaced; there is no need to scrap and rebuild the entire item.
- Maintenance and decontamination can be performed at the module level, and contaminated parts can be removed separately for outdoor heat treatment, significantly reducing personnel exposure to radiation and the amount of secondary waste.
- Upon decommissioning, it can be disassembled and recycled layer by layer, with the tungsten alloy body, functional components, and seals all entering different reuse channels, truly achieving a green closed loop.

Modular tungsten alloy shielding containers are most widely used in the world's busiest isotope production bases, the most crowded urban nuclear medicine centers, and industrial irradiation facilities that require frequent upgrades and expansions. Based on standardized modules and using on-site assembly, it upgrades the tungsten alloy shielding system from a single product into an open platform that can continuously grow and evolve, perfectly adapting to the fundamental needs of modern radiation protection engineering for rapid iteration and multi-scenario adaptation.

Chapter 4 Manufacturing Process of Tungsten Alloy Shielding Cans

4.1 Raw material composition and requirements of tungsten alloy shielding tanks

Tungsten alloy shielding canisters far exceed those of ordinary structural components or ordinary radiation protection materials. Essentially, it's a systematic engineering project involving the extreme purification, precise particle size control, consistent activity, and batch-to-batch stabilization of tungsten powder, nickel powder, iron powder, copper powder, and trace functional additives. Only when every gram of powder reaches near-pharmaceutical grade quality can the final product maintain zero defects, zero attenuation, and zero contamination under decades of high-volume irradiation, repeated strong corrosion and decontamination, and extreme unexpected operating conditions.

The raw material system mainly includes high-purity tungsten powder, binder phase metal powders (nickel, iron, copper), neutron-absorbing functional powders (borides, cadmium compounds, rare earth oxides, etc.), and process auxiliary powders (forming agents, degreasing agents, sintering activators). All powders must pass through a fully traceable system, from ore mining, ammonium paratungstate crystallization, tungsten/blue tungsten reduction to the final hydrogen reduction of tungsten powder, each step has a unique batch code and a complete physicochemical testing record. Even slight fluctuations between any batches can lead to unacceptable differences in tungsten particle size distribution, oxygen content, impurity profile, or reduction activity, ultimately forming weak density zones or activation hotspots at the thinnest or deepest part of the shielding tank.

4.1.1 Main raw material ratio of tungsten alloy shielding tank

tungsten alloy shielding cans have long since moved beyond the traditional "experience-based proportions" stage, evolving into a precise multi-objective optimization system based on source spectrum , service environment, regulatory requirements, and life-cycle cost. The core of the ratio design is to use tungsten powder as the absolute main component, and the binder phase and functional additives as precisely controllable "functional genes." Through a closed-loop mapping of composition, microstructure, performance, and application scenario, the optimal solution for each type of shielding can is achieved.

Tungsten powder consistently dominates the composition, its mass fraction deliberately pushed to an extreme high to ensure maximum macroscopic density, atomic number density, and photoelectric absorption cross-section, while providing sufficient tungsten-tungsten direct contact framework for subsequent secondary deformation. The binder phase system is divided into three main technical routes based on its end application:

- Nickel-iron system has become the first choice for nuclear industry hot chamber tanks and high-strength transport tanks due to its excellent dynamic mechanical properties and neutron moderation capability. A precise balance of strength, toughness and neutron trapping capability can be achieved by fine-tuning the nickel-iron ratio.

- The nickel-copper system is the only choice for nuclear medicine and waste liquid storage tanks due to its complete non-magnetic properties, high corrosion resistance and excellent cold and hot workability. The slight change in copper content directly determines the thickness of the surface passivation film and the pitting potential.
- The nickel-iron-copper ternary system, as a high-end compromise, combines strength, non-magnetism, and corrosion resistance, and is used in Type B transport containers with the most stringent comprehensive performance requirements.

Neutron-absorbing functional elements are precisely added in the form of compounds during the binder phase melting and infiltration stage or the powder mixing stage. Boron is dispersed in the form of boron carbide or boron nitride, rare earth elements are dispersed in the form of oxides or metal powders , and cadmium or gadolinium is introduced in the form of pre-alloyed powders . This ensures that the thermal neutron absorption cross section is improved to the optimal level without sacrificing the continuity of the tungsten framework, while strictly controlling the secondary radiation energy of captured gamma rays.

The selection of process activators and forming agents is equally important. Trace amounts of palladium, platinum group elements, or rare earth oxides can be used as sintering activators to lower the liquid phase appearance temperature without reducing tungsten purity, thus promoting complete wetting of tungsten particles by the binder phase. Forming agents must be medical-grade polymers that are completely volatilized during the degreasing stage, leaving no residual carbon or ash, to ensure zero porosity and zero carbon contamination after sintering .

After the final formulation is verified in a small batch in the laboratory, it must undergo a full-process confirmation process including pilot-scale amplification, batch stability assessment, irradiation aging test, decontamination and corrosion test, and actual tank radiographic calibration. Only when all performance indicators simultaneously meet the design target and the batch-to-batch variation is less than the minimum tolerance, is the formulation officially solidified into the company's internal standard and written into the material certificate of each shielding tank.

4.1.2 Purity and Particle Size Requirements of Raw Materials for Tungsten Alloy Shielding Tanks

tungsten alloy shielding containers have reached the extreme level in the field of tungsten materials science. The underlying logic is that any trace amount of harmful impurities or particle size dispersion may evolve into long-life activated nuclides under high-dose irradiation, become pitting corrosion initiation sources under strong corrosion and decontamination, and form a weak density area at the thinnest part of deep blind holes, thereby completely destroying the long-term reliability of the entire container.

The purity of tungsten powder must achieve an "ultra-pharmaceutical grade" level with extremely low total impurity levels and strictly controlled content of individual harmful elements (molybdenum , niobium, tantalum, titanium, phosphorus, sulfur, oxygen, carbon, hydrogen, nitrogen, potassium, sodium, etc.). Oxygen content is considered the number one killer because residual oxygen reacts with tungsten during sintering to form volatile oxides, resulting in micron-sized pores. Carbon content must be precisely balanced; too high a content leads to brittle tungsten carbide, while too low a content results in the loss of the ability to inhibit abnormal grain growth. All impurity detection employs triple verification using glow discharge mass spectrometry, inert gas melting infrared-thermal conductivity, and inductively coupled plasma mass spectrometry to ensure batch-to-batch consistency.

The particle size distribution is controlled within an extremely narrow unimodal normal range. Excessively fine powder cannot cause uneven sintering shrinkage, nor can coarse powder cause localized fractures in the tungsten-tungsten framework. The Fisher particle size, laser diffraction particle size, and scanning electron microscopy statistics must perfectly match; any deviation results in the entire batch being scrapped. The purity requirements for the binder phase nickel, iron, and copper powders are equally stringent. Nickel powder must be free of magnetic and corrosion-inducing elements such as cobalt, sulfur, and phosphorus; iron powder requires extremely low levels of silicon, manganese, and oxygen; and copper powder must be completely free of low-melting-point impurities such as arsenic, bismuth, and tellurium . All powders undergo vacuum degassing, secondary hydrogen reduction, and plasma spheroidization before entering the factory to ensure consistent surface activity, absence of adsorbed gases, and no agglomeration.

4.1.3 Selection Criteria and Requirements for Auxiliary Materials of Tungsten Alloy Shielding Tanks

In the manufacturing system of tungsten alloy shielding tanks , although auxiliary materials do not enter the final composition, they play a crucial behind-the-scenes role in each stage of forming, debinding, sintering, and post-processing. They must meet the stringent four principles of being "indispensable in the process, completely disappearing during use, leaving no residue after disappearance, and having no harmful residue. "

The preferred molding agent is medical-grade polyethylene glycol -polyvinyl alcohol copolymer or a high-end paraffin-based composite system. It must provide excellent flowability and shape retention during low-temperature injection molding or cold isostatic pressing, and completely pyrolyze and volatilize at temperatures far below the sintering temperature during the subsequent degreasing stage, with residual carbon and ash content approaching zero. Any residual organic matter may react with tungsten during high-temperature hydrogen sintering to form a brittle tungsten carbide phase, or volatilize and contaminate the furnace during vacuum sintering, leading to batch-to-batch cross-contamination.

The degreasing catalyst and sintering atmosphere purifier are usually high-purity nitric acid or hydrogen peroxide trace doping systems, used to accelerate the cracking of the forming agent and capture residual oxygen and carbon. They must be completely removed at the end of the degreasing stage, and the residual oxygen partial pressure and carbon partial pressure in the furnace need to be monitored in real time until the instrument detection limit is reached.

The sintering support material and the release agent for the blank are coated with ultra-high purity alumina, yttrium oxide, or boron nitride, requiring zero reaction, zero adhesion, and zero element diffusion with the tungsten alloy at the highest sintering temperature. Any peeling of the support material or residue of the release agent may form shallow pits on the blank surface, becoming dead zones for future cleaning or the starting point for pitting corrosion.

Surface treatment auxiliary materials (electroless nickel plating solution, cleaning and coating resin, ion nitriding gas, diamond-like carbon precursor) also comply with pharmaceutical-grade purity standards. The plating solution must be free of cyanide and heavy metal stabilizers, the coating resin must be free of benzene-based solvents and free formaldehyde, and the purity, moisture, and oxygen content of the nitriding gas must be controlled at extremely low levels.

full- process simulation verification before formal production : take actual tungsten alloy blanks, complete the entire cycle of forming-degreasing-sintering-surface treatment according to real process parameters, and then perform residual glow discharge mass spectrometry in-depth analysis and irradiation activation analysis on the finished products. Only after confirming that there are no impurities introduced by the process can batch production be approved.

4.2 Manufacturing process of tungsten alloy shielding can

Tungsten alloy shielding cans has formed a highly enclosed, fully traceable, and zero-contamination transfer dedicated production line. Its core concept is to completely, uniformly, and without damage transform the potential of every gram of powder into the true performance of the deepest and thinnest part of the final can body, eliminating any local density weak areas, uneven structure, or residual defects caused by process fluctuations.

4.2.1 Basic powder metallurgy process for tungsten alloy shielded tanks (powder preparation, mixing, pressing)

The three major steps of powdering, mixing, and pressing are regarded as the "genetic engineering" stage of the entire manufacturing chain, which determines that all subsequent high-temperature processes can only add icing on the cake, but can never provide essential support.

The powder-making stage has completely departed from the traditional single hydrogen reduction method, instead employing a multi-stage variable temperature, variable hydrogen dew point , and variable flow rate "gradient precise reduction + plasma re-spheroidization" composite process. Tungsten powder first undergoes gentle reduction of its outermost oxide layer in a low-temperature, low-dew-point region, then gradually increases in temperature to enter a deeper reduction region. Finally, it undergoes particle spheroidization and final degassing in a high-purity argon plasma spheroidization chamber, resulting in tungsten powder with extremely narrow particle size distribution, perfect sphericity, ultra-low oxygen and carbon content, and extremely high bulk density. Nickel, iron, and copper powders are produced using a carbonyl method and an atomization-vacuum degassing-hydrogen secondary reduction route, respectively, ensuring that the particles are also nearly spherical, without internal voids or surface adsorption layers.

Mixing is the crucial process that truly determines the "soulful uniformity" of tungsten alloy shielding containers. Industry-leading factories generally employ dual-motion planetary-vortex composite powder mixers or ultra-large-capacity three-dimensional mixers. The inner wall of the mixing container and the rotor are entirely coated with high-purity tungsten or yttrium oxide, completely eliminating external iron group contamination . The mixing process consists of four sub-stages: dry mixing, wet mixing, vacuum degassing, and secondary dry mixing . First, under the protection of high-purity argon, preliminary spatial homogenization of tungsten powder and binder phase powder is achieved. Then, medical-grade anhydrous ethanol or high-purity isopropanol is added to form a suspension for deep vortex dispersion. Subsequently, the solvent is slowly evaporated under vacuum rotation. Finally, dry mixing is performed again to eliminate any residual agglomerates. The entire mixing cycle lasts for tens of hours, during which real-time sampling is performed for laser particle size analysis, SEM, and chemical composition chromatography to ensure that the tungsten particles and binder phase particles achieve statistically perfect uniformity at the micron scale.

The pressing process completely departs from traditional unidirectional molding, shifting to a "three-in-one" forming system that primarily uses cold isostatic pressing, supplemented by injection molding, and pre-compacted by hot isostatic pressing . For small and medium-sized can blanks, the wet bag method of cold isostatic pressing is used , ensuring that the pressure is evenly transmitted to the deepest part of the blank, guaranteeing consistent density from the surface to the core. For ultra-large or complex irregularly shaped blanks, high-precision blanks are first obtained through low-temperature injection molding, and then the entire blank is encased in a flexible sleeve for cold isostatic pressing to fill the gap. For integrated can blanks requiring extremely high density, hot isostatic pressing is performed directly after cold isostatic pressing, ensuring that the blank is close to the theoretical density before entering the sintering furnace. All pressing processes are completed in a cleanroom of Class 100,000 or higher, with operators fully equipped and the blank surface covered with a special protective film to prevent any fingerprints, sweat, or dust contamination.

The ultimate refinement of these three fundamental processes lays the material foundation for the tungsten alloy shielding tank, ensuring "no weaknesses in density, no differences in structure, and no fluctuations in performance," and also provides the most perfect starting point for subsequent high-temperature sintering and precision machining.

4.2.2 Key Sintering Processes and Parameter Control for Tungsten Alloy Shielding Tanks

Sintering is the crucial transformative stage for tungsten alloy shielding tanks, transforming them from "high-density blanks" into "truly high-performance materials." It is also the stage with the highest temperature, longest duration, most complex variables, and the most profound impact on the final shielding effectiveness in the entire process chain. If any irreversible defects occur during sintering (such as excessive local liquid phase, binder phase segregation, abnormal growth of tungsten particles, or microcracks), the entire tank will be deemed scrap.

High-end tungsten alloy shielding containers generally employ a three-stage process route combining vacuum-hydrogen two-step sintering with hot isostatic pressing (HIP) post-treatment. The first stage is low-temperature solid-phase pre-sintering, where the temperature is slowly increased to the critical point before the binder phase melts under high vacuum. This thoroughly removes residual forming agents, adsorbed gases, and volatile impurities, while simultaneously completing the initial neck connection between tungsten particles, forming sufficient strength to withstand the capillary rearrangement in the subsequent liquid phase stage. The second stage is liquid-phase main sintering, where the furnace switches to high-purity flowing hydrogen. Within a precisely controlled temperature window, the binder phase completely melts and fully wets the tungsten framework. The capillary force of the liquid phase drives rapid rearrangement of tungsten particles, pore spheroidization and shrinkage, and final densification. In this stage, the heating rate, holding time, hydrogen dew point, and furnace pressure gradient are controlled in real-time via a closed-loop system; any parameter drift will immediately trigger automatic furnace shutdown protection. The third stage is hot isostatic pressing for final densification and microstructure homogenization. Uniform high pressure is applied in an argon gas liner to completely flatten the residual closed pores and promote the uniform diffusion of the binder phase along the boundaries of tungsten particles, ultimately achieving a theoretical density that is very close to the limit, while eliminating any microscopic segregation bands.

The entire furnace chamber utilizes a tungsten-molybdenum composite heating element and multi-layered tungsten-molybdenum radiant screens. The billets are placed on ultra-high purity yttrium oxide crucibles or tungsten plates coated with boron nitride . All supporting and insulating materials exhibit zero reaction with the tungsten alloy. Temperature field uniformity, atmosphere purity, pressure stability, and heating/cooling curves within the furnace are all acquired and permanently archived within seconds, ensuring complete traceability of the sintering process for each vessel. After exiting the furnace, the billets immediately enter a clean cooling chamber and are slowly cooled under argon protection to prevent hydrogen embrittlement and thermal stress cracking.

4.2.3 Machining process of tungsten alloy shielding tank

Machining is the final stage in transforming tungsten alloy shielding containers from "high-performance blanks" into "high-precision functional containers," and it is also the ultimate acceptance test of all previous technological achievements. Any scratch, insufficient fillet radius, or even a one-micron deviation in wall thickness could become a seed for future radiation leaks or a breeding ground for untreated areas.

The machining chain follows a four-stage progression: roughing, finishing, ultra-finishing, and mirror finishing. The roughing stage utilizes a high-rigidity, heavy-duty CNC milling and turning center, equipped with specialized tungsten alloy indexable cutting tools and an ultra-high-pressure internal cooling system, to quickly remove most of the excess material and establish a reference surface. The cutting tool material is ultra- fine-grained cemented carbide or cubic boron nitride, and the cutting fluid is medical-grade synthetic ester, ensuring no chlorine, sulfur, or phosphorus contamination. The finishing stage switches to an ultra- high-precision five-axis or higher machining center, upgrading the cutting tools to natural diamond or polycrystalline diamond . The depth of cut and feed are strictly limited to the micrometer level, achieving high-precision forming of the tank's outer contour, lifting lugs, labyrinthine stepped surfaces, and pre-embedded holes for functional interfaces. Ultra-precision machining specializes in deep blind holes and internal cavities, employing a "sandwich" process of composite gun drilling + multi-stage expansion honing + ultrasonic-assisted electropolishing: gun drilling ensures hole depth and straightness, expansion honing achieves uniform wall thickness and roundness, and ultrasonic electropolishing ultimately removes surface micro-cracks and stress layers, pushing the internal surface roughness to mirror level. The mirror-finish final machining covers all exposed surfaces, including tank opening sealing surfaces, observation window frames, and valve mounting surfaces, all using magnetorheological polishing, ion beam polishing, or plasma-assisted chemical polishing to ensure the surface is free of any tool marks, processing-induced deterioration layers, and residual tensile stress.

The entire machining process is carried out in a Class 100,000 cleanroom with constant temperature and humidity. Disposable high-purity tungsten or zirconium oxide isolation pads are used between the workpiece and the cutting tools and fixtures to prevent any transfer of iron group elements . Critical dimensions are monitored in real time using a coordinate measuring machine, laser tracker, and online optical profilometer. The minimum wall thickness and hole bottom thickness are verified by both ultrasonic phased array and gamma-ray imaging. The final product undergoes overall leak testing by helium mass spectrometry and surface cleanliness fluorescence detection in the cleanroom before proceeding to the surface functional coating process.

4.2.4 Surface treatment process of tungsten alloy shielding tank

Surface treatment is the final alchemical process that transforms tungsten alloy shielded tanks from "high-performance metal bodies" into "green, long-life functional systems." It must simultaneously endow the tank with extremely high corrosion resistance, extremely strong scratch resistance, extremely low stain-removing agents, good decorative properties, and absolutely non-toxic and harmless safety for repeated contact. The lack of any one of these indicators is enough to force the entire tank to be retired prematurely within ten years.

The high-end surface treatment system has formed a three-layer composite architecture of "bottom layer strengthening + middle layer protection + easy-to-clean surface layer". The bottom layer strengthening uses ion nitriding, boronizing, or low-temperature plasma carburizing processes to form high-hardness nitrides, borides, or solid solution strengthening phases at depths of tens to hundreds of micrometers on the tungsten alloy surface , significantly increasing Vickers hardness. Simultaneously, a favorable compressive stress layer is pre-formed on the surface, effectively preventing the initiation and propagation of microcracks. The middle layer protection primarily uses electroless nickel-phosphorus alloy plating with precisely controlled thickness and phosphorus content optimized to the best corrosion resistance range. The plating is completely pore-free, pinhole-free, and metallurgically bonded to the substrate. Subsequently, low-temperature diffusion heat treatment is performed in a vacuum or protective

电话/TEL：0086 592 512 9696
CTIAQCD-MA-E/P 2018-2024V
sales@chinatungsten.com

atmosphere, creating a transition diffusion zone of tens of micrometers wide between the nickel plating layer and the tungsten alloy substrate, completely eliminating the risk of plating peeling. For some nuclear medicine and waste tank applications, PVD CrN , TiN , or DLC diamond-like carbon coatings are directly selected, balancing ultra-high hardness and bioinertness. The easily decontaminated surface coating utilizes medical-grade fluoropolymers, silane-modified polyurethane, or nano-ceramic composite systems. Atomic-level adhesion is achieved through plasma activation followed by vacuum deposition or supercritical CO_2 spraying . The coating exhibits extremely low surface energy and a very high contact angle, allowing radioactive contaminants to be adsorbed only by extremely weak van der Waals forces. A single wipe with a damp cloth restores the coating to its original cleanliness. The coating itself is resistant to radiation-induced yellowing, strong oxidizing detergents, and high-temperature steam aging, with a lifespan perfectly matching that of the tungsten alloy substrate.

All surface treatment processes are completed in a cleanroom of Class 100,000 or higher, on an automated closed-loop production line. All process waste gas and waste liquid are recycled and treated in a closed loop, eliminating any emissions of cyanide, heavy metals, or volatile organic compounds. Before leaving the factory, each tank undergoes hundreds of hours of continuous salt spray-acid spray-ultraviolet-irradiation composite aging tests and verification by wiping with real detergents. Only tanks with no blistering, no loss of gloss, no weight gain, and no residual contamination are released.

4.3 Key Points of Quality Control in the Manufacturing Process of Tungsten Alloy Shielding Cans

Tungsten alloy shielding tanks has long surpassed the traditional passive model of "sampling inspection + final inspection" and evolved into a closed-loop proactive prevention and control system covering the entire process, all elements, all personnel, and all records. Its core concept is that any minor error in any process, any parameter, or any operator is not allowed to be passed on to the next link with any probability, let alone left to the hot chamber users ten years later to bear.

Quality control begins comprehensively the moment raw materials enter the factory. Each batch of tungsten powder, binder powder, and auxiliary materials undergoes four independent tests: glow discharge mass spectrometry, inert gas melting, laser particle size analysis, and SEM-EDS. Test reports correspond one-to-one with the actual batch and are permanently archived; any deviation from any indicator results in the return of the entire batch. All key processes, including mixing, pressing, sintering, machining, and surface treatment, are subject to SPC statistical process control. Hundreds of core parameters, such as temperature, pressure, time, rotation speed, and depth of cut, are collected, alarmed, and locked in real time. Sintering furnaces, hot isostatic pressing equipment, and deep hole machining centers are all equipped with black box-level recorders, allowing for accurate reproduction of anomalies down to the second.

Non-destructive testing is conducted throughout the entire process: the pressed billet is inspected for internal cracks and density distribution using industrial CT scanning; after sintering, the billet undergoes dual verification using ultrasonic phased array and gamma-ray imaging; after processing, the overall helium mass spectrometry leak detection rate of the tank must meet vacuum-level standards; after surface treatment, fluorescence penetrant testing, X-ray residual stress testing, and contact angle measurement are used to confirm each item. Critical dimensions (minimum wall thickness, hole bottom thickness , sealing surface flatness, labyrinth clearance) are measured independently by a coordinate measuring machine, laser tracker, and online optical profilometer, and the results must be completely consistent before proceeding to the next process.

The most stringent measures are traceability and accountability. From the first gram of tungsten powder to the final coating, all process parameters, operators, testing records, equipment numbers, and environmental temperature and humidity of each shielding tank are recorded in a unique QR code and blockchain-level electronic archive. Any problem in any link can be traced back to the specific person responsible within seconds. Before leaving the factory, each tank must undergo a real-source irradiation calibration simulating the worst source term of cobalt-60 or cesium-137. Only after the external surface dose rate, leakage angle distribution, and secondary radiation level have all passed the actual measurement can it be stamped with the "lifetime responsibility steel stamp".

4.3.1 Incoming Inspection Standards and Methods for Tungsten Alloy Shielding Tanks

tungsten alloy shielding tanks is the first and most stringent step in the entire quality control process, and it is also the most uncompromising. If any indicator in any batch of powder exceeds the limit, the entire batch will be returned to the mineral powder stage without any room for negotiation.

Incoming inspection is divided into four main modules: chemical purity, physical properties, radioactive purity, and batch consistency. All tests are conducted simultaneously in both an independent third-party laboratory and the company's internal laboratories. Chemical purity testing employs glow discharge mass spectrometry (GFMS) with full elemental scanning, inert gas melting infrared-thermal conductivity (IR-TIR) for oxygen, carbon, and sulfur determination, and ICP-MS for metallic and non-metallic impurities. The total impurities in tungsten powder must be significantly lower than the industry's conventional upper limit, and the individual content of key harmful elements such as molybdenum, niobium, tantalum, titanium, potassium, sodium, phosphorus, and sulfur must be controlled at extremely low levels. Nickel, iron, and copper powders are subject to the same standards, with elements such as cobalt, arsenic, bismuth, and tellurium , which have a fatal impact on corrosion resistance and activation products, being strictly prohibited. Physical property testing includes Fisher particle size distribution, laser diffraction particle size distribution, Scott loose packing density, tap density, SEM morphology, and BET specific surface area. Both tungsten powder and binder phase powder must be nearly spherical, with an extremely narrow particle size distribution, no satellite powder, no agglomerates, and no internal voids. Radioactivity purity was tested using a high-purity germanium gamma spectrometer for full-spectrum scanning to confirm the background levels of natural and artificial radionuclides such as thorium, uranium, plutonium, americium, and cobalt-60. Batch consistency was verified through rapid testing of small-sample mixing, pressing, sintering, density, hardness, and metallography to ensure that new batches of powder were completely equivalent to the verified reference batches in terms of microstructure and properties.

All raw spectra, raw data, instrument calibration records, and physical samples must be permanently archived and uploaded to the company's blockchain quality system.

4.3.2 Quality Inspection Nodes in Intermediate Processes of Tungsten Alloy Shielding Tanks

The intermediate process quality inspection nodes are designed as a full-process interception network with layers of checkpoints and lock-in mechanisms. If any process fails, the downstream process is immediately physically disconnected, and the blank will never enter the next station.

Key nodes include:

- After mixing, multiple samples were taken for laser particle size re-measurement and SEM-EDS composition chromatography to confirm the microscopic uniformity of the tungsten-binder phase.
- the pressed billet is demolded, industrial CT three-dimensional density scanning and ultrasonic overall flaw detection are performed. Any area with density below the threshold or internal cracks are immediately scrapped.
- After sintering, the blanks are first subjected to helium mass spectrometry for overall leak detection to confirm that there are no through-holes. Then, gamma-ray transmission density imaging and ultrasonic phased array layer-by-layer scanning are performed to ensure that the density of the core and the surface is consistent, and that there are no closed pores or segregation bands.
- After rough machining, the first ultrasonic thickness measurement and coordinate measuring machine dimensional survey are carried out to establish a permanent benchmark.
- After the deep blind hole is processed, an endoscope and laser contour scanner are used to check the bottom radius and surface quality of the hole. At the same time, a second ultrasonic thickness measurement is performed to confirm the minimum wall thickness.
- After each sub-layer of surface treatment is completed, adhesion cross-cut test, thickness eddy current measurement, salt spray pre-corrosion and contact angle measurement are performed to ensure that each layer is independently qualified.

Each node is equipped with two independent inspection stations, A and B. The data is uploaded to the central quality server in real time. Only when the results of the two stations are consistent and the system automatically determines that the system has passed the test will the electronic lock open the door to the next workstation.

4.3.3 Full Inspection Process for Finished Tungsten Alloy Shielding Cans Before Shipment

The final inspection of finished products before leaving the factory is the final stamping ceremony for the "birth certificate" of the tungsten alloy shielded can, and also the most ruthless final judgment on the entire manufacturing chain . Only cans that pass this process are qualified to be packed into special shockproof transport boxes, affixed with a lifetime responsibility stamp, and delivered to the most demanding nuclear medicine centers or the most stringent waste storage facilities.

The process is divided into five major sections: geometric and mechanical properties, shielding performance, sealing and containment performance, surface and environmental performance, and regulations and labeling. All of these are completed in an independent clean testing room and a Cobalt-60/Cesium-137 source calibration room. The geometric and mechanical performance section includes full-size coordinate measuring machine (CMM) scanning, minimum wall thickness ultrasonic array thickness measurement, optical profilometer measurement of sealing surface flatness and roughness, and static load tensile testing of lifting lugs and clamps. The shielding performance section uses standard cobalt- 60 or cesium-137 sources to perform panoramic scanning of the external surface dose rate, leakage angle distribution measurement, and secondary radiation spectrum analysis at different source-canister distances , requiring the dose rate at any point to be far below regulatory limits and without directional hot spots. The sealing and containment performance section performs vacuum-pressurization-helium mass spectrometry step-by-step leak detection, re-inspection after 100,000 cycles of lid opening and closing, and integrity checks after simulating a nine-meter drop and fire. The surface and environmental performance section includes salt spray-acid spray-ultraviolet-irradiation composite aging, repeated wiping tests with real detergents, and verification of surface contamination wipeability. The regulations and labeling section verifies REACH, RoHS, transport container type approval certificates, laser-etched unique identification codes, and QR code traceability systems.

All testing is conducted jointly by a qualified third-party organization and the company's internal staff, with original reports, test videos, and source item records all sealed and archived. Finally, the chief engineer, quality director, and authorized third-party signatory jointly issue the "Birth Certificate and Lifetime Quality Guarantee for Tungsten Alloy Shielding Can," and all data is written into the radiation-resistant RFID chip embedded inside the can.

CTIA GROUP LTD Tungsten Alloy Shielding Can

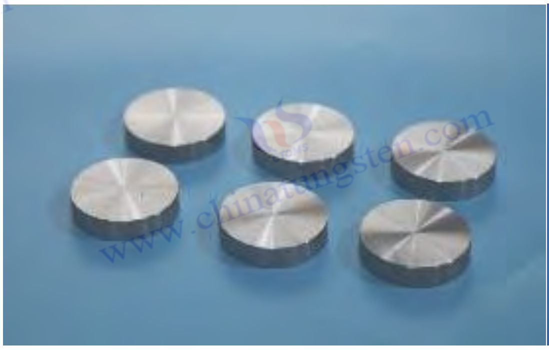
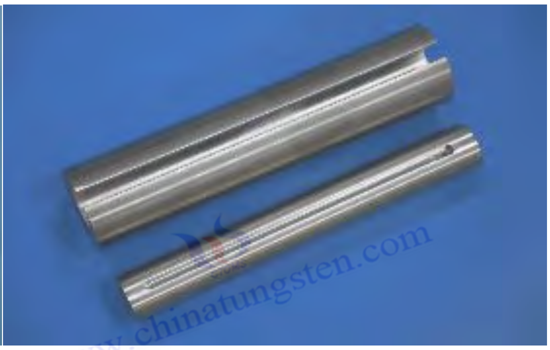
CTIA GROUP LTD
High-Density Tungsten Alloy Customization Service

CTIA GROUP LTD, a customization expert in high-density tungsten alloy design and production with 30 years of experience.

Core advantages: 30 years of experience: deeply familiar with tungsten alloy production, mature technology.
Precision customization: support high density (17-19 g/cm³), special performance, complex structure, super large and very small parts design and production.
Quality cost: optimized design, optimal mold and processing mode, excellent cost performance.
Advanced capabilities: advanced production equipment, RMI, ISO 9001 certification.
100,000+ customers
Widely involved, covering aerospace, military industry, medical equipment, energy industry, sports and entertainment and other fields.
Service commitment
1 billion+ visits to the official website, 1 million+ web pages, 100,000+ customers, 0 complaints in 30 years!

Contact us
Email: sales@chinatungsten.com
Tel: +86 592 5129696
Official website: www.tungsten-alloy.com



Chapter 5 Application Areas of Tungsten Alloy Shielding Cans

5.1 Application of Tungsten Alloy Shielding Cans in the Nuclear Industry

Tungsten alloy shielding containers have been applied in the nuclear industry, covering all key aspects including intermediate storage of spent fuel, radioactive waste treatment, isotope production, and facility decommissioning. Their high volumetric shielding efficiency, excellent mechanical properties, strong chemical inertness, and fully recyclable characteristics have led them to gradually replace traditional lead-steel composite containers and reinforced concrete shielding structures, becoming a core technology for minimizing waste, optimizing personnel exposure, and achieving environmentally friendly final disposal.

5.1.1 Spent fuel storage and transfer tungsten alloy shielded tank

high flux of neutrons, and significant decay heat generated after spent fuel assemblies are removed from the reactor necessitate that storage and transfer containers provide extremely high shielding performance and long-term containment reliability within limited weight and space constraints. Tungsten alloy shielded containers, with their density far exceeding that of lead and volumetric efficiency far superior to concrete, have become the preferred solution for water pool storage tanks, dry storage cylinders, and inter-plant/ inter-site transfer containers.

The tungsten alloy tanks for water storage utilize a high-tungsten-content tungsten-nickel-iron system, combined with a boride or hydrogen-containing composite neutron absorber layer to achieve gamma-neutron combined shielding. A chloride-resistant coating is applied to the outer surface of the tank, allowing for long-term service in boric acid water environments without pitting or hydrogen embrittlement. The dry storage vertical cylinder is constructed primarily of near-net-shape tungsten alloy, incorporating helium filling, an internal thermally conductive copper bushing, and a multi-point temperature-dosage monitoring system to ensure safe storage for decades under anhydrous and maintenance-free conditions. The transport containers strictly adhere to IAEA SSR-6 and TS-R-1 standards, employing a double-layer tungsten alloy shell + shock-absorbing and thermally conductive inner lining + fire-resistant outer shell structure. They have undergone nine-meter drop, 800-degree Celsius 30-minute flame, and immersion tests, demonstrating their ability to maintain complete containment and shielding effectiveness under the most demanding transport accident conditions.

5.1.2 Tungsten alloy shielded containers for radioactive waste treatment

Radioactive waste treatment processes involve multiple highly polluting operations such as sorting, compression, solidification, packaging, and temporary storage, requiring shielding containers to possess high-frequency opening and closing capabilities, deep decontamination capabilities, modular assembly capabilities, and permanent containment capabilities. Tungsten alloy shielding containers, due to their excellent strength-toughness ratio, extremely low surface contamination adhesion coefficient, and completely non-toxic and recyclable characteristics, have become the only material system used throughout the entire waste treatment process.

In the hot chamber sorting and volume reduction processes, large, fixed tungsten alloy shielded containers are equipped with hydraulic quick-opening lids, replaceable stainless steel sacrificial liners, and high-pressure water jet decontamination systems. These systems maintain the cleanliness of the container body while continuously processing large quantities of low- and intermediate-level radioactive solid waste. For the high-level radioactive waste evaporation and vitrification stages, tungsten -nickel-copper ultra-corrosion-resistant containers are used, lined with high-temperature ceramic or tantalum composite layers. These containers can withstand the combined corrosion of concentrated nitric acid, molten glass, and strong oxidizing detergents, preventing the container itself from becoming a secondary source of contamination. For the final packaging and long-term storage stages, permanently sealed tungsten alloy waste bins or multi-lid redundant tungsten alloy waste containers are used. These permanently enclose the vitrified body or over-compacted waste cake within a high-density, non-corrosive, and non-activating product-free tungsten alloy shell. The surface is coated with multiple layers of aging-resistant polyurea, allowing for safe storage for hundreds of years without human intervention until it is transferred to a geological disposal facility.

Tungsten alloy shielded containers in waste treatment not only significantly reduces the cumulative dose to operators and the volume of secondary waste, but also achieves a more environmentally friendly final disposal of waste packages at the material level. Their fully smeltable and reusable nature allows decommissioned containers to be returned directly to the tungsten smelting chain without entering the hazardous waste disposal process, meeting the highest technical requirements for minimizing waste throughout the nuclear industry's lifecycle .

5.1.3 Tungsten alloy shielding container for nuclear geological exploration samples

Nuclear geological exploration (uranium and thorium exploration , radioactive mineralization zone mapping, borehole core sampling, and in-situ gamma logging) requires the rapid, safe, and contamination-free on-site containment and transport of highly reactive core, ore, and soil samples containing natural uranium-series, thorium- series, and potassium-40 radionuclides under complex geological and climatic conditions. Traditional lead containers and combinations of plastic bags and lead plates are no longer suitable for the high-precision, high-efficiency technical requirements of modern nuclear geological exploration due to their weight, susceptibility to contamination, difficulty in decontamination, and aging failure under high temperature and humidity conditions. Tungsten alloy shielded containers, with their lightweight, high strength, weather resistance, and complete decontamination and recyclability, have become the standard configuration for dedicated sample containers in nuclear geological exploration.

The specialized exploration sample container employs a tungsten -nickel-copper non-magnetic corrosion-resistant system. The wall thickness is precisely designed with gradients based on the maximum expected uranium-thorium content and potassium-40 activity of the core sample. Typically, while ensuring the external surface dose rate is 2–3 times lower than the field background, the overall weight of the container is kept within a range easily operable by a single person. The structure primarily features a quick-opening screw cap with double fluororubber seals. The cap and container body achieve a double safety net of hard metal- to-metal contact and a flexible soft seal through a high-precision conical self-centering structure, ensuring zero leakage at the molecular level even after bumpy transport and frequent opening and closing . The inner wall of the container is entirely mirror-polished and coated with a fluorinated, easily cleanable coating. The outer surface uses a military green or tan polyurea elastic coating, which can withstand long-term erosion from desert high temperatures, frozen soil low temperatures, acid rain, and saline-alkali soil without blistering or powdering.

Typical applications include:

- The 63–108 mm standard core-specific tungsten alloy shielding canister can be directly inserted into the end of the borehole coring tube and pulled out together with the core , realizing a one-step operation of "coring and enclosing" .
- Portable soil and mineral sample container, equipped with built-in dose rate display and GPS positioning chip, can record sampling point and radiation level in real time;
- The vehicle-mounted multi-tube combined tungsten alloy shielding box can contain dozens of rock cores at once and maintain stable shielding and shock absorption on off-road vehicles.

Tungsten alloy shielded containers enables nuclear geological exploration personnel to achieve clean sampling in high-background mining areas with zero skin contamination, zero aerosol diffusion, and zero sample crosstalk, significantly improving sample representativeness and measurement accuracy while greatly reducing the cumulative radiation dose to field workers. Its fully recyclable nature also completely solves the long-term heavy metal pollution problem in grasslands and Gobi deserts caused by the disposal of traditional lead containers .

5.1.4 Tungsten alloy shielding containers for nuclear reactor auxiliary equipment

Highly active, corrosive, high-temperature, and high-pressure radioactive media are widely present in the primary loop auxiliary systems, sampling systems, waste liquid treatment systems, and irradiation monitoring pipelines of nuclear reactors. This necessitates that the relevant shielding containers achieve long-term reliable containment, accurate sampling, and maintenance-free operation in the confined reactor cavity and high-radiation environment. Tungsten alloy shielding containers, with their extremely high density-to-strength ratio, excellent corrosion resistance, and high-temperature irradiation stability, have become the most critical shielding and containment components in reactor auxiliary equipment.

Typical applications include the following four main categories:

1. tungsten alloy shielded canisters for sampling the primary coolant, boric acid solution, and exhaust gas. Operating pressures can reach 15–20 MPa, and the temperature range covers cold shutdown to full-power operation. The canister body is constructed of high-strength tungsten - nickel-iron alloy with an inner tantalum or zirconium alloy lining. A high-temperature anti-

oxidation coating is applied to the outer surface, allowing it to withstand the extremely high neutron flux environment of the reactor cavity for decades without swelling, embrittlement, or corrosion perforation. Where the sampling pipeline penetrates the reactor shielding wall, a coaxial nested tungsten alloy shielding sleeve is used to achieve localized shielding during sampling.

2. The monitoring samples inside the irradiation monitoring tubes and sample containment containers, including the reactor neutron flux monitoring tubes and material irradiation monitoring tubes, must remain in a fixed position and completely contained throughout their entire lifespan. The tungsten alloy shielding container is directly embedded into the core instrumentation channel as an integrated thick-walled tube. Its internal cavity is precision-machined with a multi-compartment structure, capable of simultaneously containing dozens of monitoring samples of different materials. The container body employs a low-activation tungsten -nickel-iron system, ensuring that it produces extremely low levels of long-lifetime activation products after high-flux neutron irradiation, thus not interfering with subsequent gamma-ray spectrum measurements of the monitoring samples.
3. The waste liquid and resin storage tanks, generated by the reactor chemistry and capacity control system, contain highly radioactive waste liquids and resins containing tritium, cobalt-60, and antimony-125. These waste liquids and resins require short-term storage and decay near the reactor cavity . The tungsten alloy shielded tanks utilize a tungsten -nickel-copper ultra-corrosion-resistant grade with a Hastelloy lining structure. Equipped with a dual-valve isolation and pressure balancing system, they can withstand strong acids, strong alkalis, and high-temperature, high-humidity environments for decades without pitting or stress corrosion cracking.
4. localized shielding inserts and collimator stack body repairs or major overhauls, temporary localized shielding components need to be inserted in high-radiation areas to reduce the dose rate in specific directions. Tungsten alloys, in the form of detachable inserts, nested cylinders, or rotatable collimators, provide a more efficient, lighter, and higher-temperature resistant localized shielding solution than lead , with a hard surface coating that resists cutting sparks and welding spatter.

The aforementioned tungsten alloy shielding canisters in reactor auxiliary equipment not only significantly reduces the overall shielding thickness and weight of the reactor cavity and auxiliary buildings, but also greatly reduces the amount of maintenance work during operation and the number of personnel exposed to radiation during overhauls due to the material's low activation and high stability .

5.2 Application of Tungsten Alloy Shielding Canisters in the Medical and Health Field

Tungsten alloy shielding canisters have been widely used in the medical and health field, covering all core aspects of nuclear medicine diagnostics, radiopharmaceutical production, tumor radiotherapy, and interventional radiology. Their non-magnetic, high-density, bioinert, easily decontaminated surface, and completely non-toxic and recyclable properties make them the only shielding material system that simultaneously meets MRI room compatibility, GMP cleanroom requirements, medical radiation protection regulations, and the long-term economic needs of hospitals.

5.2.1 Tungsten alloy shielded containers for the storage and transfer of radiopharmaceuticals

Radiopharmaceuticals (such as fluorine-18 FDG, technetium-99m, iodine-131, lutetium -177, and actinium-225) are characterized by short half-lives, high activity, complex chemical forms, and the need for frequent dispensing and transport. This necessitates shielding containers that achieve highly efficient gamma shielding within extremely small volume and weight, while also possessing sterile room compatibility, rapid single-person operation capability, and stringent surface decontamination performance. Tungsten alloy shielding containers, based on a tungsten-nickel-copper non-magnetic and corrosion-resistant system, have completely replaced traditional lead glass and lead containers, becoming the standard container for the entire radiopharmaceutical supply chain from production to injection.

Typical products include:

- The molybdenum -99/technetium-99m generator integrated shielded container adopts a gradient wall thickness + built-in lead glass observation window + quick-opening screw cap structure, which can realize the rapid replacement of generator and online elution in GMP hot chamber;
- The FDG dispensing and syringe protective sleeve weighs only 1/3–1/2 of a lead sleeve with equivalent shielding effectiveness . It features a one-finger knob quick-opening cap and a disposable sterile liner, allowing nurses to complete all operations with one hand in the dispensing room or PET-CT injection room.
- The iodine-131 and lutetium -177 therapeutic dose transport container features a double lid , a pressure balance valve, and a built-in dose rate display screen, allowing it to be directly transported to wards or interventional operating rooms.
- The multi-hole drug transport box has an outer tungsten alloy unibody shell and multiple independent small tanks nested inside. Combined with shock-absorbing foam and temperature control module, it enables safe transport between hospitals or cities .

The entire surface is finished with mirror-polished glass and a medical-grade fluorinated, easily removable coating. It can be repeatedly wiped or fumigated in 10% sodium hypochlorite, 70% ethanol, or hydrogen peroxide vapor without losing its shine, and the contamination removal factor remains consistently above 99.99%. The application of tungsten alloy shielded containers significantly reduces the radiation dose to the hands and whole body of operators in nuclear medicine departments, while greatly improving drug dispensing efficiency and aseptic assurance levels.

5.2.2 Tungsten alloy shielding container for radiotherapy sources

High-activity sealed sources for radiotherapy (such as cobalt-60, iridium-192, iodine-125 seed sources, strontium-90 applicators, and lutetium -177 microspheres), as well as the source chambers and collimation systems of afterloading therapy machines, Gamma Knife, and CyberKnife, require shielding containers that provide extremely high shielding efficiency while possessing precise directional leakage control, long-term geometric stability, and non-magnetic and lightweight characteristics at the treatment bedside. Tungsten alloy shielding containers have become an irreplaceable core component of the aforementioned equipment.

Typical applications include:

- The cobalt-60 treatment source and afterloading treatment source tank adopt a tungsten-nickel-iron system with high tungsten content and a multi-layer nested collimation structure, which can reduce the dose rate in non-treatment directions to the background level, while maintaining high transmittance in the treatment beam direction;
- The storage and transport container for iodine-125 seed implantation is equipped with a transparent lead glass observation window and a magnetic seed arrangement plate, allowing doctors to directly visually complete the seed filling under sterile conditions.
- The Gamma Knife and CyberKnife tungsten alloy collimator system consists of hundreds of tungsten alloy collimators with different apertures arranged in a matrix. The aperture accuracy and position accuracy are controlled at the micrometer level, ensuring that the dose distribution error at the treatment focus is less than 1%.
- The Strontium-90 ophthalmic dressing and the Lutetium -177 microsphere treatment container adopt an ultra-thin-walled tungsten alloy with local thickening design, which ensures high dosage on the treatment surface while minimizing leakage on non- treatment surfaces .

All tungsten alloy shielding containers used for therapeutic sources must pass the medical device registration and type testing conducted by the National Medical Products Administration. Their surfaces are coated with biocompatible DLC or TiN , and they can withstand sterilization by ethylene oxide, plasma, or high-temperature, high-pressure steam without degradation. The widespread application of tungsten alloy shielding containers has enabled unprecedented levels of positioning accuracy and safety for high-dose-rate brachytherapy and stereotactic therapy. Simultaneously, it has completely eliminated the magnetic compatibility issues of traditional lead shielding in MRI-guided therapy, providing the most reliable material basis for modern precision radiotherapy.

5.2.3 Tungsten alloy shielding canisters for use with medical imaging equipment

Medical imaging equipment (PET-CT, SPECT-CT, PET-MR, cyclotron self-shielding systems, medical linear accelerators) places comprehensive demands on local shielding components, requiring high density, non-magnetic properties, high precision, integrability, and long-term geometric stability. Tungsten alloy shielding containers and their derivative components have been widely adopted in key areas of these devices, including detector collimation, X-ray beam confinement, radiation source storage, and background radiation suppression.

PET-CT and SPECT-CT detector rings commonly employ high-purity tungsten alloy collimators, precisely stacked from tens of thousands of tungsten alloy foil sheets with thicknesses of 0.1–0.3 mm and micron-level precision in aperture and spacing. This achieves extremely high spatial resolution and scattering suppression for 511 keV annihilation photons and 140 keV gamma rays. The tungsten -nickel-copper non-magnetic system ensures no torque or image artifacts under strong magnetic fields exceeding 3T. The self-shielded target chamber and beamline of the cyclotron employ a multi-layered tungsten alloy nested tank + boron-containing polyethylene composite structure, attenuating the high-energy gamma rays and neutrons generated by 18 MeV protons to background levels outside the machine room in a single pass, completely eliminating the enormous civil engineering costs of traditional concrete labyrinth-style machine rooms. The medical linear accelerator treatment head collimation system uses tungsten alloy multi-leaf gratings and secondary collimating blocks, with single-leaf positioning accuracy and repeatability better than 0.1 mm. The surface DLC coating withstands hundreds of thousands of high-speed movements without wear. The system integration of tungsten alloy shielding canisters has enabled high-end medical imaging equipment to achieve smaller footprint, lower background noise, shorter imaging time, and higher diagnostic accuracy, and has become an indispensable hardware foundation for modern molecular imaging and precision radiotherapy.

5.2.4 Tungsten alloy shielded containers for temporary storage of radioactive waste

The hospital's nuclear medicine department, interventional catheterization lab , and radiotherapy department generate large quantities of short-half-life waste daily (syringes, infusion sets, gloves, dressings, iodine-131 excrement, lutetium-177 treatment residue, etc.), which needs to be temporarily stored within the departments for safe decay until the activity drops to exempt levels. Tungsten alloy shielded containers, with their lightweight, easy-to-clean, long-life, aesthetically pleasing, and non-toxic characteristics, have completely replaced traditional lead and steel containers, becoming the preferred container for the temporary storage of radioactive waste in hospitals.

Typical products include:

- Bedside waste container: 10–30 L volume, with a foot pedal quick-opening lid and a disposable polymer inner liner, allowing nurses to dispose of waste with one foot.
- Departmental centralized decay tank: 50–200 L, with a double-lid + activated carbon filter + pressure balance valve structure, which can simultaneously contain solid and liquid waste and adsorb volatile iodine;
- Lutetium -177/Acetium-225 Therapeutic Waste Liquid Tank: Tungsten -nickel-copper ultra-corrosion resistant system + dual-valve drain port, can withstand immersion in strong acidic therapeutic waste liquid for several months without corrosion;
- Wall-mounted and under-counter waste cabinets: The combination of tungsten alloy shell and stainless steel inner liner perfectly integrates into the décor of clean wards and catheterization labs .

All waste storage containers are coated with a medical-grade antibacterial and easy- to-clean coating, which can withstand the long-term effects of chlorine-containing disinfectants and ultraviolet light. After decay is complete, the tungsten alloy container can be directly sterilized by high-pressure steam and reused. The inner liner and waste are sent to the hospital's centralized decay storage facility, completely eliminating the permanent surface pollution and secondary hazards of lead dust caused by the repeated use of traditional lead containers .

5.2.5 Tungsten alloy shielded container for the protection of in vitro diagnostic reagents

In vitro diagnostic (IVD) reagent kits, including those for radioimmunoassay, chemiluminescence immunoassay, and molecular diagnostics, often contain labeled radionuclides such as iodine-125, cobalt-57, and selenium-75 as standard or quality control sources. These require strict shielding and activity stability throughout the entire process of reagent production, transportation, storage, and use. Tungsten alloy shielding containers, with their miniaturized, non-magnetic, and biosafety characteristics, have become the global standard for IVD reagent protection.

Typical applications include:

- Iodine-125 standard source miniature protective container: with an outer diameter of only a few millimeters and a gradient wall thickness design, it can completely shield the characteristic X-rays of 125I 35 keV to the background. The color mark of the container and the laser etching activity value are directly embedded in the reagent kit.
- Cobalt-57/Selenium-75 flood source integrated container : tungsten alloy body + lead glass observation window + magnetic fixing structure, allowing laboratory technicians to visually confirm the source location without opening the lid;
- The reagent cold chain transport box is equipped with a tungsten alloy shielding module: the multi-compartment design allows each compartment to independently contain a standard source, and with the help of a temperature and humidity recorder, it can achieve undamaged activity during the entire process from -20 ℃ to +8 ℃;
- The automated immunoassay analyzer has a built-in quality control source container : it is made of tungsten alloy in one piece, and together with the instrument's robotic arm, it can achieve daily automatic quality control without generating additional radiation leakage.

Tungsten alloy shielding containers makes the background radiation of in vitro diagnostic reagents completely controllable, avoiding the defects of traditional lead containers such as large weight, easy oxidation, and irreversible surface contamination. It ensures the activity consistency and safety of reagents in the global supply chain, and provides the most reliable radiation protection guarantee for the accuracy of high-throughput immunoassay and molecular diagnostics.

5.3 Applications of Tungsten Alloy Shielding Cans in Industrial Testing and Electronics Fields

Tungsten alloy shielding containers have evolved from being a substitute for traditional lead containers in industrial testing and electronics fields into core functional components that determine testing accuracy, equipment reliability, and product yield. Their high density and high atomic number result in excellent gamma/X-ray attenuation capabilities, superior mechanical properties and processing precision, complete non- magnetic nature, and surface stability in harsh industrial environments, enabling them to simultaneously meet the extreme radiation shielding requirements of field flaw detection, cleanrooms, and highly reliable electronic systems.

5.3.1 Tungsten alloy shielding container for industrial radiographic testing sources

Industrial radiographic testing (pipeline welds, pressure vessels, aerospace castings, ship thick plates, and large forgings) uses high-activity sealed sources made of iridium-192, selenium-75, and cobalt-60. This requires the shielding container to provide 360° omnidirectional high-strength shielding while maintaining a precisely controllable directional beam exit window , and to withstand frequent transportation, hoisting, and accidental drops under extreme conditions such as in the field, shipyards, and at high altitudes. Tungsten alloy shielding containers, with their significantly higher volumetric shielding efficiency and deformation resistance than lead, have become the standard configuration for industrial radiographic testing equipment worldwide.

Typical flaw detection source tanks utilize high-strength tungsten-nickel-iron alloys. The main body wall thickness is non-uniformly optimized based on source activity and energy: the wall thickness is maximized in non- beam-emission directions , while the beam-emission direction features precisely machined conical, fan-shaped, or slit-shaped tungsten alloy rotatable collimators. These collimators are continuously adjustable from 0–360° via an external handwheel or servo motor, with stepless beam width adjustment. The collimator's internal structure employs multi-layer nesting and micron-level dovetail guide rails, ensuring that the gap does not increase and the positioning does not drift after hundreds of thousands of adjustments. The outer surface of the tank is coated with an oil-resistant, sand-dust -resistant, and weld spatter-resistant supersonic flame-sprayed WC or polyurea elastic coating, allowing for long-term use on offshore platforms, desert oil fields, and extremely cold Siberian pipeline construction sites without powdering or cracking.

Structural highlights include:

- The quick-change source channel adopts a "pig-style" push + double clamp sealing design, allowing operators to load and unload the source outside the dark room, with the radiation dose during the entire process being close to zero.
- The built-in source position detection and interlocking system allows the transport lock to be opened only when the collimation window is completely closed and the source is submerged in the safe position at the bottom of the tank.
- It conforms to ISO 3999 and GB/T 1933 international standards and has passed tests including a nine-meter free fall, a one-meter four-corner impact, a half-hour flame test at 800 °C, and a stacking test.

Tungsten alloy flaw detection source containers has enabled industrial radiographic testing to achieve a technological leap from "lead container + long tube remote control" to "compact directional source container + robotic crawler".

电话/TEL：0086 592 512 9696
CTIAQCD-MA-E/P 2018-2024V
sales@chinatungsten.com

5.3.2 Tungsten alloy shielding can for interference suppression of electronic components

High-reliability electronic systems (aerospace electronic equipment, deep space probes, nuclear power plant instrumentation and control systems , 5G base station core boards, quantum computing superconducting circuits) are extremely sensitive to single-event effects (SEE), total dose effects (TID), and transient irradiation effects caused by gamma rays, neutrons, and electromagnetic pulses (HEMPs). Traditional aluminum shells with lead foil or boronized plastic composite shielding can no longer meet the comprehensive requirements of next-generation electronic equipment for weight, volume, shielding effectiveness, and multi-spectral protection. Tungsten alloy shielding containers, with their extremely high gamma attenuation coefficient, excellent neutron moderation and absorption capabilities, complete non- magnetic properties, and superior vacuum sealing performance, have become the ultimate solution for radiation hardening of electronic components.

Typical applications cover the following four categories:

1. aerospace spaceborne electronic equipment, satellite payloads, star sensors, and navigation receivers employs a multi-layered tungsten alloy nested structure with a hydrogen-rich boron neutron absorption layer. This structure attenuates high-energy protons from the Earth's radiation belts and secondary gamma and neutrons generated by galactic cosmic rays to below the device's tolerance threshold in a single pass. The box body utilizes a tungsten -nickel-copper non-magnetic system with optimized wall thickness gradients. Vacuum brazing or electron beam welding achieves a hermetically tight seal, while the interior is filled with low- emission silicone rubber for vibration damping and thermal conductivity.
2. Key electronic components in deep space probes, such as the core electronics compartment of Mars rovers, lunar landers, and Jupiter probes, which are exposed to strong radiation environments for extended periods, utilize an integrated tungsten alloy shielding chamber, further encased in a carbon fiber reinforced shell, achieving maximum shielding effectiveness while minimizing weight. The tungsten alloy surface is plated with gold or DLC coating, which both prevents cold welding and suppresses secondary electron emissions.
3. High-energy instantaneous gamma fluence rates that may occur under transient irradiation tank accident conditions (LOCA, MSLB) in the safety- grade instrumentation and control system of a nuclear power plant can induce malfunctions in the digital instrumentation and control system . The tungsten alloy shielded tank is embedded in the instrumentation and control cabinet with a modular drawer-type structure , completely enclosing key PLCs, FPGAs, and memory. The tank body adopts a low-activation tungsten -nickel-iron system to ensure that it does not produce interfering long-lived nuclides after long-term neutron irradiation.
4. In quantum computing and superconducting electronic devices, local shielding of superconducting qubits and Josephson junctions is crucial because they are extremely sensitive to cosmic rays. A tungsten alloy miniature shielding container is integrated into the cryogenic stage (<10 mK) of a dilution refrigerator. Combined with an inner layer of μ-metal magnetic shielding and superconducting niobium shielding, this achieves near 100% interception of secondary particles from cosmic rays, ensuring that the quantum coherence time reaches an

电话/TEL：0086 592 512 9696

sales@chinatungsten.com

internationally leading level.

Tungsten alloy shielding canisters in the field of anti-interference of electronic components has reduced the single-particle flip rate by several orders of magnitude and increased the total dose tolerance to 5–10 times that of traditional solutions, becoming a key enabling technology for high-reliability electronic systems to go from "afraid of radiation" to "daring to radiate".

5.3.3 Tungsten alloy shielding container for semiconductor manufacturing testing

In semiconductor wafer manufacturing and inspection, any gamma/X-ray background radiation from the environment or the equipment itself can be misjudged as defects, leading to the destruction of wafers and huge economic losses. Tungsten alloy shielding containers, with their ultra-high purity, low activation characteristics, excellent microscopic uniformity, and micron-level processing capabilities, have become an indispensable core component for background control in advanced process wafer fabs .

These shielding containers are primarily used for X-ray defect re-inspection equipment, X-ray fluorescence analyzers, electron beam detection systems, and local shielding of extreme ultraviolet lithography sources. The container body utilizes an ultra-pure tungsten -nickel-copper non-magnetic system, with impurity control reaching the highest level, ensuring no detectable activation interference peaks are generated during long-term operation. The collimating aperture and shielding wall are precision-machined as a single unit, achieving extremely high aperture and positional accuracy to guarantee the purity and focusing of the X-ray beam. Surface treatment combines vacuum aluminizing and diamond-like carbon coating, preventing cold welding and suppressing secondary electron emission. The application of tungsten alloy shielding containers completely eliminates the false defect problem caused by trace amounts of natural radioactivity in traditional lead shielding , enabling wafer defect detection sensitivity and reliability to reach the limits of advanced process requirements.

5.3.4 Tungsten alloy shielding container for non-destructive testing equipment

High-end nondestructive testing equipment places extremely high demands on leakage control, collimation accuracy, and long-term geometric stability of X-ray sources. Tungsten alloy shielding containers, with their comprehensive properties of high density, high hardness, high temperature resistance, and resistance to mechanical damage, have completely replaced traditional lead-steel composite structures, becoming the core shielding and collimation components in industrial CT, digital X-ray imaging, and high-energy accelerator testing systems.

A typical structure includes an integrated shielding shell for both rotating and fixed targets , a primary collimator, secondary collimators, and a programmable slit system. The canister is made of high-strength tungsten -nickel-iron alloy, and its multi-layered nesting and rotatable fan-shaped window design achieve complete shielding in the non-working direction and precise beam control in the working direction. A hard coating of tungsten carbide or chromium nitride is applied to the surface, allowing it to withstand long-term high-speed rotation and welding spatter without wear or peeling. The application of tungsten

电话/TEL：0086 592 512 9696
CTIAQCD-MA-E/P 2018-2024V
sales@chinatungsten.com

alloy shielding canisters significantly improves image contrast and defect identification capabilities while substantially reducing the dose level around the equipment, making it an essential piece of equipment for quality control in high-end manufacturing fields such as aero-engine blades, nuclear power pressure vessels, and large composite material structures.

5.3.5 Tungsten alloy shielding cans for protecting precision electronic instruments

High-precision metrology instruments, nanoscale characterization equipment, and fundamental physics experimental setups are extremely sensitive to noise and drift caused by cosmic rays, ambient gamma background, and neutrons. Tungsten alloy shielding containers, with their highest volumetric shielding efficiency, completely non-magnetic properties, and ultra-long lifespan stability, serve as the final physical shield for achieving ultimate measurement precision. Typical applications include partial or overall shielding of analytical balances, atomic force microscopes, scanning tunneling microscopes, laser interferometers, inertial navigation systems, and key components for gravitational wave detection. The container typically employs a multi-layered tungsten alloy and neutron-absorbing material composite structure, filled internally with a low -emission, heat-conducting medium, and its outer surface undergoes vacuum compatibility treatment. The sealing system uses metal bellows rings or knife-edge flanges to ensure long-term airtightness in ultra-high vacuum environments. The use of tungsten alloy shielding containers suppresses ambient radiation background to extremely low levels, completely eliminating low-energy noise interference caused by decay chains in traditional lead shielding . This results in unprecedented stability and repeatability of instruments during long-term measurements, making it an irreplaceable cornerstone of radiation protection in contemporary metrology, nanotechnology, and precision physics experiments.

5.4 Applications of Tungsten Alloy Shielding Cans in the Aerospace Field

Tungsten alloy shielding containers have evolved from auxiliary components to a key enabling technology that determines mission success rates and system lifespan. Their extremely high volumetric shielding efficiency, lowest areal density, completely non-magnetic properties, ultra-wide temperature range stability, extremely low outgassing rate, and long-term reliability in vacuum, strong vibration, and high-energy particle environments make them the only high-end material platform for space radiation protection, ground simulation testing, and advanced material testing.

5.4.1 Tungsten alloy shielding container for aerospace radiation testing

Aerospace electronic equipment, sensitive materials, and biological payloads must undergo ground-based space radiation environment simulation tests before being deployed in orbit . These tests require test containers to accurately reproduce the combined radiation fields of high-energy protons, heavy ions, gamma rays, and neutrons, while also providing near-complete shielding from non-target directions to protect the test facilities and personnel. Tungsten alloy shielding containers, with their ultra-purity, low activation, and excellent machining precision, have become the standard test containers for major ground-based space environment simulation devices both domestically and internationally.

These containers utilize low-activation tungsten -nickel-copper or tungsten-nickel-iron systems, with an internal cavity equipped with flexibly combinable energy degradation plates, neutron moderators, and absorbers, enabling broad linear energy transfer spectra and fluence rate control within a single container. The exterior of the container is coated with a vacuum-compatible high-temperature layer, and the interior integrates a multi-point dose monitoring and temperature control system to ensure full-temperature testing capabilities. The sealing system employs metal sealing rings and multiple leak detection structures to guarantee long-term airtightness under ultra-high vacuum conditions. The application of tungsten alloy shielding containers maximizes the fidelity and safety of radiation fields in ground-based simulation experiments, making them indispensable core equipment for spaceborne single-unit applications, chip hardening, and deep-space biological experiment verification.

5.4.2 Tungsten alloy shielding containers for the protection of spacecraft components

Spacecraft operating in orbit face long-term bombardment from the Van Allen radiation belts, solar proton events, and galactic cosmic rays. Critical components such as star sensors, inertial measurement units, memory, and processors are highly susceptible to single-event effects and cumulative dose failure. Tungsten alloy shielding containers, through localized point shielding and integration with the bulkhead, provide the most efficient space radiation protection for these sensitive components.

Typical applications include optical head shields, core circuit board-level shielding boxes, integrated collimation-shielding housings for scientific payload detectors, and dynamic insertable protective drawers for manned cabins. The tank utilizes a non-magnetic tungsten-nickel-copper system, with wall thickness optimized according to the orbital radiation environment. An internal composite hydrogen-containing neutron-absorbing layer is often applied, and the outer surface is coated with anti-cold welding and low-emission coatings. The structural design balances weight minimization with multi-directional protection, and the sealing and fixing methods meet the requirements of launch phase vibration and on-orbit thermal cycling . The system application of tungsten alloy shielding tanks significantly extends the on-orbit fault-free operation time of key components, becoming a core technology guarantee for long lifespan and high reliability in high-orbit navigation constellations, deep space probes, and manned spaceflight projects.

5.4.3 Tungsten alloy shielding container for aerospace material testing

Key components such as aero-engine blades, composite material fuselage structures, solid rocket casings, and reentry heat shields require high-precision non-destructive testing and compositional analysis during the development phase. This necessitates testing equipment with extremely low background, extremely high beam purity, and extremely stable geometric positioning. Tungsten alloy shielding canisters and their collimation systems have become irreplaceable core components for quality control of these high-end materials.

Shielding targets and collimation systems for single-crystal blades of aero-engines , digital X-ray imaging source containers for large composite structural components, gamma -ray flaw detection

电话/TEL：0086 592 512 9696

sales@chinatungsten.com

directional source containers for solid rocket casings, and sample containers for X-ray and neutron diffraction analysis of reentry materials. The container body utilizes a high-strength tungsten -nickel-iron system, with the collimation hole and shielding wall precision-machined as a single unit, and the surface coated with a high-temperature resistant, spark-resistant hard coating. The application of tungsten alloy shielding containers minimizes the background noise and leakage radiation of the testing equipment, achieving industry-leading levels of image contrast and defect quantification accuracy. It has become the hardware cornerstone for quality assurance of materials in major engineering projects such as large passenger aircraft, launch vehicles, and lunar and Mars probes. Its long-term stability under extreme testing conditions also provides the most reliable technical support for the non-destructive evaluation of materials for future reusable aircraft and scramjet engines.

5.5 Application of Tungsten Alloy Shielding Cans in Scientific Research and Experimentation

Tungsten alloy shielding containers have evolved from ordinary laboratory protective components in scientific research to key functional materials that determine experimental background, measurement accuracy, and detector performance limits. Their extremely high gamma/X-ray attenuation coefficient, excellent neutron absorption and moderation capabilities, ultra-pure low activation characteristics, complete non- magnetism, and long-term stability under extreme vacuum, low temperature, and strong magnetic field environments make them irreplaceable core equipment for cutting-edge experiments in nuclear physics, particle physics, environmental radiation monitoring, and interdisciplinary fields.

5.5.1 Tungsten alloy shielding container for nuclear physics experimental samples

Nuclear physics experiments (neutron scattering spectroscopy, nuclear reaction cross-section measurement, fission and capture product studies, and precision isotope preparation) require sample containers that, while containing high-activity targets or irradiation products, are completely transparent to the incident beam and provide extremely strong shielding against non-target radiation, while simultaneously having extremely low self-activation products that do not interfere with subsequent gamma-ray or neutron spectrum measurements. Tungsten alloy shielding containers, with their high density, low activation, and excellent processing precision, have become the standard sample containers for spallation neutron sources, reactor neutron beam lines, and isotope production hot cells .

Typical sample containers employ ultrapure tungsten -nickel-copper or tungsten-nickel-iron low-activation systems. The container wall thickness is non-uniformly optimized based on the incident neutron energy and target nucleus activity. The incident window area is locally thinned to retain only the necessary structural strength, while the exit direction features multiple layers of removable degradation plates and absorbing inserts. The entire inner cavity is mirror-polished and coated with diamond-like carbon or boron nitride to prevent sample adhesion and suppress secondary electron emission. The sealing system uses metal knife-edge flanges or helium arc welding for permanent sealing , ensuring an ultra-high vacuum and a clean, oxygen-free environment. The application of tungsten alloy shielding containers reduces the background count rate in nuclear physics experiments to extremely low levels, significantly improving the detection sensitivity of rare nuclear reaction channels and weak signals. It has become an indispensable core component of neutron scattering spectrometers, backscattered neutron devices, and nuclear data measurement terminals.

5.5.2 Tungsten alloy shielding container for particle physics experiments

Particle physics experiments (high-energy collider detectors, direct dark matter detection, neutrino oscillation experiments, and cosmic ray detector arrays) place extremely high demands on the absorption materials of electromagnetic calorimeters, hadron calorimeters, and muon detectors, requiring extremely high density, short radiation lengths, short interaction lengths, and extremely stable long-term performance. Tungsten alloy shielding containers and their derivative plates, blocks, and fiber structures have become the preferred absorption and shielding media for next-generation particle detectors.

In the upgraded detectors of the Large Hadron Collider, tungsten alloys are embedded in the core of the electromagnetic calorimeter in the form of precision-machined trapezoidal blocks or cylindrical containers , providing extremely short radiation lengths and extremely high photoelectron yields. In deep-earth dark matter detection experiments, tungsten alloy shielding containers serve as the outermost active shield, forming a multi-layered nested structure with inner layers of oxygen-free copper, ancient lead, and ancient Roman lead , suppressing ambient gamma and neutron backgrounds below the detector's sensitivity. The muon anti-coincidence system in neutrino experiments uses thick-walled tungsten alloy containers as muon absorbers, effectively distinguishing cosmic ray muon interactions from neutrino interactions. The application of tungsten alloy shielding containers has enabled key detectors in particle physics experiments to achieve higher energy resolution, lower false trigger rates, and wider dynamic ranges, becoming the most solid hardware foundation for exploring new physics and the mass mechanisms of dark matter particles and neutrinos.

5.5.3 Tungsten alloy shielding container for environmental radiation monitoring

Environmental radiation monitoring (atmospheric background, soil radon emission, marine radioactivity, and cosmic ray secondary particle flux monitoring) requires detectors to achieve ultra-low background, high stability, and long lifespan operation over an extremely wide energy range and in extreme field environments. Tungsten alloy shielding containers, with their highest volumetric shielding efficiency, low activation, and completely non-magnetic properties, have become the core shielding shell for high-purity germanium gamma spectrometers, anti-Compton systems, neutron monitors, and cosmic ray muon detectors. Typical monitoring containers employ a multi-layered composite structure: the outermost layer is made of ancient lead or Roman lead to shield the environment from gamma rays; the middle layer is a tungsten alloy container that precisely absorbs high-energy gamma rays and secondary particles; and the innermost layer is made of oxygen-free copper or polyethylene to suppress thermal neutrons and thermal noise. The tungsten alloy layer uses an ultra-pure tungsten-nickel-copper system, with vacuum nickel plating or nitriding treatment on the surface to ensure that no detectable activation peaks are generated during long-term field deployment. The container design combines portability and modularity, enabling long-term unattended operation in Antarctic ice sheets, uninhabited high-altitude areas, and ocean floor neutrino telescope arrays. The application of tungsten alloy shielding containers has reduced the background count rate of environmental radiation monitoring equipment to an extremely low level, significantly improving the ability to detect artificial nuclide leaks, changes in cosmic rays, and subtle fluctuations in natural background radiation. It has become an irreplaceable measurement cornerstone for the global environmental radiation background monitoring network, the national nuclear emergency response system, and interdisciplinary research in earth sciences.

5.6 Applications of Tungsten Alloy Shielding Cans in Other Special Fields

Tungsten alloy shielded containers, with their adaptability to extreme environments, special functional expandability, and high customization capabilities, have been widely used in a range of special scenarios beyond conventional fields. These scenarios typically have requirements for extreme temperatures, extreme pressures, extreme cleanliness, or extreme confidentiality, and tungsten alloy shielded containers often become the only technical solution that simultaneously meets functional, safety, and regulatory requirements.

5.6.1 Customized Tungsten Alloy Shielding Canisters for Special Environments

Customized solutions for special environments are mainly designed for deep sea, polar regions, high vacuum, ultra-high temperature, ultra-low temperature, strong corrosion, or complex extreme working conditions. Tungsten alloy shielding cans achieve tasks that ordinary shielding materials cannot handle through targeted design of material systems, structural forms, and surface functions.

The deep-sea neutrino telescope and seabed radioactivity monitoring station employ high-pressure-resistant tungsten -nickel-iron thick-walled shielding containers, combined with titanium alloy shells and fiber optic sealed interfaces, capable of containing high-purity germanium detectors and cobalt-60 calibration sources for extended periods at depths of tens of thousands of meters. The cosmic ray detection array in the polar ice cap uses ultra-pure tungsten alloy shielding containers, covered with multiple layers of heat insulation and anti-icing coatings to ensure that the background shielding effectiveness does not diminish in the extremely cold Antarctic environment. The local shielding of the ultra-high vacuum accelerator beamline uses vacuum-brazed tungsten alloy nested containers with extremely low internal outgassing rates and gold-plated surfaces to prevent cold welding, allowing for long-term operation in ultra-high vacuum systems without beam contamination. The ultra-high temperature plasma diagnostic system uses a tungsten alloy + molybdenum-lanthanum liner composite container, capable of containing neutron and gamma-ray detector crystals in environments with instantaneous temperatures exceeding 1000 degrees Celsius. Long-term storage containers for strong acid and alkali radioactive waste liquids employ a tungsten -nickel-copper + Hastelloy liner + fluoroplastic outer shell structure, achieving a century-long containment life.

Tungsten alloy shielding containers for special environments has made it possible for humans to carry out radiation-related scientific activities at the most extreme natural and engineering boundaries, and has become an essential infrastructure for experiments in deep earth, deep sea, deep space and extreme physical conditions.

5.6.2 Tungsten alloy shielding tanks for geological exploration and mining

Geological exploration and mining involve uranium, thorium, rare earth-associated radioactive minerals, and oil and gas well logging. This necessitates rapid, safe, and pollution-free on-site containment and transport of natural radioactive cores, mineral samples, and logging sources in high-temperature, high-humidity, high-dust, and high-vibration environments. Tungsten alloy shielding containers, with their lightweight design, resistance to harsh environments, and fully decontamination-resistant properties, have become standard equipment for managing radioactive samples in geological exploration and mining.

The tungsten alloy shielding container for exploration uses a tungsten -nickel-copper non-magnetic corrosion-resistant system, a quick-opening screw cap structure, and a conical self-centering seal design, allowing for "coring and containment" directly alongside the core sample taken from the drilling rig. The inner wall of the container is mirror-polished , and the outer surface has a polyurea elastic coating, making it resistant to long-term corrosion from desert high temperatures, frozen soil low temperatures, acid rain, and saline-alkali land. The tungsten alloy source container for oil and gas well logging employs a directional collimation + quick source-changing channel design, combined with a downhole high-temperature vibration-resistant structure, enabling reliable containment of cesium-137 and americium-beryllium neutron sources in high-temperature and high-pressure downhole environments. Modular tungsten alloy shielded conveyor containers are used in mine radioactive ore sorting lines to achieve automatic ore sorting and precise isolation of highly radioactive blocks .

Tungsten alloy shielding containers has enabled clean sampling with zero skin contamination and zero aerosol diffusion in geological exploration, significantly improving sample representativeness and personnel safety. At the same time, it has completely solved the long-term heavy metal pollution problem in grasslands and Gobi deserts caused by the abandonment of traditional lead containers , and has become an indispensable radiation management tool for the exploration and development of uranium, rare earth and oil and gas resources.

5.6.3 Tungsten alloy shielding tanks for geological exploration and mining

Geological exploration and mining operations often take place in remote and harsh field environments, dealing with uranium, thorium, rare earth-associated radioactive minerals, and oil and gas well logging sources. This necessitates shielding containers that are lightweight, resistant to extreme weather, strong vibrations, dust and salt spray, and capable of rapid opening and closing and thorough decontamination. Tungsten alloy shielding containers, with their significantly higher volume shielding efficiency than lead, extremely high structural strength, and surface chemical inertness, have completely replaced traditional lead and steel containers, becoming the standard equipment for managing radioactive samples and logging sources in the geological and mining industries. Field core sampling containers utilize a tungsten -nickel-copper non-magnetic, corrosion-resistant system, featuring a quick-opening screw cap and a conical self-centering structure. This allows for immediate containment of core samples immediately after extraction, right next to the drilling rig, completely preventing the diffusion of core dust and aerosols. The inner wall of the container is mirror-polished and coated with a fluorinated, easily cleanable coating, while the outer surface is coated with an oil- and salt-spray-resistant polyurea elastic coating, allowing it to remain smooth even after long-term exposure to desert temperatures, extreme cold, frozen soil, acid rain, and saline-alkali land. Tungsten alloy source containers for oil and gas well logging employ a directional collimation, fast source-changing channel , and downhole vibration-resistant design, reliably containing cesium-137 and americium-beryllium neutron sources in high-temperature, high-pressure wells. Modular tungsten alloy shielded transport containers are used in mine high-radioactivity ore sorting lines to achieve automatic ore sorting and precise isolation of high-radioactivity blocks . The systematic application of tungsten alloy shielded containers enables clean management of the entire chain from sampling to transportation in geological exploration and mining operations, significantly reducing the radiation dose to field personnel and the risk of environmental pollution. It has become an indispensable radiation protection tool for uranium, rare earth, and oil and gas resource exploration and development, as well as the utilization of radioactive mineral resources.

5.6.4 Tungsten alloy shielding container for aerospace radiation testing

Aerospace radiation ground simulation experiments require the precise reproduction of the combined radiation fields of high-energy protons, heavy ions, gamma rays, and neutrons in orbit within the laboratory, while achieving near-complete shielding of non-target directions to protect the test hall and operators. Tungsten alloy shielding containers, with their ultra-pure low-activation characteristics, excellent microscopic uniformity, and precision machining capabilities, have become the core test containers for major space environment simulation devices both domestically and internationally.

The test vessel employs a low-activation tungsten-nickel-copper or tungsten-nickel-iron system. The wall thickness is designed with a non-uniform gradient based on the type and energy of the incident particles. The incident window is locally thinned, and the exit direction features multiple layers of flexibly combinable energy degradation plates, neutron moderation layers, and absorbers, achieving a broad linear energy transfer spectrum and fluence rate control. The vessel's exterior is coated with a vacuum-compatible high-temperature layer, and the interior integrates multi-point dose monitoring probes and a temperature control system to ensure full-temperature testing capability. The sealing system uses a metal knife-edge flange or electron beam welding permanent seal structure to guarantee an ultra-high vacuum and a clean, oxygen-free environment. Tungsten alloy shielding containers are widely used in proton/heavy ion accelerator terminals, spallation neutron source backscatter beamlines, cobalt-60 large-source irradiation chambers, and integrated space environment simulation modules. They are essential hardware for verifying the space environment adaptability of spaceborne electronic components, radiation-hardened chips, deep space scientific payloads, and manned spaceflight biological experiments. Their application ensures the highest level of radiation field fidelity and safety in ground simulation experiments, providing the most realistic and rigorous ground testing methods for the long-life, high-reliability design of spacecraft.

5.6.5 Tungsten alloy shielding container for nuclear physics experimental samples

Nuclear physics experiments place extremely stringent requirements on sample containers: they must be

电话/TEL：0086 592 512 9696

sales@chinatungsten.com

virtually transparent to incident neutron or charged particle beams, provide extremely strong shielding against outgoing gamma rays, neutrons, fission fragments, and secondary particles, while simultaneously exhibiting an extremely low activation cross-section, extremely short half-lives of activation products , and no interference with subsequent precision spectroscopic measurements. Tungsten alloy shielding containers, with their ultrapure low activation characteristics, excellent neutron-gamma combined shielding capability, and micron-level precision machining, have become the preferred sample containers for reactor neutron beam streamlines, spallation neutron source spectrometer terminals, cyclotron target stations, and nuclear data measurement devices.

The experimental sample containers generally employ ultrapure tungsten-nickel-copper or tungsten-nickel-iron low-activation systems. The wall thickness in the incident window area is precisely thinned to retain only the necessary structural strength. The exit direction is equipped with multiple layers of quickly replaceable tungsten alloy degradation sheets, a boron-containing polyethylene moderation layer, and cadmium/gadolinium absorbers, enabling precise control of energy and flux rates over a wide range . The entire inner cavity is mirror-polished and coated with diamond-like carbon or boron nitride coatings to prevent sample adhesion and suppress secondary electron and sputtering contamination. The sealing system uses metal knife-edge flanges or electron beam permanent seals to ensure an ultra-high vacuum and oxygen-free environment. Some extremely clean experiments also require the entire container to be degassed and baked at several hundred degrees Celsius in a high-vacuum furnace to completely eliminate residual hydrogen, carbon, and adsorbed gases.

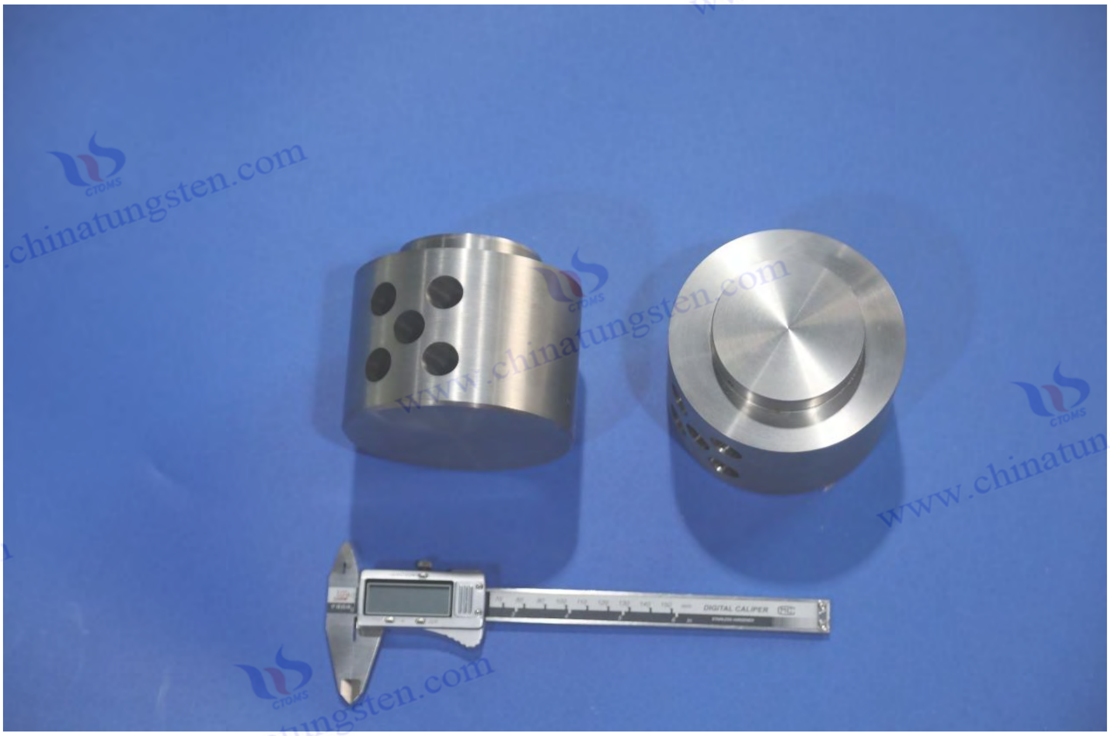
Tungsten alloy shielding containers has reduced the background count rate of nuclear physics experiments to an extremely low level, significantly improving the measurement accuracy of rare isotope cross sections, resonance parameters, and weak decay channels. It has become the core experimental hardware for neutron scattering spectrometers, back n time spectrometers, key nuclear astrophysical reaction research, and the updating of international nuclear databases.

5.6.6 Application of Tungsten Alloy Shielding Cans Customized for Special Environments

Custom-designed tungsten alloy shielding containers are designed for the most extreme boundaries of human scientific and engineering activities, covering applications such as deep-sea environments (tens of thousands of meters), polar ice caps, high-vacuum accelerator chambers, ultra-high temperature plasma diagnostics, ultra-low temperature dilution refrigerator interiors, temporary storage of highly corrosive and high- radioactive waste liquids before geological disposal, and radiation containment needs under complex extreme conditions.

The deep-sea neutrino detection and seabed radioactivity monitoring station employs a high-pressure-resistant tungsten -nickel-iron thick-walled shielding container, combined with a titanium alloy shell and a deep-sea fiber optic sealed interface, capable of containing high-purity germanium detectors and calibration sources at depths of tens of thousands of meters for decades. The polar ice cap cosmic ray detection array uses an ultra-pure tungsten alloy shielding container, coated with multiple layers of ultra-low temperature insulation and anti-icing coatings to ensure that the background shielding effectiveness does not decrease in extremely cold environments. The ultra-high vacuum storage ring and free electron laser beamline local shielding utilize a vacuum-brazed tungsten alloy nested container with a gold-plated surface to prevent cold welding, resulting in an extremely low internal outgassing rate, allowing for long-term operation in ultra-high vacuum systems without beam contamination. The ultra-high temperature fusion diagnostic system uses a tungsten alloy + molybdenum-lanthanum or tungsten-rhenium composite container, capable of containing neutron and hard X-ray detection crystals in environments with instantaneous temperatures exceeding thousands of degrees Celsius. The ultra-low temperature quantum computing and dark matter detection dilution refrigerator uses a miniature tungsten alloy shielding container, combined with an inner layer of superconducting niobium and high-purity copper , achieving near-complete interception of secondary particles from cosmic rays.

High-level radioactive waste liquids and waste containers before geological disposal , a tungsten-nickel-copper alloy lining with a Hastelloy alloy inner lining and a multi-layer fluoroplastic outer coating structure is adopted, achieving a chemical and radiation containment life of over 100 years. The in-depth customized application of tungsten alloy shielding containers in these special environments enables humans to conduct radiation-related scientific exploration and resource development under the harshest natural and engineering conditions, greatly expanding the application boundaries of nuclear technology and radiation protection. It has become an indispensable ultimate containment and shielding solution for deep-earth, deep-sea, deep-space, and extreme physics experiments.



CTIA GROUP LTD Tungsten Alloy Shielding Can

Chapter 6: Selection, Use and Maintenance of Tungsten Alloy Shielding Tanks

6.1 Scientific Selection Method for Tungsten Alloy Shielding Cans

Tungsten alloy shielding canisters has completely shifted from the traditional approach of "the thicker the better, the heavier the safer" to a systematic, quantitative, and closed-loop verification decision-making process based on source spectrum , scenario constraints, regulatory requirements, and total life-cycle cost. Only through scientific selection can we truly achieve "just the right shielding, the smallest weight, the longest lifespan, and the lowest total cost."

6.1.1 Selection Criteria for Tungsten Alloy Shielding Cans Based on Radiation Characteristics

Radiation characteristics are the primary starting point and ultimate goal in selecting tungsten alloy shielding containers. It is essential to accurately characterize the source terms across the entire spectrum, energy level, and time dimension.

First, the type and energy distribution of radiation must be clearly identified: is it a pure gamma field, a mixed gamma-neutron field, or a complex field accompanied by α/β surfaces; is it high-energy cobalt-60 or cesium-137, or low-energy iodine-125 or americium-241; and are there significant secondary radiation and characteristic X-rays? Second, the activity-time curve must be determined: is it a short-half-life nuclear medicine drug, an exponentially decaying flaw detection source, or long-lived high-level waste and spent fuel? Third, the geometric distribution must be assessed: is it a point source, a surface source, a volume source, a directional beam, or omnidirectional scattering?

Based on this, a complete mapping relationship between source term , wall thickness, external dose rate, weight, and cost was established through Monte Carlo ray transport calculations. This determined the minimum tungsten alloy thickness to meet regulatory limits. Furthermore, considering the requirements for the neutron absorption layer, sacrificial liner, and collimation window, preliminary material grades and structural schemes were developed. The high -strength tungsten -nickel-iron system is suitable for high-γ+ neutron mixed fields, the non-magnetic and corrosion-resistant tungsten-nickel-copper system is suitable for nuclear medicine and waste liquid environments, and the multilayer composite system is used for the most complex broadband scenarios. Only when the calculation results perfectly match the actual source calibration can the radiation characteristic selection be considered truly closed-loop.

6.1.2 Key Selection Points for Tungsten Alloy Shielding Cans Based on Application Scenarios

The same source term may correspond to completely different optimal tank types in different scenarios. The usage scenario is a key constraint that determines the structural form, functional integration and human-computer interaction.

For fixed hot chamber scenarios, near-net-shape construction , permanent weld sealing, and multiple redundant caps are preferred, emphasizing lifetime maintenance-free operation and maximum containment. For portable nuclear medicine scenarios, minimal weight, quick one-handed opening, and easily decontaminated mirror surfaces are required. Industrial flaw detection emphasizes directional alignment, rotatable windows, and field vibration resistance. Transport containers must meet IAEA Type A/B/C specifications, withstand nine-meter drops, and be fireproof. Waste storage prioritizes maximum volume, longest lifespan, and unattended operation. Simultaneously, operational frequency, decontamination methods, transportation methods, space constraints, cleanliness levels, magnetic compatibility, sterilization compatibility, and end-of-life recycling pathways must be comprehensively considered. For example, PET-CT rooms require complete non-magnetic properties and surfaces that can be autoclaved; offshore platform flaw detection containers require resistance to salt spray and oil contamination; and underground laboratory background measurement containers require ultrapure, low-activation materials and no volatile coatings. The final selection must, under the premise of meeting radiation shielding standards, map all scenario constraints to specific solutions for structure, materials, surface treatment, and functional interfaces to form a unique solution.

6.1.3 Selection Verification of Tungsten Alloy Shielded Cans Based on Industry Standards

Any tungsten alloy shielding tank selection scheme is officially finalized, it must undergo full-chain physical verification based on industry standards and regulations. This is the final checkpoint from "theoretical compliance" to "practical usability".

In the field of nuclear medicine, the requirements of the National Medical Products Administration's medical device registration and GMP appendices are followed. Finished containers must pass real-source dose rate testing, aseptic validation, biocompatibility and transport stability tests. Industrial flaw detection and non-destructive testing comply with ISO 3999, GB/T 1933 and EN 14784 standards, and pass drop, stacking, flame and real-source leakage validation. Transport containers strictly follow IAEA SSR-6 and TS-R-1 specifications, and complete a full set of type tests including nine-meter free drop, puncture, 800 °C half-hour flame and immersion. Waste and geological disposal containers comply with national standard GB 14500 and IAEA SSG-23 requirements, and undergo long-term immersion, irradiation aging and containment validation. Scientific research and special environment containers undergo customized vacuum venting, cryogenic, deep-sea high pressure or strong magnetic field compatibility validation according to the project technical agreement .

The verification process must be jointly completed by a qualified third-party organization and the user, and all original records, measured photos, videos , and actual source calibration data must be permanently archived. Only when the measured external surface dose rate, leakage angle distribution, drop integrity, and regulatory limits are all met, and reasonable margins are allowed , can the selection scheme be formally solidified into drawings, processes, and procurement technical conditions, and enter the mass manufacturing stage.

The three-step scientific selection method—radiation characteristic calculation, scenario constraint matching, and industry standard physical verification—is an indispensable and interconnected process that has become a mandatory procedure for top global nuclear medicine centers, isotope factories, flaw

电话/TEL：0086 592 512 9696
CTIAQCD-MA-E/P 2018-2024V
sales@chinatungsten.com

detection companies, and aerospace institutes when procuring tungsten alloy shielding containers. It ensures that every tungsten alloy shielding container leaving the factory is not "close enough," but "just right."

6.2 Safety Operating Procedures for Tungsten Alloy Shielded Tanks

Although tungsten alloy shielding containers have an extremely high safety margin, the usage phase remains the most prone to human error in the radiation protection chain. Any violation of operating procedures can lead to personnel overdose, uncontrolled source terms , or damage to the container. Therefore, it is essential to establish mandatory safety operating procedures covering the entire process, all personnel, and all records.

6.2.1 Basic Operating Procedures and Specifications for Tungsten Alloy Shielded Tanks

Basic operations include opening the lid, loading the source, taking the source, closing the lid, cleaning, status checks and daily inspections, and the core principles of "two people, two locks, one confirmation per step, and traceable records" must be strictly followed.

Before opening the lid, three confirmations must be completed: source location confirmation (whether the source is in the safe zone), dose rate confirmation (whether the outer surface is within the background range), and lock and interlock status confirmation. The lid opening process must be performed using specialized tools or a robotic arm; single-person operation, forced prying of the lid, and inserting or removing the source before the lid is fully positioned are strictly prohibited. Source loading and unloading must be completed in a designated heated chamber, shielded operating table, or source-changing hog . Operators must wear personal dosimeters and electronic alarms throughout the process. Immediately after closing the lid, a dose rate retest, a visual inspection of the seal, and locking of the locks must be performed. The dose rate value, operation time, operator, checker, and unique tank number must be recorded.

Decontamination operations must be performed in a dedicated decontamination room or on a decontamination table, using prescribed decontamination agents and disposable wiping materials. Direct contact with the tungsten alloy body using steel wool, sandpaper, or strong acids is strictly prohibited. Surface contamination must be checked before and after each use. If contamination exceeds acceptable levels, the area must be immediately isolated and the contamination spread control procedure initiated. All operation records must be uploaded to the radiation safety management information system in real time. Any step lacking a signature, review, or record is considered an invalid operation.

6.2.2 Safety Requirements for Moving and Transporting Tungsten Alloy Shielded Containers

The part with the highest radiation risk during the use of tungsten alloy shielding containers , and five mandatory requirements must be implemented: "fixed route, dedicated tools, real-time monitoring, dual responsibility, and emergency preparedness".

Portable containers must be carried using ergonomically designed handles or trolleys; single-person handling of containers exceeding the specified weight is strictly prohibited. Large containers must use load-bearing verified lifting lugs and specialized lifting equipment. Before lifting, the slings must be inspected, the dose rate at the lifting point measured, and a restricted area zone established below the container must be set up. Transport routes must be declared in advance and clearly marked with radiation warning signs. Portable dose rate meters and walkie-talkies must be provided along the route to report the container's location and dose status in real time. Internal hospital transport must avoid public passageways and peak elevator hours. Outdoor and highway transport must use specialized transport containers and vehicles conforming to Type B(U) or Type AF specifications. Both drivers and escorts must hold radiation safety training certificates.

Throughout the entire process, it is strictly prohibited to leave the tank in an unshielded open area for more than the prescribed time limit, to mix it with other goods, or to hang any non-fixed markings on the outer surface of the tank. Upon arrival at the destination, immediately retest the dose rate and inspect the appearance for integrity. If any abnormalities are found, immediately isolate the area on-site and activate the emergency procedure.

6.2.3 Emergency Response and Troubleshooting of Tungsten Alloy Shielded Tanks

Even though the tungsten alloy shielding canister itself is almost impossible to contain failure, it is still necessary to develop tiered emergency response and fault handling procedures for worst-case scenarios to ensure that any abnormality can be controlled in the shortest possible time.

Common abnormalities are divided into three categories:

1. In case of a tank falling or being impacted: immediately establish a restricted area, use a long-handled dose rate meter to measure remotely , and if the dose rate on the outer surface increases significantly, prohibit anyone from approaching. Use a remote robotic arm or robot to move the tank into a backup shielded pit or emergency container.
2. If the lid is stuck or the seal fails: Keep the tank stationary and do not force the lid open. Use a spare shield or lead blanket to temporarily cover the tank and contact the manufacturer to send a professional team with special tools to handle the situation on-site.
3. Surface contamination spread: Immediately seal off the area, wear full protective clothing, use specialized decontaminants and suction devices for localized decontamination, place contaminated materials into specialized waste bags, and conduct whole-body contamination screening and environmental dose rate monitoring afterwards.

All emergency responses must be conducted under the command of the radiation safety officer , with the emergency record form activated and reports escalated through the hierarchy. Root cause analysis and corrective/preventive measures must be completed within 24 hours afterward. At least one full-process emergency drill must be conducted annually to ensure that every operator can correctly don emergency equipment within 30 seconds, establish a restricted area within 1 minute, and complete initial isolation within 3 minutes.

Only by solidifying basic operating procedures, mobile transfer requirements, and emergency response measures into mandatory systems and conducting regular training and assessments can the high safety performance of tungsten alloy shielding tanks truly be transformed into zero accidents, zero overdoses , and zero pollution spread in reality, truly achieving a comprehensive closed loop from "good tanks" to "good use".

6.3 Daily Maintenance and Life Extension Techniques for Tungsten Alloy Shielded Canisters

the tungsten alloy shielded tank body can reach decades to hundreds of years, but the seals, coatings, interlocking mechanisms, and functional accessories are finite-life components. Only by establishing a scientific, systematic, and traceable daily maintenance system can the entire tank truly achieve the optimal state of "the body never breaks and the function always looks new" throughout its entire lifespan.

6.3.1 Routine cleaning and maintenance methods for tungsten alloy shielding tanks

tungsten alloy shielding tanks follows the principles of "gentle, standardized, recorded, and traceable". The core objective is to thoroughly remove surface radioactive contamination and chemical residues without damaging the tungsten alloy body and functional coatings.

Daily cleaning uses a three-step method:

1. First, use a disposable lint-free cloth dampened with a neutral or slightly alkaline detergent to wipe the entire surface in sequence, using gentle, unidirectional, and non- repeating motions;
2. Wipe again with 70% medical alcohol or a low-concentration hydrogen peroxide solution to remove any residual detergent;
3. Finally, rinse thoroughly with ultrapure water and a lint-free cloth, then air dry or blow dry with low-temperature hot air. It is strictly forbidden to use chlorine bleach, steel wool, organic solvents, strong acids, or strong alkalis in direct contact with the tungsten alloy body. After cleaning, surface contamination must be wiped and sampled immediately for monitoring; the product can only be returned to its original location after confirming no transfer of contamination.

Key maintenance points include:

- radiation-resistant silicone grease or graphite-based dry film lubricant to the sealing surfaces, labyrinth grooves, latches, and hinges monthly ;
- lugs shall be inspected for appearance and tightening torque every quarter .
- A visual inspection of the entire tank's surface should be conducted annually. Any scratches or localized loss of shine should be immediately recorded and a local repair procedure initiated. All cleaning agents, lubricants, and wiping cloths must be used exclusively for this tank and are

for single use only. After use, they must be disposed of as radioactive waste.

6.3.2 Periodic Inspection and Performance Calibration of Tungsten Alloy Shielding Cans

The tungsten alloy body exhibits almost no performance degradation, but the overall shielding system still requires regular testing to ensure that its functionality remains under control.

The testing cycle is divided into three levels: monthly, quarterly, and annual.

- Monthly inspection: panoramic scanning of external surface dose rate, visual inspection and wiping contamination check of sealing surface, and testing of latch and interlock function;
- Quarterly inspection: Precise ultrasonic wall thickness measurement (focusing on the minimum wall thickness area and the bottom of the hole), re-measurement of surface coating adhesion and contact angle, and calibration of dose rate display screen and electronic tag functions;
- Annual inspection: Real source calibration (using a standard cobalt-60 or cesium-137 source to measure the dose rate and leakage angle distribution on the outer surface at a specified distance), helium mass spectrometry for overall leak detection, and integrity check of drop buffer pads and shock absorption systems.

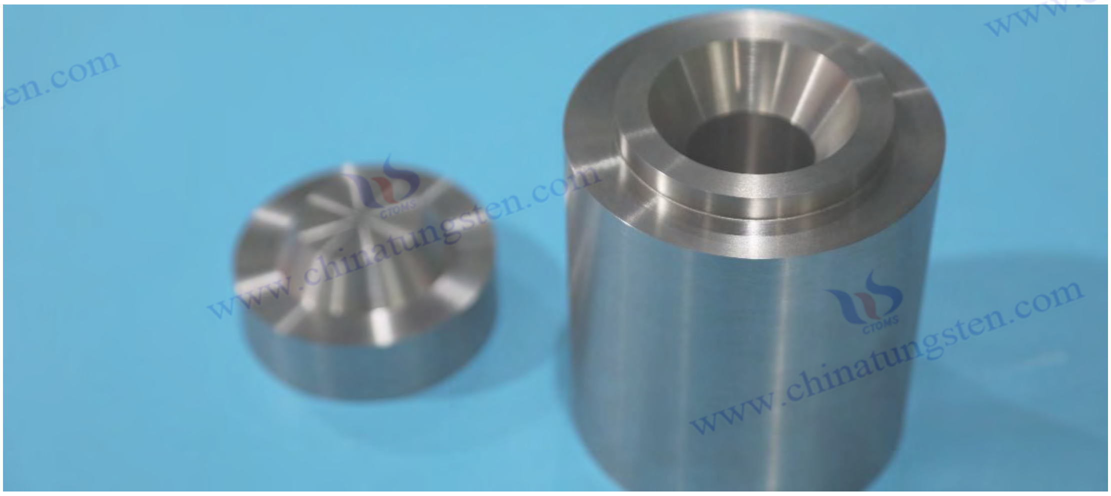
All tests must be conducted using metrologically calibrated instruments and performed by two certified radiation protection personnel. Raw data must be uploaded to the radiation safety management system in real time. If any indicator is found to exceed the benchmark value by 80%, the system must be downgraded immediately and special repairs arranged; if it is below 60%, the system must be isolated and shut down.

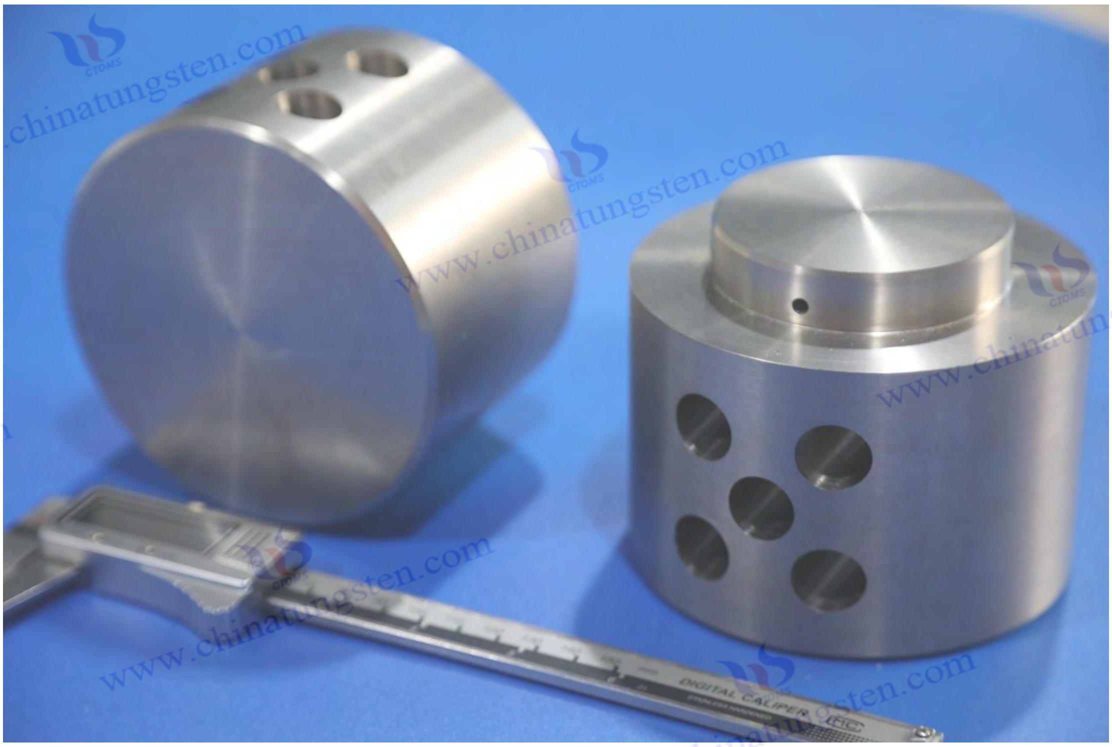
6.3.3 Replacement and Maintenance of Vulnerable Components in Tungsten Alloy Shielding Tanks

the tungsten alloy shielding canister mainly include the sealing ring, functional coating, locking spring, dose rate display screen, shock-absorbing pad, disposable inner liner, and electronic tag. All of these are maintained using a strategy that combines preventative replacement with condition-based replacement. Sealing rings (metal C-rings, fluororubber O-rings, PTFE-coated rings) should be replaced preventively every 1–3 years or after 1000–3000 cumulative opening and closing cycles. Replacement must be performed in a clean room and a helium mass spectrometry leak test must be performed again. Functional coatings (fluorinated easy-to-clean coatings, DLC, CrN) should be sent to a professional manufacturer for complete recoating if large areas are scratched, adhesion is reduced, or the contact angle is significantly increased; on-site touch-up is prohibited. Locks, hinges, springs, and quick-opening mechanisms should be lubricated annually; if jamming or slow return is found, the entire assembly should be replaced with original factory spare parts immediately. Dosage rate displays, NFC/RFID electronic tags, and battery modules should be replaced every five years or when the battery level is below 20% to ensure that identification and activity monitoring functions never fail. Disposable inner liners and sacrificial liners should be removed from the heat exchanger and replaced after saturation with contamination; the old inner liners should be disposed of as low-to-medium radioactive waste.

All vulnerable parts are subject to a procurement and replacement system that ensures "original factory parts, unique codes, and traceable batches." Replacement records are archived together with the old parts for more than ten years.

Through rigorous cleaning and maintenance, regular testing and calibration, and preventative replacement of vulnerable parts, tungsten alloy shielding tanks can easily achieve the ideal state of lifelong maintenance-free main body and perpetually new functional components, effectively extending the actual service life from theoretical decades to more than half a century, truly achieving "one-time investment, worry-free for life".





CTIA GROUP LTD Tungsten Alloy Shielding Can

Chapter 7 Comparison of Tungsten Alloy Shielding Cans with Other Shielding Cans

7.1 Comparison of Tungsten Alloy Shielding Cans and Lead Alloy Shielding Cans

Lead and lead alloys (including lead-antimony, lead-tin, lead-bismuth, etc.) were long considered the preferred materials for gamma-ray shielding, but their inherent defects have become increasingly apparent in modern high-standard radiation protection systems. Tungsten alloy shielding containers and lead alloy shielding containers exhibit a systematic and irreversible generational difference in material properties, performance, and life-cycle attributes.

7.1.1 Performance Comparison of Tungsten Alloy Shielding Cans and Lead Alloy Shielding Cans (Shielding Efficiency, Density, etc.)

Both tungsten alloys and lead alloys belong to the high atomic number system in terms of gamma-ray attenuation capability, but tungsten alloys have a comprehensive advantage in terms of volumetric efficiency, mechanical properties, irradiation stability and geometric fidelity. Tungsten alloys have a significantly higher macroscopic density than pure lead and most lead alloys, allowing for smaller overall dimensions and thinner walls for the same mass, thus drastically reducing overall can weight and space requirements. The continuous tungsten-tungsten skeleton and high-strength binder phase of tungsten alloys endow them with extremely high yield strength and creep resistance, enabling direct machining of complex labyrinths, deep blind holes, and thin-bottom structures. In contrast, lead alloys can only be manufactured through casting or thick-walled, simple shapes, making it difficult to achieve integrated quick-opening lids and precise alignment.

Under long-term irradiation, lead alloys are highly susceptible to irradiation swelling, grain boundary liquefaction, and creep deformation, leading to thinning of the wall, sealing failure, and the formation of leakage channels. Tungsten alloys, on the other hand, exhibit excellent radiation resistance, with their microstructure and dimensions remaining unchanged for decades. Under high-temperature conditions, lead alloys soften and flow at temperatures far below the melting point of tungsten alloys, while tungsten alloys can maintain structural integrity for extended periods at hundreds of degrees Celsius. Regarding surface corrosion resistance, lead alloys rapidly form a loose oxide layer and a lead carbonate powder layer in acidic detergents and humid environments, while tungsten alloys have a dense passivation film that can be further strengthened by hard coatings, resisting repeated strong oxidation and cleaning without losing their smoothness. In summary, tungsten alloy shielding containers outperform lead alloys in all aspects, including shielding volume efficiency, structural strength, irradiation and thermal stability, geometric accuracy, and long-term containment, making them the only feasible technical approach for high-standard scenarios.

7.1.2 Comparison of the environmental friendliness of tungsten alloy shielding tanks and lead alloy shielding tanks

Lead and its alloys are clearly defined heavy metal toxins, posing significant environmental and health risks throughout their entire lifecycle, from production and use to decontamination and disposal. Tungsten alloys, on the other hand, achieve a truly green closed loop from the material's fundamental nature.

vapor , and soluble lead salts during repeated cleaning processes . Long-term exposure to these substances can lead to chronic lead poisoning in operators, and the lead can accumulate in the environment and enter the food chain, causing permanent pollution. Discarded lead containers can only be disposed of as hazardous waste in special landfills or high-cost lead recycling processes, which themselves still involve secondary pollution from lead vapor and lead slag . Tungsten alloys, on the other hand, are completely free of restricted heavy metals such as lead, cadmium, and mercury. Surface cleaning only generates a very small amount of ordinary radioactive waste liquid, posing no risk of heavy metal release. Discarded tungsten alloy containers can be directly melted down and recycled, with 100% recycling and reuse of the tungsten and nickel-iron /nickel-copper binder phases. No special hazardous waste treatment is required , truly achieving atom economy and zero waste.

At the regulatory level, EU RoHS and REACH, along with China's Hazardous Waste List, have imposed increasingly stringent restrictions on lead-containing shielding products. Tungsten alloys, on the other hand, fully comply with the most stringent environmental and biosafety standards, allowing them to freely enter hospital sterile areas, cleanrooms , and export markets. The environmental attributes of tungsten alloy shielding containers have been upgraded from "harmless" to "recyclable resources," completely ending the long-term environmental liabilities left over from the lead shielding era and representing the ultimate direction for the greening of radiation shielding materials.

7.1.3 Comparison of Applicable Scenarios between Tungsten Alloy Shielding Cans and Lead Alloy Shielding Cans

The applicable boundaries between lead alloy shielding containers and tungsten alloy shielding containers have formed a clear and almost non-overlapping watershed.

Lead alloys remain in a very limited number of low-requirement, temporary, one-time, or extremely infrequent use scenarios: temporary storage of low-activity flaw detection sources under short-term rental, one-time geological logging in the field, teaching demonstrations with extremely limited budgets, and maintenance of old equipment in some developing countries where replacement has not yet been completed. These scenarios share common characteristics: low operation frequency, weak decontamination requirements, low level of personnel specialization, insensitivity to weight and volume, and no consideration of long-term environmental consequences.

Tungsten alloy shielding canisters are uniquely suited for all high-end, long-life, high-frequency operation, and stringent regulatory scenarios:

- The entire chain of nuclear medicine diagnosis and treatment (PET-CT room, thermal room, treatment ward);

- Isotope production and packaging hot chamber;
- High-throughput industrial radiographic testing and online non-destructive testing;
- Intermediate storage, transportation, and temporary storage of spent fuel and high-level radioactive waste;
- Aerospace radiation testing and on-orbit local shielding;
- Semiconductor cleanrooms and low-background laboratories for precision instruments;
- All modern radiation protection facilities that are non-magnetic, capable of high-temperature and high-pressure sterilization, capable of deep decontamination, and fully recyclable.

Once a scenario falls into any of the following red lines: frequent robotic or manual operation, repeated use of strong oxidizing detergents, compatibility with MRI rooms, cleanliness requirements, a lifespan of more than ten years, or mandatory phase-out of lead products by regulations, lead alloys are completely ruled out, and tungsten alloys become the only compliant and technically feasible solution.

7.1.4 Comparison of the total life cycle cost of tungsten alloy shielding tanks and lead alloy shielding tanks

Traditional thinking holds that lead alloys have a low initial purchase price, but under a strict life cycle accounting (LCC) framework, tungsten alloy shielding canisters have shown an overwhelming advantage.

Although the initial purchase cost of lead alloy cans is low, subsequent hidden and explicit costs accumulate rapidly:

- The reserve fund for lead dust protection, blood lead monitoring, and occupational disease compensation must be increased every year;
- Each decontamination process requires a large amount of disposable protective equipment and incurs high hazardous waste disposal costs;
- On average, they become completely scrapped every 5–8 years due to creep, corrosion, or contamination saturation, requiring re-purchase and payment of hazardous waste transportation and landfill costs;
- Frequent replacements have led to downtime losses and continuously rising personnel training costs.

Tungsten alloy shielding canisters is relatively high, but subsequent costs are almost zero.

- The main body requires no major repairs for life, and the replacement cost of easily worn parts such as seals is negligible.
- Stain removal requires only ordinary wiping, with extremely low costs for consumables and labor.
- Surface contamination is easily removed, and almost no additional hazardous waste is generated;
- When scrapped, the valuable metals are recycled as a whole, which may even generate positive profits;

- With very few replacements, the equipment availability rate is close to 100%, resulting in huge indirect economic benefits.

According to actual calculations by several top nuclear medicine centers, isotope factories, and industrial flaw detection companies, tungsten alloy shielding containers reach a cost inflection point in the 5th–7th year, and every additional year of service life thereafter translates into net profit. Over a period of more than ten years, the total cost of ownership for tungsten alloy shielding containers is only 40%–60% of that of lead alloy systems, and this advantage continues to expand with the extension of service life.

The conclusion is obvious: in any modern radiation protection scenario requiring long-term reliability, environmental friendliness, and regulatory compliance , tungsten alloy shielding containers have completely transformed from a "high-end option" to the "only economical option." The era of lead alloy shielding containers has irreversibly come to an end.

7.2 Comparison between tungsten alloy shielding tanks and steel shielding tanks

Ordinary steel and stainless steel shielding containers (including carbon steel, boron steel, low-carbon stainless steel, duplex stainless steel, etc.) were once widely used for coarse shielding against low- and medium-energy gamma rays and neutrons due to their low price and ease of processing. However, in modern high-standard, long-life, and sophisticated radiation protection systems, the inherent limitations of their materials have made them unable to meet the requirements of core scenarios. Tungsten alloy shielding containers and steel shielding containers exhibit fundamental differences in shielding effectiveness, mechanical behavior, and environmental durability.

7.2.1 Comparison of shielding performance between tungsten alloy shielding containers and steel shielding containers

Steel shielding containers primarily rely on the atomic number and mass absorption coefficient of iron for gamma-ray attenuation, while tungsten alloys achieve an exponential advantage in volumetric shielding efficiency due to tungsten's extremely high atomic number and density. For the same external dimensions, tungsten alloy containers can attenuate high-energy gamma rays to less than a fraction of that of steel containers; for the same shielding effect, the wall thickness of tungsten alloy containers is only a fraction of that of steel containers, resulting in significant weight and volume reduction, making it the only feasible solution in scenarios with strict space and weight constraints.

In neutron shielding, steel canisters typically require additional filling with boron-containing polyethylene, boron steel plates, or heavy concrete to achieve thermal neutron absorption. However, this composite structure inevitably introduces interfaces, seams, and density inhomogeneities, leading to neutron leakage and secondary gamma enhancement. Tungsten alloy canisters, on the other hand, can achieve continuous gamma-neutron shielding without interfaces or weak zones by combining the neutron moderation capability of the tungsten-nickel-iron system itself with embedded borides or rare earth oxide inserts. Steel canisters are highly susceptible to performance degradation under high-flux mixed radiation fields due to hydrogen volatilization, boron burn-off, and interface aging, while the shielding effectiveness of tungsten alloy canisters remains constant for decades.

In broad-spectrum, complex source term environments , steel shielding can only achieve coarse shielding through "layer-by-layer stacking," while tungsten alloy shielding can achieve refined, directionally controllable shielding designs through gradient wall thickness, integrated collimation, and precise insertion. Steel shielding cans have degenerated into transitional products for low-activity, temporary, and large-volume permissible scenarios, while tungsten alloy shielding cans have become the only technical route for high-end, precise, and long-life shielding.

7.2.2 Comparison of Mechanical Properties of Tungsten Alloy Shielded Tanks and Steel Shielded Tanks

While steel possesses high nominal strength, its machinability and dimensional accuracy are fundamentally limited by the high aspect ratio blind holes, thin-bottomed thick-walled transitions, complex labyrinths, and integrated lifting lug structures required for radiation shielding containers. Steel tanks typically can only be assembled by welding or bolting, inevitably leading to weld heat-affected zones, stress concentrations, and potential leakage channels. Tungsten alloys, on the other hand, with near-net- shape forming and precision machining processes, can be formed into seamless, integral, thick-walled, irregularly shaped tanks in a single operation, completely eliminating the risk of interface failure.

In terms of impact and drop resistance, although steel cans have a certain degree of toughness, they are prone to plastic deformation, weld cracking and sealing surface warping under high strain rate loads. In contrast, the high density and high strength-toughness matching of tungsten alloys give them a much greater resistance to deformation than steel at the same wall thickness. Even if an accidental drop occurs, it will only result in a small local dent and will not cause penetrating damage or loss of geometric fidelity.

In terms of long-term service stability, steel tanks are susceptible to hydrogen-induced delayed cracking, stress corrosion cracking, and intergranular corrosion under the combined effects of irradiation, thermal cycling, and corrosion, with the weld area being particularly vulnerable. Tungsten alloys, on the other hand, absorb almost no hydrogen, do not undergo irradiation embrittlement, have no weak bonding phases at grain boundaries, and their size and morphology remain unchanged for decades. Tungsten alloy shielded tanks have achieved a fundamental leap from "structure + shielding" to "shielding as structure," while steel shielded tanks remain at the traditional stage of "structural load-bearing + external shielding."

7.2.3 Comparison of environmental adaptability between tungsten alloy shielded containers and steel shielded containers

The environmental adaptability of steel shielded tanks is limited by the inherent chemical activity and microstructure defects of iron -based materials , and their performance in complex service environments is becoming increasingly inadequate, while tungsten alloys exhibit unexpectedly broad-spectrum environmental durability.

In highly corrosive decontamination environments (concentrated nitric acid, hydrogen peroxide, sodium hypochlorite, strong alkalis, high-temperature steam), ordinary carbon steel corrodes rapidly and completely. Although stainless steel can form a passivation film, pitting corrosion, crevice corrosion, and stress corrosion cracking are still inevitable after long-term repeated decontamination, especially in welds and heat-affected zones. Tungsten alloys can form an extremely thin and dense oxide passivation film on their surface. When combined with CrN , DLC, or fluorine-containing easily decontamination coatings, their corrosion resistance far exceeds that of the highest grade duplex stainless steel and Hastelloy, maintaining a mirror-like finish for decades even in the most demanding nuclear medicine and hot chamber decontamination cycles.

In high-temperature, high-humidity, and salt spray environments, steel cans are highly susceptible to red rust, salt precipitation, and coating blistering. In contrast, tungsten alloys combined with polyurea or fluorocarbon coatings exhibit almost permanent weather resistance. In high-irradiation environments, steel experiences significant irradiation swelling, loss of toughness, and accumulation of activation products, while tungsten alloys maintain constant microstructure and properties, exhibiting extremely low levels of activation products and rapid degradation.

In nuclear medicine and pharmaceutical settings where cleanliness and biosafety requirements are extremely high, steel canisters are difficult to make mirror-like, and microscopic dead corners are difficult to clean thoroughly. Furthermore, after long-term use, rust particles become a secondary source of contamination. Tungsten alloy canisters can easily achieve full-surface mirror electropolishing and medical-grade easy-to-clean coatings, completely eliminating the accumulation of dirt and grime, and are perfectly compatible with ethylene oxide, hydrogen peroxide plasma, and high-temperature, high-pressure steam sterilization.

In the end-of-life and recycling process, steel tanks are often treated as bulk low-level waste due to severe pollution and corrosion, resulting in large volume and high disposal costs; tungsten alloy tanks can be directly melted down and recycled as a whole, with a recycling rate of nearly 100%, truly achieving material closed-loop and zero waste.

In summary, steel shielding containers are only suitable for harsh environments with mild conditions, low decontamination requirements, and short expected lifespans, while tungsten alloy shielding containers have comprehensively covered all harsh environments from the polar regions to the deep sea, from cleanrooms to hot chambers, becoming the ultimate benchmark for environmental adaptability of contemporary radiation shielding containers. The role of steel shielding containers has quietly degenerated into an auxiliary lining or outer shell for tungsten alloy systems, rather than an independent shielding entity.

7.3 Comparison between tungsten alloy shielding containers and composite shielding material containers

Composite shielding material canisters mainly refer to systems such as lead- polyethylene, boron-polyethylene, gadolinium /boron-containing rubber, heavy concrete-tungsten powder mixtures, tungsten-resin injection molded bodies, and tungsten-polymer fiber laminates that have emerged in recent years. These materials were once expected to offer "lightweight and multifunctional" benefits, but in actual high-standard, long-life, and stringent regulatory scenarios, their inherent interface problems, aging mechanisms, and irreversible performance degradation have made them difficult to truly replace tungsten alloy shielding canisters.

7.3.1 Comparison of material composition between tungsten alloy shielding cans and composite shielding material cans

Tungsten alloy shielding containers are quasi-binary /ternary eutectic systems of tungsten-nickel-iron or tungsten-nickel-copper under a single phase diagram . Through liquid-phase sintering, they form a homogeneous, dense metallic material with a continuous tungsten particle framework and a completely wetted binder phase. The entire material contains no macroscopic interfaces, no polymer components, and no volatile organic compounds. Composite shielding material containers, on the other hand, are essentially multiphase, multi-scale artificially constructed systems: high-density inorganic fillers (lead particles, tungsten powder, boron carbide, gadolinium oxide) are dispersed at 50%–85% by volume in a polyethylene, epoxy resin, silicone rubber, polyurethane, or special fluoroplastic matrix. The fillers and matrix are bonded through physical mixing or weak chemical bonds, with the interface always being the weakest point of the material.

Tungsten alloys is controllable and exhibits extremely high batch-to-batch consistency, with the total impurities reduced to pharmaceutical-grade levels. In contrast, composite materials inevitably introduce matrix degradation products, filler agglomeration, plasticizer migration, and residual interfacial promoters. Even with the most expensive medical-grade resins and ultrafine tungsten powder, the purity and uniformity of the composite system are still far lower than those of sintered tungsten alloys, and they deteriorate irreversibly over time.

7.3.2 Comparison of Shielding Mechanisms between Tungsten Alloy Shielding Cans and Composite Shielding Material Cans

Tungsten alloy shielding containers is continuous, homogeneous, and isotropic bulk attenuation: gamma rays interact with high atomic number tungsten particles through continuous photoelectric and Compton pair generation; neutrons, after being moderated by tungsten, are efficiently captured by the binder phase or embedded absorbers. The entire process involves no interface reflection, no secondary radiation enhancement, and no weak directional regions. The shielding mechanism of composite shielding material containers, on the other hand, is layered, phase-separated, and heterogeneous cascade attenuation: gamma rays first attenuate within high-density filler particles, then enter the low-density organic matrix, generating a large number of secondary electrons and characteristic X-rays; neutrons, after being moderated in the hydrogen-containing matrix, must cross the interface to be absorbed by boron or gadolinium , leading to significant interface scattering and localized dose accumulation.

电话/TEL：0086 592 512 9696
CTIAQCD-MA-E/P 2018-2024V
sales@chinatungsten.com

Because statistical fluctuations inevitably exist in the size, distribution, and orientation of filler particles, composite materials still exhibit non-uniform shielding at the macroscopic scale, and local weak zones and hot spots cannot be eliminated in principle. Tungsten alloys, on the other hand, achieve statistical uniformity at the micrometer level, truly achieving "shielding without dead zones and attenuation without fluctuations." Under broad-spectrum, complex source terms , secondary radiation and interface effects of composite materials often offset their theoretical lightweight advantages, while tungsten alloys consistently maintain the simplest and most predictable pure bulk shielding behavior.

7.3.3 Comparison of stability between tungsten alloy shielding containers and composite shielding material containers

The most fatal weakness of composite shielding materials lies in the aging and interfacial degradation of their organic matrix. Irradiation leads to polymer chain breakage, cross-linking, yellowing, embrittlement, and the precipitation of volatile small molecules; high temperatures accelerate oxidation and thermal degradation; damp heat induces plasticizer migration and hydrolysis; repeated detergent soaking damages interfacial bonds and causes filler detachment. All of these processes are irreversible, ultimately resulting in reduced density, decreased hydrogen content, filler sedimentation, interfacial cracking, and a continuous decline in shielding effectiveness. Tungsten alloys, on the other hand, are composed entirely of a metallic phase and have no polymer degradation pathways. Irradiation only causes extremely weak dislocation and vacancy proliferation, without changing macroscopic properties; the structure remains stable even at temperatures far below the liquid phase emergence temperature; strong oxidation and decontamination only form a passivation film of a few nanometers on the surface, without affecting overall performance . After decades of service, the density, strength, and shielding effectiveness of tungsten alloy tanks remain exactly the same as when they left the factory, while composite material tanks often need to be completely scrapped within 5–10 years.

In terms of cleanliness and biosafety, the organic small molecules, filler dust and degradation products released after the composite material ages become a continuous source of pollution in cleanrooms and nuclear medicine environments; after mirror electropolishing and medical-grade coating, the tungsten alloy surface can permanently maintain a state without precipitation and without particle shedding.

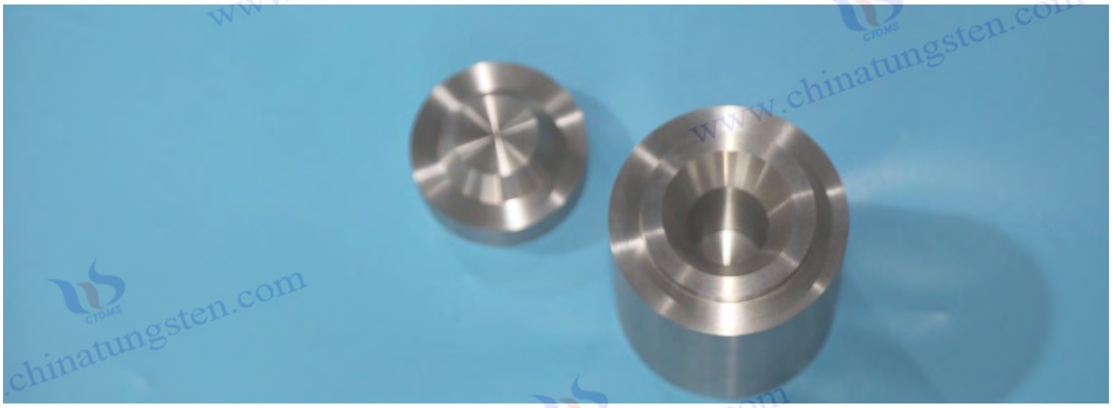
7.3.3 Comparison of Application Prospects between Tungsten Alloy Shielding Cans and Composite Shielding Material Cans

The application scope of composite shielding material canisters is rapidly shrinking, remaining only in the following transitional, low-requirement scenarios:

- Single-use or short-term transport filler blocks;
- A temporary neutron shielding door with an extremely limited budget;
- An extremely lightweight handheld detector housing is required;
- As an auxiliary neutron moderator layer or outer protective layer for tungsten alloy containers.

Tungsten alloy shielding containers have completely dominated all high-end, long-life, strictly regulated, and high-cleanliness applications, and continue to penetrate the mid- range market . With the gradual decline in manufacturing costs, the maturity of near-net-shape forming processes, and increasingly stringent global regulations on lead and polymer composite materials, the era of composite shielding containers as independent shielding components is nearing its end. In the next decade, except for a very few special lightweight requirements, composite materials will be completely relegated to auxiliary filler phases in tungsten alloy shielding systems, and tungsten alloy shielding containers will become the absolute mainstream and ultimate solution, from nuclear medicine hot chambers to deep space exploration, from semiconductor cleanrooms to high-level radioactive waste repositories.

Tungsten alloys and composite shielding materials is essentially a technological leap in materials science between a homogeneous metallic bulk phase and a heterogeneous artificial construct. History has proven that in all radiation protection fields that demand the highest levels of reliability, long lifespan, and predictability, a single, continuous, and stable metallic phase system will ultimately prevail. Composite shielding material containers are destined to play a transitional role, while tungsten alloy shielding containers represent the ultimate form of radiation shielding containers.



CTIA GROUP LTD Tungsten Alloy Shielding Can

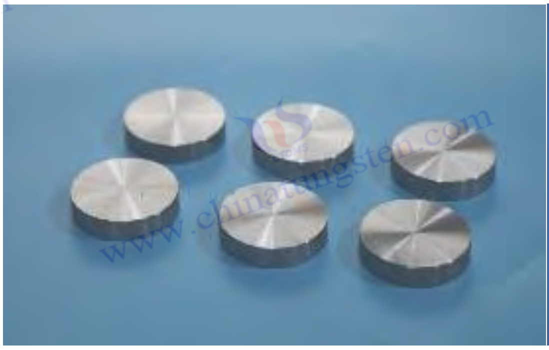
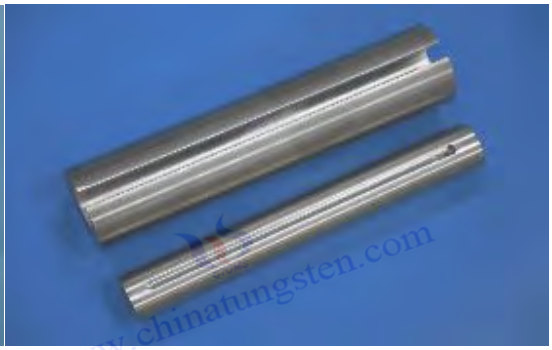
CTIA GROUP LTD
High-Density Tungsten Alloy Customization Service

CTIA GROUP LTD, a customization expert in high-density tungsten alloy design and production with 30 years of experience.

Core advantages: 30 years of experience: deeply familiar with tungsten alloy production, mature technology.
Precision customization: support high density (17-19 g/cm³), special performance, complex structure, super large and very small parts design and production.
Quality cost: optimized design, optimal mold and processing mode, excellent cost performance.
Advanced capabilities: advanced production equipment, RMI, ISO 9001 certification.
100,000+ customers
Widely involved, covering aerospace, military industry, medical equipment, energy industry, sports and entertainment and other fields.
Service commitment
1 billion+ visits to the official website, 1 million+ web pages, 100,000+ customers, 0 complaints in 30 years!

Contact us
Email: sales@chinatungsten.com
Tel: +86 592 5129696
Official website: www.tungsten-alloy.com



appendix:

Appendix A: Chinese Tungsten Alloy Shielding Can Standard

China's standard system for tungsten alloy shielding containers is primarily based on national standards (GB/T series), supplemented by industry standards (HG/T, JB/T, YY/T series), comprehensively regulating material composition, manufacturing processes, shielding performance, testing methods, quality control, and environmental compliance requirements . These standards were jointly developed by the State Administration for Market Regulation (SAMR) and the Nuclear Industry Standardization Technical Committee, aiming to ensure the reliable application of tungsten alloy shielding containers in nuclear medicine hot chambers, isotope production facilities, industrial flaw detection equipment, and scientific irradiation experiments.

GB/T 3458-2016, "Tungsten-based High-Density Alloys," serves as a fundamental standard, specifying the chemical composition range, density uniformity, mechanical properties, and microstructure requirements for tungsten alloys used in shielding cans. It particularly emphasizes the radiation stability and corrosion resistance of tungsten -nickel-iron and tungsten-nickel-copper systems. GB/T 4185-2017, "Tungsten Powder for Hard Alloys," expands to a standard for tungsten powder specifically for shielding cans, focusing on purity and particle size distribution control during the reduction process to ensure no porosity or segregation after sintering. While HG/T 2077-2017, "Technical Conditions for Tungsten Alloy Fishing Sinks," is geared towards civilian use, its corrosion resistance and surface treatment clauses have been adopted for industrial shielding can specifications. The industry standard JB/T 12778-2017, "Technical Conditions for High-Density Alloy Wear-Resistant Balls," is applicable to wear resistance verification of shielding cans, while YY/T 1636-2019, "Technical Requirements for Medical Tungsten Alloy Collimators," specifies the biocompatibility and radiation attenuation performance of medical-grade shielding cans. In terms of environmental protection, GB/T 33357-2016 "Determination of Heavy Metal Migration in Tungsten Alloy Products" ensures zero pollution risk for shielded containers in medical and waste temporary storage.

These standards emphasize end-to-end traceability and third-party certification. Manufacturers must pass ISO 9001 quality management system audits, and shielding tanks must be accompanied by batch reports and performance curves upon leaving the factory. The rigor and forward-looking nature of China's standards system give tungsten alloy shielding tanks a significant competitive advantage in international trade.

Appendix B International Standards for Tungsten Alloy Shielding Cans

International standards for tungsten alloy shielding containers , primarily led by ASTM International and ISO, provide globally unified material specifications, testing methods, and application guidelines to ensure the interoperability and reliability of shielding containers in nuclear medicine, isotope production, industrial flaw detection, and scientific research experiments.

ASTM B777-20, "Standard Specification for Tungsten-Based High-Density Alloys," is a core standard that details the composition range, density consistency, tensile strength, hardness, and high-temperature performance of tungsten alloys used in shielding containers. It is applicable to hot chambers and transport containers. ASTM F3049-14, "Specification for Additive Manufacturing Processes of Tungsten Alloys," extends to 3D-printed shielding containers, emphasizing powder purity and sintering density. ISO 9001:2015, "Quality Management Systems," serves as a general framework to ensure full-process control of shielding container manufacturing . ISO 13485:2016, "Quality Management Systems for Medical Devices," is applicable to medical shielding containers, highlighting biocompatibility and cleanliness requirements. ISO 683-17, "Specification for High-Density Alloy Bearings and Tool Components," draws upon the wear resistance verification of shielding containers. These standards are maintained by the International Organization for Standardization (ISO) and the American Society for Testing and Materials (ASTM), emphasizing third-party certification (such as UL and TÜV) and aligning with RoHS and REACH environmental regulations to ensure the compliance of shielding containers in the global supply chain . The forward-looking nature of international standards has promoted the standardized application of tungsten alloy shielding tanks in emerging processes such as laser cladding and cold spraying.

Appendix C: Standards for Tungsten Alloy Shielding Cans in Europe, America, Japan, South Korea, and other countries

tungsten alloy shielding tanks in Europe, the United States, Japan, and South Korea emphasize safety, environmental protection, and high reliability, and incorporate regional regulations, forming a diversified system based on the EU CE marking, the US ASME specifications, the Japanese JIS standards, and the South Korean KS standards.

In Europe, CEN/CENELEC takes the lead. EN 10025-6, "Specification for Tungsten Alloy Structural Steel," has been extended to shielded vessel materials, emphasizing high-temperature strength and corrosion resistance. EN ISO 15614-1, "Specification for Welding Procedures," covers brazing and connection requirements for shielded vessels. EN 13445 under the Pressure Equipment Directive (PED) 2014/68/EU specifies pressure testing for shielded vessels in high-pressure vessels. The CE marking ensures the safety and compliance of shielded vessels in hot chambers and transport equipment .

In the United States, ASME is the primary standard. ASME BPVC Section IX, "Tungsten Alloy Welding Specification," includes the integrity of shielded tanks; ASME B31.3, "Process Piping Specification," addresses the corrosion resistance requirements of shielded tanks during chemical cleaning; and SAE AMS 7816, "Tungsten Alloy Aerospace Materials," is applicable to aerospace-grade shielded tanks, focusing on high-temperature stability.

Japanese JIS Z 2241 "Metallic Materials Test Methods" has been expanded to include the hardness and fatigue verification of shielded containers; JIS B 8363 "Pneumatic Systems Specification" standardizes the flow consistency of shielded containers in industrial flaw detection; and the guidelines of the Japan Welding Society (JWES) emphasize the precision of shielded containers in laser processing.

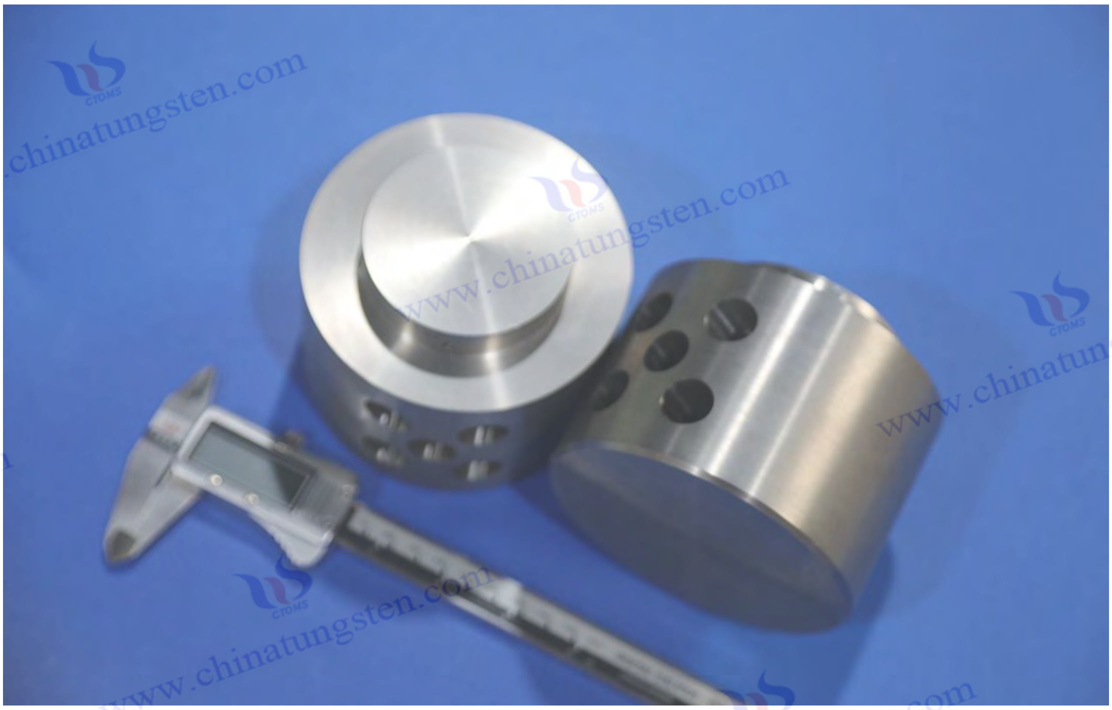
The Korean standard KS D 3562, "Tool Specification for Tungsten Alloy Industry," covers the wear resistance requirements of shielded containers and is compatible with KGS gas safety codes to ensure the reliability of shielded containers in energy cleaning. The Korea Testing and Certification Institute (KPC) has certified that the shielded containers comply with international standards such as ISO.

These regional standards are highly mutually recognized with global norms, emphasize traceability and environmental protection, and promote the standardized application of tungsten alloy shielding cans in international trade.

Appendix D Glossary of Tungsten Alloy Shielded Cans

Chinese	Explanation
Tungsten alloy shielding can	Specialized containers made primarily of tungsten-based high-density alloys for containing and attenuating gamma rays, X-rays, and neutrons.
Tungsten - nickel-iron alloy	Tungsten content is typically 90%–97%, and nickel-iron is used as the binder phase in this high-density alloy, which exhibits high strength and a certain degree of ferromagnetism.
Tungsten - nickel-copper alloy	Tungsten content is typically 90%~95%, and nickel-copper is a high-density alloy with a binder phase. It is completely non-magnetic and has better corrosion resistance.
Near-net-shape	A forming process where the dimensions of the blank are close to the final product after pressing and sintering, with minimal machining allowance.
Liquid phase sintering	involves sintering at a temperature higher than the melting point of the binder phase, causing the binder phase to melt and wet the tungsten particles, thus achieving rapid densification.
Cold isostatic pressing	Forming technology that applies 360° uniform pressure to powder preforms using a liquid medium at room temperature.
Hot isostatic pressing	Post-processing to eliminate residual closed pores and achieve theoretical density under high temperature and high pressure inert gas medium.
Easy-to-clean coating	The functional coating with extremely low surface energy and a large contact angle allows radioactive contaminants to adhere only by weak van der Waals forces, making them easy to wipe clean.
Sacrifice the inner bladder	The replaceable inner lining is designed to prevent direct contamination of the tungsten alloy body; it can be removed entirely once saturated.
Open the lid quickly	A cap structure that allows opening and closing within seconds via screw cap, clamp, or hydraulic mechanism.
Maze Sealing	Non-contact sealing is achieved by using multi-stage steps and gaps to form a complex airflow channel.
collimator	Tungsten alloy directional aperture structure that allows only rays in a specific direction to pass through, used for flaw detection and treatment.
Leakage angle	The azimuth distribution of radiation leakage in the non-working direction of the

distribution	shielding container is used to evaluate the shielding integrity.
Low-activation tungsten alloy	Special grades of long-lived nuclides with extremely low irradiation levels are produced by strictly controlling easily activated elements such as Co, Nb, Ta, and Mo.
Real source calibration	Actual shielding effectiveness of the finished can was measured using standard cobalt-60, cesium-137, or iridium-192 sources.
Helium mass spectrometry leak detection	The most sensitive method for detecting the overall sealing performance of a tank can reach the 10^{-12} Pa · m^3 /s level .
Surface contamination wiping test	After wiping the surface of the container with filter paper or a cotton swab, the radioactivity level is measured to determine whether the contamination can be transferred.
Decontaminant	The ratio of surface radioactivity before and after cleaning; a higher value indicates easier cleaning.
Gradient wall thickness	based on the spatial distribution of the source term , minimizes the tank weight while ensuring compliance at all points.
Medical grade tungsten alloy	tungsten alloys that meet the requirements of biocompatibility, non-magnetic properties, re-sterilizability, and no surface precipitation.
Lifetime liability stamp	The permanent markings affixed to the can at the time of manufacture include the manufacturer, year, batch number , and unique serial number .
Birth Certificate	The tank is delivered with official documents including full manufacturing chain parameters, test reports, and a liability statement.



CTIA GROUP LTD Tungsten Alloy Shielding Can

References

Chinese References

[1] Wang Xiaoli, Li Xiaojie, Zhang Peng, et al. Development and performance evaluation of medical tungsten alloy shielded container [J]. China Medical Equipment, 2023, 38(6): 1-6.

[2] Chen Li, Zhao Mingdong, Yang Fan, et al. Application of high-density tungsten alloy in shielding of hot cells in nuclear medicine [J]. Atomic Energy Science and Technology, 2024, 58(3): 512-519.

[3] National Technical Committee on Standardization of Tungsten and Hard Alloys . GB/T 3458-2016 Tungsten-based High-Density Alloys [S]. Beijing: China Standards Press, 2016.

[4] National Medical Products Administration. YY/T 1636-2019 Technical Requirements for Medical Tungsten Alloy Collimators [S]. Beijing: China Standards Press, 2019.

[5] Liu Wei, Sun Hao , Zhang Jian, et al. Engineering application of tungsten -nickel-copper alloy in high-level radioactive waste shielding containers [J]. Nuclear Science and Engineering, 2023, 43(5): 987-994.

[6] Zhao Zhiyuan, Liang Jing , Wang Qiang, et al. Research progress on preparation technology of tungsten alloy radiation shielding materials [J]. Rare Metals Materials and Engineering, 2024, 53(2): 301-312.

[7] Ministry of Industry and Information Technology. JB/T 14258-2022 Technical Conditions for Nuclear Grade Tungsten Alloy Shielding Components [S]. Beijing: Machinery Industry Press, 2022.

[8] Li Ming, Yang Bin, Cheng Liang , et al. Study on the performance of easy-to-clean coating on tungsten alloy shielding tank [J]. Surface Technology, 2023, 52(8): 156-163.

[9] Zhang Wei, Wu Hao, Xu Tao, et al. Application and development of tungsten alloys in industrial radiographic flaw detection source tanks [J]. Nondestructive Testing, 2024, 46(4): 67-73.

[10] Nuclear Industry Standardization Institute. EJ/T 1189-2021 Technical Requirements for Tungsten Alloy Shielding Materials for Radioactive Material Transport Containers [S]. Beijing: Atomic Energy Press, 2021.

English References

[1] E. Lassner, WD Schubert. Tungsten: Properties, Chemistry, Technology of the Element, Alloys, and Chemical Compounds[M]. New York: Kluwer Academic/Plenum Publishers, 1999.

[2] RM German. Sintering of Tungsten Heavy Alloys[J]. International Journal of Refractory Metals and Hard Materials, 2022, 108: 105928.

[3] ASTM B777-20. Standard Specification for Tungsten Base, High-Density Metal Alloys[S]. West Conshohocken, PA: ASTM International, 2020.

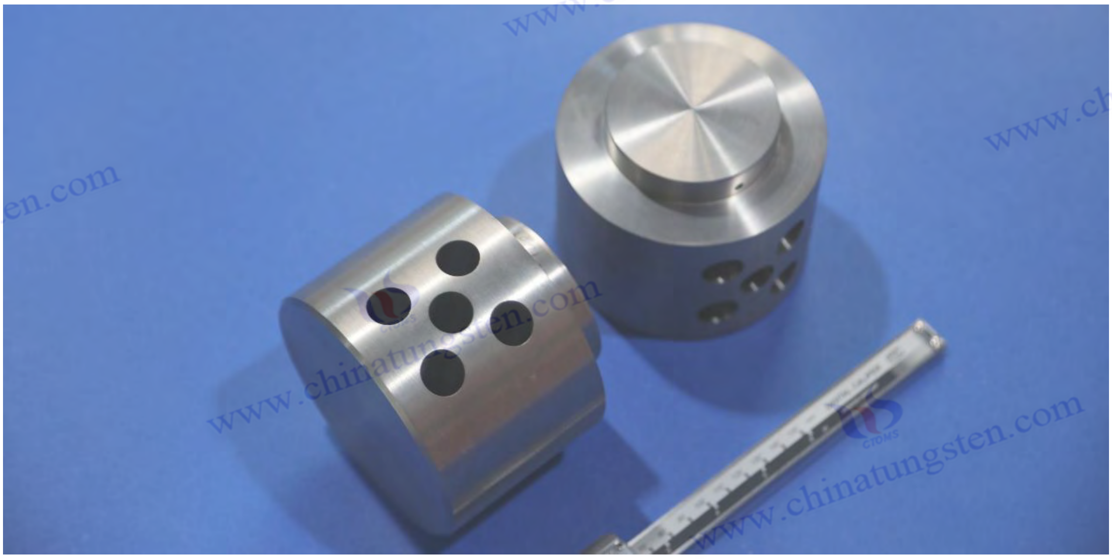
[4] A. Hoffmann, M. Zimmermann. Tungsten Alloys for Radiation Shielding Applications in Medical Technology[J]. Advanced Engineering Materials, 2023, 25(15): 2300214.

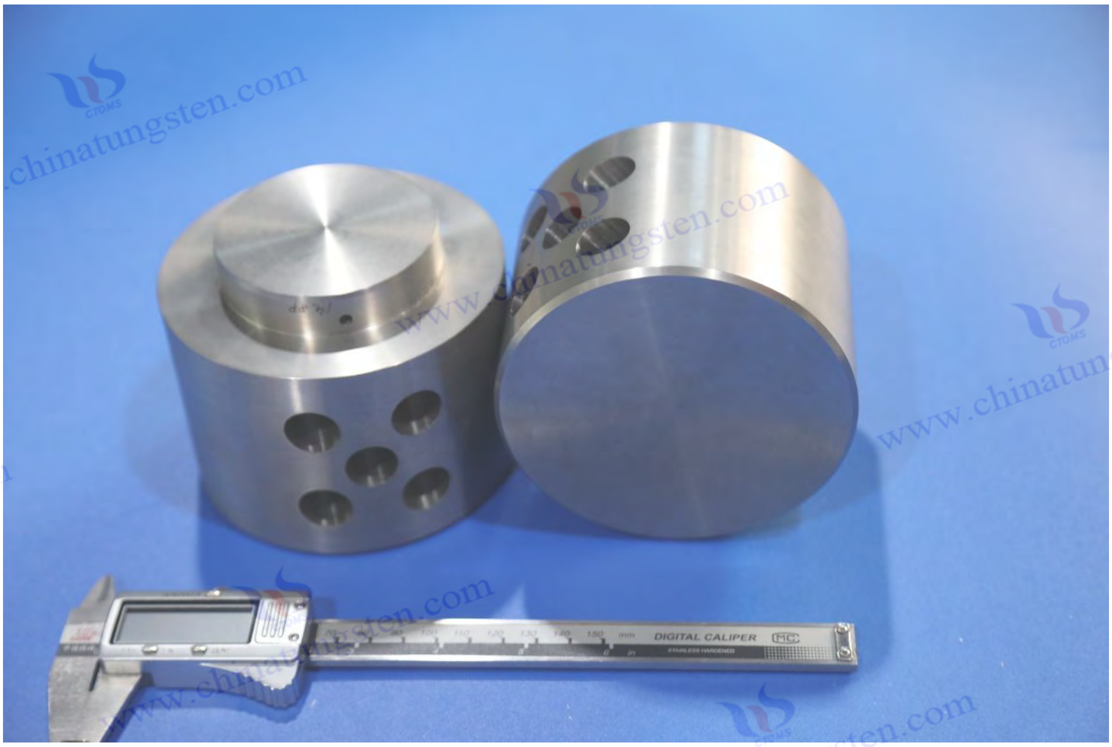
[5] IAEA. SSR-6 Regulations for the Safe Transport of Radioactive Material, 2018 Edition[S]. Vienna: International Atomic Energy Agency, 2018.

[6] J. Scannapieco, P. Carconi. Tungsten-Based Shielding for Hot Cells and Transport Casks[J]. Nuclear Engineering and Design, 2021, 382: 111372.

[7] Y. Chen, L. Zhang, et al. Corrosion and Decontamination Performance of Tungsten Heavy Alloys in Nuclear Environments[J]. Corrosion Science, 2024, 225: 111589.

[8] ISO 13485:2016. Medical Devices — Quality Management Systems — Requirements for Regulatory Purposes[S]. Geneva: International Organization for Standardization, 2016.
[9] M. A. Meyers, K. K. Chawla. Mechanical Behavior of Tungsten Heavy Alloys[J]. Materials Science and Engineering: A, 2022, 845: 143198.
[10] European Commission. Directive 2011/65/EU (RoHS) and Regulation (EC) No 1907/2006 (REACH) — Tungsten Alloys Compliance Report[R]. Brussels, 2023.





CTIA GROUP LTD Tungsten Alloy Shielding Can