

What Are Tungsten Alloy Weights

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

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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.



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CTIA GROUP LTD Tungsten Alloy Weights

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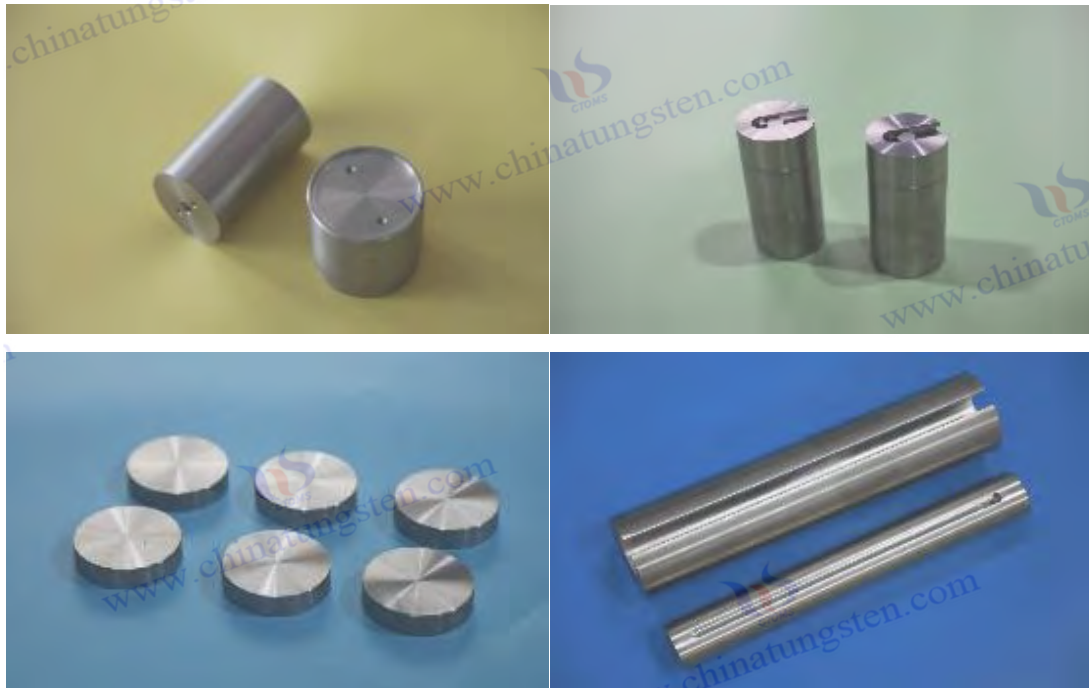
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Chapter 1 Basic Knowledge of Tungsten Alloy Weights

Tungsten alloy weights play an important role in many fields. Their unique physical and chemical properties make them highly favored in industrial, scientific research, and commercial applications.

1.1 Definition and Classification of Tungsten Alloy Weights

Tungsten alloy weights are standard mass instruments made primarily of tungsten and combined with other metal elements (such as nickel, iron, and copper). They are used to calibrate balances and scales, ensuring the accuracy and reliability of measurement results. Their high density, corrosion resistance, and mechanical strength give them significant advantages in precision measurement. Tungsten alloy weights are available in various categories based on their application, accuracy level, and shape, meeting diverse measurement needs.

1.1.1 Definition of Tungsten Alloy Weights

tungsten alloy weights can be understood from three perspectives: composition, function, and application. First, from the perspective of material composition, tungsten alloy weights are alloy products primarily composed of tungsten, typically containing over 90% tungsten, supplemented by elements such as nickel, iron, or copper to enhance their processability and mechanical strength. Tungsten's high density (approximately 19.25 g/cm³) allows it to achieve a high mass within a small volume, a key characteristic that distinguishes it from other metal weights, such as stainless steel or brass. The chemical stability of tungsten alloys also makes it resistant to oxidation and corrosion over long-term use, ensuring consistent quality.

From a functional perspective, tungsten alloy weights are standardized instruments used to calibrate and verify the quality of weighing instruments. In metrology, the quality of weights must conform to international or national standards (such as OIML or JJG standards) to ensure their reliability during the calibration process. Tungsten alloy weights, due to their high density and low volume, are particularly suitable for calibrating small balances requiring high precision, such as laboratory analytical balances or microbalances. Furthermore, tungsten alloy weights exhibit excellent wear resistance, maintaining their surface finish and mass stability even during frequent use, thereby reducing errors caused by wear.

From an application perspective, tungsten alloy weights are widely used in laboratories, industrial production, and commercial metrology. For example, in the pharmaceutical industry, tungsten alloy weights are used to calibrate high-precision scales to ensure the accuracy of drug formulations; in the jewelry industry, their high-precision properties meet the needs of precious metal weighing; and in scientific research, tungsten alloy weights provide a reliable mass benchmark for high-precision experiments. The terminology definition of tungsten alloy weights extends beyond their physical properties to encompass their functional role within standardized metrology systems, making them an indispensable component of modern metrology.

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Tungsten alloy weights can be further clarified by considering their manufacturing process and standardization requirements. During the manufacturing process, tungsten alloy weights are typically made using powder metallurgy, where tungsten powder is mixed with other metal powders, pressed into a compact shape, and then subjected to high-temperature sintering and precision machining. This process ensures the weights' high density and uniformity, while polishing and surface treatment further enhance their corrosion resistance and aesthetics. Regarding standardization, tungsten alloy weights must meet the accuracy grade requirements of international metrology organizations, such as the E1, E2, and F1 grades in the OIML R111 standard. Each grade corresponds to a different error range and usage scenario.

It's important to note that the terminology and definition of tungsten alloy weights are not static but are constantly evolving with advances in materials science and metrology. For example, the development of new tungsten-based alloys may further enhance the performance of weights, such as higher density or improved resistance to environmental interference. In the future, the definition of tungsten alloy weights may also incorporate intelligent elements, such as embedded sensors for real-time quality monitoring. In short, the terminology and definition of tungsten alloy weights are multidimensional, covering aspects such as materials, functions, applications, and standardization, laying the foundation for their important position in modern metrology.

Classification of Tungsten Alloy Weights

Tungsten alloy weights can be classified from many perspectives, including accuracy grade, shape, purpose and manufacturing process.

by precision grade

according to international metrology standards (such as OIML R111), including E1, E2, F1, F2, and M1. E1-grade weights offer the highest accuracy and are suitable for calibrating high-precision laboratory balances, such as for micro-weighing in analytical chemistry experiments. E2 and F1 grades are suitable for general laboratory and industrial use. F2 and M1 grades are more commonly used for routine measurement in commercial and industrial settings. Each precision grade of weight has strict manufacturing requirements for material purity, machining accuracy, and calibration to ensure that its mass tolerances remain within acceptable limits.

weights directly affects their ease of use and applicable scenarios. Common shapes include cylindrical, sheet, block, and hook. Cylindrical weights are often used for laboratory balance calibration due to their simple structure and easy stacking; sheet weights are small and easy to carry, making them suitable for calibrating microbalances; block weights are suitable for calibrating large industrial scales; and hook weights are often used in hanging scales and are convenient for use in dynamic weighing. When designing weights of different shapes, it is necessary to consider center of gravity stability, surface finish, and ease of operation to meet the needs of specific scenarios.

categorized by application

into laboratory weights, industrial weights, and commercial weights. Laboratory weights require high

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precision and stability and are commonly used for balance calibration in chemical, physical, and biological experiments. Industrial weights prioritize durability and a wide weight range, making them suitable for weight testing on production lines. Commercial weights are widely used in markets, trade, jewelry weighing, and other fields, emphasizing portability and affordability. Furthermore, certain specialized tungsten alloy weights, such as calibration weights for aerospace applications, may require additional resistance to vibration and temperature fluctuations.

Mainstream

manufacturing methods include powder metallurgy, precision casting, and CNC machining. Powder metallurgy is the most commonly used process, achieving high density and uniformity, suitable for producing high-precision weights; precision casting is suitable for manufacturing large weights at a relatively low cost; and CNC machining is used to produce weights with complex shapes or customization. In addition, the surface treatment process (such as electroplating, polishing, or coating) also affects the classification of the weight. For example, nickel-plated tungsten alloy weights have higher corrosion resistance and are suitable for use in humid environments.

1.1.2 Classification of Tungsten Alloy Weights by Accuracy Grade

Tungsten alloy weights are categorized by precision grade based on international metrology standards, designed to meet the metrological accuracy requirements of various applications. These precision grades are primarily determined by the weight's mass tolerance, manufacturing process, and calibration requirements. These grades are suitable for a wide range of applications, from high-precision laboratories to routine commercial metrology.

Tungsten alloy weights are typically classified into E1, E2, F1, F2, and M1 grades, each corresponding to different mass tolerances and usage scenarios. E1 grade weights are the most precise, with extremely tight mass tolerances, making them suitable for calibrating high-precision analytical balances. For example, in chemical laboratories, E1 grade weights are often used to calibrate microbalances to ensure that the weighing errors of pharmaceutical formulations or chemical reagents are controlled to the microgram level. The manufacturing process for these weights is extremely rigorous, requiring the use of high-purity tungsten alloy, precision machining, and multiple calibrations to ensure absolute mass accuracy. The surface of E1 grade weights is typically highly polished to reduce mass deviations caused by surface imperfections.

The accuracy of E2-grade weights is slightly lower than that of E1, but they are still suitable for most high-precision laboratory scenarios. For example, in biological experiments, E2-grade weights can be used to calibrate analytical balances to ensure the reliability of sample weighing. E2-grade weights are slightly lower in manufacturing cost than E1, but still require strict quality control, including material selection, processing accuracy and environmental adaptability testing. F1-grade weights are more suitable for general laboratories and industrial scenarios, such as physical experiments or quality inspections in industrial production. F1-grade weights have a slightly looser tolerance range, but their high density and stability can still meet the needs of most high-precision measurement.

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F2 and M1 weights have relatively low precision requirements and are suitable for commercial and general industrial use. For example, in the food processing industry, F2 weights are used to calibrate electronic scales on production lines to ensure that product packaging meets weight standards. M1 weights are often used to calibrate scales in the marketplace, such as those used at farmers' markets. F2 and M1 weights have relatively low requirements for material purity and processing precision during manufacturing, making them more cost-effective. However, their durability and stability are still superior to weights made of other materials, such as brass or cast iron.

Tungsten alloy weights of different precision grades must be selected based on specific application needs. For example, in scenarios requiring extremely high precision, E1 or E2 grade weights are preferred; in cost-sensitive commercial scenarios, F2 or M1 grade weights are more advantageous. Furthermore, the precision grade of a tungsten alloy weight is closely related to its calibration frequency and operating environment. High-precision weights (such as E1 and E2) typically require regular inspection to ensure their quality consistency, while lower precision weights (such as M1) prioritize durability and long-term stability.

From a technical perspective, the accuracy grade of tungsten alloy weights is closely related to their material properties and manufacturing process. Tungsten alloy's high density and low coefficient of thermal expansion enable it to maintain stable quality across varying temperature and humidity environments, which is particularly important for high-precision weights. Furthermore, the powder metallurgy techniques and surface treatment processes (such as electroplating or polishing) used during manufacturing also directly impact the accuracy grade of the weight. For example, E1-grade weights typically require multiple polishing steps to ensure a smooth surface finish, while M1-grade weights may only require basic surface treatment.

1.1.3 Classification of Tungsten Alloy Weights by Application

Tungsten alloy weights are categorized by application scenario based on their practical uses across various industries and fields, encompassing three primary scenarios: laboratory, industrial, and commercial. This classification not only reflects the functional differences of weights but also reflects their diversity in material selection, design, and manufacturing processes. The following will explore the application scenarios and characteristics of tungsten alloy weights from three perspectives: laboratory, industrial, and commercial.

In laboratory settings, tungsten alloy weights are primarily used to calibrate high-precision analytical balances and microbalances, and are widely used in experiments in disciplines such as chemistry, biology, and physics. For example, in pharmaceutical laboratories, tungsten alloy weights are used to calibrate balances to ensure the accuracy of drug formulations; in materials science, weights are used to test the quality characteristics of materials. Laboratory tungsten alloy weights typically have high-precision grades (such as E1 or E2). Their high density enables them to achieve a large mass in a small volume, making them easy to operate in confined spaces. Furthermore, laboratory weights require high surface finish and corrosion resistance to avoid mass deviations caused by environmental factors. Tungsten alloy

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weights also have the advantage of low magnetic susceptibility in the laboratory, which effectively reduces the impact of magnetic field interference on balance calibration.

industrial scenarios , tungsten alloy weights are primarily used to calibrate scales or testing equipment on production lines, and are suitable for fields such as manufacturing, food processing, and chemical production. For example, in automotive manufacturing, tungsten alloy weights can be used to calibrate component weight testing equipment to ensure that product quality meets standards; in the food industry, weights are used to calibrate weighing systems on packaging lines to ensure the accuracy of product weights. Industrial tungsten alloy weights typically have a wide mass range (e.g., from a few grams to several kilograms) to accommodate the calibration needs of scales of varying sizes. In addition, industrial scenarios require high durability and wear resistance from weights. The excellent mechanical properties of tungsten alloy enable them to remain stable under frequent use and in harsh environments. In terms of shape design, industrial weights are mostly block-shaped or hook-shaped , making them easy to operate on large equipment.

commercial applications , tungsten alloy weights are primarily used to calibrate weighing equipment used in market trade, such as electronic scales and platform scales. They are widely used in retail, the jewelry industry, and logistics. For example, in the jewelry market, tungsten alloy weights are used to calibrate high-precision scales to ensure the accurate weighing of precious metals; in farmers' markets, weights are used to calibrate weighing equipment used in daily transactions. Commercial tungsten alloy weights typically have an F2 or M1 accuracy rating, emphasizing portability and affordability. Their design prioritizes ease of use, such as using sheet or small cylindrical designs for easy portability and storage. Furthermore, commercial weights must exhibit a certain degree of resistance to environmental interference to withstand humidity, dust, and other conditions that may exist in the market environment.

Tungsten alloy weights for different application scenarios have different design and manufacturing emphases. For example, laboratory weights prioritize precision and surface finish, industrial weights emphasize durability and a wide weight range, and commercial weights prioritize cost and portability. Furthermore, certain specialized applications may require customized tungsten alloy weights. For example, in aerospace, weights may require additional vibration resistance, while in marine engineering, weights may require special corrosion-resistant coatings. These customized requirements further enrich the application scenarios of tungsten alloy weights.

Looking at development trends, the application scenarios of tungsten alloy weights are likely to expand further with the introduction of intelligent technologies. For example, future weights may be embedded with sensors for real-time quality monitoring or integrated with smart balance systems to improve calibration efficiency. This intelligent trend will bring new possibilities to the application scenarios of tungsten alloy weights, while also placing higher demands on materials and manufacturing processes.

1.2 Composition system and property basis of tungsten-based alloy

Tungsten-based alloys are composite materials primarily composed of tungsten and other metallic or

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non-metallic elements. Their composition directly determines the physical properties, chemical stability, and application range of weights. Tungsten alloy weights' high density, corrosion resistance, and mechanical strength make them ideal for high-precision metrology tools.

1.2.1 Composition of Tungsten Alloy Weights

Tungsten alloy weights are primarily composed of tungsten (W), which typically accounts for over 90% of the alloy's mass. Other metal elements, such as nickel (Ni), iron (Fe), copper (Cu), or cobalt (Co), form a stable alloy system. The selection and proportion of these auxiliary elements significantly influence the alloy's performance.

Tungsten is the core component of tungsten alloy weights. Its high density (approximately 19.25 g/cm³) is key to their ability to achieve high mass within a compact size. Tungsten's high melting point (approximately 3422°C) and excellent chemical stability ensure consistent mass under diverse conditions, which is particularly important for metrological instruments requiring long-term use. Furthermore, tungsten's high hardness reduces wear caused by frequent use, thereby extending the lifespan of the weights. The high tungsten content ensures high density, enabling weights to meet the demands of high precision and compact size in both laboratory and industrial applications.

The selection of auxiliary elements plays a key role in the composition of tungsten alloy weights. Nickel is one of the most commonly used auxiliary elements because it improves the alloy's machinability and toughness. The addition of nickel makes the tungsten alloy easier to form during the powder metallurgy process and improves the surface finish of the weight, facilitating subsequent polishing. Iron is often used in combination with nickel to further enhance the alloy's mechanical strength while reducing manufacturing costs. Copper is used as a binder in some tungsten alloy formulations because of its good ductility and conductivity, which can improve the alloy's machinability. Cobalt is used in some weights with high strength requirements to improve the alloy's wear resistance and impact resistance.

Tungsten alloy weights is often adjusted based on specific application requirements. For example, tungsten alloys used in high-precision laboratory weights may contain a higher proportion of tungsten (above 95%) to maximize density and stability; while weights for industrial or commercial use may have an increased proportion of nickel or copper to balance performance and cost. Furthermore, certain tungsten alloy weights for specialized applications may contain trace elements, such as molybdenum (Mo) or chromium (Cr), to further enhance corrosion resistance or high-temperature performance. These trace element additions undergo rigorous testing to ensure they do not affect the weight's mass accuracy.

Tungsten alloy weights are typically produced using powder metallurgy. This process involves mixing high-purity tungsten powder with other metal powders in appropriate proportions. The final product is then formed through compaction, high-temperature sintering, and precision machining. During the sintering process, auxiliary elements (such as nickel or copper) act as a binder, helping the tungsten particles form a uniform microstructure, thereby increasing the alloy's density and strength. Surface treatments (such as polishing or electroplating) are also crucial to the composition. For example, nickel

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plating further enhances the weight's corrosion resistance and extends its service life in humid or chemical environments.

Tungsten alloy weights also need to consider environmental adaptability. For example, in certain high-humidity or acidic environments, the weight may require a higher nickel or copper content to enhance corrosion resistance. In high-temperature environments, elements such as molybdenum may be added to improve thermal stability. These composition adjustments require precise control during the manufacturing process to ensure that the weights meet the accuracy requirements of international metrology standards (such as OIML R111).

1.2.2 Effect of composition on basic properties of tungsten alloy weights

Tungsten alloy weights have a direct and profound impact on their fundamental properties, such as density, mechanical strength, corrosion resistance, and stability. The choice and proportion of different elements significantly alters the weight's physical and chemical properties, thus determining its suitability for a specific application.

Density : Density is one of the most important properties of tungsten alloy weights, directly determining their ability to achieve high mass within a small volume. Tungsten's high density (approximately 19.25 g/cm³) is the primary source of this high density, significantly higher than stainless steel (approximately 7.9 g/cm³) or brass (approximately 8.5 g/cm³). By adjusting the tungsten content, the alloy's density can be precisely controlled. For example, alloys containing over 95% tungsten have a density close to pure tungsten, making them suitable for high-precision laboratory weights. Alloys containing 80%-90% tungsten have slightly lower densities but lower costs, making them suitable for industrial or commercial use. Supporting elements such as nickel and copper have lower densities (8.9 g/cm³ and 8.96 g/cm³, respectively). Increasing their proportions slightly reduces the alloy's overall density, necessitating a balance between density and cost.

Mechanical strength and toughness : Tungsten itself has high hardness but is brittle and prone to cracking during processing or use. The addition of auxiliary elements such as nickel and iron significantly improves the mechanical strength and toughness of the alloy. Nickel, as a binding phase, can enhance the bonding force between tungsten particles, making the alloy less likely to break when subjected to external force. The addition of iron further improves the tensile strength of the alloy, allowing the weights to withstand certain mechanical stresses during frequent use. For example, in industrial scenarios, tungsten alloy weights may need to withstand impacts during transportation or stacking, and a reasonable ratio of nickel and iron can ensure the structural integrity of the weights. In addition, the addition of cobalt can further enhance the hardness and wear resistance of the alloy, making it suitable for applications requiring high durability.

Corrosion Resistance : The corrosion resistance of tungsten alloy weights is crucial to their long-term stability. Tungsten itself possesses excellent chemical stability and can resist corrosion in most acidic and alkaline environments. However, pure tungsten may undergo slight oxidation under certain specific

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conditions (such as high temperature and high humidity). The addition of nickel and copper significantly enhances the alloy's corrosion resistance. In particular, the surface nickel plating effectively isolates the weight from direct contact with the external environment, reducing the risk of oxidation or corrosion. For example, in pharmaceutical laboratories or marine environments, nickel-plated tungsten alloy weights can maintain long-term quality stability and surface finish. It is important to note that the proportion of auxiliary elements must be strictly controlled. Excessive copper content may reduce the alloy's corrosion resistance in acidic environments.

Thermal Stability : The thermal stability of tungsten alloy weights is key to maintaining consistent mass across varying temperatures. Tungsten's high melting point and low coefficient of thermal expansion (approximately $4.5 \mu\text{m}/\text{m}\cdot\text{K}$) enable it to maintain stable volume and mass despite temperature fluctuations. Ancillary elements such as nickel and iron have higher coefficients of thermal expansion ($13 \mu\text{m}/\text{m}\cdot\text{K}$ and $12 \mu\text{m}/\text{m}\cdot\text{K}$, respectively), so their content must be kept within a reasonable range to minimize the impact of temperature fluctuations on weight accuracy. In certain high-temperature applications (such as calibration in aerospace), high-melting-point elements such as molybdenum can be added to further enhance thermal stability. Furthermore, the high-temperature sintering process during manufacturing optimizes the alloy's microstructure, reducing the impact of thermal stresses on weight performance.

Other Properties : Composition also influences other properties of tungsten alloy weights, such as magnetic susceptibility and surface finish. Tungsten alloy's low magnetic susceptibility makes it less susceptible to interference in electromagnetic environments, making it suitable for calibrating high-precision electronic balances. The addition of nickel helps improve the alloy's machinability, enabling a high-quality surface finish on the weight, reducing mass deviations caused by surface defects. Furthermore, certain tungsten alloy weights for specialized applications may utilize trace elements (such as chromium) to optimize specific properties, such as enhanced UV resistance for outdoor use.

1.2.3 Differences in the properties of commonly used forming processes for tungsten alloy weights

tungsten alloy weights significantly impacts their properties, such as density, mechanical strength, surface quality, and cost. Common molding processes include powder metallurgy, precision casting, and CNC machining, each with distinct process flows, applicable scenarios, and performance characteristics.

most mainstream process for manufacturing tungsten alloy weights, particularly suitable for producing high-precision, high-density weights. The process involves mixing high-purity tungsten powder with other metal powders (such as nickel, iron, or copper) in appropriate proportions. The weights are then formed through compaction, high-temperature sintering, and subsequent precision machining. The advantage of powder metallurgy lies in its ability to achieve extremely high density (approaching 98% or above of theoretical density), ensuring that the weights possess a high mass within a small volume. Furthermore, the process creates a uniform microstructure, reducing internal defects and thereby enhancing the mechanical strength and stability of the weights. After surface polishing, powder metallurgy weights achieve an exceptionally smooth surface finish, helping to reduce quality variations

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caused by surface defects. This makes them suitable for the manufacture of high-precision laboratory weights (such as E1 and E2 grades). However, powder metallurgy carries high process costs, stringent requirements for equipment and raw material purity, and a long production cycle. Therefore, it is more suitable for high-precision, small-batch production.

Tungsten alloy weights by pouring molten metal into a mold. Tungsten and other metal elements are first melted into a liquid alloy, which is then poured into a precision mold and cooled to form the alloy. Finally, the alloy is machined and surface treated. The advantages of precision casting include the ability to quickly produce large weights (such as several kilograms for industrial use) at a lower cost than powder metallurgy. Furthermore, the process is suitable for manufacturing weights with more complex shapes, such as hooks or blocks. However, due to the potential for porosity and inclusions introduced during the casting process, the density and uniformity of precision cast weights are slightly lower than those of powder metallurgy weights, typically requiring F2 or M1 grades. Surface quality may also require additional processing due to casting defects. Precision casting is suitable for mass production of weights in industrial and commercial applications where lower precision is required.

CNC machining involves cutting, grinding, or engraving tungsten alloy blanks using high-precision CNC machine tools to create the final weight. This process is typically performed as a subsequent step in powder metallurgy or precision casting, but it can also be used directly to manufacture small or customized weights. The advantages of CNC machining lie in its high flexibility and precision, enabling the production of weights with complex shapes or non-standard dimensions to meet specific application requirements. For example, certain special-purpose weights may require specific geometries or embedded structures, and CNC machining can accurately achieve these designs. Furthermore, CNC machining ensures surface finish and dimensional accuracy, making it suitable for the final processing of high-precision weights. However, CNC machining results in significant material waste and requires high equipment precision and operating skills, resulting in relatively high costs.

There are significant differences between the three processes in terms of density, surface quality, production efficiency and cost. Powder metallurgy can achieve the highest density and uniformity, and is suitable for high-precision weights, but the cost is high and the cycle is long; precision casting is suitable for the rapid production of large-mass weights, with lower costs, but the density and precision are slightly inferior; CNC machining has advantages in flexibility and surface accuracy, and is suitable for customized needs, but the material utilization rate is low. In actual applications, the choice of process needs to be weighed according to the accuracy level and usage scenario of the weights. For example, high-precision weights for laboratories usually use powder metallurgy combined with CNC machining to ensure quality and surface finish; large-mass weights for industrial use tend to be precision cast to reduce costs; customized weights may rely entirely on CNC machining to meet special design requirements.

1.3 Accuracy grades of weights and measurement transfer systems

Tungsten alloy weights are the core foundation of their application in metrology. The accuracy grade

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determines the weight's mass tolerance and applicable scenarios, while the value transfer system ensures that the weight's mass value remains consistent and traceable across different metrological systems .

1.3.1 Comparison of domestic and international precision standards for tungsten alloy weights

Tungsten alloy weights are crucial regulations in metrology, ensuring that the weight's mass value meets specific tolerances, thereby guaranteeing the reliability and consistency of measurement results. International and domestic accuracy grade standards differ in their definition, classification, and application, but all are based on international metrology organizations (such as OIML) or national metrology regulations. The following detailed analysis of the accuracy grade standards for tungsten alloy weights focuses on international and domestic standards, as well as their correlation .

The R111 standard of the International Organization of Metrology (OIML) is the primary reference for tungsten alloy weight accuracy grades and is widely used in metrology worldwide. This standard categorizes weights into seven accuracy grades: E1, E2, F1, F2, M1, M2, and M3, with E1 being the highest accuracy and M3 being the lowest. E1-grade weights have extremely tight tolerances (for example, a 1kg weight has a tolerance of $\pm 0.5\text{mg}$) and are suitable for calibrating high-precision analytical balances, such as micro-weighing in chemical or pharmaceutical laboratories. E2-grade weights have slightly wider tolerances ($\pm 1.6\text{mg}$ for a 1kg weight) and are suitable for general laboratory balance calibration. Grades F1 and F2 are designed for high-precision industrial and general industrial applications, respectively, with progressively wider tolerances ($\pm 5\text{mg}$ and $\pm 16\text{mg}$ for a 1kg weight, respectively). Grades M1 through M3 are used in commercial and low-precision industrial applications and have wider tolerances ($\pm 50\text{mg}$ for an M1-grade 1kg weight). The OIML R111 standard also clearly stipulates the material, surface quality and calibration requirements for weights. For example, E1 and E2 grade weights must be made of high-density, low-magnetic susceptibility materials (such as tungsten alloy) and require a high-smoothness surface.

China's National Metrology Verification Regulations for Weights (JJG 99-2006) are the primary basis for determining the accuracy grades of tungsten alloy weights. While highly consistent with the OIML R111 standard in terms of classification, there are slight differences in specific requirements and terminology. JJG 99-2006 classifies weights into E1, E2, F1, F2, M1, M2, and M3 grades, with tolerances largely identical to those in OIML R111. For example, the tolerance for an E1 1kg weight is $\pm 0.5\text{mg}$, for an E2, $\pm 1.6\text{mg}$, and so on. The domestic standard also has similar manufacturing and calibration requirements for weights as the international standard, but places greater emphasis on adapting to the specific characteristics of the domestic metrology system. For example, the domestic standard includes more detailed provisions on the environmental compatibility of weights to accommodate China's diverse climate and industrial environment. Furthermore, JJG 99-2006 specifies the calibration cycle and verification process for weights to ensure the stability of their values over long-term use.

OIML R111 and JJG 99-2006 share a similar classification of accuracy grades and tolerance ranges, both using mass tolerance as their core indicator and applying to the same scenarios. For example, both E1 and E2 grades are used in high-precision laboratories, F1 and F2 grades are used in industrial metrology,

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and M1 through M3 grades are used in commercial metrology. However, there are subtle differences in their implementation. As an international standard, OIML R111 emphasizes global applicability and has relatively universal requirements for weight materials and surface treatments. JJG 99-2006, however, incorporates more specific requirements for weight environmental compatibility and verification procedures, tailored to China's specific circumstances.

Tungsten alloy weights enjoy high compatibility with both domestic and international standards. Due to its high density and low magnetic susceptibility, tungsten alloys can meet the high-precision requirements of both OIML R111 and JJG 99-2006 (e.g., grades E1 and E2). In international trade or multinational laboratories, tungsten alloy weights are typically produced and calibrated according to OIML R111 to ensure global traceability. However, in domestic applications, they must comply with the verification requirements of JJG 99-2006 to enter the national metrology system. Furthermore, specialized applications may require customized weights that meet specific requirements of both domestic and international standards.

Comparison of domestic and international precision grade standards provides a foundation for the global application of tungsten alloy weights. For example, in the international pharmaceutical industry, E1-grade tungsten alloy weights must comply with the OIML R111 standard to ensure global consistency in drug formulations. In the Chinese market, M1-grade weights must pass JJG 99-2006 certification for trade settlement purposes. In the future, with advances in metrology technology, precision grade standards may be further refined, for example, through the introduction of tighter tolerances or intelligent calibration methods. Furthermore, the manufacturing processes for tungsten alloy weights (such as powder metallurgy or CNC machining) must be continuously optimized to meet increasingly stringent standards.

1.3.2 Basic process of transferring the value of tungsten alloy weights

Quantity transfer refers to the process of transferring the value of a national or international mass standard to working weights through a series of standardized calibration and verification processes, ensuring the accuracy and consistency of measurement results. Tungsten alloy weights are often used in high-precision quantity transfer systems due to their high density and stability. The basic process includes benchmark establishment, calibration chain construction, verification and transfer, and use and maintenance.

The starting point for the transfer of measurement values is a national or international mass standard, typically implemented using reference weights maintained by the International Bureau of Weights and Measures (BIPM) or a national metrology institute (such as the China National Institute of Metrology). These reference weights are typically made of highly stable materials (such as platinum-iridium alloys), with mass values measured in kilograms (kg) traceable directly to the International Prototype Kilogram or a redefined kilogram based on Planck's constant. While tungsten alloy weights are not used directly as reference weights, their high-precision grades (such as E1 and E2) often serve as secondary standards, accepting measurement values transferred from reference weights. The benchmark establishment phase

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requires high-precision environmental control (such as a constant temperature and humidity laboratory) and measurement equipment (such as a high-precision mass comparator) to ensure the absolute accuracy of the measurement values.

The calibration chain is the core link in the transfer of measurement values. Through the progressive calibration of multiple weights, the value of a reference weight is transferred to the working weight. Tungsten alloy weights are typically used in the calibration chain as secondary reference weights (E1 and E2 grades) or working weights (F1, F2, and M1 grades). The calibration chain follows a strict hierarchical structure: reference weights calibrate primary standard weights (typically E1 grade), which in turn calibrate secondary standard weights (E2 grade), and so on, ultimately transferring the value to the working weights. Tungsten alloy weights, due to their high density and low magnetic susceptibility, reduce environmental interference during the calibration process, ensuring accurate measurement value transfer. Calibration is typically performed in laboratories compliant with international standards (such as OIML R111) or national standards (such as JJG 99-2006), using high-precision balances to compare and calibrate the weight masses.

Verification is a key step in the transfer of measurement values, verifying that the mass value of a weight conforms to its nominal value and accuracy grade. For tungsten alloy weights, the verification process includes mass comparison, environmental control, and error assessment. Mass comparison typically uses a mass comparator to determine the actual mass value and deviation of the tungsten alloy weight by comparing it with a standard weight of the next higher level. Environmental control requires the laboratory to maintain constant temperature, humidity, and air pressure to prevent environmental factors from affecting the calibration results. Error assessment verifies that the mass deviation is within the allowable tolerance range based on the weight's accuracy grade (for example, the tolerance of an E1-grade 1kg weight is $\pm 0.5\text{mg}$). Tungsten alloy weights that pass verification receive a calibration certificate documenting their mass value and uncertainty, serving as proof of the transfer of measurement value. The transfer process may involve multiple levels of metrology institutions, such as from a national metrology institute to a provincial metrology institute, then to a local metrology station, and ultimately to the user.

The final step in the transfer of measurement value is the application of calibrated tungsten alloy weights in actual metrological scenarios, such as laboratory balance calibration, industrial production line testing, or commercial trade weighing. During use, tungsten alloy weights must follow strict operating specifications, such as using special fixtures to avoid direct contact and prevent surface contamination or wear. In terms of maintenance, weights need to be inspected regularly to ensure their quality stability. Especially in high-precision scenarios (such as E1 and E2 grades), the calibration cycle is usually 1-2 years. The high corrosion resistance and mechanical strength of tungsten alloy weights enable them to maintain stable mass values during long-term use, but they still need to avoid exposure to extreme environments (such as strong acids and alkalis or high temperatures) to extend their service life.

Tungsten alloy weights in measurement transfer lies in their high density and stability, enabling high-precision measurement in a small volume, making them suitable for calibration needs in a variety of

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scenarios. For example, in laboratories, E1-grade tungsten alloy weights can be used to calibrate microbalances; in industry, F1-grade weights can be used to calibrate electronic scales on production lines. The measurement transfer process emphasizes traceability and standardization, ensuring that the quality value of tungsten alloy weights can be traced back to international or national benchmarks, thereby ensuring the consistency of global measurement results. In the future, with the development of intelligent metrology technology, the measurement transfer process may be integrated into automated calibration systems, such as using sensors to monitor weight quality in real time, further improving transfer efficiency and accuracy.

1.3.3 Transfer requirements for different grades of tungsten alloy weights

Tungsten alloy weights of different accuracy levels have different requirements for measuring value transfer, involving calibration equipment, environmental conditions, verification cycles, and usage specifications. These requirements directly affect the quality stability of the weights and the reliability of the measurement results.

E1-grade tungsten alloy weights are the most precise, with extremely tight tolerances (for example, ± 0.5 mg for a 1 kg weight). They are primarily used for calibrating high-precision laboratory balances, such as those used in chemical analysis or pharmaceutical testing. Transfer requirements are extremely stringent: calibration must be performed at a national metrology institute or an accredited high-quality laboratory using a high-precision mass comparator (with microgram resolution). Environmental conditions must be strictly controlled, with a stable temperature of $20 \pm 0.5^{\circ}\text{C}$, humidity of $50 \pm 10\%$, and minimal air pressure fluctuations. The calibration process utilizes a multi-point comparison method, with multiple measurements against a reference weight, to reduce uncertainty. E1-grade weights require an extremely high surface finish and are typically manufactured using powder metallurgy combined with CNC machining and nickel-plated for corrosion resistance. Verification cycles are short (typically one year), and specialized fixtures must be used to prevent hand contamination. The transfer of E1-grade weights is primarily used to establish secondary standards and ensure traceability in high-precision metrology systems.

E2-grade weights have slightly looser tolerances (± 1.6 mg for a 1 kg weight) and are suitable for general laboratory balance calibration, such as in biological experiments or materials testing. Transfer requirements are slightly lower than those for E1-grade weights, but they still need to be performed in a high-precision laboratory, typically using a mass comparator with a resolution of 0.01 mg. Environmental conditions require a controlled temperature of $20 \pm 1^{\circ}\text{C}$ and a humidity of 40-60% to minimize the effects of thermal expansion and moisture on mass. Calibration uses the standard comparison method, comparing the mass with an E1 or reference weight, and recording mass deviations and uncertainties. The manufacturing process for E2-grade weights is similar to that for E1, but with slightly lower requirements for surface finish and material purity, resulting in a more economical cost. Calibration intervals are typically one to two years, and weights must be protected from mechanical damage and chemical corrosion. E2-grade weights are often used as primary standard weights to transfer values to secondary standards or working weights.

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The tolerance of F1-grade weights is $\pm 5\text{mg}$ (1kg weights), which are suitable for high-precision industrial scenarios or general laboratories, such as physical experiments or production line quality inspections. The transfer requirements are relatively loose and can be carried out in provincial metrology institutes or accredited laboratories, using a mass comparator with a resolution of 0.1mg . Environmental conditions require that the temperature be controlled at $20\pm 2^\circ\text{C}$ and the humidity be between 30-70%, with low sensitivity to air pressure fluctuations. The calibration process is mainly based on the single-point comparison method, which is highly efficient. F1-grade weights are usually manufactured using powder metallurgy or precision casting processes, and the surface can be polished or coated to enhance durability. The calibration cycle is 2-3 years, and care should be taken to avoid gravity shock and long-term exposure to humid environments during use.

F2 (1kg weight tolerance $\pm 16\text{mg}$) and M1 ($\pm 50\text{mg}$) grade weights are suitable for commercial and general industrial applications, such as food processing, trade settlement, and logistics weighing. Transfer requirements are further relaxed, allowing them to be performed at local metrology stations or user laboratories using a standard balance with a 1mg resolution. Environmental conditions are relatively relaxed, with a temperature of $20\pm 5^\circ\text{C}$ and a humidity range of 20-80%, making them highly tolerant of environmental interference. The calibration process is simple, typically using the direct comparison method, which is efficient and low-cost. F2 and M1 grade weights are often precision-cast, which is low-cost and suitable for mass production. Basic polishing is the primary surface finish. Calibration intervals are 3-5 years, with emphasis on durability and portability. F2 and M1 grade weights are primarily used for calibrating daily working weights in value transfer, meeting the basic needs of commercial metrology.

different grades of tungsten alloy weights reflect the balance between precision, cost, and application scenarios. E1 and E2 grade weights have stringent transfer requirements and are suitable for high-precision laboratories; F1 grade is suitable for industrial high-precision applications; and F2 and M1 grades prioritize economy and durability to meet commercial needs. The high density and stability of tungsten alloy weights ensure excellent performance in all grades of transfer, especially in high-precision applications.



CTIA GROUP LTD Tungsten Alloy Weights

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Chapter 2 Basic Characteristics of Tungsten Alloy Weights

Tungsten alloy weights, due to their unique physical and chemical properties, demonstrate exceptional performance in metrology, making them an ideal choice for high-precision calibration and scale verification. This chapter will focus on the fundamental characteristics of tungsten alloy weights, particularly their density and volumetric properties, which directly determine their advantages in various applications.

2.1 Density and Volume Characteristics of Tungsten Alloy Weights

Tungsten alloy weights are their core advantages over weights made of other materials, such as stainless steel or brass. Tungsten's high density and excellent material stability enable it to achieve a large mass within a small volume, which is particularly important for high-precision metrology and space-constrained applications.

2.1.1 Parameter range of high density tungsten alloy weights

One of the most striking properties of tungsten alloy weights is their high density, a result of both the inherent high density of tungsten and an optimized alloying process. Tungsten has a density of approximately 19.25 g/cm³, close to that of gold (19.32 g/cm³) and significantly higher than common metals such as stainless steel (approximately 7.9 g/cm³) or brass (approximately 8.5 g/cm³). By adding auxiliary elements (such as nickel, iron, or copper) to the tungsten-based alloy, the density of tungsten alloy weights can be adjusted within a certain range, typically between 15 and 18 g/cm³, depending on the alloy composition and manufacturing process.

Tungsten alloy weights is primarily determined by the tungsten content. Alloys with a higher tungsten content (90%-97%) typically have a density between 17-18 g/cm³, close to the theoretical density of pure tungsten, making them suitable for high-precision laboratory weights (such as grades E1 and E2). For example, alloys with a 95% tungsten content can reach a density of 17.5-18 g/cm³, enabling a large mass within a very small volume, ideal for microbalance calibration. Alloys with a lower tungsten content (80%-90%) have a density between 15-16.5 g/cm³ and are suitable for industrial or commercial weights (such as grades F2 and M1), maintaining high density while reducing manufacturing costs. The addition of auxiliary elements such as nickel (density 8.9 g/cm³) and copper (8.96 g/cm³) slightly reduces the overall density but improves the alloy's workability and toughness.

The manufacturing process also has a crucial impact on the density of tungsten alloy weights. Powder metallurgy is the mainstream process for producing high-density tungsten alloy weights. Through high-temperature sintering and press molding, the alloy density can reach over 98% of the theoretical density. For example, tungsten alloy weights using an optimized sintering process can achieve a stable density of 17.8-18 g/cm³, close to the level of pure tungsten. In contrast, the precision casting process may result in a slightly lower density (approximately 15-16.5 g/cm³) due to pores or microscopic defects, making it suitable for scenarios with slightly lower density requirements. CNC machining further optimizes the

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dimensional accuracy of weights through precision cutting, but has little effect on density and is mainly used to improve surface quality and shape accuracy.

The high-density parameters of tungsten alloy weights are also affected by trace elements and surface treatment. For example, adding small amounts of cobalt or molybdenum can slightly increase density and mechanical strength, but this may increase cost. Surface plating (such as nickel plating) forms a thin coating on the weight surface, slightly changing the overall density, but the effect is generally negligible. Furthermore, the stability of density parameters is a key advantage of tungsten alloy weights. Tungsten's low thermal expansion coefficient (approximately $4.5 \mu\text{m} / \text{m} \cdot \text{K}$) and high chemical stability enable it to maintain a constant density under varying temperature and humidity conditions, thus ensuring the long-term stability of the weight's quality.

In practical applications, the high density parameter range enables tungsten alloy weights to meet diverse metrological needs. For example, in laboratories, high-density weights ($17\text{-}18 \text{ g/cm}^3$) can achieve masses of 1g to 100g in a small volume, making them suitable for calibrating high-precision analytical balances. In industrial settings, slightly lower density weights ($15\text{-}16.5 \text{ g/cm}^3$) can be used to calibrate large-mass scales, balancing performance and cost. The high density parameter range of tungsten alloy weights also opens up potential for application in specialized applications, such as aerospace and marine engineering, which often require weights to achieve high-precision measurement within limited space.

2.1.2 Advantages of Tungsten Alloy Weights: Small Volume and High Weight Capacity

Tungsten alloy weights to carry large amounts of weight in a small volume is a direct reflection of their high density, making them a significant advantage in space-constrained or high-precision metrology applications. Compared to traditional materials (such as stainless steel or cast iron), tungsten alloy weights can achieve the same mass in a smaller volume, thereby improving metrology efficiency, portability, and ease of use.

The advantage of carrying a large weight in a small volume stems from tungsten alloy's high density. Density (ρ) is defined as the ratio of mass (m) to volume (V) ($\rho = m/V$). Given the same mass, tungsten alloy's high density allows it to be significantly smaller than less dense materials. For example, a 1kg tungsten alloy weight (density approximately 17.5 g/cm^3) has a volume of only 57 cm^3 , while a stainless steel weight of the same mass (density approximately 7.9 g/cm^3) has a volume of approximately 126 cm^3 , nearly double the volume difference. This volume advantage enables tungsten alloy weights to more efficiently complete calibration tasks in space-constrained environments, while also reducing the space required on balances or scale trays.

The ability to carry large weights in a small volume makes tungsten alloy weights excellent in a variety of scenarios. In laboratory environments, high-precision analytical balances typically have smaller weighing pans, and the small size of tungsten alloy weights can be easily adapted to facilitate the calibration of micro-samples (e.g., 0.1mg to 10g). For example, in pharmaceutical laboratories, tungsten alloy weights can be used to calibrate microbalances to ensure the accuracy of drug formulations. In

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industrial scenarios, the small size of tungsten alloy weights makes them easy to operate in compact scales on production lines, such as calibrating small weighing equipment in electronics manufacturing. Furthermore, in commercial fields (such as the jewelry industry), the small size of tungsten alloy weights makes them easy to carry and store, making them suitable for on-site calibration of precious metal weighing equipment.

Compared with weights made of traditional materials, tungsten alloy weights have a significant advantage in their small size. Traditional stainless steel weights have a lower density and are larger for the same mass, which may cause overloading of the balance pan or inconvenience in operation. Although cast iron weights are low-cost, they are larger and are susceptible to corrosion, affecting quality stability. The small size of tungsten alloy weights not only improves space utilization but also reduces transportation and storage costs. For example, a set of tungsten alloy weights ranging from 1g to 100g can be placed in a small calibration box, which is convenient for laboratory or field use, while stainless steel weights of the same mass may require larger storage space. In addition, the low magnetic susceptibility and corrosion resistance of tungsten alloy weights enable them to maintain stable performance even in complex environments, further enhancing their application value.

Tungsten alloy weights in a compact package, capable of carrying large amounts of weight, is closely related to their manufacturing process. Powder metallurgy produces tungsten alloy weights with a high density and uniform structure, ensuring consistent quality despite their compact size. CNC machining further optimizes the weight's shape and dimensional accuracy, adapting it to the design requirements of various balances. For example, cylindrical or sheet-shaped tungsten alloy weights maximize space utilization, making them easy to stack or combine. Surface treatments (such as nickel plating or polishing) not only enhance corrosion resistance but also reduce quality deviations caused by surface defects, ensuring high precision for these compact weights.

2.1.3 The matching ratio characteristics of volume and weight of tungsten alloy weights

Tungsten alloy weights allows them to flexibly measure varying masses within a specific volume range. This characteristic stems from the high density of tungsten alloy and the precise control of the manufacturing process. This adaptive ratio enables tungsten alloy weights to achieve efficient and accurate measurement in laboratories, industry, and commercial settings.

tungsten alloy weights is based on their high density. The density formula $\rho = m/V$ states that, given a constant mass (m), the higher the density (ρ), the smaller the volume (V). Tungsten alloy typically has a density between 15 and 18 g/cm³, significantly higher than stainless steel (approximately 7.9 g/cm³) or brass (approximately 8.5 g/cm³). This means that tungsten alloy weights can achieve the same mass within a smaller volume. For example, a 100g tungsten alloy weight (density approximately 17.5 g/cm³) has a volume of approximately 5.7 cm³, while a stainless steel weight of the same mass has a volume of approximately 12.7 cm³. This high density gives tungsten alloy weights an excellent balance between volume and weight, allowing weights with varying mass and volume combinations to be designed to meet application requirements.

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The design of tungsten alloy weights requires a comprehensive consideration of their accuracy grade, shape, and manufacturing process. High-precision weights (such as E1 and E2 grades) typically utilize alloys with a high tungsten content (density 17-18 g/cm³) to achieve the target mass within the smallest possible volume, making them suitable for microbalance calibration. Shape also influences the matching ratio. For example, cylindrical weights are easier to stack and handle, sheet weights are suitable for micro-mass calibration, and block weights are suitable for large-mass industrial applications. Manufacturing processes (such as powder metallurgy) optimize alloy density and microstructure to ensure a precise matching of volume and weight. For example, through precision pressing and high-temperature sintering, the density of a weight can be brought close to the theoretical value, minimizing the impact of volume fluctuations on mass. Surface treatments (such as polishing or nickel plating) further optimize the weight's dimensional accuracy and ensure the stability of the matching ratio.

The volume-weight adaptation ratio makes tungsten alloy weights perform well in a variety of scenarios. In the laboratory, high-density tungsten alloy weights can achieve a mass of 1mg to 100g in a tiny volume, which is suitable for the tray space of small analytical balances, such as for calibration of pharmaceutical formulations or chemical experiments. In industrial scenarios, tungsten alloy weights can be designed as block structures with large mass (1kg to 50kg) but moderate volume, suitable for calibrating large scales on production lines, such as weighing equipment in automotive manufacturing or food processing. In the commercial field, the small size of tungsten alloy weights makes them easy to carry and store, for example, they are used to calibrate precious metal weighing equipment in the jewelry industry. The flexibility of the adaptation ratio is also reflected in customized needs. For example, the aerospace field may require weights of specific mass and volume to adapt to compact calibration equipment.

Tungsten alloy weights, with their well-matched volume and weight ratio, lies in their efficient space utilization and flexible design capabilities. Their small size and high weight reduce the need for balance trays or storage space, improving operational convenience and transportation efficiency. Furthermore, their high density enables weights to achieve finer mass grading in high-precision scenarios, meeting the needs of micro-measurements. However, this characteristic also presents some challenges, such as the high manufacturing cost of alloys with high tungsten content and the stringent requirements on processing equipment and process accuracy.

2.2 Mechanical and Durability Characteristics of Tungsten Alloy Weights

Tungsten alloy weights are key to their stable performance over long-term use. These include high hardness, wear resistance, impact resistance, and corrosion resistance. These characteristics enable tungsten alloy weights to maintain mass accuracy and physical integrity despite frequent operation and complex environments.

2.2.1 The manifestation of high hardness of tungsten alloy weights

Tungsten alloy weights is an important manifestation of their mechanical properties, which directly affects their wear resistance and deformation resistance, thereby ensuring quality stability and reliability

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in long-term use.

Tungsten alloy weights stems from the inherent properties of tungsten . Pure tungsten has a Mohs hardness of approximately 7.5, close to that of some ceramics and significantly higher than stainless steel (approximately 5.5) or brass. By adding auxiliary elements such as nickel, iron, or cobalt, the hardness of tungsten alloys can be adjusted within a certain range, typically between 250 and 400 Vickers hardness (HV), depending on the alloy formulation and manufacturing process. This high hardness enables tungsten alloy weights to resist surface scratches and wear, maintaining consistent quality over long-term use. For example, in situations where weights are frequently handled or stacked, their high hardness effectively reduces surface damage and prevents quality deviations caused by wear.

Tungsten alloy weights is directly affected by its composition. Alloys with a high tungsten content (90%-97%) have a high hardness, approaching that of pure tungsten, making them suitable for high-precision weights (such as E1 and E2 grades) and able to withstand frequent calibration operations in the laboratory. The addition of auxiliary elements such as nickel and iron, while slightly reducing hardness, significantly improves the alloy's toughness, preventing brittle fracture caused by excessive hardness. For example, a tungsten alloy containing 5% nickel and 3% iron has a hardness of approximately HV 300, maintaining high hardness while providing sufficient impact resistance. The addition of cobalt further increases hardness (to over HV 400), making it suitable for industrial weights requiring extremely high wear resistance, but at a higher cost. The addition of trace elements such as chromium or molybdenum can also optimize hardness while enhancing corrosion resistance.

The manufacturing process is crucial to the hardness of tungsten alloy weights. Powder metallurgy is the mainstream process for producing high-hardness weights. Through high-temperature sintering and press molding, a dense microstructure is formed, improving hardness and strength. For example, optimizing the sintering process can tightly bond tungsten particles with a binder phase (such as nickel), resulting in a hardness close to the theoretical value. Weights produced using precision casting have a slightly lower hardness (HV 250-300) due to the possible presence of tiny pores, but are suitable for the manufacture of large-mass weights. CNC machining further improves surface hardness and finish through precision cutting and polishing, reducing the risk of wear caused by surface defects. Surface treatments (such as nickel plating or nitriding) can form a protective layer with even higher hardness. For example, the hardness of the nickel plating can reach over HV 500, significantly improving the wear resistance of the weight.

The high hardness enables tungsten alloy weights to excel in a variety of scenarios. In the laboratory, high-hardness weights can withstand frequent clamping and stacking operations, maintaining surface finish and mass accuracy, such as E1-grade weights used to calibrate microbalances. In industrial scenarios, high-hardness weights can withstand mechanical shock and wear on the production line and are suitable for calibrating large scales, such as weighing equipment in food processing or automotive manufacturing. In the commercial field, the wear resistance of high-hardness weights ensures their long-term reliability in market trade, such as maintaining stable quality in jewelry weighing. In addition, high hardness reduces the risk of dust or contaminants being attracted to the weight due to surface damage,

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helping to maintain measurement accuracy.

Tungsten alloy weights' high hardness lie in their excellent wear resistance and deformation resistance, which extend their service life and ensure accurate measurement. However, high hardness can increase machining difficulties, such as increased tool wear in CNC machining, driving up manufacturing costs. Furthermore, excessive hardness can make the weights somewhat brittle, necessitating a balance between hardness and toughness by optimizing the ratio of auxiliary elements (such as increasing nickel content). Future development of new tungsten-based composite materials may further enhance hardness while also improving toughness and processability. For example, the addition of nanoscale reinforcements (such as tungsten carbide particles) can achieve hardness exceeding HV 450 while maintaining good impact resistance, offering new avenues for the manufacture of high-durability weights.

2.2.2 High Strength of Tungsten Alloy Weights

Tungsten alloy weights is a key component of their mechanical properties, enabling them to maintain structural integrity and quality stability despite frequent handling, stacking, and external impact. Strength reflects a material's ability to resist deformation or fracture. Tungsten alloy weights, through their unique material composition and manufacturing process, demonstrate exceptional strength in a variety of applications.

Tungsten inherently possesses extremely high tensile and compressive strengths, but it is also brittle and prone to fracture under impact. To overcome this limitation, tungsten alloy weights are often infused with auxiliary elements such as nickel, iron, or cobalt to create a composite material that combines both strength and toughness. These elements act as a binder, strengthening the bonds between tungsten particles and making the alloy less susceptible to cracking or deformation when subjected to external forces. The high strength of tungsten alloy weights enables them to withstand high-intensity operating environments, such as frequent handling on industrial production lines or repeated clamping in laboratories, without causing structural damage due to external forces.

Tungsten alloy weights is directly affected by their composition. Alloys with a high tungsten content (usually over 90%) retain tungsten's high strength properties and are suitable for applications requiring high durability, such as high-precision laboratory weights. The addition of nickel significantly improves the alloy's toughness, allowing it to absorb some impact energy while maintaining high strength and prevent brittle fracture. Iron, as a supporting element, further enhances the tensile strength, allowing the weights to withstand greater mechanical stress when stacked or transported. The addition of cobalt plays a key role in certain weights with high strength requirements, improving the alloy's fatigue resistance and making it suitable for long-term, high-intensity use. Optimizing the composition ratio requires balancing strength, toughness, and cost to meet the needs of different precision levels and application scenarios.

The manufacturing process is crucial to the strength of tungsten alloy weights. Powder metallurgy is the mainstream process for producing high-strength weights. Through high-pressure pressing and high-

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temperature sintering, a dense microstructure is formed, strengthening the bond between the tungsten particles and the binder phase. This process maximizes the alloy's strength and reduces internal defects such as pores or cracks. Precision casting is suitable for the manufacture of large-mass weights. Although its strength is slightly lower than that of powder metallurgy, it can still achieve high tensile strength through optimized mold design and cooling processes. CNC machining further improves the structural integrity of the weight through precision cutting and surface treatment, ensuring its stability during high-intensity operation. Surface coatings (such as nickel plating) can also enhance surface strength to a certain extent and reduce local damage caused by external forces.

Tungsten alloy weights excels in a variety of scenarios. In the laboratory, high-strength weights can withstand frequent clamping and stacking operations. For example, when calibrating analytical balances, E1 or E2 grade weights must withstand multiple operations while maintaining their shape. In industrial scenarios, high-strength weights are suitable for calibrating large scales, such as weighing equipment on production lines, and can withstand the impact of handling, stacking, and even accidental drops. In the commercial field, the durability of high-strength weights ensures their long-term reliability in market trade, such as weights used repeatedly in farmers' markets or the jewelry industry. High strength also reduces the risk of quality deviation caused by mechanical damage to the weights, ensuring measurement accuracy.

2.2.3 Long-term wear resistance of tungsten alloy weights

tungsten alloy weights is a key indicator of their durability, enabling them to maintain surface finish and quality stability during long-term, frequent use. Wear resistance directly affects the metrological accuracy of weights, especially in high-precision applications, where surface wear can lead to mass deviation or calibration errors.

Tungsten alloy weights stems from tungsten's high hardness and wear resistance. Tungsten has a high Mohs hardness, making it highly resistant to surface scratches and abrasion. The addition of auxiliary elements such as nickel and cobalt further optimizes the alloy's wear resistance. Nickel increases surface toughness, reducing material loss due to friction, while cobalt enhances wear resistance, making it suitable for high-intensity use. Tungsten alloy's low coefficient of friction also makes it less susceptible to wear when in contact with the balance pan or other weights, preserving surface integrity over long-term use. This wear resistance ensures that the weights maintain their high quality and precision even after repeated use.

The manufacturing process significantly impacts the wear resistance of tungsten alloy weights. Powder metallurgy creates a dense microstructure through high-temperature sintering, reducing surface porosity and defects and improving wear resistance. Precision polishing is a key step in improving wear resistance. The polished weights achieve a smooth surface finish and a low coefficient of friction, effectively reducing wear on fixtures or balance pans. Surface coatings (such as nickel or chrome) further enhance wear resistance. The high-hardness of the coating forms a protective layer against external friction and minor scratches.

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Tungsten alloy weights excels in a variety of scenarios. In laboratories, high-precision weights (such as E1 and E2 grades) are subject to frequent handling and placement. Their wear resistance ensures surface finish remains intact, preventing quality deviations caused by wear. In industrial settings, weights may face frequent handling and stacking on production lines. Their wear resistance enables them to withstand repeated contact with metal surfaces, making them suitable for calibrating large scales.

While tungsten alloy weights offer excellent wear resistance, they still require proper maintenance for long-term use. For example, using specialized fixtures to avoid direct hand contact and regularly cleaning to remove surface contaminants can prevent further wear. Future improvements in wear resistance may be achieved through the development of new surface coatings (such as nanocoatings) or by optimizing alloy formulations, such as adding tungsten carbide particles to further enhance surface hardness and wear resistance.

2.2.4 Environmental adaptability of tungsten alloy weights to corrosion resistance

Tungsten alloy weights is an important indicator of their environmental adaptability, enabling them to maintain mass stability and surface integrity in humid, acidic, alkaline, and other challenging environments. Corrosion resistance is crucial for the long-term use of weights, especially in high-precision metrology, where corrosion can cause mass deviation or calibration failure.

Tungsten inherently possesses excellent chemical stability, resisting attack from most acidic and alkaline environments. It exhibits exceptional resistance to oxidation and corrosion at room temperature. Tungsten alloy weights further enhance their corrosion resistance by adding auxiliary elements such as nickel, copper, or chromium. Nickel forms a stable oxide layer that effectively isolates the alloy from moisture and chemicals; copper enhances the alloy's stability in humid environments; and chromium, in certain specialized formulations, enhances resistance to acid and alkaline corrosion. These properties enable tungsten alloy weights to maintain consistent quality in a variety of environments, preventing surface damage or weight loss due to corrosion.

Tungsten alloy weights is closely related to their composition and manufacturing process. Alloys with a high tungsten content (above 90%) retain tungsten's corrosion resistance and are suitable for use in harsh environments. A balanced ratio of nickel and copper optimizes the alloy's performance in humid or slightly acidic or alkaline environments, such as those found in coastal areas or chemical laboratories. During the manufacturing process, powder metallurgy creates a dense structure through high-temperature sintering, reducing porosity and microscopic defects, thereby reducing the risk of corrosion. Surface treatment is key to improving corrosion resistance. For example, nickel or chrome plating creates a protective layer on the weight's surface, effectively resisting erosion by moisture, acid, alkali, or salt spray. Polishing further enhances environmental adaptability by reducing surface roughness and reducing the number of attachment points for corrosive media.

Tungsten alloy weights makes them suitable for use in a variety of challenging environments. In the commercial sector, corrosion-resistant weights are ideal for outdoor or humid market environments, such

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as calibrating weighing equipment at farmers' markets. Their corrosion resistance also reduces the need for maintenance due to environmental factors, extending the weight's lifespan.

2.3 Metrological stability characteristics of tungsten alloy weights

Tungsten alloy weights is their core advantage in high-precision metrology applications, which is reflected in the long-term stability of mass value, the accuracy of surface state, and the ability to resist magnetic interference.

Factors that contribute to the long-term stability of the mass value of tungsten alloy weights

Tungsten alloy weights refers to their ability to maintain their nominal mass over extended periods of use and under a variety of environmental conditions. This property is crucial for ensuring the accuracy and traceability of measurement results, especially in high-precision applications such as laboratory calibration. The following analyzes the key factors influencing the long-term stability of tungsten alloy weights, including material properties, composition design, manufacturing process, and environmental adaptability.

Tungsten alloy weights is primarily due to tungsten's high chemical stability and low thermal expansion coefficient. At room temperature, tungsten is extremely resistant to oxidation, acids, alkalis, and other chemicals, effectively preventing mass loss due to corrosion. Its low thermal expansion coefficient ensures minimal volume change with temperature fluctuations, thus maintaining stable quality. The addition of auxiliary elements such as nickel and iron further enhances the alloy's structural stability, minimizing microstructural changes caused by long-term use. These material properties enable tungsten alloy weights to maintain consistent quality over time in a variety of environments.

Tungsten alloy weights is crucial to quality stability. Alloys with a high tungsten content (typically above 90%) maximize tungsten stability and are suitable for high-precision weights (such as E1 and E2 grades). Nickel, as the primary binder phase, not only enhances the alloy's toughness but also forms a stable oxide layer, protecting the weight from environmental degradation. The addition of iron or cobalt enhances the alloy's mechanical strength and reduces quality deviations caused by external impact or wear. The composition ratio must be precisely optimized to balance stability, cost, and processability. For example, increasing the nickel content improves corrosion resistance, but excessively high proportions of auxiliary elements may slightly reduce density, requiring careful consideration during design.

The manufacturing process directly impacts the quality stability of tungsten alloy weights. Powder metallurgy is the mainstream process for producing high-precision weights. Through high-pressure pressing and high-temperature sintering, it forms a dense microstructure, reduces internal porosity and defects, and ensures long-term quality stability. Precision polishing and surface coatings (such as nickel plating) further enhance the weight's resistance to corrosion and wear, preventing quality fluctuations caused by surface damage. CNC machining, by precisely controlling dimensions and surface finish, ensures that the weight's mass reaches the nominal value during manufacturing and remains consistent

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over long-term use. High-quality manufacturing processes minimize quality fluctuations caused by process defects.

2.3.2 Effect of surface condition on the measurement accuracy of tungsten alloy weights

Tungsten alloy weights significantly impacts their metrological accuracy. Surface finish, flatness, and the quality of the protective coating directly determine the weight's mass stability and calibration reliability. Poor surface condition can lead to mass deviation, adsorption of contaminants, or calibration errors, a particularly significant impact in high-precision metrology scenarios.

Tungsten alloy weights primarily involves smoothness, flatness, and the integrity of the surface protective layer. A high-quality surface reduces friction and wear, preventing quality loss due to surface scratches. Flatness ensures even force distribution when the weight contacts the balance pan, avoiding measurement errors caused by uneven contact. A surface protective layer (such as nickel or chrome plating) shields the weight from external moisture and chemicals, preventing corrosion that can affect quality. The high hardness and machinability of tungsten alloy weights enable precision machining to achieve high smoothness and flatness, meeting the requirements of high-precision measurement.

The impact of surface condition on the metrological accuracy of tungsten alloy weights is significant in various scenarios. In the laboratory, high-precision weights (such as E1 and E2 grades) require an extremely smooth surface finish to prevent mass deviations caused by surface defects that attract dust or moisture. For example, in microbalance calibration, surface scratches can increase mass uncertainty and affect experimental results. In industrial settings, weight surfaces are subject to frequent handling and contact, and good surface condition reduces wear and ensures calibration accuracy. In the commercial sector, surface stability directly impacts the reliability of weights used in trade weighing. For example, in the jewelry industry, weights with a smooth surface maintain long-term metrological consistency. To maintain the surface condition's role in ensuring metrological accuracy, tungsten alloy weights require strict maintenance protocols. Use specialized fixtures to avoid direct hand contact and prevent contamination from sweat or oil. Regular cleaning is required to remove dust and chemical residues and maintain a smooth finish. Use a dedicated calibration box for storage to prevent scratches caused by contact with hard objects. Regular inspection and maintenance of the surface coating also prolongs the weight's corrosion resistance and ensures metrological accuracy. In the future, new surface treatment technologies (such as nanocoating) may further improve the stability of surface conditions and reduce maintenance frequency.

2.3.3 Metrological assurance characteristics of tungsten alloy weights against magnetic interference

Tungsten alloy weights' resistance to magnetic interference is a crucial factor in ensuring metrological stability, particularly in high-precision electronic balance calibrations, where magnetic interference can lead to significant metrological errors. Tungsten alloy's low magnetic susceptibility enables it to maintain

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accurate mass values in electromagnetic environments, providing reliable support for high-precision metrology.

Tungsten alloys stem from tungsten's low magnetic susceptibility. Pure tungsten is non-magnetic or weakly paramagnetic, with an extremely low magnetic susceptibility, far lower than that of ferromagnetic materials such as steel or nickel. The choice of auxiliary elements significantly influences the ability to resist magnetic interference. Although nickel exhibits some magnetic properties, its content in tungsten alloys is relatively low (typically 5%-10%). The alloying process forms a uniform microstructure, significantly reducing the overall magnetic susceptibility. The addition of iron must be strictly controlled due to its strong magnetic properties. Excessive iron content can increase the magnetic susceptibility and affect measurement accuracy. The low magnetic susceptibility of tungsten alloy weights enables them to maintain stable mass in electromagnetic fields or the magnetic environment of electronic balances, avoiding calibration errors caused by magnetic interference.

Tungsten alloy weights are achieved through optimized composition and manufacturing processes. Alloys with a high tungsten content (above 90%) maximize tungsten's low magnetic susceptibility, making them suitable for high-precision weights. A balanced ratio of nickel and copper balances antimagnetic and mechanical properties, avoiding the introduction of excessive magnetic susceptibility due to auxiliary elements. Powder metallurgy processes achieve a uniform microstructure through high-temperature sintering, minimizing areas of magnetic inhomogeneity. Surface coatings require controlled thickness to avoid increasing magnetic susceptibility while ensuring corrosion resistance. CNC machining and polishing optimize the surface condition to minimize magnetic interference caused by surface defects.

The anti-magnetic interference property gives tungsten alloy weights a significant advantage in high-precision measurement. In laboratories, electronic balances are often sensitive to magnetic fields. The low magnetic susceptibility of high-precision weights (such as E1 and E2 grades) ensures that calibration results are not affected by electromagnetic interference, making them suitable for chemical or biological experiments. In industrial scenarios, weighing equipment on production lines may be close to motors or electromagnetic equipment. The anti-magnetic properties of tungsten alloy weights can ensure calibration accuracy. In the commercial field, anti-magnetic weights are suitable for calibrating electronic scales to avoid weighing errors caused by environmental magnetic fields. The anti-magnetic property also reduces the risk of metal particles being attracted to the weights due to magnetic fields during transportation or storage, ensuring measurement stability.

2.4 Environmental and Safety Characteristics of Tungsten Alloy Weights

Tungsten alloy weights are key advantages in modern metrology. These include the environmentally friendly nature of the material itself, the low-pollution nature of the production process, and the ease of waste disposal. These characteristics enable tungsten alloy weights to meet the demands of high-precision metrology while complying with sustainable development requirements and minimizing environmental impact.

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2.4.1 Environmental characteristics of tungsten alloy weights

Tungsten alloy weights stems from their material composition and chemical stability, minimizing their impact on the environment and human health during use. Tungsten alloy weights, primarily composed of tungsten and supplemented with elements such as nickel, iron, or copper, exhibit low toxicity and high stability, making them suitable for safe use in a variety of environments. The following analysis examines the environmental characteristics of tungsten alloy weights from the perspectives of material properties, application safety, environmental impact, and sustainability .

Tungsten is a chemically stable metal that is inherently non-toxic and non-reactive with environmental substances. Compared to traditional weight materials such as lead (which carries toxicity and environmental risks), tungsten alloy weights do not release harmful substances and do not pollute soil, water, or air. The alloy contains relatively low levels of supporting elements such as nickel and copper , and the alloying process creates a stable microstructure, minimizing the possibility of elemental dissolution or volatilization. Tungsten alloy's high corrosion resistance prevents the release of harmful substances due to oxidation or chemical reactions over long-term use, ensuring its environmental friendliness.

In practical applications, the environmentally friendly nature of tungsten alloy weights is reflected in their low impact on users and the environment. In laboratories, industrial, and commercial settings, weights are frequently handled, and the low toxicity of tungsten alloy ensures operator safety. For example, in pharmaceutical laboratories, tungsten alloy weights do not release harmful substances, preventing contamination of the experimental environment or samples. In commercial applications such as food processing or jewelry weighing, the stability of tungsten alloy weights prevents chemical reactions caused by contact with food or precious metals, ensuring product safety and environmental friendliness.

Tungsten alloy weights is also reflected in their low impact on ecosystems. Traditional materials, such as lead, can release toxic substances through corrosion or wear, potentially contaminating soil or water. The high chemical stability of tungsten alloy weights prevents this problem. Furthermore, the wear resistance of tungsten alloy weights reduces particulate emissions due to surface damage, further minimizing the risk of environmental pollution. Tungsten alloy weights remain stable outdoors or in high-humidity environments, without negatively impacting surrounding ecosystems. From a sustainability perspective, the environmentally friendly nature of tungsten alloy weights is also reflected in their high durability and recyclability .

2.4.2 Low pollution characteristics of tungsten alloy weight production process

Tungsten alloy weights offers significant environmental advantages, with low pollution levels reflected in raw material procurement, manufacturing processes, and waste disposal. By optimizing production processes and utilizing advanced technologies, the manufacture of tungsten alloy weights minimizes environmental impact.

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Tungsten alloy weights primarily consist of tungsten powder and auxiliary metals (such as nickel, iron, or copper). These materials are relatively environmentally friendly during mining and processing. While tungsten mining does have certain environmental impacts, the extraction process produces less hazardous waste than toxic metals like lead. Accessorial elements such as nickel and copper are also relatively readily available, and modern smelting techniques can effectively reduce harmful emissions. Furthermore, the raw materials used in tungsten alloy weight production typically have high purity requirements. Rigorous screening reduces the introduction of impurities, further minimizing the risk of contamination during the production process.

Tungsten alloy weights is powder metallurgy, which is less polluting than traditional casting or chemical processing. Powder metallurgy creates weights by mixing tungsten powder with auxiliary metal powders, compacting the mixture, and sintering it at high temperatures. This process eliminates the need for large amounts of chemical reagents, reducing waste liquid and gas emissions. The sintering process is typically carried out in a controlled environment, and the resulting waste gas can be effectively treated through filtration and recovery systems. While surface treatments such as polishing or nickel electroplating involve small amounts of chemicals, modern electroplating techniques utilize environmentally friendly solutions, reducing harmful emissions. CNC machining reduces material waste through precise cutting, further enhancing the environmental friendliness of the production process.

Waste management during the production of tungsten alloy weights is a key aspect of their low-pollution properties. Waste materials generated during the powder metallurgy process (such as unsintered powder and swarf) can be recycled and reused, reducing resource waste. Wastewater generated during the electroplating process can be effectively neutralized and recycled through modern wastewater treatment technologies, reducing environmental pollution risks. Furthermore, regular maintenance and optimization of production equipment can reduce energy consumption and waste emissions. For example, the use of high-efficiency sintering furnaces and low-energy processing equipment can significantly reduce the carbon footprint of the production process.

Tungsten alloy weights is highly energy-efficient, particularly in powder metallurgy processes, where energy consumption can be reduced by optimizing sintering temperature and time. Modern production facilities also utilize renewable energy or energy-saving technologies to further minimize environmental impact. Future improvements in low-pollution properties could be achieved through the introduction of green manufacturing technologies, such as more efficient sintering equipment or the development of chemical-free surface treatments. These improvements would further reduce emissions during production and enhance the environmental advantages of tungsten alloy weights.

2.4.3 Environmentally friendly properties of tungsten alloy weights that are easy to dispose of after disposal

Tungsten alloy weights after disposal is a key aspect of their environmental credentials, as reflected in their recyclability, low toxicity, and minimal environmental impact. The high durability of tungsten alloy weights allows for a long service life, but when they reach the end of their useful life or are discarded for

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other reasons, their material properties and recycling processes ensure minimal negative environmental impact.

Tungsten alloy weights, is a high-value metal with excellent recyclability. Discarded tungsten alloy weights can be smelted and reprocessed to separate tungsten and other auxiliary elements (such as nickel and iron) and reused in the production of new weights or other alloy products. The recycling process typically includes crushing, smelting, and chemical purification. Modern recycling technology can efficiently separate different metals, reducing resource waste. Compared to non-recyclable or costly materials (such as certain plastics or composite materials), the recyclability of tungsten alloy weights significantly reduces the environmental cost of waste disposal, meeting the requirements of a circular economy.

Tungsten alloy weights is relatively simple and environmentally friendly. Due to their high chemical stability, discarded weights will not release harmful substances during long-term storage, preventing soil or water contamination. Recycling is typically carried out by specialized metal recycling facilities, which separate the tungsten from the other metals through mechanical crushing and high-temperature smelting. Electroplated coatings (such as nickel) are removed using environmentally friendly chemical processes to ensure that wastewater is properly disposed of. Exhaust gases and wastewater generated throughout the recycling process can be effectively controlled through modern filtration and neutralization technologies, minimizing environmental pollution. Furthermore, the small size and high density of discarded weights facilitate collection and transportation, reducing disposal costs.

Tungsten alloy weights have minimal environmental impact after disposal. Tungsten and its supporting elements (such as nickel and copper) are not easily decomposed or release toxic substances in the natural environment, making them safer to dispose of than lead weights, which may release heavy metal pollution. Even in extreme conditions (such as long-term exposure to acidic environments), the chemical stability of tungsten alloy prevents the release of harmful substances. Furthermore, the high durability of discarded weights prevents particulate contamination from wear and corrosion, reducing potential threats to ecosystems.

2.5 Adaptability characteristics of tungsten alloy weights

Tungsten alloy weights is reflected in their ability to adapt to a wide range of environments, equipment, and industry requirements. Their high density, corrosion resistance, and mechanical strength ensure stable performance under various conditions. This adaptability is achieved through optimized materials and manufacturing processes, ensuring the weights' reliable use in complex scenarios.

2.5.1 Adaptability of tungsten alloy weights in multiple environments

Tungsten alloy weights' adaptability in diverse environments is the foundation of their widespread application. They maintain mass stability and measurement accuracy in high and low temperatures, humidity, dryness, and other challenging conditions. This adaptability stems from tungsten alloy's

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excellent physical and chemical properties, making it suitable for a wide range of environments, from the laboratory to the outdoors.

Tungsten alloy weights are primarily reflected in their resistance to temperature fluctuations. Tungsten's low coefficient of thermal expansion minimizes volume changes in environments with large temperature fluctuations, thereby maintaining a constant mass. For example, in a laboratory setting, weights may be subject to temperature fluctuations caused by air conditioning, while in industrial settings, they may be exposed to production heat sources. The thermal stability of tungsten alloy ensures that weights do not experience metrological deviations due to thermal expansion and contraction under these conditions. Furthermore, the mechanical strength of tungsten alloy does not significantly decrease in low-temperature environments, making it suitable for calibration tasks in cold chain logistics or low-temperature experiments.

Another key aspect of tungsten alloy weights' adaptability to both wet and dry environments is their adaptability. Tungsten alloy's high corrosion resistance allows it to resist oxidation and rust in high-humidity environments. The addition of auxiliary elements such as nickel forms a protective layer, further enhancing its moisture resistance. For example, in coastal areas or high-humidity laboratories, tungsten alloy weights can maintain their surface finish and stable quality over time, avoiding damage caused by moisture. In dry environments, tungsten alloy's low electrostatic adsorption reduces dust adhesion, maintaining metrological accuracy. This adaptability makes weights suitable for metrological tasks in food processing plants or desert environments.

Tungsten alloy weights are also noteworthy for their adaptability to chemical environments. Tungsten's chemical stability makes it resistant to attack by most acids and bases, making it suitable for use in pharmaceutical or chemical laboratories. For example, tungsten alloy weights remain unaffected by exposure to chemical vapors, ensuring the safety and accuracy of calibration processes. In industrial environments with high levels of dust or particulate matter, the weights' high hardness and wear resistance allow them to withstand minor impacts and friction without compromising their structural integrity. Manufacturing processes such as surface coatings further enhance this adaptability. For example, nickel plating improves durability in acidic environments.

The multi-environmental adaptability of tungsten alloy weights is reflected in the reliability of high-precision calibration in laboratories. For example, E1-grade weights used in analytical balances can operate stably in constant temperature and humidity chambers or standard laboratory environments. In industrial scenarios, weights can adapt to the high temperatures and vibrations of production lines and are used to calibrate electronic scales or conveyor belt weighing systems. In the commercial sector, weights can withstand the humidity and dust of markets or warehouses and are used for the calibration of trade weighing. This adaptability reduces the impact of environmental factors on measurement results and improves overall efficiency.

The multi-environmental adaptability of tungsten alloy weights is also due to their optimized manufacturing. Powder metallurgy creates a dense structure through high-temperature sintering,

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reducing the impact of internal defects on environmental sensitivity. CNC machining ensures precise shape and surface condition, facilitating operation in various environments.

2.5.2 Compatibility of Tungsten Alloy Weights with Multiple Devices

Tungsten alloy weights are compatible with a wide range of devices, meaning they work seamlessly with a variety of balances, scales, and measuring instruments, ensuring accuracy and convenience during calibration. This compatibility stems from their standardized design and high stability, making them suitable for use with a wide range of devices, from manual balances to electronic scales.

Tungsten alloy weights are based on their high density and uniform mass distribution. This high density allows them to pack a large mass into a small volume, making them suitable for space-constrained equipment such as microbalances or portable electronic scales. This uniform mass distribution ensures stable placement of the weights on various equipment trays, preventing measurement errors caused by shifting centers of gravity. For example, in analytical balances, the low magnetic susceptibility of tungsten alloy weights minimizes interference with electronic components, ensuring compatibility. In mechanical balances, their high hardness prevents surface damage, maintaining long-term compatibility.

Design features further enhance the multi-device compatibility of tungsten alloy weights. Standardized shapes such as cylindrical or sheet designs fit most balance pans. Cylindrical weights are easy to stack and combine, making them suitable for multi-level calibration equipment; sheet weights are compact and compatible with microscopes. Hook-shaped weight designs are optimized for hanging scales, making them convenient for use in dynamic measurement equipment. The smooth surface finish and corrosion resistance of tungsten alloy ensure clean contact surfaces with equipment, preventing contamination or wear that may affect compatibility. For example, in electronic scale calibration, the weight's low-friction surface reduces the risk of slippage and improves operational compatibility.

In terms of application compatibility, tungsten alloy weights are adaptable to a variety of equipment types. In laboratory equipment, they are compatible with high-precision analytical balances and microbalances for fine calibration. In industrial equipment, they are compatible with electronic scales and conveyor systems on production lines, ensuring the accuracy of large-scale calibrations. In commercial equipment, they are compatible with bench scales and electronic scales for everyday trade use. The durability of tungsten alloy weights enables them to maintain stable performance during frequent equipment changes, such as when transferring from a laboratory balance to an industrial scale, without the need for additional adjustments.

2.5.3 Tungsten alloy weights' application and adaptability in various industries

Tungsten alloy weights across multiple industries demonstrates their universal value as a metrological tool. Their design and performance can be tailored to meet diverse metrological requirements, from pharmaceuticals to logistics. This flexibility stems from the material's plasticity and manufacturing versatility, enabling them to be used in high-precision or high-mass applications.

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The application needs of various industries drive the adaptability of tungsten alloy weights. In the pharmaceutical industry, weights require high precision and small size to calibrate drug formulation scales; the food processing industry requires weights that are corrosion-resistant and easy to clean to adapt to humid environments; in the jewelry industry, weights require micro-level precision for weighing precious metals; and the logistics industry may require large weights for calibrating warehouse scales. The high density and stability of tungsten alloys enable flexible adaptation to these needs through adjustment of composition and morphology. For example, alloys with high tungsten content are suitable for high-precision industries, while alloys with increased nickel content improve corrosion resistance and are suitable for the food industry.

Adaptation mechanisms include material optimization and design adjustments. The composition of tungsten alloys can be adjusted to meet industry needs. The addition of auxiliary elements such as copper improves thermal conductivity, making it suitable for temperature-sensitive industries; the addition of cobalt enhances strength, making it suitable for heavy-duty applications. Flexible design allows for custom cylindrical shapes for laboratory use and block shapes for industrial applications. Manufacturing processes such as powder metallurgy support mass production of standardized weights, while CNC machining facilitates custom customization of specialized shapes. This mechanism ensures seamless adaptation of weights across diverse industries.

2.6 CTIA GROUP LTD Tungsten Alloy Weights MSDS

CTIA GROUP LTD , a company specializing in the research, development, production, and trade of tungsten and molybdenum products, offers tungsten alloy weights widely used in metrology. MSDS documents, compiled in accordance with national standards such as GB/T 16483 and GB/T 17519, are designed to provide users with comprehensive safety information to ensure the safe use of tungsten alloy weights in laboratories, industry, and commercial settings.

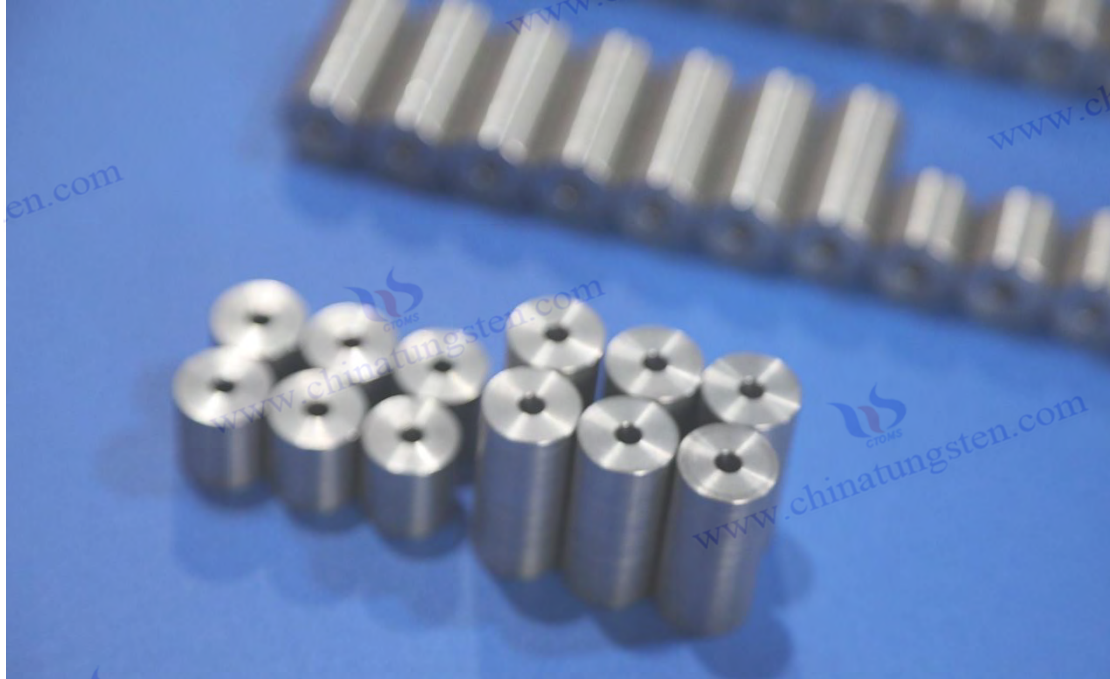
Tungsten alloy weights are primarily composed of tungsten, supplemented by elements such as nickel and iron, resulting in a high-density and stable measuring tool. The typical composition of tungsten alloy weights is as follows: tungsten (W) accounts for the largest proportion, typically exceeding 90%, providing high density and stability; supplementary elements include nickel (Ni, approximately 5-10%) for enhanced toughness, iron (Fe, approximately 2-5%) for enhanced strength, and trace amounts of copper (Cu) or cobalt (Co) for improved processing properties. The physical properties of tungsten alloy weights are described in the MSDS as high density (approximately 17 g/cm³), high melting point (over 3000°C), and low solubility, ensuring stability at room temperature. Chemical properties include an inert surface that does not react with water or air, but may oxidize at high temperatures.

According to GHS classification, tungsten alloy weights are generally non- hazardous substances, but the MSDS identifies specific risks: physical hazards include mechanical damage (such as edge cuts) and the risk of heavy objects falling.

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Storage instructions include storing in a dry, ventilated warehouse, avoiding moisture to prevent surface corrosion. The MSDS recommends using dedicated shelving to isolate heavy items and labeling with clear product information. Transport using shockproof packaging that complies with UN standards.

The waste part emphasizes recycling first: tungsten alloy can be melted and recycled to reduce the environmental burden.



CTIA GROUP LTD Tungsten Alloy Weights

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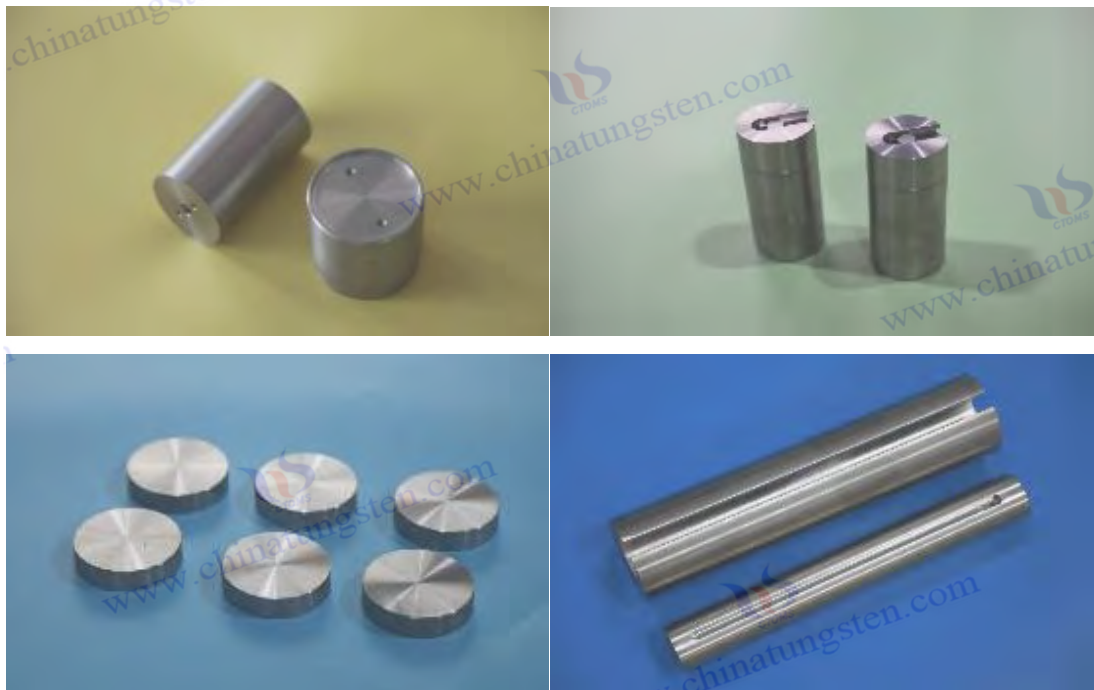
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Chapter 3 Testing Standards for Tungsten Alloy Weights

Tungsten alloy weights require testing standards that are crucial for ensuring quality stability and reliable application. This chapter systematically explores the testing standards for tungsten alloy weights, focusing on the methods and processes for density and volume stability testing. These tests not only comply with international and national metrological regulations but also utilize precision instruments and standardized procedures to verify the weights' performance in various environments, providing technical support for their application in laboratories, industry, and commerce.

3.1 Density and Volume Stability Test of Tungsten Alloy Weights

Tungsten alloy weights is a core component of their quality control. High density is the core advantage of tungsten alloy weights, while volume stability ensures their metrological accuracy despite environmental factors such as temperature and humidity. These tests are typically performed in a professional metrology laboratory or production workshop, following standards such as OIML R111 and JIG 99 to ensure traceability and reliability of the results.

3.1.1 Standard method for density testing of tungsten alloy weights

Tungsten alloy weights aims to accurately measure the ratio of mass to volume to verify the alloy's homogeneity and high density. This test is an essential step in weight manufacturing and quality certification. It typically uses immersion or gas displacement methods based on the Archimedean principle to ensure that the results meet metrological standards. The following comprehensively analyzes the standard method for density testing of tungsten alloy weights from the aspects of method principle, equipment preparation, operation steps, error control, and application verification.

The core principle of density testing is based on Archimedes' law of buoyancy, which states that when an object is immersed in a liquid or gas, the buoyant force it experiences is equal to the mass of the medium displaced. By measuring the weight difference between the weight of a weight in air and the weight of the medium it is immersed in, the volume of the weight is calculated, and thus the density is determined. The high density of tungsten alloy weights makes them particularly suitable for this method, as their small size and high mass reduce measurement errors. For tungsten alloy, the immersion method often uses water or ethanol as the medium, while the gas displacement method is suitable for situations where liquid corrosion is avoided. These methods comply with standards such as GB/T 1423 and ASTM B328, ensuring scientific and repeatable testing.

Density testing requires a precision balance and a density meter. The high-precision balance must have a resolution of micrograms and be suitable for testing E1-grade weights. The density meter includes a suspension bracket, a medium container, and a temperature control device. When using water as the medium, distilled water should be used to avoid interference from impurities. Gas displacement methods require a helium or nitrogen generator to ensure gas purity. Auxiliary equipment includes a constant temperature water bath (maintaining the medium temperature at approximately 20°C) and a draft shield

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to minimize the impact of environmental fluctuations on the measurement. All equipment must be regularly calibrated in accordance with JJF 1001, Standard for Metrological Confirmation of Measuring Instruments, to ensure test accuracy.

The standard density test procedure consists of three stages: preparation, measurement, and calculation. First, the preparation stage involves cleaning the weight surface using an ultrasonic cleaner to remove contaminants and ensure the surface is free of scratches and deposits. The balance is calibrated, and the zero point and linearity errors are verified using a standard weight. The medium is prepared by filling the container with water or ethanol, controlling the temperature, and recording the initial conditions. Next, the measurement stage begins: The weight is placed on the balance, and the mass in air (m_1) is recorded. Using a hanging bracket, the weight is completely immersed in the medium, and the submerged mass (m_2) is recorded, ensuring that no bubbles adhere. For the gas displacement method, a gas generator is used to fill the displacement container, and the volume of the displaced gas is recorded. Repeat the measurement multiple times (at least three times) and obtain an average value to improve reliability. Finally, the calculation stage begins: Volume $V = (m_1 - m_2) / \rho_{\text{medium}}$, where ρ_{medium} is the medium density; density $\rho = m_1 / V$. The entire process must be performed in a constant temperature and humidity environment, and operators must wear gloves to prevent contamination.

Error control is crucial for density testing, ensuring that the results are within acceptable tolerances. Systematic errors primarily arise from medium temperature fluctuations and surface tension, which are corrected using temperature compensation formulas. Random errors are minimized through multiple measurements and statistical analysis, such as using standard deviation to assess repeatability. The surface coating of tungsten alloy weights may affect buoyancy during immersion, so the uniformity of the coating must be verified beforehand. Environmental factors such as air pressure changes can be compensated for using a barometer. After testing, an uncertainty assessment is performed in accordance with the GUM (Guide to the Expression of Uncertainty in Measurement) to ensure the integrity of the report.

Density testing results are directly applied to the quality classification and certification of tungsten alloy weights. For example, on the production line, testing ensures uniform alloy density, making it suitable for high-precision laboratory weights. At the Metrology Institute, verification results are used for measurement transfer to ensure that weights comply with OIML standards. In practical cases, density testing helps identify manufacturing defects, such as density gradients caused by uneven sintering, thereby optimizing the process. This method also supports batch testing and improves efficiency through automated density meters. In the future, with advances in precision measurement, such as the introduction of laser volume scanning, the accuracy of density testing will be further improved, providing stronger support for the performance assurance of tungsten alloy weights.

In the standard method for density testing of tungsten alloy weights, these steps and control measures work together to ensure the reliability and practicality of the test. Through rigorous operation, manufacturers and users can confidently verify the core characteristics of the product and promote the standardization of metrology technology.

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3.1.2 Testing Process for Volume Stability of Tungsten Alloy Weights

Tungsten alloy weights evaluate their volume change characteristics under environmental conditions, ensuring that metrological accuracy is unaffected by temperature, humidity, or mechanical stress. This testing is a crucial step in long-term performance verification and typically combines static and dynamic testing in accordance with ISO 376 and JJG 99 standards.

The principle of volume stability is based on the quantitative analysis of a material's thermal expansion and mechanical deformation. Tungsten alloy's low coefficient of thermal expansion minimizes volume changes, but testing requires simulation of real-world environments, such as temperature cycling (from low to high temperatures) and humidity exposure. Stability is assessed by measuring the difference between the initial volume and the volume after environmental exposure. Static testing verifies long-term storage stability, while dynamic testing simulates operational conditions. These principles ensure that testing covers potential factors affecting weights in laboratory or industrial settings.

The testing process is divided into five stages: preparation, initial measurement, environmental exposure, subsequent measurement, and reporting. First, the preparation stage: sample weights (at least five representing different batches) are selected, cleaned, and their initial state is recorded, including surface inspection and environmental records. All instruments are calibrated to ensure measurement accuracy. Second, the initial measurement stage: a coordinate measuring machine or laser scanner is used to record the initial volume and calculate geometric parameters such as diameter and height. Mass is also measured to verify density consistency. Third, the environmental exposure stage: the weights are placed in an environmental simulation chamber and subjected to temperature cycling (for example, multiple cycles from 10°C to 40°C) and humidity exposure (from low humidity to high humidity). Mechanical stress testing involves mild vibration or pressure simulation. Exposure time is set according to standards and typically ranges from several hours to several days. Fourth, the subsequent measurement stage: the volume is remeasured immediately after exposure, the initial measurement steps are repeated, and the changes are recorded. Fifth, the reporting stage: the rate of volume change is calculated, and a report is generated, including charts and conclusions.

Instrument configuration requires high precision and stability. A coordinate measuring machine (CMM) is used for 3D volume scanning, achieving micron-level resolution. A laser scanner is suitable for non-contact measurement, minimizing surface damage. An environmental simulation chamber is equipped with a temperature and humidity control system, maintaining an accuracy of $\pm 0.5^{\circ}\text{C}$ and $\pm 2\%$ RH. Auxiliary instruments include a vibration table to simulate mechanical stress and a constant temperature balance to verify mass stability. All instruments must be traceable to national standards to ensure test reliability. The operating environment is a cleanroom with a constant temperature to minimize external interference.

Statistical methods are used for data analysis to assess volume stability. The volume change (ΔV) is calculated as $V_{\text{after}} - V_{\text{initial}}$, and the rate of change ($\Delta V/V$) is calculated. Uncertainty is quantified using standard deviation and confidence intervals. During thermal expansion testing, linear regression is

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used to analyze the relationship between temperature and volume, verifying the low expansion properties of the tungsten alloy. Humidity testing assesses the effects of moisture absorption, identifying potential issues by comparing pre- and post-exposure data. Abnormal data must be traced back to the cause, such as surface coating defects, and a root cause analysis must be performed. Reports must comply with metrological specifications and include uncertainty estimates and stability conclusions.

The results of volume stability testing are used to certify weight performance and provide guidance for use. For example, at the National Institute of Metrology, testing ensures the volume stability of E1-grade weights under temperature fluctuations, making them suitable for high-precision balance calibration. In industrial production, verification results are used to optimize manufacturing processes, such as adjusting sintering parameters to reduce volume fluctuations. In practical applications, this process helps predict weight performance in humid environments and supports maintenance planning. In the future, digital simulation combined with AI analysis may streamline the process and improve testing efficiency.

3.2 Mechanical Properties and Durability Testing of Tungsten Alloy Weights

Tungsten alloy weights is a critical process for evaluating their mechanical strength, wear resistance, and corrosion resistance. These tests ensure that weights maintain their structural integrity and metrological accuracy despite frequent operation and challenging environments. These tests are typically performed in specialized laboratories or during production quality control, adhering to standards such as ASTM and GB/T.

3.2.1 Testing Method for Hardness of Tungsten Alloy Weights

Tungsten alloy weights is designed to quantify their surface resistance to deformation, ensuring wear resistance and stability over long-term use. This test, fundamental to mechanical property evaluation, uses either indentation or scratch testing, using precision instruments to assess hardness.

The core principle of hardness testing is based on a material's resistance to external load. The indentation method applies a load to the surface of a weight, creating an indentation and then measures the size of the indentation to calculate hardness. The scratch method uses a stylus to scratch the surface and measure the width or depth of the scratch. Tungsten alloy's high hardness makes it suitable for these methods, as its uniform microstructure provides consistent test results. These principles comply with standards such as GB/T 230 and ASTM E18, ensuring scientific and comparable testing.

Hardness testing requires instruments such as a Vickers hardness tester or a Rockwell hardness tester. The Vickers hardness tester is suitable for precise measurements of tungsten alloys, using a diamond indenter to apply the load; the Rockwell hardness tester is suitable for rapid assessments, using a spherical or conical indenter. Auxiliary equipment includes a sample holder, a microscope for indentation observation, and an environmental control chamber to maintain a constant test temperature. All instruments must be regularly calibrated in accordance with JJF 1059, Standard for the Calibration of

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Measuring Instruments, to ensure test accuracy. The surface of the weight sample must be cleaned to remove any oxide layers or contaminants, and the test area must be flat.

The standard operation of hardness testing is divided into three stages: preparation, testing, and analysis. First, the preparation stage: select a representative surface of the weight, such as the side or top, avoiding the edge area; fix the weight on the test bench to ensure horizontal stability; set the load and holding time, and adjust the parameters according to the size of the weight. Second, enter the testing stage: start the instrument to apply the load to form an indentation; use a microscope to measure the diagonal or depth of the indentation; repeat the test at multiple points (at least five), covering different areas to evaluate uniformity. For the scratch method, a fixed stylus is scratched across the surface and the scratch characteristics are recorded. The entire process must be carried out in a vibration-free environment, and the operator records each measurement value. Finally, the analysis stage: calculate the average hardness value and compare the differences at different points to evaluate the uniformity of the material. The report includes the test conditions and the results chart.

Error control ensures the reliability of hardness testing. Systematic errors, primarily due to load inaccuracy or indenter wear, are eliminated through regular instrument calibration. Random errors are minimized through multi-point measurement and statistical averaging, such as by using analysis of variance to assess repeatability. Surface coatings on tungsten alloys may affect hardness readings, requiring pre-stripping or adjustment of the test depth. Environmental factors such as temperature fluctuations can be controlled using a thermostat. Post-test, uncertainty assessment is performed in accordance with metrological guidelines to ensure objective reporting.

Hardness testing results are directly applied to the quality classification and optimization of tungsten alloy weights. For example, in production, testing ensures uniform hardness for highly wear-resistant industrial weights. In metrological verification, results support the transfer of measurement values, ensuring that weights meet standards. In practical cases, hardness testing helps identify alloy formulation flaws, such as hardness gradients caused by uneven auxiliary elements, leading to manufacturing improvements. This method also supports batch screening and improves efficiency through automated hardness testing.

3.2.1 Testing Methods for the Strength of Tungsten Alloy Weights

Tungsten alloy weight strength testing focuses on assessing its ability to resist tensile, compressive, or bending deformation, ensuring the weight will not experience structural failure during operation. This test is key to durability assessment and is typically performed using tensile or compression testing, with specialized instruments verifying strength characteristics.

Strength testing is based on the laws of material mechanics, applying a progressively increasing load to measure deformation and fracture point. Tensile testing measures tensile strength by stretching the sample; compression testing measures compressive strength by applying pressure. Tungsten alloy's high strength makes it suitable for these methods, as its toughness combined with its toughness provides

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reliable fracture data. These principles comply with standards such as GB/T 228 and ASTM E8, ensuring standardized and accurate testing.

Strength testing requires a universal materials testing machine capable of both tension and compression modes. The instrument is equipped with a fixture to secure the sample weight, and sensors to measure load and deformation. Auxiliary equipment includes strain gauges to record micro-deformations and a data acquisition system for real-time monitoring. Samples must be machined into standard shapes, such as rods or blocks, to ensure the test area is free of defects. All equipment must be calibrated in accordance with metrological specifications to ensure reliable results.

Strength testing operations are divided into preparation, testing, and analysis stages. First, the preparation stage: process the weight sample to ensure uniform size; fix the sample in the testing machine fixture and align the axis; set the test speed and load range. Second, the testing stage: start the machine to apply the load and record the load-deformation curve; continue until the sample deforms or breaks, and repeat the test on multiple samples to evaluate consistency. For compression testing, observe the sample compression deformation without breaking it. The process must be carried out in a controlled environment to avoid vibration interference. Finally, the analysis stage: extract strength values from the curve, such as yield strength and fracture strength; calculate the average value and coefficient of variation. The report includes a curve graph and conclusions.

Error control focuses on measurement accuracy. Systematic errors, such as fixture misalignment or sensor drift, are eliminated through calibration, while random errors are minimized through multi-sample testing. Microstructural inhomogeneities in tungsten alloys can affect results and require preliminary microscopic inspection. Ambient temperature can be controlled using a constant-temperature chamber. Uncertainty assessment ensures the scientific integrity of the report.

3.2.2 Testing Method for Wear Resistance of Tungsten Alloy Weights

Tungsten alloy weights assess their surface's ability to resist frictional wear, ensuring they maintain consistent quality during repeated use. This test utilizes friction testing or wear simulation to instrumentally quantify wear. Wear resistance testing is based on tribology, measuring mass loss or volume change by simulating contact friction. Reciprocating friction methods simulate operational wear, while rotational friction methods are suitable for surface evaluation. These methods comply with GB/T 12444 and ASTM G99 standards.

Equipment preparation requires a tribometer equipped with a wear plate and a load system. Auxiliary equipment includes an electronic scale to measure mass loss and a microscope to observe the surface. The sample must be secured to ensure the test surface is flat. The instrument must be calibrated to specifications.

The process is divided into preparation, testing, and analysis. First, preparation involves cleaning the sample and securing it to the machine; setting the load and friction distance. Next, testing involves

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starting the friction process and recording the progress; stopping the process and measuring the mass loss. The test is repeated. Finally, analysis involves calculating the wear rate and providing a report including surface photographs.

Error control controls load fluctuations and ambient humidity. Multiple tests minimize random errors. Uncertainty assessment ensures reliability.

Application verification is used to optimize the durability of weights. In industry, it ensures long-term use; in the laboratory, it supports design and helps improve processes. In the future, automated testing will increase efficiency.

3.2.3 Standard Process for Evaluating the Corrosion Resistance of Tungsten Alloy Weights

Tungsten alloy weights involves assessing their ability to resist corrosion through simulated environmental exposure, ensuring stability in humid or chemical environments. This process utilizes either immersion testing or electrochemical methods, following standard specifications.

The process is based on corrosion kinetics, measuring corrosion rates by exposure to a medium. Salt spray tests simulate humidity, while immersion tests assess chemical stability. Complies with GB/T 10125 and ASTM B117 standards.

The design steps are divided into preparation, exposure, measurement and reporting. First, prepare the sample and clean it; second, expose it to the salt spray chamber or immersion solution; third, measure the mass loss or surface change; and fourth, report the conclusion.

The instrument is equipped with a salt spray chamber to control the environment and an electrochemical workstation to measure the corrosion current. Auxiliary equipment includes a pH meter and a microscope.

Data analysis: Calculate corrosion rates and use statistics to estimate uncertainty. Analyze surface changes.

Application verification is used for environmental adaptation. In pharmaceuticals, it ensures stability and helps optimize coatings. In the future, accelerated testing will improve efficiency.

3.3 Testing the metrological performance stability of tungsten alloy weights

Tungsten alloy weights is a process that evaluates their ability to maintain metrological accuracy over time and under varying environmental conditions. This testing, which covers key indicators such as mass value, surface condition, and magnetic interference, is typically performed by professional metrology institutes or during production quality control, adhering to standards such as OIML R111 and JJG 99. These tests ensure the reliability of weights for high-precision laboratory calibration, industrial production line verification, and commercial trade weighing.

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3.3.1 Standard monitoring cycle for the stability of mass values of tungsten alloy weights

Tungsten alloy weights refers to the intervals between regular calibration and verification to ensure that their mass values remain stable despite environmental changes and use. This monitoring is a core component of metrological stability testing. Through systematic cycle settings and operational procedures, the long-term reliability of weights is assessed.

The monitoring principle for mass value stability is based on the metrological principles of traceability and repeatability. Regular comparison with a reference weight verifies whether the mass deviation of the weight is within the permitted range. The high chemical stability and low thermal expansion of tungsten alloy weights result in minimal mass value fluctuations, but monitoring must take into account the influence of environmental factors such as temperature, humidity, and mechanical wear. These principles comply with the stability requirements of the OIML R111 standard, ensuring scientific and consistent monitoring. The cycle setting takes into account the weight's precision grade, frequency of use, and environmental conditions. High-precision weights require more frequent monitoring to maintain metrological accuracy.

The monitoring cycle needs to be determined based on the accuracy level and application scenario of the weight. High-precision weights such as E1 and E2 are usually used in laboratory environments, and their monitoring cycle needs to be shorter to cope with potential environmental interference. Lower accuracy levels such as F2 and M1 are used in industrial or commercial scenarios, and the cycle can be appropriately extended, but the intensity of use still needs to be considered. The cycle is also affected by environmental factors. For example, in high humidity or high temperature environments, the monitoring frequency needs to be increased to assess the impact of corrosion or thermal expansion. The standard specification recommends dynamically adjusting the cycle based on the historical data of the weights and risk assessment to ensure the targeted and effective monitoring.

The monitoring operation process of mass value stability is divided into four stages: preparation, calibration, recording and review. First, the preparation stage: select the monitoring weight, clean the surface and record the initial state, including the ambient temperature and humidity; prepare the reference weight and precision balance to ensure the calibration of the equipment. Secondly, enter the calibration stage: use the mass comparison method to compare the weight with the reference and record the deviation; repeat the measurement multiple times to evaluate the repeatability. For dynamic monitoring, the use conditions such as stacking or moving can be simulated and recalibrated. Third, the recording stage: document all data, including deviation values and environmental parameters, and store them using a spreadsheet or dedicated software. Fourth, the review stage: compare the current data with historical records to evaluate the stability trend; if the deviation exceeds the limit, perform root cause analysis and adjust the cycle. The entire process must be carried out in a constant temperature and humidity laboratory, and the operators must follow safety regulations.

Data evaluation uses statistical methods to quantify stability. The mean and standard deviation of mass deviations are calculated, and trend charts are plotted to identify patterns of change. The evaluation takes

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into account uncertainty, including the effects of balance resolution and environmental fluctuations. Stability is assessed through confidence interval analysis. If deviations remain within the permitted range, the weights are considered reliable. Abnormal data is traced to the cause, such as surface contamination or magnetic interference, and corrective measures are implemented. The evaluation report includes a data summary and periodic recommendations to ensure continuous monitoring and improvements.

Standardized monitoring cycles for mass value stability are crucial in practical applications. In laboratories, regular monitoring ensures the accuracy of high-precision calibrations and supports the reliability of scientific research. In industrial settings, monitoring cycles help predict weight life and optimize maintenance plans. In the commercial sector, stable monitoring ensures fairness in trade weighing. Cyclic monitoring also promotes standardized weight management and reduces economic losses caused by mass drift.

Through these monitoring standard cycles, the stability of the mass value of tungsten alloy weights is effectively guaranteed, ensuring their long-term performance in a variety of metrological scenarios. The standardized implementation of this process not only improves the reliability of weights, but also provides a data foundation for the continuous development of metrological technology.

3.3.2 Detection method of tungsten alloy weight surface condition

Tungsten alloy weights is designed to assess surface finish, flatness, and integrity to ensure metrological accuracy is not affected by surface defects. This test is a key component of stability testing, combining visual inspection with instrumental measurement to identify potential issues such as scratches, corrosion, or contamination.

Surface condition testing is based on optical and contact measurement principles, observing or quantifying surface features to assess their impact on metrological performance. Finish testing utilizes light reflection to assess surface roughness, while flatness testing measures geometric deviations to ensure uniform contact. The surface coating and polishing characteristics of tungsten alloy weights require a focus on microscopic defects during testing. These principles comply with the surface quality requirements of OIML R111, ensuring objectivity and comprehensiveness of testing.

Surface condition inspection methods can be categorized as visual inspection, contact measurement, and non-contact measurement. Visual inspection uses a magnifying glass or microscope to observe the surface and identify macroscopic defects such as scratches or rust spots. Contact measurement uses a surface roughness tester, which quantifies roughness parameters through probe scanning. Non-contact measurement uses a laser scanner or optical profiler and is suitable for high-precision weights to avoid contact damage. The choice of these methods depends on the weight grade, with non-contact methods being preferred for high-precision weights to preserve surface integrity.

The inspection process involves preparation, inspection, measurement, and documentation. First, there's the preparation phase: clean the surface of the weight and remove contaminants with a dust-free cloth

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and a neutral detergent. Prepare the inspection instrument and calibrate the roughness meter or laser scanner. Next, there's the inspection phase: perform a visual inspection and record the location and type of visible defects. For contact measurements, set the probe path to scan the surface and collect data. For non-contact measurements, fix the weight and start scanning to obtain a three-dimensional surface image. Repeat the operation for multiple areas to achieve comprehensive coverage. Third, there's the measurement phase: quantify parameters such as roughness average or flatness deviation. Fourth, there's the documentation phase: generate a report with photos, data tables, and conclusions, noting any anomalies.

Results analysis evaluates surface condition by comparing measured values with standard limits. Roughness indices are calculated, and surface profiles are plotted to assess uniformity. Analysis must account for uncertainties, including instrument resolution and operational variation. Abnormal results, such as high roughness, require analysis of the cause, such as manufacturing defects or wear and tear, and recommendations for remediation are provided. Reports highlight the impact of surface condition on metrological accuracy, ensuring practical analysis.

Surface condition detection methods can be used to optimize weight design and maintenance. In production, detection guides polishing process improvements and enhances surface quality. In metrological applications, regular testing prevents accuracy degradation and supports adjustments to maintenance cycles. This flexible method is adaptable to diverse scenarios, and in the future, AI image analysis can be used to automate detection and improve efficiency.

3.3.3 Detection Method of Magnetic Interference of Tungsten Alloy Weights

Tungsten alloy weights focus on evaluating their magnetic susceptibility and permanent magnetization to ensure they are not affected by magnetic fields during electronic balance calibration. This test is a specialized component of stability testing, quantifying the magnetic properties through magnetometry and environmental simulation.

Magnetic interference testing, based on electromagnetic induction and magnetic balance, assesses the magnetic properties of a weight by measuring its response to a magnetic field. Magnetic susceptibility testing calculates the weight's response to an external magnetic field, while permanent magnetization testing assesses the strength of the internal magnetic field. Tungsten alloy's low magnetic susceptibility requires highly sensitive instrumentation for testing. These principles comply with the magnetic requirements of OIML R111, ensuring accurate and relevant testing.

Magnetic interference detection methods include magnetic susceptibility measurement and permanent magnetization testing. Magnetic susceptibility measurement uses a magnetometer or gaussmeter to observe changes in the weight's force in a known magnetic field; permanent magnetization testing uses a suspension method or Hall effect probe to detect the strength of the weight's magnetic poles. These methods are suitable for weights of varying precision, with high-precision E1-grade weights requiring more sensitive measurements to meet standard limits.

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The testing process covers preparation, measurement, verification, and reporting. First, the preparation phase: shielding from external magnetic fields and using a non-magnetic laboratory; preparing weight samples and recording the initial state. Second, the measurement phase: for magnetic susceptibility, placing the weight in a uniform magnetic field and measuring the force deviation; for permanent magnetization, using a probe to scan the surface and record the magnetic field strength. Repeat the measurement at multiple points to assess uniformity. Third, the verification phase: comparing the results with standard thresholds to confirm compliance. Fourth, the reporting phase: documenting the data, including magnetic field diagrams and conclusions, and making demagnetization recommendations if necessary.

Data processing uses computational models to quantify magnetic properties. The permanent magnetization is estimated by calculating the magnetic susceptibility $\chi = (\text{force deviation}) / (\text{magnetic field intensity} \times \text{volume})$. This processing must account for uncertainties, including instrument noise and background magnetic fields. Statistical analysis of multiple data sets is performed to determine the mean and variance. Abnormal data should be analyzed for reasons such as alloy impurities and corrected.

Magnetic interference detection methods safeguard electronic metrology accuracy in practice. In laboratories, they ensure that weights do not interfere with balance readings; in industry, they support calibration in electromagnetic environments. Implementation of this method optimizes alloy formulations and reduces magnetic risks. In the future, automated magnetic field scanners will improve detection efficiency.

3.4 Environmental Testing of Tungsten Alloy Weights

Tungsten alloy weights is a key step in assessing their environmental impact during production and disposal, ensuring low material toxicity, low pollution levels during production, and recyclability during disposal. These tests adhere to environmental standards such as GB/T 27948 and ISO 14001 and are typically conducted in specialized laboratories or during production. They combine chemical analysis and environmental simulation techniques to verify the weights' environmental performance.

3.4.1 Environmental Testing Methods for Tungsten Alloy Weights

Tungsten alloy weights are designed to assess the potential impacts of their material composition and use on the environment and human health, ensuring compliance with environmental regulations and safety requirements. These methods verify the low toxicity and environmental friendliness of the weights through chemical analysis, toxicity assessment, and emissions testing.

Environmental testing is based on chemical analysis of materials and environmental impact assessment. Chemical composition analysis uses spectroscopy to identify the content of hazardous substances in weights; toxicity assessment tests the material's solubility under specific conditions to determine whether toxic substances are released; and emissions testing simulates usage scenarios to assess volatile or particulate emissions. These methods comply with GB/T 26572 (Limits of Hazardous Substances) and

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REACH regulations, ensuring that test results are consistent with international environmental standards. Tungsten alloys generally perform well in these tests due to their low toxicity and high stability.

Environmental testing methods include compositional analysis, dissolution testing, and environmental exposure testing. Compositional analysis utilizes inductively coupled plasma mass spectrometry (ICP-MS) or X-ray fluorescence spectroscopy (XRF) to detect the content of elements such as tungsten, nickel, and iron, as well as harmful impurities. Dissolution testing evaluates the dissolution characteristics of weights in water or acidic solutions through immersion testing. Environmental exposure testing simulates humid or chemical environments to assess surface release. These methods are selected based on the weight's intended use; high-precision weights require more rigorous dissolution testing to ensure laboratory safety.

The operational process of environmental testing is divided into three stages: preparation, testing, and analysis. First, the preparation stage: select representative weight samples, clean the surface to remove contaminants; prepare instruments, such as ICP-MS, calibrate to ppb-level sensitivity, and prepare solutions that meet standards. Second, the testing stage: for component analysis, dissolve or directly scan the sample and record the element concentration; for dissolution testing, immerse the weight in a neutral or acidic solution and take samples for analysis at regular intervals; for environmental exposure testing, place the weight in a simulation chamber and record the release. Repeated testing ensures data reliability. Third, the analysis stage: compare the results with regulatory limits and generate a report including concentration data and compliance conclusions.

Results analysis assesses environmental performance through quantitative comparison. Compositional analysis confirms that hazardous substances (such as lead and cadmium) are below the specified limits. Dissolution testing calculates the dissolution rate to ensure no toxic release. Exposure testing assesses emissions to confirm low environmental impact. Analytical uncertainties, such as instrument sensitivity and sample variation, must be considered. Abnormal results, such as manufacturing impurities, must be traced back to their cause, and recommendations for improvement must be provided. Reports must comply with ISO 17025 requirements to ensure traceability.

3.4.2 Testing Specifications for Environmental Protection Indexes in Tungsten Alloy Weight Production

Tungsten alloy weight production environmental performance testing specifications are designed to assess the potential environmental impact of the production process, including indicators such as exhaust gas, waste liquid, solid waste, and energy consumption. These specifications ensure that production complies with environmental management system requirements such as ISO 14001 and GB/T 24001, thereby reducing pollution emissions.

Our production environmental performance testing is based on environmental impact assessment principles. We monitor emissions and resource usage throughout the production process to quantify environmental impact. Exhaust gas testing analyzes volatile organic compounds (VOCs) and particulate

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matter; waste liquid testing assesses chemical concentrations; solid waste testing evaluates recycling rates; and energy consumption testing optimizes efficiency. These principles comply with GB/T 27948 and local environmental regulations to ensure sustainable production.

The testing covers four indicators: exhaust emissions (particulate matter and nitrogen oxides in sintering furnace flue gas), waste liquid emissions (heavy metals in electroplating baths), solid waste (recovery rate of cuttings and unsintered powder), and energy consumption (energy consumption per unit of product). Each indicator must be compared with regulatory limits. For example, exhaust emissions must comply with GB 16297. Testing also focuses on noise and heat emissions to ensure a comprehensive assessment.

The testing process is divided into preparation, monitoring, recording, and analysis. First, the preparation phase involves identifying testing points, such as sintering furnace outlets, electroplating tanks, and waste dumps; and calibrating instruments, such as gas analyzers and flow meters. Second, the monitoring phase involves collecting exhaust gas samples in real time and analyzing VOC concentrations; sampling wastewater for heavy metal testing; calculating the weight and amount of solid waste recovered; and recording energy consumption data. Third, the recording phase involves using environmental monitoring software to store data and generate time series. Fourth, the analysis phase involves comparing data with regulatory limits, assessing compliance, and proposing corrective measures.

Data evaluation quantifies environmental performance through statistical analysis. Emission concentrations, recovery rates, and energy efficiency are calculated, and trend charts are plotted to identify changes. The evaluation takes into account uncertainties such as sampling error and instrument accuracy. Abnormal data requires analysis of the cause, such as excessive emissions due to aging equipment, and the development of improvement plans. Reports include compliance statements and optimization recommendations.

Production environmental performance testing standards support process optimization. In practice, testing helps adjust sintering parameters to reduce waste gas emissions and optimize electroplating solution formulations to reduce wastewater pollution. In the future, green manufacturing technologies such as low-energy sintering furnaces will further enhance environmental performance, while automated monitoring systems will improve testing efficiency.

3.4.3 Compliance Testing Requirements for the Disposal of Waste Tungsten Alloy Weights

Compliance testing requirements for the treatment of waste tungsten alloy weights are designed to assess whether their recycling and disposal processes comply with environmental regulations and minimize environmental impact. These requirements, based on GB/T 18575 and REACH regulations, verify treatment compliance by testing the chemical properties of the waste and recycling efficiency.

Compliance testing is based on the principles of a circular economy and pollution control. Chemical analysis and recycling rate assessments ensure that discarded weights do not release hazardous

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substances. Testing verifies the recyclability and waste classification of tungsten alloys in compliance with the Law on the Prevention and Control of Environmental Pollution by Solid Waste. Tungsten alloy's low toxicity and high recycling value give it an environmental advantage in waste disposal.

The testing process includes sample collection, chemical analysis, recovery efficiency testing, and compliance assessment. First, discarded weights are collected and cataloged; second, they are analyzed for hazardous substances using ICP-MS; third, recovery rates are tested and the amount of tungsten and other metals extracted is calculated; and fourth, compliance with regulations is assessed and a report is generated.

Evaluation indicators include hazardous substance content (below the limit), recovery rate (target: above 90%), and disposal safety (no secondary contamination). These indicators must be compared with the GB/T 18575 standard, and the uncertainty must be reported.

The implementation steps include sample preparation, component analysis, recovery testing, and recording results. Professional recovery facilities and equipment are required to ensure accurate data. The report includes a compliance statement and recommendations.

Compliance testing supports a circular economy and reduces disposal costs. In practice, it ensures recycling safety and promotes resource reuse. In the future, intelligent recycling technology will improve efficiency .

By meeting these compliance testing requirements, the disposal of discarded tungsten alloy weights can be environmentally friendly and efficient, providing support for the sustainable development of the metrology industry.



CTIA GROUP LTD Tungsten Alloy Weights

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Chapter 4 Industry Application and Technology Adaptation of Tungsten Alloy Weights

Tungsten alloy weights, with their high density, excellent mechanical properties, and metrological stability, have demonstrated remarkable application value across a wide range of industries, becoming a key tool in metrological calibration, industrial verification, and commercial weighing. This chapter will focus on the application and adaptation of tungsten alloy weights in metrological calibration, analyzing their technical requirements and adaptability in the calibration of electronic balances and the verification of instruments such as platform and floor scales. These applications not only demonstrate the advantages of tungsten alloy weights in high-precision and diverse applications, but also highlight their flexibility in meeting the needs of diverse equipment and industries through material optimization and design adaptation.

4.1 Application and Adaptation of Tungsten Alloy Weights in Measurement and Calibration

Tungsten alloy weights are widely used in metrology and calibration, encompassing a wide range of applications, including high-precision laboratory calibration, industrial equipment verification, and commercial weighing systems. Their high density, low magnetic susceptibility, and durability enable them to meet the precision, stability, and environmental adaptability requirements of diverse metrological equipment. Through standardized design and customized adjustments, tungsten alloy weights ensure seamless compatibility with electronic balances, platform scales, floor scales, and other equipment, safeguarding the reliability of measurement value transfer and calibration.

4.1.1 Compatibility requirements for tungsten alloy weights used for electronic balance calibration

Tungsten alloy weights in electronic balance calibration is a key demonstration of its application in high-precision metrology. Electronic balances, with their high resolution and sensitivity, are widely used in laboratory analysis, pharmaceutical formulation, and scientific research. The calibration process places stringent demands on the weights' accuracy, stability, surface condition, and anti-magnetic properties. Tungsten alloy weights, with their superior material properties and manufacturing process, meet these requirements, making them an ideal choice for electronic balance calibration. The following details the requirements for tungsten alloy weights in electronic balance calibration, focusing on the principles of adaptation, material properties, design requirements, operational considerations, and practical applications.

Electronic balance calibration requires weights to provide a precise and stable mass reference to verify the balance's linear response and repeatability. The high density of tungsten alloy weights allows them to pack a large mass into a small package, making them suitable for the limited tray space of electronic balances. Their low magnetic susceptibility ensures that the weights do not interfere with the balance's electromagnetic sensors, maintaining calibration accuracy. Their high hardness and corrosion resistance ensure that the weights maintain their mass even under frequent handling and in laboratory environments. These properties combine to meet the high-precision weight requirements of electronic balances and ensure traceability of calibration results.

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Tungsten alloy weights are fundamental to their compatibility with electronic balances. Tungsten's high density allows for the manufacture of compact weights, making them suitable for calibrating microbalances (such as analytical balances with microgram resolution). The addition of auxiliary elements such as nickel enhances toughness, preventing surface damage caused by frequent handling. Low magnetic susceptibility is a key characteristic. Tungsten itself is a weakly paramagnetic material, and optimizing the alloy formula (such as controlling the iron content) can further reduce magnetic interference, ensuring electromagnetic compatibility with electronic balances. Corrosion resistance enables the weights to withstand the chemical vapors that may occur in the laboratory, maintaining long-term stability. These material properties are enhanced through precision manufacturing processes, ensuring that the weights meet the requirements of high-precision calibration.

Tungsten alloy weights must be designed to meet the strict standards for electronic balance calibration. Standardized shapes such as cylindrical or sheet weights are common choices. Cylindrical weights are easy to stack and combine, while sheet weights are suitable for micro-calibration and adapt to the shape and size of the balance pan. Surface finish requirements are extremely high, requiring precision polishing to achieve micron-level roughness to reduce the adhesion of contaminants and the effects of friction. Surface coatings (such as nickel plating) further enhance corrosion and wear resistance while maintaining low magnetic susceptibility. The quality grade (such as E1, E2) must match the accuracy of the balance and comply with the OIML R111 standard to ensure the transfer of calibrated values. The design also needs to consider the clarity of the weight labeling, such as engraving the mass value, to facilitate user identification and operation.

During electronic balance calibration, the handling of tungsten alloy weights must adhere to strict specifications to meet compatibility requirements. Before calibration, the weights must be cleaned with a dust-free cloth and neutral detergent to prevent grease or dust from affecting accuracy. Operators should use a dedicated clamp to grip the weights to prevent hand contact, contamination, or static interference. The calibration process must be performed in a constant temperature and humidity environment to minimize the effects of temperature and humidity on the balance reading. The weights must be placed stably to prevent sliding or tilting, ensuring uniform force on the balance pan. After calibration, the weights should be stored in a dedicated calibration box to prevent external factors from damaging their surface or mass. These operational considerations ensure the compatibility of the weights with the balance and maximize the calibration effect.

In practical applications, tungsten alloy weights are widely used to calibrate electronic balances in pharmaceutical, chemical, and biological laboratories. For example, in pharmaceutical formulations, microbalances need to be calibrated to milligram or even microgram levels. The small size and high precision of tungsten alloy weights enable precise verification of balance performance and ensure accurate formulations. In scientific research experiments, the weights' low magnetic susceptibility prevents interference with highly sensitive balances, ensuring data reliability. In environmental monitoring laboratories, the weights' corrosion resistance enables long-term use in calibrating analytical balances, adapting to environments exposed to chemical reagents. In the future, as balance resolution increases, tungsten alloy weights may be further improved in adaptability through more sophisticated

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manufacturing processes (such as nanoscale surface treatment) to meet even higher precision requirements.

4.1.2 Accuracy matching of tungsten alloy weights used for calibration of platform scales, floor scales, and other weighing instruments

Tungsten alloy weights in the calibration of instruments such as platform scales and floor scales is a significant manifestation of tungsten alloy weights in industrial and commercial metrology. These large-scale weighing devices are widely used in logistics, manufacturing, and trade. Their calibration requires weights that provide a reliable mass reference while meeting the requirements for accuracy, stability, and ease of use. Tungsten alloy weights, with their high density and durability, precisely match the precision requirements of these instruments, ensuring the accuracy and reliability of calibration results.

Tungsten alloy weights of bench and floor scales requires verification of their weighing range and linearity, typically involving calibration of large masses (e.g., hundreds of kilograms to several tons) or medium masses (e.g., tens of kilograms). The high density of tungsten alloy weights enables large masses to be accommodated in a compact volume, reducing space requirements at the calibration site while maintaining consistent quality. Accuracy matching requires that the mass of the weights be compatible with the scale's scale. For example, F2 or M1 grade weights are suitable for industrial scales and comply with OIML R111. The weights' resistance to wear and corrosion ensures they maintain accuracy despite frequent handling and complex environments, providing a reliable reference for calibration.

Tungsten alloy weights provide the foundation for their precision matching in platform and floor scale calibration. Their high density allows for the manufacture of large weights without excessive bulk, making block weights suitable for floor scale calibration, facilitating stacking and handling. The addition of auxiliary elements such as nickel and iron enhances the weights' strength and toughness, preventing deformation or damage caused by handling or stacking. Their corrosion resistance allows them to withstand exposure to moisture or chemicals in industrial environments, such as those found in food processing plants or logistics warehouses. Their low magnetic susceptibility ensures that the weights do not interfere with the sensors of electronic floor scales, maintaining calibration accuracy. These material advantages are further enhanced through optimized alloy formulations to meet the diverse needs of scale calibration.

Tungsten alloy weights for platform and floor scale calibration must balance accuracy and operability. Block weights are a common choice, as their regular shape allows for easy stacking and stable placement, making them suitable for large-scale calibration. Hook weights are ideal for hanging platform scales, where the included lifting rings facilitate lifting and calibration. Weight dimensions must match the scale tray or platform, avoiding weights that are too large or too small to affect operation. Surface treatments such as nickel plating or polishing enhance wear and corrosion resistance, ensuring stable accuracy during long-term calibration.

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During the calibration of platform and floor scales, the handling of tungsten alloy weights must adhere to strict specifications to ensure accurate matching. Before calibration, the weights must be cleaned and inspected for surface integrity to avoid scratches or contamination that could affect quality. Operators should use specialized equipment (such as a forklift or crane) to move large weights safely and prevent damage. The calibration process must be conducted in a stable environment to prevent vibration or wind from interfering with the scale reading. The weights must be evenly distributed on the platform. For example, in floor scale calibration, weights must be stacked in a standard layout to test the response of different areas. After calibration, the weights should be properly stored in a moisture-proof and dust-proof warehouse and inspected regularly to ensure long-term accuracy. These operational requirements are implemented through standardized processes to improve calibration efficiency and reliability.

4.1.3 Stability Adaptation of Tungsten Alloy Weights for Dynamic Weighing Equipment Calibration

Dynamic weighing equipment, such as conveyor belt weighing systems, assembly line scales, or vehicle dynamic scales, is widely used in logistics, food processing, and manufacturing. Calibration requires weights that maintain mass stability and metrological accuracy in dynamic environments. Tungsten alloy weights, with their high density, wear resistance, and vibration resistance, are an effective fit for these devices, ensuring the reliability of the calibration process.

The key to calibrating dynamic weighing equipment lies in simulating actual operating conditions, ensuring that the weight provides a stable mass reference in environments with motion, vibration, or rapid loading. The high density of tungsten alloy weights enables them to achieve a large mass within a small volume, reducing the effects of inertia during dynamic loading and making them suitable for rapid calibration of conveyor or vehicle scales. Their low coefficient of thermal expansion and vibration resistance ensure that the weight maintains volume and mass stability in dynamic environments, preventing deviations caused by mechanical stress. Their corrosion resistance and low magnetic susceptibility further ensure metrological accuracy in challenging environments, such as moisture and electromagnetic interference, complying with standards such as OIML R134.

Tungsten alloy weights provide the foundation for their stability in the calibration of dynamic weighing equipment. Tungsten's high density allows for compact weights, minimizing wobble or displacement during dynamic loading, ensuring calibration accuracy. The addition of auxiliary elements such as nickel and iron enhances the weight's toughness and shock resistance, enabling it to withstand conveyor belt vibrations or the rapid loading of vehicle scales. Its corrosion resistance makes it suitable for dynamic environments with humid or chemical exposure, such as the humidity or cleaning fluids found in food processing lines. Its low magnetic susceptibility prevents interference with electronic sensors in dynamic equipment, ensuring the reliability of calibration data.

Tungsten alloy weights for the calibration of dynamic weighing equipment must focus on stability and operability. Block or flat weights are common choices. Their low center of gravity design reduces the risk of tipping in dynamic environments and is suitable for quick placement on conveyor scales. Hook-

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shaped weights are suitable for suspended dynamic equipment, and the hanging ring design allows for quick installation and removal. Surface treatments such as high-gloss polishing or nickel plating reduce the coefficient of friction, reduce wear on the equipment surface, and ensure long-term stability. The quality grade (such as F2 or M1) must match the accuracy of the equipment to ensure that the calibration results meet the standard. The design must also consider ease of handling, such as adding handles or fixing slots to facilitate quick operation in dynamic environments.

Operations during the calibration of dynamic weighing equipment must strictly follow specifications to ensure stability and adaptability. Before calibration, the weights must be cleaned and checked for surface integrity to prevent contaminants from affecting dynamic readings. Operators should use dedicated equipment (such as a robotic arm or crane) to place the weights to ensure fast and smooth loading and avoid impact on the equipment sensor. During the calibration process, the actual operating speed must be simulated, such as gradually adding weights while the conveyor belt runs at a constant speed to test the response of different mass points. The calibration environment should control vibration and temperature fluctuations to avoid external interference. After calibration, the weights must be stored in a dedicated shock-proof and moisture-proof box and checked regularly to maintain stability. These operational requirements are implemented through standardized processes to ensure the efficiency and accuracy of calibration.

4.2 Application and Adaptation of Tungsten Alloy Weights in Precision Manufacturing

Tungsten alloy weights are widely used in precision manufacturing, demonstrating their value in high-precision weighing and quality control. Their high density, miniaturization capabilities, and durability make them suitable for the demanding accuracy and reliability requirements of precision manufacturing.

4.2.1 Accuracy Adaptation of Tungsten Alloy Weights for Automotive Parts Weighing

Tungsten alloy weights in automotive component weighing is a key example of its advancement in precision manufacturing. Automotive manufacturing involves verifying the weight of numerous components, such as engine parts, brake discs, and suspension systems. Weighing accuracy directly impacts assembly quality and vehicle performance. Tungsten alloy weights, designed with high density and stability, meet the automotive industry's requirements for high precision and durability.

Weighing automotive parts requires precise mass references to verify the performance of balances or weighing equipment, ensuring that component weights meet design specifications. The high density of tungsten alloy weights enables them to achieve high mass within a small footprint, making them suitable for space-constrained weighing equipment in automotive manufacturing. Their high hardness and wear resistance ensure that the weights maintain consistent mass even during frequent operation, meeting the accuracy requirements of standards such as ISO 17025. Their low magnetic susceptibility prevents interference with electronic weighing equipment, ensuring metrological consistency. These properties combine to ensure that these weights are suitable for the high-precision weighing needs of the automotive industry.

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Tungsten alloy weights support their precise adaptation to automotive component weighing. Tungsten's high density allows for compact weights, making them suitable for calibrating small or medium-mass weighing equipment, such as verifying the weight of bolts or gears. The addition of auxiliary elements such as nickel enhances the weight's toughness, preventing minor deformation caused by handling or stacking. Its corrosion resistance enables it to withstand the oil and humidity found in automotive manufacturing environments, ensuring long-term accuracy. Low magnetic susceptibility, achieved through an optimized alloy formulation, reduces interference with electronic scales. These properties are enhanced through precision manufacturing processes to meet the high standards of the automotive industry.

Tungsten alloy weights for automotive component weighing requires a focus on precision and ease of use. Cylindrical or block-shaped weights are common. Cylindrical weights facilitate assembly and calibration, while block-shaped weights are suitable for verifying large-mass components. The surface should be high-polished or plated to reduce friction and wear and maintain accuracy. The quality grade (e.g., F1 or F2) must match the scale graduation of the weighing equipment to ensure that calibration results meet standards. The design should also consider ease of handling, such as providing fixed points or handles for large-mass weights to facilitate quick operation on the production line. Clearly marked weight values and serial numbers facilitate management and traceability.

When weighing automotive parts, the handling of tungsten alloy weights requires strict specifications to ensure accurate fit. Before calibration, the weights must be cleaned and inspected for surface integrity to prevent oil or scratches from affecting the results. Operators should use specialized fixtures or mechanical equipment to handle the weights to prevent contamination from direct contact. The calibration process must be performed in a stable environment to control vibration and temperature fluctuations to ensure accurate readings from the weighing equipment. The weights must be evenly distributed on the weighing platform, and different mass points must be tested to verify linear response. After calibration, the weights should be stored in a dedicated dust- and moisture-proof box and regularly maintained to maintain performance. These specifications are implemented through standardized processes to improve calibration efficiency.

4.2.2 Miniaturization Application of Tungsten Alloy Weights for Semiconductor Wafers

Tungsten alloy weights in semiconductor wafer weighing is a unique example of its application in precision manufacturing. The semiconductor industry's high-precision wafer weight requirements stem from its stringent demands for production consistency and quality control. Miniaturized weights can be adapted to small weighing equipment, providing an accurate mass reference.

Weighing conductor wafers requires micro-scale mass references, typically in the milligram to gram range, to calibrate high-resolution balances and ensure wafer weights meet design specifications. The high density of tungsten alloy weights enables precise mass measurement in a very small footprint, meeting the semiconductor industry's demand for miniaturized devices. Their low magnetic susceptibility prevents interference with electromagnetic sensors in precision balances, while their corrosion resistance

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ensures stability in cleanroom environments. These features ensure compliance with ISO 9001 and semiconductor industry standards, ensuring reliable and consistent calibration.

Tungsten alloy weights provide key support for their miniaturization applications. Tungsten's high density allows for the manufacture of micro-weights (such as discs or small cylinders) suitable for calibrating microbalances. Ancillary elements such as nickel enhance the weight's toughness, preventing damage to the tiny structures during processing or handling. Its corrosion resistance and chemical stability enable its use in cleanroom environments with high humidity or chemical gases, preventing surface reactions from affecting accuracy. Low magnetic susceptibility, achieved through an optimized alloy formulation, ensures compatibility with high-sensitivity balances. These properties are enhanced through precision manufacturing processes to meet the demanding requirements of the semiconductor industry.

Tungsten alloy weights for semiconductor wafer weighing emphasizes miniaturization and precision. Sheet weights are the predominant form factor. Their thin, uniform structure fits neatly within the tray of a microbalance, typically measuring only millimeters thick. Their surface requires ultra-high finish, achieved through nano-level polishing, to reduce electrostatic adsorption and contaminant adhesion. The quality grade (e.g., E1 or E2) must match the balance's resolution to ensure calibration accuracy. The design also needs to consider operational convenience, such as laser engraving of the weight value for easy identification in a cleanroom. Miniaturized weights are manufactured using CNC machining or powder metallurgy to ensure precise control of size and quality.

In semiconductor wafer weighing, the handling of tungsten alloy weights must adhere to cleanroom specifications to ensure reliability in miniaturized applications. Prior to calibration, the weights must be cleaned in an ultrasonic cleaner and wiped with a dust-free cloth to prevent particulate contamination. Operators must wear anti-static gloves and cleanroom clothing and use specialized tweezers to handle the weights to avoid hand contact, which could cause contamination or static interference. The calibration process must be performed in a cleanroom with controlled temperature and humidity (e.g., $20^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$, 40%-60% humidity) to ensure stable balance readings. The weights must be placed gently and precisely to avoid vibrations that could affect the microbalance. After calibration, the weights should be stored in a dust-free calibration box and regularly inspected to maintain performance. These operations require compliance with cleanroom process specifications to ensure calibration accuracy.

4.2.3 Miniaturization of tungsten alloy weights for chip support

Tungsten alloy weights in chip carriers is a key example of their application in precision manufacturing. Chip carriers involve verifying the weight of chips or substrates in semiconductor manufacturing, often requiring a mass reference in the milligram range or even smaller to calibrate high-precision weighing equipment. Tungsten alloy weights, with their high density and miniaturization, are ideally suited for microbalances used in chip manufacturing, providing a precise mass standard.

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Chip-loaded weighing requires a micro-scale mass reference to verify balance performance and ensure the chip or substrate weight meets production standards. The high density of tungsten alloy weights enables precise mass measurement in a very small volume, making them suitable for space -constrained weighing equipment used in chip manufacturing. Their low magnetic susceptibility prevents interference with the electromagnetic sensors of highly sensitive balances, while their corrosion resistance and chemical stability ensure they maintain performance in cleanroom environments. These properties, in compliance with ISO 9001 and semiconductor industry standards, ensure reliable and consistent calibration, meeting the demanding high-precision requirements of chip manufacturing.

Tungsten alloy weights provide the core support for their miniaturization applications. Tungsten's high density allows for the manufacture of microweights (such as flakes or tiny particles), suitable for calibrating microbalances with microgram resolution . The addition of auxiliary elements such as nickel enhances the weight's toughness, preventing damage to the tiny structures during processing or handling. Its corrosion resistance enables its use in cleanroom environments with high humidity or chemical gases, preventing surface reactions from affecting mass accuracy. Low magnetic susceptibility, achieved through optimized alloy formulations (such as reduced iron content), ensures electromagnetic compatibility with high-sensitivity balances. These properties are enhanced through precision manufacturing processes, enabling the weights to meet the stringent requirements of chip loading.

Tungsten alloy weights for chip supports must focus on miniaturization and high precision. Sheet weights are the predominant form factor, and their ultra-thin structure (submillimeter thickness) fits neatly within the tray of a microbalance, minimizing footprint. Nano-polishing is required to achieve an exceptionally smooth surface, reducing the risk of electrostatic adsorption and particle adhesion. The quality grade (e.g., E1 or E2) must match the balance resolution to ensure calibration accuracy meets standards. The design must also consider operational ease, such as laser engraving of mass values and serial numbers for quick identification in cleanrooms. Miniaturized weights are manufactured using high-precision CNC machining or powder metallurgy techniques to ensure precise control of size and quality, meeting the stringent requirements of chip manufacturing.

In chip-loaded weighing, the handling of tungsten alloy weights must adhere to strict cleanroom specifications to ensure reliability in miniaturized applications. Before calibration, the weights must be cleaned in an ultrasonic cleaner and wiped with a dust-free cloth to prevent particulate contamination that could affect accuracy. Operators must wear anti-static gloves and cleanroom clothing and use specialized tweezers or vacuum grippers to handle the weights to avoid hand contact, which could cause contamination or static interference. The calibration process must be performed in a cleanroom with controlled temperature and humidity (e.g., $20^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$, 40%-60% humidity) to ensure stable balance readings. The weights must be placed gently and precisely to avoid vibration or offset that could affect the microbalance. After calibration, the weights should be stored in a dedicated, dust-free, anti-static calibration box and inspected regularly to maintain performance. These operational requirements are implemented through standardized cleanroom procedures to ensure accurate and reliable calibration.

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In semiconductor manufacturing, tungsten alloy weights are used to calibrate microbalances in chip-carrying processes. For example, during the chip packaging process, weights verify the weight of the substrate or chip to ensure consistent packaging quality. After wafer dicing, weights calibrate the balance to support weight detection to ensure process accuracy. In R&D laboratories, weights are used to calibrate experimental equipment to assist in the development of new chip materials. The miniaturized design of tungsten alloy weights reduces the need for calibration space, and their durability supports high-frequency use in clean rooms. In the future, as chip size continues to shrink and precision requirements increase, tungsten alloy weights may be further optimized for miniaturized applications through more advanced micromachining technologies (such as laser micro-engraving) or intelligent design to meet the needs of next-generation chip manufacturing.

4.2.4 Compatibility and Adaptation of Tungsten Alloy Weights for Online Weighing Modules in Automated Production Lines

Tungsten alloy weights in inline weighing modules on automated production lines is another important manifestation of its application in precision manufacturing. Automated production lines are widely used in industries such as food processing, pharmaceuticals, and logistics. Inline weighing modules must quickly and accurately verify product weights, and weights, as calibration tools, require high compatibility and stability. Tungsten alloy weights, with their high density, durability, and design flexibility, are adaptable to the dynamic demands of automated systems.

Automated production line inline weighing modules require weights to provide a stable mass reference in high-speed, continuous dynamic environments to calibrate load cell performance. The high density of tungsten alloy weights enables them to achieve a large mass within a small footprint, reducing space requirements in automated equipment and facilitating rapid loading and unloading. Their vibration and wear resistance ensures stable mass during dynamic operation, while their low magnetic susceptibility prevents interference with electronic sensors, complying with standards such as ISO 9001 and OIML R76 (for non-automatic weighing instruments). These properties ensure efficient compatibility with inline weighing modules, providing reliable calibration for automated production.

Tungsten alloy weights are widely used in automated production lines to calibrate inline weighing modules. For example, in food processing, weights verify packaging line weighing systems to ensure product weights meet standards; in the pharmaceutical industry, weights calibrate tablet packaging equipment to ensure accurate dosage; and in the logistics industry, weights are used to calibrate weighing modules in automated sorting systems to improve efficiency. The small size and durability of tungsten alloy weights reduce calibration time and maintenance costs, and their compatibility and adaptability support high-frequency operations.

4.3 Adaptation of tungsten alloy weights in special environmental applications

Tungsten alloy weights for specialized applications is a key factor in their ability to maintain performance under extreme conditions. These environments include high temperatures, low temperatures, high

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humidity, chemical corrosion, or high vibration, such as those found in marine engineering, aerospace, and chemical laboratories. Tungsten alloy weights, with their high density, corrosion resistance, and vibration resistance, are well-suited to the demanding requirements of these environments, ensuring metrological accuracy and reliability.

Specialty weights require stable mass and volume under extreme conditions, providing a reliable metrological reference. The low thermal expansion coefficient of tungsten alloy weights ensures minimal volume change in high or low temperature environments, maintaining metrological accuracy. Their corrosion resistance and chemical stability make them resistant to acid, alkali, and salt spray, making them suitable for use in chemical laboratories or marine environments. Their vibration resistance and high strength ensure that the weights maintain structural integrity in high-vibration environments, such as aerospace testing. These properties comply with standards such as OIML R111 and ISO 17025, ensuring reliable calibration in these challenging environments.

Tungsten alloy weights provide the foundation for their suitability in specialized environments. Tungsten's high density allows for compact weights, suitable for space-constrained equipment such as aerospace test platforms. Ancillary elements such as nickel and copper enhance corrosion resistance, preventing reactions in high-humidity or chemical environments. Its low coefficient of thermal expansion allows it to withstand temperature fluctuations, making it suitable for high-temperature chemical reactors or cold chain environments. Vibration resistance, achieved through a high-strength alloy formulation, ensures the weights' stability in dynamic environments. These properties are enhanced through optimized manufacturing processes to meet the diverse demands of specialized environments.

Tungsten alloy weights designed for use in challenging environments must prioritize stability and durability. Cylindrical or block-shaped weights are suitable for environments with high temperatures or vibration, as their regular shape and low center of gravity reduce the risk of displacement. Special coatings (such as chrome plating or ceramic coatings) are required to enhance corrosion resistance and make them suitable for marine or chemical environments. The quality grade should be selected based on the environmental requirements, such as E1 for high-precision laboratories and M1 for marine engineering. The design should also consider ease of use, such as adding fixing points or protective housings to facilitate handling and installation in extreme environments. These optimizations ensure the weights' stable performance in challenging environments.

Tungsten alloy weights must be handled according to strict specifications in specialized environments to ensure their suitability. Before calibration, the weights must be cleaned and the coating integrity inspected to prevent environmental factors from affecting performance. In high or low temperature environments, temperature-resistant fixtures or mechanical equipment must be used to transport the weights to ensure safety and accuracy. The calibration process requires controlled environmental parameters, such as using a dehumidifier in high-humidity environments and a vibration-damping platform in high-vibration environments. The weights must be placed stably and evenly, and the equipment response must be tested to verify performance. After calibration, the weights should be stored

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in a dedicated protective box and regularly inspected to maintain their environmental resistance. These specifications, implemented through standardized processes, ensure the reliability of calibration.

4.3.1 High temperature resistance of tungsten alloy weights for high temperature environments

Tungsten alloy weights in high temperature environments is mainly aimed at scenarios such as aerospace, metallurgy and high temperature experiments. It is necessary to maintain stable mass and volume under high temperature conditions to ensure calibration accuracy.

High-temperature environments, such as high-temperature laboratory furnaces or aircraft engine test platforms, require weights to maintain metrological stability despite temperature fluctuations. The low thermal expansion coefficient of tungsten alloy weights minimizes volume change at high temperatures, maintaining a constant mass. Their high melting point and oxidation resistance ensure that the weights will not decompose or oxidize in high-temperature environments, making them suitable for calibrating high-temperature weighing equipment. Their vibration resistance ensures stability in high-temperature dynamic environments, complying with standards such as OIML R111 and providing a reliable reference for high-temperature calibration.

Tungsten alloy weights provide the foundation for their high-temperature resistance. Tungsten's high melting point and low coefficient of thermal expansion enable it to withstand high-temperature environments without significant deformation. The addition of auxiliary elements such as nickel enhances oxidation resistance at high temperatures and prevents surface degradation. The high hardness and toughness of tungsten alloy ensure that the weights maintain their structural integrity under high-temperature vibration or mechanical stress. Its low magnetic susceptibility prevents interference with electronic weighing equipment used in high-temperature environments. These properties, achieved through an optimized alloy formulation, ensure stable performance of the weights in high-temperature environments.

tungsten alloy weights for high-temperature environments must prioritize heat resistance and stability. Cylindrical or block-shaped weights are common; their regular shape and low center of gravity reduce the risk of shifting in high-temperature environments. The surface should be treated with a high-temperature coating (such as a ceramic coating) or a high-gloss polish to enhance oxidation resistance and wear resistance. The quality grade (such as F1 or F2) must match the accuracy of the high-temperature equipment to ensure that calibration results meet standards. The design must also consider thermal conductivity, for example, by optimizing the shape to reduce heat buildup and protect the metrological performance of the weight. Markings must utilize high-temperature-resistant engraving technology to ensure legibility even at high temperatures.

Tungsten alloy weights are widely used in high-temperature environments to calibrate weighing equipment in aerospace test platforms, such as verifying the weight of engine components. In the metallurgical industry, weights calibrate weighing systems in high-temperature furnaces to ensure material processing accuracy. In laboratories, weights support the calibration of high-temperature

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experimental equipment and meet the needs of thermal analysis instruments. The high-temperature resistance of tungsten alloy weights reduces calibration frequency, and their stability supports high-intensity operation.

4.3.2 Radiation Protection Design and Adaptation of Tungsten Alloy Weights for Radiation Environments

Tungsten alloy weights in radiation environments is mainly aimed at scenarios such as the nuclear industry, medical imaging, and scientific research laboratories, which need to maintain metrological stability and material safety under radiation conditions.

Radiation environments, such as nuclear laboratories or medical radiation equipment, require weights that resist radiation-induced material degradation while maintaining stable mass and volume. The high density and chemical stability of tungsten alloy weights enable them to partially shield radiation, minimizing changes in material properties. Their low magnetic susceptibility prevents interference with electronic equipment in radiation-exposed environments, while their corrosion resistance ensures stability in complex chemical environments. These properties, in compliance with standards such as ISO 17025, ensure the reliability of weight calibration in radiation-exposed environments.

Tungsten alloy weights support their radiation protection. Tungsten's high density and atomic number provide it with certain radiation shielding capabilities, reducing the effects of radiation on the material's structure. Supplementary elements such as nickel enhance oxidation resistance, preventing radiation-induced chemical reactions. The high hardness and toughness of tungsten alloy ensure that the weights withstand mechanical stresses and maintain structural integrity in radiation environments. Low magnetic susceptibility, achieved through an optimized formulation, ensures compatibility with sensors used in radiation-resistant equipment. These properties are enhanced through precision manufacturing to meet the stringent requirements of radiation environments.

Tungsten alloy weights for use in radiation environments must prioritize radiation protection and stability. Block or cylindrical weights are suitable for radiation environments, as their compact shape reduces the area exposed to radiation. The surface should be treated with a radiation-resistant coating (such as a lead composite coating) or a high-gloss polish to minimize radiation-induced surface degradation. The quality grade (such as F1 or E2) must match the accuracy of the radiation equipment to ensure calibration accuracy. The design must also consider operational safety, such as using sealing to prevent the adhesion of radioactive particles to protect operators and equipment. Markings should be made of radiation-resistant materials to ensure long-term readability.

When handling tungsten alloy weights in a radiation environment, radiation safety regulations must be followed. Before calibration, the weights must be inspected for surface integrity and coating condition to prevent radiation damage. Operators must wear protective equipment and use specialized fixtures or mechanical equipment to handle the weights to minimize radiation exposure. Calibration must be performed in a shielded environment, such as a lead-shielded box, to isolate radiation interference.

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Weights must be precisely positioned to prevent vibration from affecting equipment readings. After calibration, weights should be stored in a radiation-proof container and regularly tested for residual radiation to ensure safety. These regulations, implemented through standardized processes, ensure the reliability and safety of calibration.

4.3.3 Pressure-resistant seal adaptation of tungsten alloy weights for deep-sea environments

Tungsten alloy weights in deep-sea environments is mainly aimed at marine engineering and deep-sea research, which require stable measurement under high pressure, high humidity and corrosive conditions.

Deep-sea environments, such as those used to calibrate deep-sea exploration equipment, require weights to withstand high pressure and saltwater corrosion while maintaining stable mass and volume. The high density of tungsten alloy weights allows them to achieve high mass within a small footprint, adapting to the space constraints of deep-sea equipment. Their high strength and corrosion resistance ensure that the weights will not deform or deteriorate in high-pressure and saltwater environments, complying with OIML R111 standards and providing reliable support for deep-sea calibration.

Tungsten alloy weights provide the foundation for their pressure-resistant sealing. Tungsten's high density and strength enable it to withstand the high pressures of the deep sea without deformation. Ancillary elements such as nickel and copper enhance resistance to saltwater corrosion, preventing degradation caused by long-term exposure. A low coefficient of thermal expansion ensures the weights maintain volume stability in the cold ocean temperatures. Low magnetic susceptibility prevents interference with electronic sensors in deep-sea equipment. These properties are achieved through an optimized alloy formulation to meet the demanding requirements of the deep-sea environment.

Tungsten alloy weights designed for deep-sea environments must prioritize pressure resistance and sealing. Block or streamlined weights are common choices, as their compact shape reduces pressure points and enhances pressure resistance. They should be coated with a corrosion-resistant coating (such as ceramic or titanium alloy) and sealed to prevent saltwater penetration. The quality grade (such as M1 or F2) should match the precision of deep-sea equipment. The design should also consider ease of installation, such as through the use of retaining rings or grooves to accommodate deep-sea machinery. Markings should be made of corrosion-resistant materials to ensure legibility in saltwater environments.

4.3.4 Corrosion-resistant adaptation of tungsten alloy weights for use in wet/corrosive environments

Tungsten alloy weights in humid/corrosive environments is mainly aimed at chemical laboratories, food processing and coastal industries, etc., which need to maintain stable measurement under high humidity or chemical corrosion conditions.

Wet/corrosive environments, such as chemical laboratories or coastal factories, require weights that resist corrosion from moisture, acids, alkalis, or salt spray, maintaining a stable mass and surface. The chemical

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stability of tungsten alloy weights resists corrosion, while their low coefficient of thermal expansion minimizes volume changes caused by moisture. Their high hardness and wear resistance ensure that the weights maintain integrity during frequent operation, complying with OIML R111 standards and providing assurance for calibration in corrosive environments.

Tungsten alloy weights support their corrosion resistance. Tungsten's chemical inertness makes it unreactive with most acids and bases, making it suitable for chemical environments. Ancillary elements such as nickel and copper enhance corrosion resistance to salt spray and moisture, extending service life. A low coefficient of thermal expansion ensures the weights maintain volume stability in high humidity environments. Low magnetic susceptibility prevents interference with electronic weighing equipment. These properties are achieved through optimized formulation and surface treatment to meet the stringent requirements of wet/corrosive environments.

Tungsten alloy weights must be handled according to strict specifications in humid/corrosive environments. Before calibration, weights must be cleaned and the coating integrity inspected to prevent corrosion that could affect accuracy. Operators should use corrosion-resistant fixtures to handle weights to prevent liquid contamination. Humidity must be controlled during calibration, using a dehumidifier or sealed box to minimize moisture interference. Weights must be placed securely to prevent slippage that could affect readings. After calibration, weights should be stored in a moisture-proof and corrosion-resistant container and regularly maintained to maintain performance. These specifications ensure reliable calibration.

4.4 Application and Adaptation of Tungsten Alloy Weights in Trade Settlement

Tungsten alloy weights in trade settlement covers scenarios such as import and export trade, precious metal trading and industrial raw material measurement. Its high density, durability and standardized design enable it to be adapted to a variety of weighing equipment, from large floor scales to high-precision balances, to meet the needs of fair trade.

4.4.1 Compliance and Adaptation of Tungsten Alloy Weights for Import and Export Commodity Weighing

Tungsten alloy weights in the weighing of imported and exported commodities is a key manifestation of their role in trade settlement. Trading bulk commodities (such as grain, minerals, and petroleum products) involves weighing large quantities, typically using scales or port weighing systems. Calibration must comply with international trade regulations and metrology standards. Tungsten alloy weights, designed with high density and durability, meet regulatory compliance and operational requirements, ensuring fair trade practices.

Bulk commodities for import and export requires a high-mass reference weight to verify the performance of floor scales or large-scale weighing equipment, ensuring that measurement results comply with international trade standards. The high density of tungsten alloy weights enables them to achieve high

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mass in a compact package, adapting to space constraints in ports or warehouses. Their corrosion and wear resistance ensures they remain stable despite frequent handling and complex environments, complying with standards such as OIML R111 and ISO 17025. Their low magnetic susceptibility prevents interference with electronic weighing equipment, ensuring calibration accuracy. These properties ensure that these weights meet the compliance requirements of trade settlements and support the transfer of value.

Tungsten alloy weights provide the foundation for their regulatory compliance. Tungsten's high density allows for the manufacture of large weights (ranging from tens of kilograms to several tons), reducing handling complexity and space requirements. Ancillary elements such as nickel and iron enhance the weights' toughness and impact resistance, preventing damage from stacking or transportation. Their corrosion resistance allows them to withstand the humid environments of ports and warehouses, resisting salt spray and chemical attack. Low magnetic susceptibility, achieved through an optimized alloy formulation, ensures electromagnetic compatibility with electronic floor scales. These properties are enhanced through precision manufacturing processes to meet the regulatory compliance requirements of trade settlements .

Tungsten alloy weights for import and export commodity weighing must prioritize compliance and operability. Block weights are the predominant form, as their regular shape and low center of gravity facilitate stacking and stable placement, making them suitable for floor scale calibration. Nickel plating or a high-gloss polish should be used to enhance corrosion and wear resistance, ensuring stable accuracy over long-term use. The quality grade (e.g., M1 or M2) must match the scale's graduation value and comply with international metrology standards. The design should also consider ease of handling, such as adding handles or fixing rings to accommodate forklift or crane operation. Labels should clearly engrave the weight value and serial number to ensure traceability and compliance .

When weighing bulk commodities for import and export, the handling of tungsten alloy weights must adhere to strict specifications to ensure proper fit . Prior to calibration, weights must be cleaned and inspected for surface integrity to prevent contaminants or scratches that could affect accuracy. Operators should use mechanical equipment (such as a forklift or crane) to move large weights safely and prevent damage. Calibration must be performed in a stable environment to control vibration and wind interference to ensure accurate scale readings. Weights must be evenly distributed across the weighing platform, and testing at various mass points is performed to verify linear response. After calibration, weights should be stored in a moisture- and dust-proof warehouse and regularly inspected to maintain performance. These specifications, enforced through standardized processes, ensure calibration results comply with trade regulations.

In import and export trade, tungsten alloy weights are used to calibrate port scales or warehouse weighing systems, for example, to verify the weight of grain or ore and ensure fair transactions. In cross-border logistics, weights support the calibration of container weighing equipment to comply with international trade regulations. In energy trade, weights are used to calibrate petroleum product weighing systems to

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ensure measurement accuracy. The small size and high mass of tungsten alloy weights simplify handling at the calibration site, and their durability supports high-frequency operation.

4.4.2 tungsten alloy weights for precious metal trading weighing

Tungsten alloy weights in precious metals trading demonstrates their high precision in trade settlement. Precious metals (such as gold and silver) trading requires extremely high weighing accuracy, typically using high-resolution balances calibrated to meet stringent metrological standards. Tungsten alloy weights, through their high density and miniaturized design, provide a precise mass reference, adapting to the demands of precious metals trading.

Precious metals trading requires weights that provide milligram- or even microgram-level mass references to verify the performance of high-precision balances and ensure fair and accurate transactions. The high density of tungsten alloy weights enables precise mass measurement in a very small footprint, accommodating the limited tray space of balances. Their low magnetic susceptibility prevents interference with the electromagnetic sensors of highly sensitive balances, and their corrosion resistance ensures stability during frequent operation. These properties comply with standards such as OIML R111 and ISO 9001, supporting the value transfer and accuracy requirements of precious metals trading.

Tungsten alloy weights support their high-precision adaptation. Tungsten's high density allows for the manufacture of micro-weights (such as sheets or small cylinders), suitable for calibrating analytical balances with microgram resolution. Ancillary elements such as nickel enhance the weight's toughness, preventing damage to the tiny structures during handling. Its corrosion resistance allows it to withstand moisture and chemicals in trading environments, maintaining consistent quality. Low magnetic susceptibility, achieved through an optimized alloy formulation, ensures electromagnetic compatibility with electronic balances. These properties, enhanced through precision manufacturing processes, meet the high-precision demands of precious metals trading.

tungsten alloy weights for precious metals trading requires a focus on miniaturization and high precision. Sheet weights are the predominant form factor, their ultra-thin structure fitting comfortably within the tray of a microbalance, minimizing footprint. Nano-polishing is required to achieve an exceptionally smooth surface, minimizing the risk of static electricity and contaminant adhesion. The quality grade (e.g., E1 or E2) must match the balance's resolution to ensure calibration accuracy meets standards. The design also needs to incorporate ease of use, such as laser engraving of the weight value and serial number for quick identification. Miniaturized weights are manufactured using high-precision CNC machining or powder metallurgy to ensure precise control of size and quality.

4.4.3 Stability Adaptation of Tungsten Alloy Weights for Industrial Raw Materials Settlement

Tungsten alloy weights in industrial raw material settlements is another important manifestation of their use in trade settlements. Settlement of industrial raw materials (such as steel, chemical raw materials, and timber) involves weighing large or medium masses, typically using platform or floor scales.

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Calibration must ensure long-term stability and metrological reliability. Tungsten alloy weights, with their high density and durability, meet the stability requirements of industrial environments.

Industrial raw material settlements require weights to provide a stable mass reference, verify the performance of weighing equipment, and ensure accurate settlement results. The high density of tungsten alloy weights enables them to achieve high mass within a compact footprint, adapting to the space constraints of industrial weighing equipment. Their wear and corrosion resistance ensures they maintain stable quality despite frequent handling and complex environments, complying with OIML R111 standards. Their low magnetic susceptibility prevents interference with electronic weighing equipment, ensuring calibration consistency. These properties ensure the weights meet the stability requirements of industrial settlements and support fair trade.

Tungsten alloy weights for industrial raw material settlement must prioritize stability and operability. Block weights are the predominant form, as their regular shape facilitates stacking and stable placement, making them suitable for bench or floor scale calibration. Nickel plating or a high-gloss polish are required to enhance corrosion and wear resistance, ensuring long-term accuracy. The quality grade (e.g., M1 or F2) must match the scale graduations of the weighing equipment and comply with metrological standards. The design should also consider ease of handling, such as by adding a retaining ring or handle to accommodate mechanical handling equipment. Clear markings should be applied to ensure traceability. In industrial raw material settlement, the handling of tungsten alloy weights must adhere to standardized procedures to ensure stability and fit. Before calibration, the weights must be cleaned and inspected for surface integrity to prevent contaminants from affecting accuracy. Operators should use a forklift or crane to transport large weights safely and prevent damage. Calibration must be performed in a stable environment to control vibration and temperature fluctuations to ensure accurate readings from the weighing equipment. The weights must be evenly distributed on the platform, and different mass points must be tested to verify linear response. After calibration, the weights should be stored in a moisture- and dust-proof warehouse and regularly maintained to maintain performance. These procedures are implemented through standardized processes, improving calibration efficiency.

In industrial raw material settlements, tungsten alloy weights are used to calibrate platform scales in steel processing plants to ensure accurate material weights. In the chemical industry, weights verify raw material weighing equipment to ensure accurate batching. In the timber trade, weights calibrate floor scales to ensure fair settlements. The stability of tungsten alloy weights reduces calibration frequency, and their durability supports high-intensity operations in industrial environments. In the future, as industrial automation increases, tungsten alloy weights may further optimize stability and adaptability through intelligent design (such as embedded sensors), thereby improving settlement efficiency.

4.5 Application and Adaptation of Tungsten Alloy Weights in Scientific Research Experiments

Tungsten alloy weights in scientific research and experiments covers multiple branches such as material mechanics, astrophysics and environmental simulation. Its high density, low magnetic susceptibility and durability make it suitable for high-precision balances, counterweight systems and simulation equipment.

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4.5.1 Standard weight adaptation for tungsten alloy weights used in material mechanics experiments

Tungsten alloy weights are primarily used as counterweights in material mechanics experiments to test the tensile, compression, and bending properties of materials. These experiments simulate the load on the sample, and counterweights must provide a stable and accurate mass reference to ensure the reliability of experimental data. Tungsten alloy weights are designed with high density and durability to meet the requirements of standard counterweights.

Materials mechanics experiments require counterweights to provide uniform loading within the experimental setup to simulate realistic stress conditions. The high density of tungsten alloy weights allows for a large mass within a small footprint, making them suitable for the limited space of experimental equipment. Their low coefficient of thermal expansion ensures that the weights maintain volume stability despite temperature fluctuations, preventing degradation of experimental accuracy. Their vibration resistance and high strength ensure stability under dynamic loading, complying with standards such as ISO 6892 and providing reliable support for materials testing.

Tungsten alloy weights provide the foundation for their suitability as standard counterweights. Tungsten's high density allows for compact weights, ideal for use in tensile testing machines or compression testing equipment. Supplementary elements such as nickel enhance toughness, protecting the weight from damage during repeated loading. Its corrosion resistance allows it to withstand moisture and chemical reagents in experimental environments, ensuring long-term stability. Its low magnetic susceptibility prevents interference with electronic experimental equipment, ensuring data accuracy. These properties are achieved through an optimized alloy formulation to meet the stringent requirements of material mechanics experiments.

Tungsten alloy weights for material mechanics experiments requires attention to standardization and stability. Hook-shaped or block-shaped weights are common choices. Hook-shaped weights facilitate hanging loads, while block-shaped weights are suitable for compression tests, as their regular shape ensures uniform loading. The surface should be high- polished or plated to reduce friction and wear, ensuring experimental accuracy. The quality grade should match the experimental equipment to ensure that the weight meets the standard. The design should also consider ease of installation, such as using retaining rings or grooves to adapt to experimental fixtures. The weight value should be clearly engraved on the label to ensure traceability.

In material mechanics experiments, the handling of tungsten alloy weights must adhere to specifications to ensure standard weight compatibility. Before the experiment, the weights must be cleaned and inspected for surface integrity to prevent contaminants from affecting the load. Operators should use specialized fixtures or mechanical devices to load the weights evenly and safely. Temperature and vibration must be controlled during the experiment, and weights should be added gradually to test the material's response. Weights must be placed stably to prevent drift from affecting the results. After the experiment, the weights should be stored in a dust- and moisture-proof cabinet and regularly inspected

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to maintain performance. These specifications, implemented through standardized processes, ensure experimental reliability.

4.5.2 High-precision applications of tungsten alloy weights in astrophysical experiments

Tungsten alloy weights are primarily used in astrophysics experiments as high-precision mass references, simulating gravitational fields or calibrating measurement equipment. Astrophysics experiments involve simulating the mass and gravity of celestial bodies, and weights must provide a precise mass standard to ensure the reliability of experimental data. Tungsten alloy weights are designed with high density and low magnetic susceptibility to meet these high-precision requirements.

Astrophysical experiments require weights to simulate small-scale gravitational effects, providing a high-precision mass reference to validate theoretical models. The high density of tungsten alloy weights enables them to achieve a large mass within a small volume, adapting to the spatial constraints of experimental equipment. Their low magnetic susceptibility prevents interference with magnetic field-sensitive equipment, and their vibration resistance ensures stability during dynamic simulations. These properties conform to international metrology standards, providing precise support for astrophysical experiments.

Tungsten alloy weights for astrophysics experiments requires high precision and stability. Cylindrical or spherical weights are common choices. Cylindrical weights are easier to secure, while spherical weights are suitable for gravitational simulations, as their regular shape ensures uniform mass distribution. Nano-level polishing is required to minimize interference. High-precision matching of mass grades is required to ensure experimental accuracy. The design also needs to consider ease of installation, such as using a fixed bracket to adapt to the experimental setup. Markings should be precisely engraved to ensure readability.

In astrophysics experiments, the handling of tungsten alloy weights requires strict specifications to ensure high-precision applications. Before the experiment, the weights must be cleaned and inspected for surface integrity to prevent contaminants from affecting accuracy. Operators should use a dedicated fixture to position the weights for stability and security. During the experiment, environmental factors such as temperature and vibration must be controlled, and the weights must be gradually adjusted to test gravitational effects. The weights must be precisely placed to prevent drift from affecting the results. After the experiment, the weights should be stored in a dustproof box and regularly inspected to maintain performance. These specifications ensure experimental reliability.

4.5.3 Stability Adaptation of Tungsten Alloy Weights for Environmental Simulation Experiments

Tungsten alloy weights are primarily used in environmental simulation experiments as a stable mass reference for simulating climate change or weighing tests within ecosystems. These experiments involve controlling temperature, humidity, or pressure, and the weights must maintain stability to ensure data

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reliability. Tungsten alloy weights meet these stability requirements through their low thermal expansion and corrosion resistance.

Environmental simulation experiments require weights that maintain consistent mass in fluctuating environments, providing a reliable weighing reference. Tungsten alloy weights' low coefficient of thermal expansion minimizes volume change during temperature fluctuations, while their corrosion resistance ensures stability in high humidity or chemical environments. These properties comply with international metrology standards and support environmental simulations.

Tungsten alloy weights provide the foundation for their stability and adaptability. Tungsten's high density allows for the manufacture of stable weights, making them suitable for simulation equipment. Supplementary elements enhance corrosion resistance and protect against moisture. Low thermal expansion ensures stability during temperature fluctuations. Low magnetic susceptibility prevents interference with electronic equipment. These properties meet the demands of environmental simulation. Tungsten alloy weights must be handled in a standardized manner to ensure stability during environmental simulations. Inspect integrity before the experiment. Use a fixture to position the weight. Ensure process parameters are controlled to avoid interference. Ensure stable placement. After completion, store in a moisture-proof cabinet and inspect regularly. In environmental simulations, tungsten alloy weights are used to calibrate weighing systems in climate chambers, support soil testing in ecological experiments, and verify chemical reaction weights in pollution simulations. The weight's stability reduces errors and supports long-term operation.

4.6 Application and Adaptation of Tungsten Alloy Weights in Medical Equipment

Tungsten alloy weights in the medical equipment field covers scenarios such as medical scale calibration, radiotherapy equipment counterweights and precision instrument component verification. Its high density, low magnetic susceptibility and corrosion resistance make it adaptable to the requirements of precision, hygiene and special performance in the medical environment.

4.6.1 Sanitary Adaptation of Tungsten Alloy Weights for Calibration of Medical Scales

Tungsten alloy weights are primarily used in medical scale calibration, primarily for calibrating weight scales, baby scales, and pharmaceutical weighing equipment in hospitals and clinics, ensuring that measurement accuracy meets medical standards. Medical scales require extremely high hygienic properties from weights to prevent cross-contamination. Tungsten alloy weights meet these hygienic requirements through their high density and corrosion-resistant design.

Medical scale calibration requires precise mass references to verify equipment performance while also meeting medical hygiene standards and avoiding contamination risks. The high density of tungsten alloy weights allows them to pack a large mass into a small package, making them suitable for the limited tray space of medical scales. Their corrosion resistance and easy-to-clean surface ensure that they are bacteria-free in medical environments, complying with standards such as ISO 13485 (Quality

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Management for Medical Devices). Their low magnetic susceptibility prevents interference with electronic scales, ensuring calibration accuracy. These properties ensure that these weights meet the hygienic and precision requirements of medical scale calibration.

Tungsten alloy weights provide the foundation for their hygienic suitability. Tungsten's high density allows for compact weights, making them ideal for calibrating small medical scales, such as baby scales or pharmacy balances. Auxiliary elements such as nickel enhance toughness, preventing surface damage from frequent handling. Corrosion resistance enables them to withstand disinfectants and moisture found in medical environments, ensuring a clean surface. Low magnetic susceptibility, achieved through an optimized alloy formulation, prevents interference with the sensors of electronic scales. Tungsten alloy weights used in medical scale calibration must be designed with a focus on hygiene and precision. Cylindrical or disc-shaped weights are common. Cylindrical weights facilitate modular calibration, while disc-shaped weights are suitable for microbalances, where their smooth surface reduces the adhesion of contaminants. Surface treatments such as high-gloss polish or antimicrobial coatings ensure compliance with medical hygiene standards and resistance to cleaning with alcohol or disinfectants. The quality grade must match the accuracy of the scale to ensure that calibration results meet standards.

During the calibration of medical scales, the handling of tungsten alloy weights must adhere to medical hygiene standards. Before calibration, the weights must be cleaned and disinfected in an ultrasonic cleaner and wiped with a sterile cloth to prevent bacterial contamination. Operators must wear sterile gloves and use specialized tweezers or clamps to handle the weights to avoid contamination from hand contact. The calibration process must be conducted in a clean environment with controlled temperature and humidity to ensure stable scale readings. The weights must be placed gently and precisely to avoid vibration that affects accuracy. After calibration, the weights should be stored in a sterile, dust-proof, dedicated box and disinfected regularly to maintain hygienic properties. These standards, implemented through standardized processes, ensure the hygiene and reliability of calibration.

4.6.2 Radiation protection of tungsten alloy weights used as counterweights in radiotherapy equipment

Tungsten alloy weights are primarily used in radiotherapy equipment for calibrating and balancing the weighing systems of radiotherapy equipment, such as linear accelerators or gamma knife weight verification. The radiotherapy environment places stringent demands on the radiation protection of weights to ensure material stability and operational safety. Tungsten alloy weights meet these requirements through their high density and radiation-resistant design.

Counterweights for radiotherapy equipment must maintain stable mass in radiation environments, providing a reliable calibration or balancing reference. They also require radiation shielding to protect operators and equipment. Tungsten alloy weights' high density and atomic number provide them with radiation shielding capabilities, minimizing the effects of radiation on material properties. Their chemical stability prevents radiation-induced degradation, and their low magnetic susceptibility prevents

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interference with equipment sensors. These properties comply with ISO 13485 and radiation safety standards, providing reliable support for radiotherapy equipment.

Tungsten alloy weights support their radiation protection. Tungsten's high density and atomic number enable it to effectively shield against gamma rays and X-rays, protecting the surrounding environment. Supplementary elements such as nickel enhance oxidation resistance, preventing radiation-induced chemical reactions. High hardness and toughness ensure the weights withstand mechanical stress and maintain structural integrity in radiation environments. Low magnetic susceptibility, achieved through an optimized formulation, ensures electromagnetic compatibility with radiotherapy equipment. These properties are enhanced through precision manufacturing to meet the stringent requirements of radiation environments.

Tungsten alloy weights in radiotherapy equipment requires attention to radiation protection and stability. Block or cylindrical weights are common choices, as their compact shape reduces the area exposed to radiation. The surface should be treated with a radiation-resistant coating (such as a lead composite coating) or a high-gloss polish to minimize radiation-induced surface degradation. The quality grade must match the accuracy of the equipment to ensure accurate calibration or counterweighting. Safety considerations must also be considered in the design, such as through sealing to prevent the adhesion of radioactive particles and protect operators. Labeling should be made of radiation-resistant materials to ensure long-term readability.

In radiotherapy environments, the handling of tungsten alloy weights must adhere to radiation safety regulations. Before calibration, the weights must be inspected for coating and seal integrity to prevent radiation damage. Operators must wear protective equipment and use specialized fixtures or mechanical equipment to handle the weights to minimize radiation exposure. Calibration must be performed in a shielded environment, such as a lead-shielded box, to isolate radiation interference. Weights must be precisely positioned to prevent vibration from affecting equipment readings. After calibration, weights should be stored in a radiation-proof container and regularly tested for residual radiation to ensure safety. These regulations, implemented through standardized processes, ensure the safety and reliability of calibration.

4.6.3 Micro-applications of tungsten alloy weights for precision medical instrument components

Tungsten alloy weights are primarily used in weighing precision medical instrument components for calibrating microbalances or verifying the weight of small medical components, such as surgical instruments or implants. Precision medical instruments require extremely high weighing accuracy, and weights must provide a micro-scale mass reference and be compatible with cleanroom environments. Tungsten alloy weights meet these requirements through their high density and miniaturized design.

Weighing precision medical instrument components requires milligram- or microgram-level mass references to calibrate high-resolution balances and ensure component weights meet design specifications. The high density of tungsten alloy weights enables precise mass measurement in a very

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small footprint, fitting comfortably within the tray of microbalances. Their low magnetic susceptibility prevents interference with electromagnetic sensors, while their corrosion resistance and easy-to-clean surface ensure stability in clean environments. These properties comply with ISO 13485 and meet the high-precision requirements of medical instruments.

Tungsten alloy weights support their miniaturization applications. Tungsten's high density allows for the manufacture of micro-weights (such as flakes or tiny particles), suitable for calibrating analytical balances with microgram resolution. Ancillary elements such as nickel enhance toughness, preventing damage to the tiny structures during handling. Its corrosion resistance makes it suitable for cleanroom environments exposed to moisture or disinfectants, preventing surface reactions that could affect accuracy. Its low magnetic susceptibility, achieved through an optimized formulation, ensures compatibility with high-sensitivity balances. These properties are enhanced through precision manufacturing to meet the stringent requirements of medical instruments.

Tungsten alloy weights for precision medical instruments requires a focus on miniaturization and hygiene. Sheet weights are the predominant form factor. Their ultra-thin structure fits neatly within the tray of a microbalance, with thicknesses reaching submillimeter levels. Surface treatment with nano-polishing or antimicrobial coating is required to reduce the risk of static electricity and contamination. The quality grade (e.g., E1 or E2) must match the balance's resolution to ensure calibration accuracy. The design also needs to consider ease of use, such as laser engraving of the weight value for easy identification in cleanrooms. Sealed designs prevent liquid penetration and enhance hygiene.

When weighing precision medical instruments, the handling of tungsten alloy weights must adhere to cleanroom standards. Before calibration, the weights must be cleaned and disinfected in an ultrasonic cleaner and wiped with sterile cloths to prevent particulate contamination. Operators must wear anti-static gloves and cleanroom clothing and use specialized tweezers or vacuum grippers to handle the weights to avoid hand contact, which could cause contamination or static interference. The calibration process must be performed in a cleanroom with controlled temperature and humidity (e.g., $20^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$, 40%-60% humidity) to ensure stable balance readings. The weights must be placed gently and precisely to avoid vibration that affects accuracy. After calibration, the weights should be stored in a sterile, anti-static container and disinfected regularly to maintain performance. These standards ensure accurate and hygienic calibration.

In precision medical instruments, tungsten alloy weights are used to calibrate microbalances in surgical instrument production, ensuring consistent weight. In implant manufacturing, weights verify the weight of pacemakers or bone screws to ensure quality. In medical research, weights support the calibration of laboratory equipment and aid in the development of new devices. The miniaturized design of tungsten alloy weights reduces the space required for calibration, and their durability supports high-frequency operation.

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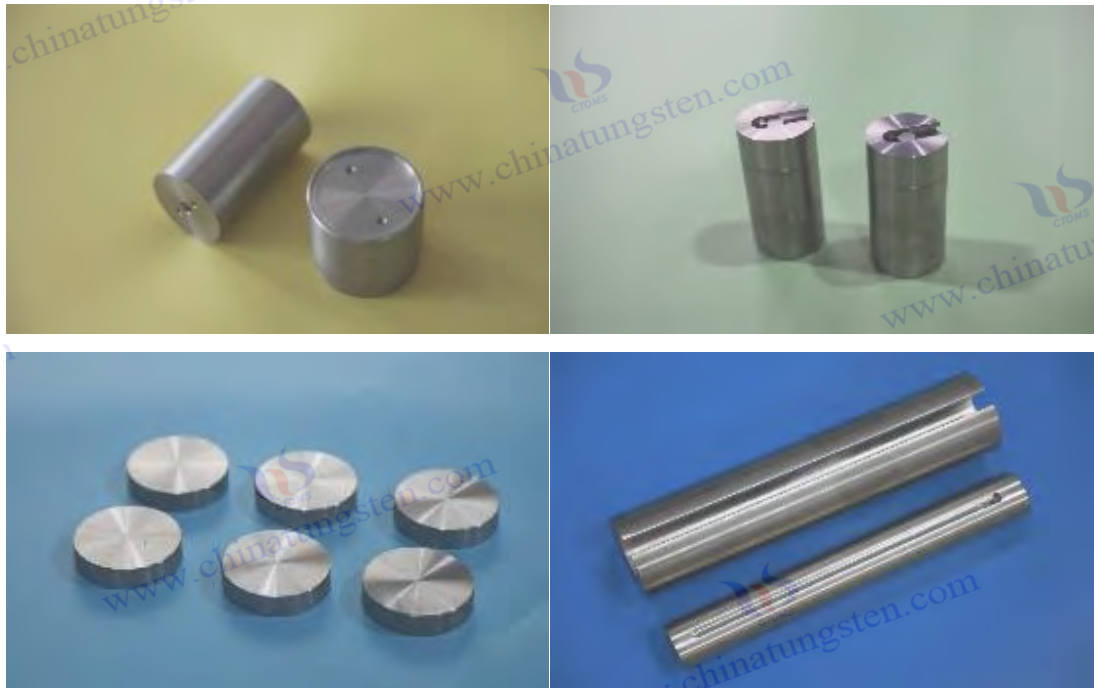
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Chapter 5 Selection, Calibration and Life Cycle Management of Tungsten Alloy Weights

Tungsten alloy weights, due to their high density, excellent mechanical properties, and metrological stability, are widely used in metrology and calibration, precision manufacturing, scientific research, and trade settlement. To ensure their performance meets specific requirements, selection, calibration, and full lifecycle management are crucial.

5.1 Technical Guidelines for the Selection of Tungsten Alloy Weights

Tungsten alloy weights is fundamental to ensuring their suitability for specific applications, encompassing multiple dimensions such as weighing range, environmental conditions, and precision requirements. This selection requires comprehensive consideration of equipment characteristics, operating environment, and metrological standards to ensure the weight's performance matches actual needs.

5.1.1 Tungsten Alloy Weight Selection Principles Based on Weighing Range

Tungsten alloy weights should be selected based on the equipment's graduation value and maximum weighing capacity in applications with different weighing ranges to ensure calibration accuracy and operational efficiency.

The key to selecting a weight based on weighing range is matching the weight mass with the equipment's weighing capacity to ensure calibration covers the entire operating range of the device. The high density of tungsten alloy weights allows for a large mass in a compact size, making them suitable for a wide range of weighing scenarios, from micro- to large-volume measurements. When selecting a weight, consider the device's maximum capacity and minimum scale interval to ensure that the weight's mass covers the calibration points while avoiding calibration errors caused by weights that are too large or too small. Selection principles should adhere to international metrology standards to ensure that the weights and equipment transmit consistent values.

Tungsten alloy weights depends on the equipment type and weighing requirements. Microbalances (such as laboratory analytical balances) typically require milligram- or gram-range weights to verify high-resolution equipment, while bench scales or floor scales require weights ranging from tens of kilograms to several tons to calibrate large-mass weighing equipment. When selecting a weight, choose a weight combination that covers the equipment's weighing range, for example, by combining weights of varying masses for multi-point calibration. The nominal weight value should match the equipment's graduation value to avoid calibration errors caused by excessively coarse or fine weights.

The weight shape should be selected based on the weighing range and equipment tray design. Small weights (e.g., milligram-level) are typically sheet-shaped to fit the limited tray space of a microbalance. Medium-mass weights (e.g., a few grams to a few kilograms) can be cylindrical for easy assembly and stacking. Large weights (e.g., tens of kilograms and above) are often block-shaped, suitable for floor

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scales or large weighing equipment. The weight shape should be considered in the equipment tray size and shape to ensure stable placement of the weights and prevent slippage or tilting that could affect calibration accuracy.

When selecting a weight based on its weighing range, ease of use is a key factor. Small weights should be easy to grasp and equipped with specialized tweezers or clamps to prevent hand contamination. Large weights should be designed with handles or retaining rings to accommodate forklift or crane handling. Calibration frequency and the operating environment should also be considered when selecting a weight. For example, equipment that is frequently calibrated should require wear-resistant weights to ensure long-term stability. Storage and maintenance of the weights should also be considered ; choose a weight that is easy to clean and store to extend its lifespan.

In practical applications, weight selection based on weighing range is widely used in different scenarios. Laboratory microbalance calibration uses milligram-grade sheet weights to ensure high-precision analysis; industrial floor scale calibration uses ton-grade block weights suitable for bulk cargo weighing; and platform scale calibration for trade settlement uses medium-mass cylindrical weights to meet diverse needs. The high density of tungsten alloy weights reduces calibration space requirements, and their durability supports high-frequency operation. In the future, intelligent weight design (such as embedded mass sensors) can further optimize weight selection efficiency and meet the needs of more complex weighing ranges.

Through these selection principles, tungsten alloy weights can accurately match the weighing range of the equipment, ensuring the scientificity and reliability of calibration, and providing support for a variety of measurement scenarios.

5.1.2 Tungsten Alloy Weight Selection Considerations Based on Environmental Conditions

Tungsten alloy weights must fully consider the environmental conditions of use, such as temperature, humidity, corrosion and vibration, to ensure that they maintain stable performance in a specific environment.

Environmentally-based weight selection requires evaluating the weight's stability and durability in the target environment. High-temperature environments require weights with a low coefficient of thermal expansion to prevent volume changes that affect accuracy. Humid or corrosive environments require corrosion-resistant materials to prevent surface degradation. High-vibration environments require weights with shock resistance and structural stability. Selection also needs to consider the impact of the environment on the equipment. For example, electronic balances operating in electromagnetic environments require weights with low magnetic susceptibility. These considerations adhere to international metrology standards to ensure that weights are suitable for specific environments.

Tungsten alloy weights provide the foundation for their environmental adaptability. Tungsten's high density and low coefficient of thermal expansion ensure volume stability in both high and low

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temperature environments, making it suitable for aerospace and cold chain applications. Ancillary elements such as nickel and copper enhance corrosion resistance, making it suitable for use in chemical laboratories or marine environments subject to moisture and salt spray. The high hardness and toughness of tungsten alloy ensure that the weights will not deform or damage in vibrating environments. Low magnetic susceptibility is achieved through an optimized formulation to avoid interference with electronic equipment. These properties are enhanced through precision manufacturing to meet the needs of diverse environments.

Surface treatment is crucial for selecting weights suitable for the environment. High-temperature environments require heat-resistant coatings (such as ceramic coatings) or high-gloss polishing to prevent oxidation. Humid or corrosive environments require corrosion-resistant coatings (such as nickel plating or polymer coatings) to ensure surface cleanliness. High-vibration environments require enhanced surface hardness to prevent wear. Surface treatment also needs to consider cleanability, such as smoothing the surface to reduce contaminant adhesion and ensuring compatibility with cleanroom or medical environments. When selecting a weight, choose the appropriate surface treatment based on the specific environment to ensure long-term stability.

Weight design must be optimized for environmental conditions. For high-temperature environments, use block-shaped weights with a low center of gravity to reduce the effects of heat convection. For corrosive environments, use sealed designs to prevent liquid penetration. For vibrating environments, use streamlined weights or fixed ring designs for enhanced stability. The quality level must match the accuracy requirements of the environment. For example, cleanrooms require high-precision weights, while industrial environments can choose medium-precision weights. The design must also consider operational ease, such as adding fixed points to accommodate mechanical operation in deep-sea environments. Labels must be made of environmentally resistant materials to ensure readability.

5.1.3 Tungsten Alloy Weight Selection Based on Precision Requirements

Tungsten alloy weights requires choosing the appropriate quality grade and design based on the accuracy requirements to ensure that the calibration results meet the requirements of the equipment and application.

The key to selecting a weight based on accuracy requirements lies in matching the weight's quality grade with the equipment's requirements, ensuring calibration errors are within acceptable limits. The high density and low magnetic susceptibility of tungsten alloy weights make them a highly accurate mass reference, suitable for a wide range of equipment, from microbalances to large floor scales. The equipment's graduation value and calibration standard should also be considered when selecting a weight. For example, high-precision balances require E1 or E2 grade weights, while industrial floor scales can use F2 or M1 grades. These principles adhere to international metrology standards and ensure the accuracy of value transfer.

Tungsten alloy weights should be selected based on the equipment accuracy and application scenario. For high-precision applications (such as laboratory analytical balances), E1 or E2 grade weights are

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recommended, as they have extremely tight tolerances and are suitable for microgram-level resolution. For medium-precision applications (such as trade settlement scales), F1 or F2 grade weights can be used, meeting gram-level requirements. For high-mass, low-precision applications (such as floor scales), M1 or M2 grade weights can be used, suitable for kilogram-level resolution. When selecting a weight, refer to the equipment's calibration specifications to ensure that the weight tolerance matches the equipment's scale, avoiding wasted resources or errors caused by excessively high or low precision.

Weight design must be optimized for precision requirements. High-precision weights (such as E1 grade) are typically sheet-shaped or small cylindrical to fit the tray space of a microbalance. Their surfaces require nano-polishing to reduce electrostatic adsorption. Medium-precision weights (such as F1 grade) can be cylindrical for easier calibration. Low-precision weights (such as M1 grade) are often block-shaped and suitable for high-mass equipment. Surface treatment should be selected based on precision requirements. For example, high-precision weights require an antimicrobial coating for cleanroom use. Labels should clearly engrave the mass value and grade to ensure traceability.

5.2 Verification and Calibration Process of Tungsten Alloy Weights

Tungsten alloy weights are core processes that ensure their metrological performance meets standards. These processes involve mass value verification, surface condition inspection, and environmental compatibility assessment. These processes, through specialized equipment and standardized operations, ensure the accuracy and reliability of weights in laboratories, industry, and trade.

5.2.1 Basic Items and Requirements for Verification of Tungsten Alloy Weights

Tungsten alloy weights is the process of verifying their metrological performance. This includes key indicators such as mass, surface condition, and magnetism, ensuring compatibility with high-precision weighing equipment. The following provides a comprehensive analysis of the basic verification procedures and requirements for tungsten alloy weights, including verification principles, basic items, operational requirements, result evaluation, and application implications.

Basic calibration procedures include mass verification, surface condition inspection, and magnetic testing. Mass verification compares a weight with a reference weight using a precision balance, measuring mass deviation and ensuring compliance with tolerances. Surface condition inspection assesses smoothness, flatness, and integrity, identifying defects such as scratches or corrosion that could affect measurement accuracy. Magnetic testing examines the weight's magnetic susceptibility and permanent magnetization to ensure it does not interfere with electronic equipment. These procedures vary depending on the weight grade, with high-precision weights requiring more stringent calibration standards.

Calibration must be performed in a laboratory environment with constant temperature and humidity, using a calibrated precision balance and magnetometer. Operators must wear clean-clean gloves and use a dedicated fixture to handle the weights to avoid contamination. Mass values must be verified by

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repeated measurements, with deviations recorded and averaged. Surface condition inspection uses a microscope or roughness meter to quantify surface parameters. Magnetic testing uses a magnetometer or suspension method to ensure accurate results. Environmental parameters, such as temperature and humidity, must be recorded during the operation to ensure traceability.

Verification results are evaluated by comparing measured values with standard limits. Mass deviations must be within tolerance, surface roughness must meet standards, and magnetic susceptibility must be below specified thresholds. Abnormal results, such as surface contamination or manufacturing defects, must be analyzed and documented in a verification report. The report must include measurement data, environmental conditions, and conclusions to ensure traceability. Acceptable weights are issued a verification certificate, while unacceptable weights are processed.

5.2.2 Basis for setting the calibration period of tungsten alloy weights

Tungsten alloy weights is the key to ensuring their long-term metrological stability and should be reasonably determined based on the frequency of use, environmental conditions and accuracy requirements.

The principle behind setting calibration intervals is based on the stability assessment of metrological performance. By regularly comparing the weights with reference weights, the trend of changes in their mass values is monitored. Tungsten alloy weights exhibit minimal mass fluctuations due to their high chemical stability and low thermal expansion, but environmental factors and frequency of use may cause minor deviations. Setting intervals requires balancing calibration costs with accuracy, adhering to international metrological standards, and ensuring consistent value transfer.

The calibration interval is influenced by several factors. Frequency of use is a primary factor; frequently used weights require shorter intervals to monitor for wear or contamination. Environmental conditions such as high temperature, humidity, or corrosive environments can accelerate weight degradation, requiring shorter intervals. Precision requirements also influence the interval; high-precision weights require more frequent calibration to meet tight tolerances. Historical weight data, such as deviation trends, can be used as a basis for dynamically adjusting the interval.

The calibration cycle is typically determined based on the weight class and application scenario. High-precision weights (such as E1 and E2) are recommended to be calibrated annually in laboratory environments, with frequent use reducing this to six months. Medium-precision weights (such as F1 and F2) can be calibrated every two years in industrial settings, depending on environmental conditions. High-mass weights (such as M1) can be calibrated every three to five years in commercial settings. Dynamic adjustment methods are based on historical calibration data and risk assessment. If deviations approach tolerance limits, the calibration cycle should be shortened.

Implementation of a calibration cycle includes planning, calibration execution, and record management. Planning should determine the calibration schedule based on weight usage records and environmental

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data. Calibration is performed in a constant temperature and humidity laboratory, using a precision balance to compare weights to a reference, recording deviations and environmental parameters. Record management requires documentation of all data and the generation of trend charts to analyze stability. Abnormalities require adjustment of the calibration cycle and analysis of the causes. Calibration must be performed by a professional organization or authorized personnel to ensure traceability of results.

Well-defined calibration cycles ensure the accuracy of weights over long-term use. In laboratories, they support the reliability of scientific research data; in industry, they optimize equipment maintenance; and in trade, they ensure fairness. In the future, intelligent monitoring systems may enable real-time deviation analysis, further optimizing cycle settings.

Through these setting bases, the calibration cycle of tungsten alloy weights can be scientifically determined to ensure the continuous stability of measurement performance.

5.2.3 Processing Procedure for Unqualified Tungsten Alloy Weights

Unqualified tungsten alloy weights is an important part of ensuring the reliability and safety of measurement, which involves steps such as identification, isolation, analysis and disposal.

The principles for handling defective weights are based on metrological regulations and quality control, aiming to prevent them from affecting metrological accuracy. Disposal involves identifying the cause of the defect, such as mass deviation, surface defects, or excessive magnetism, and taking appropriate measures to prevent it from entering use. The process adheres to international metrological regulations to ensure compliance and traceability.

Unacceptable weights are identified through verification or calibration. Weights with mass deviations outside the tolerance limits, severe surface scratches or corrosion, or magnetic susceptibility exceeding the specified threshold are considered unacceptable. This identification process requires the use of a precision balance, microscope, and magnetometer. Abnormal data is recorded and the cause, such as manufacturing defects or wear and tear, is analyzed. The identification results are recorded in a report, with the unacceptable status noted.

The processing process includes isolation, analysis, disposal, and record-keeping. During the isolation phase, unqualified weights are marked and stored in a dedicated area to prevent misuse. The analysis phase examines the data and physical condition to determine the cause of the failure, such as material impurities or environmental corrosion. The disposal phase involves repair, downgrading, or scrapping, depending on the cause. Repaired weights require recalibration. The record-keeping phase documents all steps, including cause analysis and disposal results, to ensure traceability.

Disposal methods are determined by the degree of noncompliance. Minor deviations can be repaired by polishing or demagnetizing, then recalibrated for use. Severely deviated or irreparable weights must be downgraded to lower-precision applications or scrapped. Scraped weights must be recycled according to

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environmental regulations to prevent environmental pollution. Disposal must be carried out by a professional organization and in compliance with relevant regulations.

5.3 Daily Maintenance and Failure Determination of Tungsten Alloy Weights

Tungsten alloy weights are crucial for ensuring long-term metrological performance. This involves cleaning, storage, damage identification, and failure assessment. These measures, through standardized operation and scientific judgment, extend the life of the weights and prevent metrological errors caused by performance degradation.

5.3.1 Cleaning and Storage Specifications for Tungsten Alloy Weights

Tungsten alloy weights are the basis of daily maintenance, aiming to keep their surface clean and measurement accuracy, and prevent contamination or damage from affecting performance.

The purpose of cleaning and storage is to remove contaminants (such as dust and grease) from the weight's surface and prevent degradation caused by environmental factors (such as moisture and chemicals). The high density and corrosion resistance of tungsten alloy weights make them easy to clean, but proper cleaning procedures are necessary to avoid surface damage. Storage requires controlled environmental conditions to ensure that the weights are not affected by moisture, vibration, or contamination, maintaining metrological stability. These regulations adhere to international metrological standards and ensure that the weights meet performance requirements.

The cleaning method depends on the weight's accuracy and the environment in which it will be used. High-precision weights (such as E1 and E2 grades) require an ultrasonic cleaner with a neutral detergent or deionized water to remove particles and grease, and avoid scratching the surface. Medium-precision weights (such as F1 and F2 grades) can be cleaned with a dust-free cloth dampened with alcohol or a neutral detergent to remove surface stains. Heavy weights (such as M1 grade) can be cleaned with a soft brush and detergent to ensure no residue. After cleaning, dry with a dust-free cloth to avoid residual water spots. Do not use acidic or alkaline cleaning agents to prevent corrosion of the surface coating.

The storage environment must maintain a constant temperature and humidity (e.g., $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$, 40%-60% humidity) to prevent moisture or temperature fluctuations from affecting the stability of the weights. High-precision weights should be stored in a dedicated, dust-free, anti-static calibration box lined with shock-absorbing material to prevent impact. Large weights should be stored in a moisture-proof and dust-proof warehouse on stable supports to avoid stacking and squeezing. The storage area should be away from chemicals and electromagnetic interference to ensure that the surface and magnetic properties of the weights are not affected. Weights should be stored by quality grade and clearly labeled for easy management and access.

The cleaning and storage process consists of four stages: preparation, cleaning, inspection, and storage. During the preparation stage, inspect the weight surface, record its initial condition, and select

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appropriate cleaning tools and storage containers. During the cleaning stage, follow the selected method to ensure the surface is free of residue. During the inspection stage, use a microscope or visually inspect the surface integrity to confirm the absence of scratches or corrosion. During storage, place the weight in a dedicated container, and record the storage time and environmental parameters. These operations must be performed by qualified personnel and follow standardized procedures to ensure effective cleaning and storage.

5.3.2 Identification of Common Damage to Tungsten Alloy Weights

Tungsten alloy weights is an important part of maintenance and failure determination. It aims to promptly detect surface defects, mass deviations, or magnetic anomalies to prevent them from affecting measurement accuracy.

Common damage identification relies on metrology and materials science principles. Through visual inspection, instrumental measurement, and performance testing, we assess whether a weight's physical and metrological properties have been damaged. While tungsten alloy weights are less susceptible to damage due to their high hardness and corrosion resistance, they may develop minor defects over time. Identification requires analyzing the cause of damage in conjunction with environmental factors and usage records to ensure scientific and accurate identification results.

tungsten alloy weights includes surface scratches, corrosion, mass deviation, and magnetic anomalies. Surface scratches, caused by improper handling or handling, can increase the presence of contaminants. Corrosion, caused by moisture or chemicals, can alter surface quality. Mass deviation, caused by wear or material flaking, can affect measurement accuracy. Magnetic anomalies, caused by external magnetic fields or material impurities, can interfere with electronic equipment. These types of damage require systematic detection and identification.

Identification methods include visual inspection, instrumental measurement, and performance testing. Visual inspection uses a magnifying glass or microscope to observe surface scratches, corrosion, or stains, noting their location and extent. Instrumental measurement uses a surface roughness tester to quantify scratch depth or a precision balance to detect mass deviation. Magnetic testing uses a magnetometer or Hall probe to measure magnetic susceptibility and determine if it exceeds the specified limit. Performance testing simulates actual use conditions, such as checking mass stability after loading, to ensure comprehensive identification. The method selected depends on the weight grade; high-precision weights require more detailed testing.

The damage identification analysis process includes inspection, recording, analysis, and reporting. The inspection phase uses the aforementioned methods to assess the condition of the weight and record the type and extent of damage. The recording phase documents data, including photographs, measurements, and environmental parameters. The analysis phase traces the cause of damage, such as improper operation or environmental corrosion, and assesses its impact on metrological performance. The

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reporting phase generates a detailed report with recommendations for repair or disposal. This process must be conducted in a controlled environment to ensure traceability of results.

5.3.3 Technical Standards for Determining Failure of Tungsten Alloy Weights

Tungsten alloy weights is the process of evaluating their suitability for metrological purposes. This is based on technical criteria such as mass deviation, surface condition, and magnetic properties to ensure the reliability of the metrological system.

Failure determination is based on a metrological performance conformity assessment. By comparing the actual performance of a weight against standard limits, we determine whether it meets the intended use. The high stability of tungsten alloy weights reduces the probability of failure, but long-term use or improper maintenance may lead to performance degradation. This determination must be based on international metrological standards to ensure scientific and consistent results.

Technical criteria for failure determination include mass deviation, surface condition, and magnetic properties. Mass deviation must be within tolerance; any deviation outside these limits is considered a failure. Surface condition must be free of significant scratches, corrosion, or deformation; defects that affect measurement accuracy are considered a failure. Magnetic properties must be below a specified threshold; any deviation above this threshold could interfere with equipment and result in a failure. These standards are adjusted based on the weight grade, with higher requirements for high-precision weights.

The failure determination process includes inspection, evaluation, documentation, and disposal. The inspection phase uses precision balances, microscopes, and magnetometers to measure mass deviation, surface condition, and magnetic properties. The evaluation phase compares measured values with standard limits to determine failure. The documentation phase documents the test results and cause analysis. The disposal phase involves repair, downgrading, or scrapping based on the determination. Repaired products require recalibration. This process must be performed by a professional organization to ensure traceability.

Disposal of failed weights depends on the severity of the failure. Minor deviations can be corrected by polishing or demagnetization and then recalibrated for use. Severely failed weights must be downgraded to lower-precision applications or scrapped. Scrapped weights must be recycled according to environmental regulations to avoid contamination. Disposal must be recorded and a report generated to ensure regulatory compliance .

5.4 Traceability System for Tungsten Alloy Weights

Tungsten alloy weights is the key to ensuring that their quality values are consistent with international standards. By establishing a hierarchical traceability chain, standardized record management and cross-regional collaboration mechanisms, traceability and consistency of measurement values can be achieved.

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5.4.1 Tier classification of tungsten alloy weight traceability

Tungsten alloy weights is the basis for building a traceability system. By clarifying the roles and functions of weights at different levels, the accurate transmission of mass values is ensured.

The principle of measurement traceability is to link the mass values of tungsten alloy weights to international or national mass standards through a series of comparisons, ensuring the traceability of measurement results. The high density and stability of tungsten alloy weights make them suitable as traceability standards at all levels. The traceability chain is divided into layers, enabling the transfer of measurement values from reference weights to working weights. This layered system adheres to international metrology standards, ensuring global metrological consistency.

Tungsten alloy weights is generally divided into three levels: benchmark weights, reference weights, and working weights. Benchmark weights are the highest level, stored in national metrology institutions, and are directly compared with the International Prototype Kilogram or national benchmarks, with the highest accuracy. Reference weights are the middle level, stored in provincial or professional metrology institutions. The value is obtained by comparing with the benchmark weights and is used to calibrate working weights. Working weights are the lowest level and are used for routine calibration of equipment, directly serving laboratories, industry, or trade scenarios. The quality level of weights at each level decreases, such as E1, E2 to F1, F2, and M1.

Weights at each level of the traceability chain perform different functions. Reference weights serve as the starting point for value transfer, ensuring consistency with international standards and maintaining the highest accuracy. Reference weights act as a bridge, transferring values from reference weights to working weights for regional or industry calibration. Working weights are directly used for equipment calibration, meeting practical application requirements. The high stability and low magnetic susceptibility of tungsten alloy weights provide excellent performance at each level, ensuring reliable value transfer.

The tiered classification must be implemented in a controlled environment. Reference weights must be calibrated in a national laboratory using high-precision balances under controlled temperature and humidity. Reference weights must be calibrated by an authorized organization and regularly compared to reference weights. Working weights must be calibrated by the user or a professional organization and compared to reference weights. Environmental parameters and calibration data must be recorded to ensure traceability. Weights at each tier must be regularly verified to prevent performance degradation that could compromise the traceability chain.

5.4.2 Management requirements for traceability records of tungsten alloy weights

Tungsten alloy weights is key to ensuring value traceability and data integrity, and involves the generation, storage, and maintenance of records.

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Traceability records management is based on metrological data traceability. By systematically recording calibration data, environmental parameters, and usage history of weights, this ensures transparency and verifiability in the transfer of measurement values. The high stability of tungsten alloy weights makes recorded data more reliable, but standardized management is required to prevent omissions or errors. Management requires compliance with international metrology standards to ensure the legal validity of records.

Traceability records must include weight identification (serial number, mass value, grade), calibration data (deviation, tolerance, calibration date), environmental parameters (temperature, humidity), calibration agency information, and operator qualifications. The weight's usage history, such as calibration frequency, application scenarios, and maintenance, must also be documented. Records must be accompanied by a calibration certificate or report to ensure data integrity. Special circumstances (such as damage or repair) must be specifically noted, along with the appropriate handling procedures.

Traceability records must be stored in secure and reliable media. Paper records must be stored in moisture-proof and damage-resistant storage in a constant temperature and humidity environment. Electronic records must be backed up in a database, encrypted to prevent tampering, and the storage device must be updated regularly. The retention period for records is determined by the weight grade. High-precision weight records must be retained for an extended period, and working weight records must be retained for at least the next calibration. Storage must be easy to retrieve and support quick access.

The records management process includes generation, review, storage, and updating. During the generation phase, data is recorded after calibration to ensure accuracy. During the review phase, professionals check the records for completeness and consistency, confirming compliance with regulations. During the storage phase, records are archived, with both paper and electronic versions managed simultaneously. During the updating phase, records are updated based on calibration cycles or abnormalities, documenting the reasons for changes. Management must be performed by authorized organizations or personnel to ensure compliance with regulations.

Standardized traceability record management supports the traceability of weight values. In laboratories, this ensures the reliability of experimental data; in industry, it optimizes quality control; and in trade, it maintains fairness. In the future, digital management systems may enable real-time record sharing and improve management efficiency.

5.4.3 Collaborative Mechanism for Cross-Regional Traceability of Tungsten Alloy Weights

Tungsten alloy weights is an important means to ensure the consistency of measurement values in different regions or countries, involving coordination and data sharing among multiple institutions.

The principle of cross-regional traceability collaboration is based on international metrology mutual recognition. Through collaboration between regional and international metrology organizations, the mass values of weights are linked to international benchmarks. The high stability of tungsten alloy weights

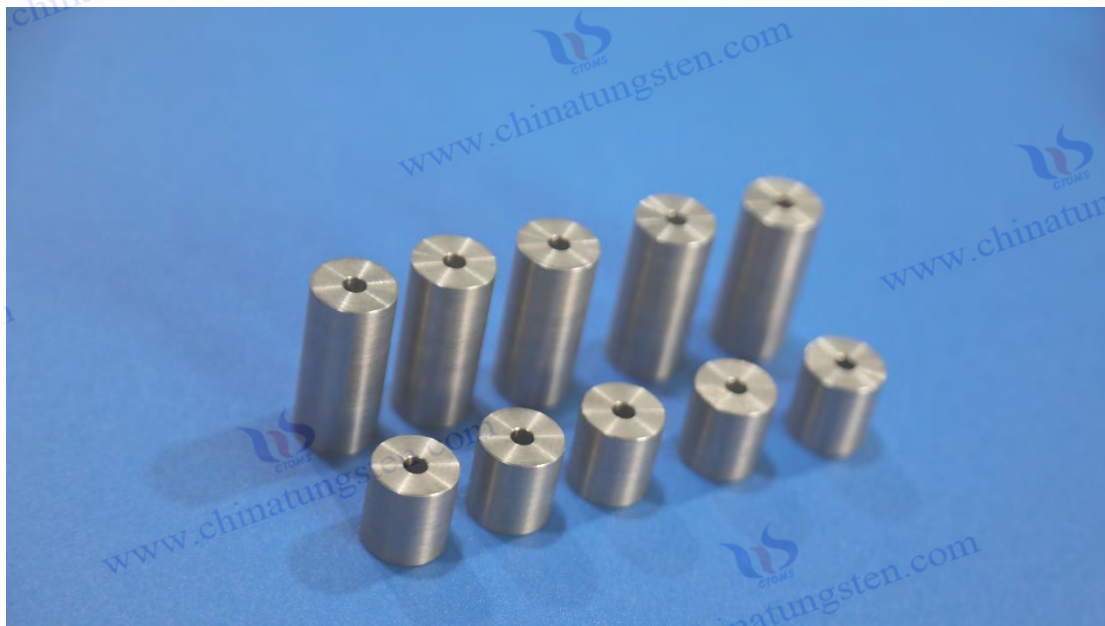
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makes them suitable for cross-regional traceability. Collaboration must ensure the consistency and comparability of calibration data. This mechanism adheres to international metrology standards and promotes global metrology harmonization.

Cross-regional traceability collaboration involves cooperation among national metrology institutions, regional metrology centers, and user organizations. National institutions provide reference weights and are responsible for comparing them with international benchmarks. Regional metrology centers act as intermediaries, calibrating reference weights and transmitting the values to user organizations. User organizations calibrate working weights for practical application. Collaboration can also be achieved through international comparison projects or bilateral agreements to ensure consistent values.

The collaborative process includes requirements confirmation, calibration execution, data sharing, and result verification. The requirements confirmation phase clarifies traceability objectives, identifies participating organizations, and determines weight grades. During the calibration execution phase, the superior organization calibrates the subordinate weights and records the data. During the data sharing phase, calibration results are exchanged in a standardized format to ensure transparency. During the result verification phase, all parties review data consistency and address any discrepancies. Regular process evaluation is required to optimize collaborative efficiency.

Collaboration must be ensured through standardized protocols, calibration certificates, and data management. The protocols should clearly define the responsibilities of each party and the data format. Calibration certificates must include environmental parameters and traceability information. Data management should utilize an encrypted database to ensure security and traceability. Regular training and technical exchanges should be conducted to enhance collaboration. Exceptions should be resolved through negotiation to ensure consistent measurement values.



CTIA GROUP LTD Tungsten Alloy Weights

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Chapter 6 Basic Knowledge and Horizontal Comparison of Tungsten Alloy Weights

Tungsten alloy weights, with their high density, excellent mechanical properties, and metrological stability, are widely used in measurement and calibration, precision manufacturing, scientific research, and trade settlement. Understanding their basic knowledge and comparison with other weight types can help users better select and use them, ensuring measurement accuracy and reliability.

6.1 Basic Knowledge of Tungsten Alloy Weights

Tungsten alloy weights, including their material properties, proper usage, and key maintenance tips, helping users understand their advantages and avoid common operational issues. Tungsten alloy weights, with their high density, low magnetic susceptibility, and corrosion resistance, are ideal for high-precision metrology applications.

6.1.1 Common Misunderstandings in Using Tungsten Alloy Weights and How to Avoid Them

Tungsten alloy weights often suffer from performance degradation or measurement errors due to improper operation during use. Understanding common misunderstandings and taking measures to avoid them can effectively improve the use effect.

Common usage errors include handling weights directly, ignoring environmental influences, improper calibration procedures, and neglecting regular maintenance. Handling weights directly can lead to contamination from oil or sweat, affecting mass accuracy, especially for high-precision weights. Ignoring environmental influences, such as using in high-humidity or high-temperature environments, can cause corrosion or mass deviation. Improper calibration procedures, such as rapid placement or unstable stacking, can damage weights or cause erroneous readings. Neglecting regular maintenance can lead to undetected surface defects or magnetic anomalies, compromising long-term performance.

The key to avoiding these pitfalls lies in adherence to standardized procedures and environmental controls. Avoid direct contact during handling, and use specialized tools to grip the weights. Maintain a constant temperature and humidity to minimize external interference. Calibration should be performed stepwise according to specifications to ensure equipment stability. Regular maintenance should be incorporated into the usage schedule, and the weights' condition should be checked promptly. These principles, based on international metrology standards, ensure stable weight performance.

To avoid errors, operators should wear clean gloves or use special tweezers to handle high-precision weights to avoid contamination. Large weights should be handled with mechanical equipment to prevent them from falling or scratching. The calibration environment should be maintained at $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and a humidity of 40%-60% to avoid temperature or humidity effects. During calibration, place the weights slowly to ensure the equipment tray is evenly loaded. Inspect the weight surface after each use, note any abnormalities, and clean promptly.

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Preventive measures include operator training, establishing operating procedures, and regular inspections. Training should cover the use and maintenance of weights to ensure operators are familiar with the procedures. Operating procedures should clearly define cleaning, handling, and calibration processes and be integrated into daily management. Regular inspections should use a microscope or precision balance to assess surface condition and quality deviations to identify potential problems. Preventive measures should be tailored to the specific use scenario, such as requiring stricter anti-contamination measures in cleanrooms.

Avoiding misuse improves the measurement accuracy and lifespan of weights. In laboratories, this ensures reliable experimental data; in industry, it reduces calibration errors; and in trade, it ensures fairness. In the future, intelligent monitoring systems may provide real-time alerts to operational errors, further optimizing usage outcomes.

6.1.2 Precautions for daily storage and handling of tungsten alloy weights

Tungsten alloy weights directly affect their performance and lifespan. Standardized operation can prevent damage and contamination and maintain measurement accuracy.

Storage and handling require precautions to prevent contamination, damage, and environmental influences. High-precision weights should be protected from dust and grease to prevent surface contamination that could affect their quality. Large weights should be protected from drops and collisions to prevent deformation or scratches. Humidity and temperature should be controlled in the storage environment to prevent corrosion and thermal expansion. Use appropriate tools when handling and avoid direct contact or improper stacking. These precautions are based on the material properties and metrological requirements of tungsten alloy weights.

The storage environment should maintain a constant temperature and humidity, recommended at $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and 40%-60% humidity, to prevent moisture or temperature fluctuations from affecting weight stability. High-precision weights should be stored in a dedicated, dust-free, anti-static calibration box lined with shock-absorbing material to prevent impact. Large weights should be placed in a moisture-proof and dust-proof warehouse, secured to a stable bracket to avoid crushing. Weights should be classified by quality grade and clearly labeled for easy management and access. The storage area should be away from chemicals and electromagnetic interference to ensure optimal weight performance.

When handling high-precision weights, use specialized tweezers or vacuum grippers to avoid hand contamination. For small and medium-mass weights, use non-slip gloves or specialized grippers to ensure stability. Large weights should be handled with a forklift or crane equipped with a securing ring or handle to prevent them from falling. During handling, avoid collisions with each other or contact with hard objects to protect the surface coating. Handling operations should be recorded, including the time and personnel involved, to ensure traceability.

The storage and handling process includes preparation, execution, inspection, and record-keeping.

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During the preparation phase, storage containers and handling tools are inspected to ensure they are clean and intact. During the execution phase, weights are stored or handled according to specifications and environmental conditions are controlled. During the inspection phase, the condition of the weights is assessed visually or instrumentally to confirm they are free of damage or contamination. During the record-keeping phase, detailed operation details, including environmental parameters and any abnormalities, are documented. This process must be performed by qualified personnel and adhere to standardized management.

6.1.3 Common Causes and Preventions of Tungsten Alloy Weight Accuracy Loss

Tungsten alloy weights is a key issue affecting their metrological reliability. Understanding the causes and taking preventive measures can effectively extend their service life.

Common causes of accuracy degradation include surface wear, corrosion, magnetic changes, and mass deviation. Surface wear, caused by improper handling or frequent use, can alter mass distribution. Corrosion, triggered by moisture or chemicals, can degrade the surface. Magnetic changes, caused by external magnetic fields or material impurities, can interfere with electronic equipment. Mass deviation, caused by long-term wear or material flaking, can affect measurement accuracy. These causes are closely related to the operating environment and habits.

Accuracy degradation is affected by frequency of use, environmental conditions, and maintenance level. Frequent use, especially in dynamic weighing, accelerates wear. Harsh environments such as heat, humidity, or chemical exposure exacerbate corrosion. Lack of regular maintenance allows minor damage to accumulate undetected, affecting accuracy. Weight grade also affects degradation; high-precision weights are more sensitive to minor deviations.

Preventing accuracy degradation requires addressing three key aspects: operation, environment, and maintenance. For operation, use specialized fixtures to handle weights to avoid direct contact; apply load slowly during calibration to reduce mechanical stress. For the environment, control temperature and humidity to prevent corrosion and thermal expansion; and avoid magnetic fields to prevent magnetic changes. For maintenance, clean weights regularly with a neutral detergent and perform regular calibrations to monitor for quality deviations. Preventative measures need to be tailored to the specific usage scenario, such as requiring stricter anti-contamination measures in cleanrooms.

Monitoring accuracy degradation requires regular calibration and instrument testing. Use a precision balance to measure mass deviation and compare it to the nominal value. Use a surface roughness tester or microscope to check for surface wear or corrosion. Use a magnetometer to detect changes in magnetic susceptibility. Monitoring requires recording data, generating trend charts, and analyzing degradation patterns. Any abnormalities require prompt analysis of the cause and implementation of repair or replacement measures.

Preventing precision degradation ensures the long-term reliability of weights. In laboratories, it supports

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accurate experimental data; in industry, it reduces production errors; and in trade, it maintains fairness. In the future, intelligent monitoring systems may analyze degradation trends in real time and optimize prevention strategies.

6.2 Performance Comparison between Tungsten Alloy Weights and Cast Iron Weights

Tungsten alloy weights and cast iron weights are two commonly used weight materials in metrology. They differ significantly in their material properties, manufacturing processes, and application scenarios. Tungsten alloy weights are known for their high density, low magnetic susceptibility, and corrosion resistance, making them suitable for high-precision and complex environments. Cast iron weights, on the other hand, are known for their low cost and ease of manufacturing, making them suitable for high-mass, low-precision applications.

6.2.1 Density Comparison between Tungsten Alloy Weights and Cast Iron Weights

Density is a key factor affecting the volume and application of weights, directly determining their ability to achieve mass within a confined space. The high density of tungsten alloy weights allows them to achieve high mass within a small volume, making them suitable for high-precision and space-constrained applications. Cast iron weights have a lower density and require a larger volume to achieve the same mass.

Tungsten alloy weights typically have a density between 17-19 g/cm³, significantly higher than the 7.2-7.8 g/cm³ of cast iron weights. This density advantage allows tungsten alloy weights to occupy only 1/2 to 1/3 the volume of cast iron weights of the same mass, making them suitable for microbalances or precision equipment calibration. Cast iron weights, due to their lower density, are suitable for large-scale weighing equipment, such as floor scales, but they take up more space.

Tungsten alloy weights gives them an advantage in laboratories, semiconductor manufacturing, and medical equipment, where they meet the demands of high precision and miniaturization. Cast iron weights are suitable for industrial and trade scenarios such as weighing bulk goods, but are not suitable for space-constrained or high-precision applications.

Tungsten alloy weights are significantly superior to cast iron weights in density and are suitable for high-precision and compact applications, but they are more expensive; cast iron weights have lower density and lower cost, making them suitable for large mass and low-precision scenarios.

6.2.2 Volume Comparison of Tungsten Alloy Weights and Cast Iron Weights

Volume directly impacts the handling, storage, and usability of weights, and is closely related to density. Tungsten alloy weights' high density makes them compact and suitable for space-constrained applications. Cast iron weights are larger and suitable for large-mass calibrations, but they take up more space.

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For the same mass, the volume of a tungsten alloy weight is approximately 1/2 to 1/3 that of a cast iron weight. For example, a 1 kg tungsten alloy weight has a volume of approximately 53-59 cm³, while a 1 kg cast iron weight has a volume of approximately 128-139 cm³. The compact size of tungsten alloy weights makes them suitable for use in microbalances or small equipment, while the larger size of cast iron weights makes them more suitable for floor scales or bench scales.

Tungsten alloy weights is particularly prominent in clean rooms, laboratories and medical equipment, reducing pallet space occupation; the larger size of cast iron weights is suitable for industrial scenarios, but may increase the difficulty of handling and storage.

Tungsten alloy weights are superior to cast iron weights in terms of volume and are suitable for space-constrained scenarios, but the manufacturing cost is high; cast iron weights are larger in volume, suitable for large-mass calibration, and have lower costs.

6.2.3 Comparison of Weight-Bearing Capacity between Tungsten Alloy Weights and Cast Iron Weights

Weight bearing capacity refers to the structural stability of a weight when subjected to mechanical stress or stacking, affecting its suitability for dynamic or high-mass applications. The high strength of tungsten alloy weights allows them to withstand higher stresses, while cast iron weights are weaker and more susceptible to damage.

Tungsten alloy weights offer superior compressive strength and toughness compared to cast iron, making them suitable for high-load or dynamic weighing applications, such as conveyor scale calibration. Cast iron weights are less strong and can crack or deform when stacked or loaded rapidly, especially with large weights. The increased weight-bearing capacity of tungsten alloy weights makes them more suitable for high-intensity operations.

Tungsten alloy weights perform excellently in industrial dynamic weighing and scientific research experiments, and can withstand frequent handling and loading. Cast iron weights are suitable for static weighing but are easily damaged in large mass or high-intensity scenarios.

Tungsten alloy weights have better weight bearing capacity than cast iron weights and are suitable for high-intensity scenarios, but they are more expensive; cast iron weights have weaker bearing capacity and are suitable for low-cost static applications.

6.2.4 Comparison of Wear Resistance between Tungsten Alloy Weights and Cast Iron Weights

Wear resistance affects the surface integrity and quality stability of weights over long-term use. The high hardness and surface treatment of tungsten alloy weights make them excellent in wear resistance, while cast iron weights are less hard and more susceptible to wear.

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Tungsten alloy weights have a much higher hardness (approximately 7.5-8 on the Mohs scale) than cast iron (approximately 4-5). Their surfaces are typically polished or nickel-plated to reduce wear. Cast iron weights are often painted or simply polished, which can easily lead to scratches from friction or impact, affecting their quality. Tungsten alloy weights maintain a stable surface even with frequent use, while cast iron weights require more frequent maintenance.

Tungsten alloy weights are suitable for high-frequency operation scenarios, such as automated production line calibration; cast iron weights are suitable for low-frequency static weighing, but surface wear must be checked regularly.

Tungsten alloy weights are better than cast iron weights in wear resistance and are suitable for high-frequency use, but the cost is high; cast iron weights have poor wear resistance and are suitable for low-cost scenarios.

6.2.5 Comparison of Corrosion Resistance of Tungsten Alloy Weights and Cast Iron Weights

Corrosion resistance determines the stability of a weight in a humid or chemical environment. The chemical inertness and surface treatment of tungsten alloy weights make them highly corrosion resistant, while cast iron weights are easily attacked by moisture and chemicals.

Tungsten alloy weights contain elements such as nickel and copper, and are combined with corrosion-resistant coatings (such as nickel plating) to effectively resist moisture, salt spray, and chemicals. Cast iron weights are prone to rust and require protective coatings, but these coatings can easily flake off, and long-term exposure can lead to corrosion. Tungsten alloy weights are stable in humid and chemical environments, while cast iron weights require additional protection.

Tungsten alloy weights are suitable for corrosive environments such as marine engineering and chemical laboratories; cast iron weights are suitable for dry environments but require frequent maintenance in humid scenes.

Tungsten alloy weights are better than cast iron weights in corrosion resistance and are suitable for complex environments, but the cost is higher; cast iron weights have poor corrosion resistance and are suitable for simple environments.

6.2.6 Comparison of service life between tungsten alloy weights and cast iron weights

The service life is affected by the durability of the material, environmental adaptability, and maintenance frequency. Tungsten alloy weights have a long service life due to their high hardness, corrosion resistance, and stability, while cast iron weights are susceptible to wear and corrosion.

Tungsten alloy weights can last for decades with minimal surface damage and quality deviation when properly maintained. Cast iron weights have a shorter lifespan in humid or high-frequency environments,

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typically 5-10 years, and require frequent maintenance to extend their useful life. Tungsten alloy weights offer superior long-term stability to cast iron weights.

Tungsten alloy weights are suitable for long-term, high-precision applications, such as laboratories and medical equipment; cast iron weights are suitable for short-term or low-precision scenarios, such as industrial weighing.

Tungsten alloy weights have a long service life and are suitable for high-precision long-term use, but they are expensive; cast iron weights have a shorter service life and are suitable for low-cost applications.

6.2.7 Comparison of Measurement Accuracy and Stability between Tungsten Alloy Weights and Cast Iron Weights

Stability of measurement accuracy refers to the ability of a weight to maintain its mass value over long periods of use. Tungsten alloy weights offer stable accuracy due to their low thermal expansion and corrosion resistance, while cast iron weights are more susceptible to environmental influences.

Tungsten alloy weights' low thermal expansion coefficient (approximately $4.5-5.5 \mu\text{m}/\text{m}\cdot\text{K}$) and corrosion resistance ensure consistent quality, making them suitable for high-precision applications in the E1 and E2 grades. Cast iron weights have a higher thermal expansion coefficient (approximately $10-12 \mu\text{m}/\text{m}\cdot\text{K}$) and are susceptible to quality deviation due to corrosion and wear, making them suitable for low-precision applications in the M1 and M2 grades. Tungsten alloy weights also have a low magnetic susceptibility and do not interfere with electronic equipment, whereas cast iron weights may have magnetic issues.

Tungsten alloy weights are suitable for high-precision scenarios, such as semiconductor manufacturing and scientific research experiments; cast iron weights are suitable for low-precision scenarios, such as bulk trade.

6.2.8 Comparison of Environmental Adaptability between Tungsten Alloy Weights and Cast Iron Weights

Environmental suitability refers to how a weight performs in environments with high temperatures, humidity, corrosion, or vibration. The versatility of tungsten alloy weights makes them suitable for complex environments, while cast iron weights are less adaptable.

Tungsten alloy weights' low thermal expansion, corrosion resistance, and vibration resistance make them suitable for high-temperature, humid, chemical, and dynamic environments. Cast iron weights tend to expand at high temperatures, corrode in humid environments, and are easily damaged by vibration, making them suitable only for dry, static environments. Tungsten alloy weights are significantly more environmentally adaptable than cast iron weights.

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Tungsten alloy weights are suitable for complex environments such as marine engineering, chemical laboratories, and aerospace; cast iron weights are suitable for simple environments such as warehouses or factories.

Tungsten alloy weights are superior to cast iron weights in environmental adaptability and are suitable for complex scenarios, but they are expensive; cast iron weights have limited adaptability and are suitable for simple environments.

Through these performance comparisons, tungsten alloy weights are superior to cast iron weights in density, volume, load-bearing capacity, wear resistance, corrosion resistance, service life, precision stability and environmental adaptability. They are suitable for high-precision and complex environments, but the cost is higher. Cast iron weights are low in cost and suitable for large mass and low-precision scenarios.

6.3 Performance Comparison of Tungsten Alloy Weights and Stainless Steel Weights

Tungsten alloy weights and stainless steel weights are two commonly used high-performance weight materials in metrology. However, they differ significantly in material properties, manufacturing costs, and application scenarios. Tungsten alloy weights are known for their high density and excellent physical properties, making them suitable for high-precision applications and specialized environments. Stainless steel weights, characterized by their corrosion resistance and reasonable cost, are widely used in a variety of scenarios.

6.3.1 Comparison of Material Cost and Cost-Effectiveness between Tungsten Alloy Weights and Stainless Steel Weights

Material cost and price/performance are important factors in selecting weights, which involve raw material prices, manufacturing process complexity, and performance returns. Tungsten alloy weights are more expensive due to their rare metal content, but they offer superior performance. Stainless steel weights are lower cost, offer balanced performance, and are suitable for general use.

Tungsten alloy weights are primarily composed of rare metals such as tungsten and nickel. The raw materials are relatively expensive, and their manufacturing requires precision powder metallurgy or CNC machining, making them significantly more expensive than stainless steel weights. Stainless steel weights, on the other hand, are made from common stainless steel materials (such as 304 or 316L), which have lower raw material and casting costs. The high density and durability of tungsten alloy weights make them more cost-effective than stainless steel weights in high-precision and specialized environments. However, in low-precision or general applications, stainless steel weights are more cost-effective due to their lower cost.

Tungsten alloy weights are suitable for high-precision and specialized environments, such as semiconductor manufacturing and medical device calibration. Their high cost is compensated by their

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long-term stability and compact design. Stainless steel weights are suitable for general use in laboratories, industry, and trade, and are low-cost and suitable for applications with limited budgets.

Tungsten alloy weights are expensive, but they are cost-effective in high-precision and complex environments; stainless steel weights are low-cost, suitable for general scenarios, and have a balanced cost-effectiveness.

6.3.2 Comparison of Diamagnetism between Tungsten Alloy Weights and Stainless Steel Weights

Diamagnetism affects the compatibility of weights with electronic weighing equipment and is particularly crucial in high-precision applications. Tungsten alloy weights achieve low magnetic susceptibility through optimized formulations, while the diamagnetic properties of stainless steel weights depend on the alloy composition.

Tungsten alloy weights are manufactured by adding non-magnetic elements (such as nickel and copper) and optimizing the manufacturing process to achieve extremely low magnetic susceptibility (typically less than 0.001 SI unit), preventing interference with highly sensitive electronic balances. Stainless steel weights (such as 304 stainless steel) contain ferrite and may be slightly magnetic. 316L stainless steel has improved anti-magnetic properties through low-carbon treatment, but this is still slightly inferior to tungsten alloy weights. Tungsten alloy weights perform better in high-precision electromagnetic environments.

Tungsten alloy weights are suitable for high-precision scenarios, such as clean rooms and astrophysical experiments, to ensure no magnetic interference; stainless steel weights are suitable for medium-precision scenarios, but may require additional demagnetization in highly sensitive equipment.

Tungsten alloy weights are superior to stainless steel weights in anti-magnetic properties and are suitable for high-precision electromagnetic environments. Stainless steel weights are slightly less anti-magnetic and require targeted optimization.

6.3.3 Comparison of impact resistance between tungsten alloy weights and stainless steel weights

Impact resistance reflects the structural stability of a weight during handling or dynamic use, affecting its durability and measurement accuracy. Tungsten alloy weights exhibit excellent impact resistance due to their high hardness and toughness, while the performance of stainless steel weights varies depending on the alloy type.

Tungsten alloy weights have a harder (Mohs hardness of approximately 7.5-8) and tougher properties than stainless steel. The addition of elements like nickel enhances their impact resistance, allowing them to withstand frequent handling and dynamic loading. Stainless steel weights (such as 304 or 316L) have a lower hardness (approximately 5-6) and better toughness, but are less impact-resistant and more susceptible to minor deformation or scratches. Tungsten alloy weights are more durable even under high-

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intensity handling.

Tungsten alloy weights are suitable for dynamic weighing or high-intensity scenarios, such as automated production lines and aerospace testing; stainless steel weights are suitable for static or medium-intensity scenarios, such as laboratory balance calibration.

Tungsten alloy weights are better than stainless steel weights in impact resistance and are suitable for high-intensity scenarios; stainless steel weights are slightly less impact-resistant and are suitable for static applications.

6.3.4 Comparison of Application Scenarios and Industry Adaptability of Tungsten Alloy Weights and Stainless Steel Weights

The applicable scenarios and industry suitability of the weight depend on its physical properties, cost, and environmental adaptability. Tungsten alloy weights are suitable for high-precision and special environments, while stainless steel weights are suitable for general-purpose and medium-precision applications.

tungsten alloy weights (17-19 g/cm³) makes them compact and suitable for space-constrained environments such as cleanrooms, medical equipment, and astrophysics experiments. Their corrosion resistance and low magnetic susceptibility make them suitable for chemical, marine, and electromagnetic environments. Stainless steel weights (density approximately 7.9-8.0 g/cm³) are larger and have good corrosion resistance (especially 316L), making them suitable for medium-precision applications such as laboratories, pharmaceuticals, and food processing, but their performance may be less favorable in extreme environments.

Tungsten alloy weights excel in demanding industries such as semiconductor manufacturing, medical instrumentation, and aerospace, meeting the demands of high precision and complex environments. Stainless steel weights are widely used in laboratories, industrial production, and trade settlements, making them suitable for general use cases with limited budgets, but they may require additional handling in high-precision or extreme environments.

Tungsten alloy weights are better than stainless steel weights in high-precision and special environments, but they are more expensive. Stainless steel weights are more adaptable, suitable for general scenarios, and have a lower cost. Through these performance comparisons, tungsten alloy weights are superior to stainless steel weights in material cost, anti-magnetism, impact resistance and adaptability to special scenarios, and are suitable for high-precision and complex environments; stainless steel weights have advantages in cost and general scenarios, and are suitable for medium-precision applications.

6.4 Performance Comparison of Tungsten Alloy Weights and Lead Alloy Weights

Tungsten alloy and lead alloy weights are two common weight materials in metrology. They differ

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significantly in material properties, environmental performance, and application scenarios. Tungsten alloy weights are known for their high density, low toxicity, and excellent stability, making them suitable for applications requiring high precision and environmental protection. Lead alloy weights are commonly used in some traditional applications due to their low cost and high density, but they are less environmentally friendly. This section will compare the performance differences between the two in detail, focusing on environmental performance, density uniformity and metrological stability, and disposal costs and environmental impact.

6.4.1 Comparison of Environmental Performance between Tungsten Alloy Weights and Lead Alloy Weights

Environmental friendliness is a key criterion for evaluating weight materials, encompassing material toxicity, production processes, and environmental impact during use. Tungsten alloy weights are renowned for their low toxicity and environmental friendliness, while lead alloy weights pose potential risks to the environment and human health due to the toxicity of lead.

Tungsten alloy weights are primarily composed of tungsten, nickel, and copper. They are extremely low in toxicity, have minimal impact on the environment and human health during production and use, and comply with strict environmental regulations. Lead alloy weights contain lead, a toxic heavy metal. Long-term exposure may be harmful to human health, especially during production, processing, and disposal, where lead vapor or particles are easily released, contaminating soil and water. Tungsten alloy weights are significantly more environmentally friendly than lead alloy weights.

Tungsten alloy weights are suitable for environmentally sensitive applications such as healthcare, laboratories, and food processing, reducing health and environmental risks. Lead alloy weights are increasingly restricted due to toxicity concerns and are only used in low-cost, environmentally friendly industrial applications such as temporary counterweights.

Tungsten alloy weights are far superior to lead alloy weights in terms of environmental protection and are suitable for scenarios with high environmental standards, but they are more expensive; lead alloy weights are less environmentally friendly and are suitable for scenarios with low costs and low environmental requirements, but their use is limited.

6.4.2 Comparison of Density Uniformity and Measuring Stability between Tungsten Alloy and Lead Alloy Weights

Density uniformity and metrological stability directly impact the accuracy and long-term reliability of weights. Tungsten alloy weights achieve high density uniformity and stability through precision manufacturing. Lead alloy weights exhibit poor density uniformity and stability due to their material properties.

Tungsten alloy weights have a density of 17-19 g/cm³. Powder metallurgy achieves high density

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uniformity, consistent mass distribution, and a low thermal expansion coefficient (approximately $4.5\text{--}5.5\text{ }\mu\text{m}/\text{m}\cdot\text{K}$). These weights maintain stable volume and mass despite temperature fluctuations, making them suitable for high-precision measurement. Lead alloy weights have a density of $11\text{--}11.3\text{ g}/\text{cm}^3$. The casting process can result in internal porosity or uneven density, and their higher thermal expansion coefficient (approximately $29\text{ }\mu\text{m}/\text{m}\cdot\text{K}$) makes them susceptible to temperature fluctuations, leading to mass deviation. Tungsten alloy weights are superior to lead alloy weights in terms of density uniformity and metrological stability.

Tungsten alloy weights are suitable for high-precision applications such as laboratory analytical balances and semiconductor manufacturing, ensuring long-term metrological reliability. Lead alloy weights are suitable for low-precision applications such as rough balancing or temporary calibration, but are not suitable for high-precision or dynamic environments.

Tungsten alloy weights are superior to lead alloy weights in density uniformity and metrological stability, and are suitable for high-precision applications. Lead alloy weights have poor stability and are suitable for low-precision scenarios.

6.4.3 Comparison of Disposal Costs and Environmental Impacts of Tungsten Alloy and Lead Alloy Weights

Disposal costs and environmental impact are important indicators for evaluating the life cycle of weight materials. Tungsten alloy weights have higher recycling costs but lower environmental impact, while lead alloy weights have lower disposal costs but higher environmental risks.

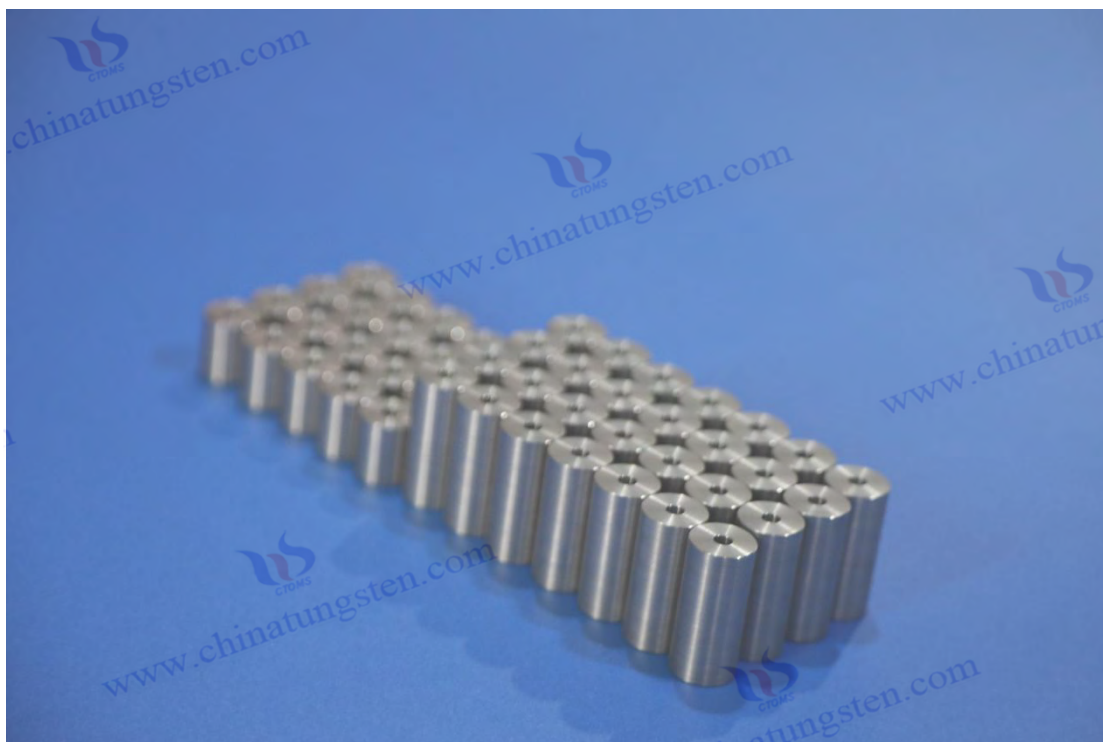
Tungsten alloy weights requires specialized recycling facilities. Due to tungsten's rarity and high melting point, the recycling process is complex and costly. However, its low toxicity has minimal environmental impact, and the recycled materials can be reused. Disposal of lead alloy weights is less expensive, but requires strict anti-pollution measures, such as dedicated sealed containers and chemical treatment, to prevent lead leakage from contaminating soil and water, posing a significant environmental risk. Tungsten alloy weights are less environmentally friendly than lead alloy weights, but the disposal cost is higher.

Tungsten alloy weights are suitable for environmentally sensitive industries, such as medical and scientific research, and their disposal complies with green regulations. Lead alloy weights are subject to strict environmental regulations, increasing compliance costs and limiting their use in sensitive applications.

Tungsten alloy weights are superior to lead alloy weights in terms of the environmental impact of waste disposal and are suitable for scenarios with high environmental requirements, but the disposal cost is high. Lead alloy weights have low disposal costs, but have high environmental risks and limited applications.

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Through these performance comparisons, tungsten alloy weights are significantly superior to lead alloy weights in terms of environmental protection, density uniformity, measurement stability, and waste disposal environmental impact, and are suitable for scenarios with high precision and high environmental protection requirements. Lead alloy weights have low cost, but due to toxicity and stability issues, their scope of application is narrow.



CTIA GROUP LTD Tungsten Alloy Weights

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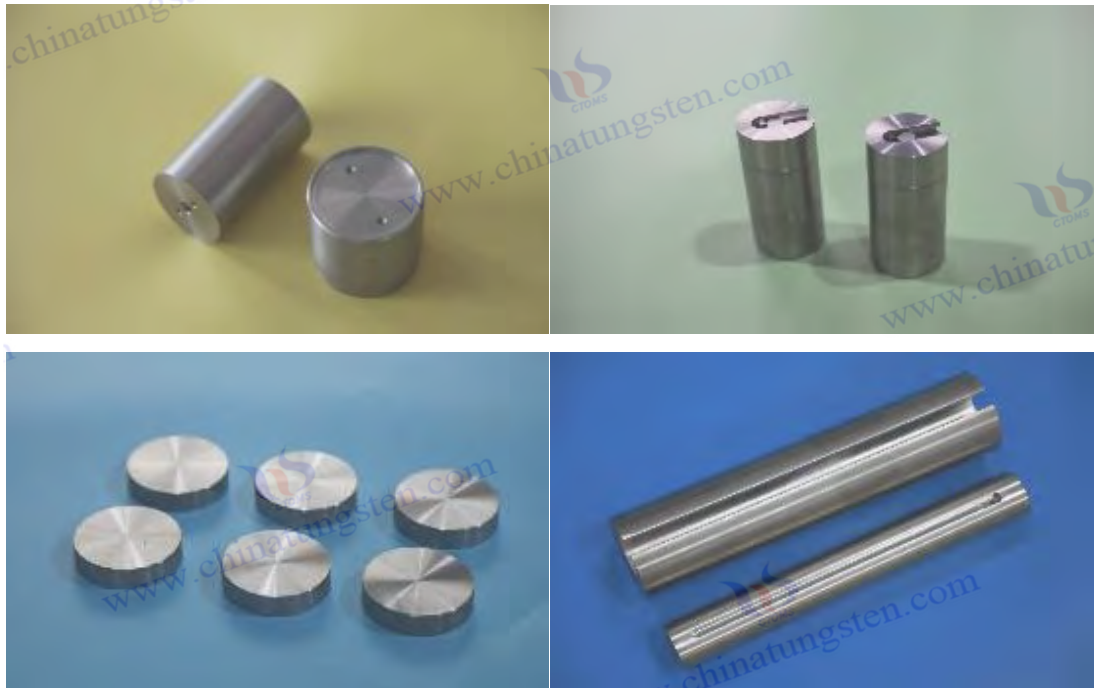
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appendix

To fully understand the standardization requirements for [tungsten alloy weights](#), this appendix compiles relevant standards for tungsten alloy weights from China, international standards, and national standards from Europe, the United States, Japan, and South Korea. These standards cover material properties, quality grades, manufacturing processes, verification requirements, and usage specifications, providing a regulatory basis for the design, production, and application of tungsten alloy weights.

Appendix 1 China Tungsten Alloy Weight Standard

China's tungsten alloy weight standards are mainly based on national metrology technical specifications and industry standards, and are suitable for metrology calibration in laboratories, industry, trade settlement and other fields.

Standard system

China's tungsten alloy weight standards are primarily issued by the State Administration for Market Regulation. The core standard is the "JJG 99-2006 Weight Verification Procedure," which applies to all types of weights, including tungsten alloy weights. Additionally, industry standards such as "GB/T 11883-2008 Tungsten Alloy Material Technical Requirements" define the performance requirements for tungsten alloy materials. These standards align with international metrology regulations, ensuring accurate traceability of measurement values.

Main content

- **Quality Grade** : According to JJG 99-2006, tungsten alloy weights are divided into E1, E2, F1, F2, M1, and M2 grades, with tolerances ranging from 0.005 mg (E1) to 500 mg (M2), suitable for different precision scenarios.
- **Material requirements** : Tungsten alloy weights must have a high density (17-19 g/cm³), a low thermal expansion coefficient (approximately 4.5-5.5 $\mu\text{m}/\text{m}\cdot\text{K}$), and a low magnetic susceptibility (less than 0.001 SI unit) to ensure metrological stability.
- **Manufacturing process** : Powder metallurgy or precision machining technology is required, the surface needs to be high-gloss polished or nickel-plated, with a roughness of $R_a \leq 0.2 \mu\text{m}$ to prevent contamination and wear.
- **Verification requirements** : Weights must be calibrated regularly to check mass deviation, surface condition and magnetism. The calibration environment must be controlled at $20^\circ\text{C} \pm 2^\circ\text{C}$ and humidity 40%-60%.
- **Marking specification** : The weight surface must be engraved with the mass value, grade and serial number to ensure traceability.

Scope of Application:

China's tungsten alloy weight standards are suitable for laboratory analytical balances, industrial floor scales, trade settlement equipment, scientific research experiments and other scenarios, covering high-

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precision (such as semiconductor manufacturing) and large-mass (such as port weighing) applications.

Implementation requirements

Implementation must be carried out by a nationally authorized metrology institute or specialized laboratory. Calibration equipment must meet accuracy requirements, and records must be retained for at least five years. Weight manufacturers must obtain quality management system certification (such as ISO 9001) to ensure compliance with the standard.

Appendix 2 International Tungsten Alloy Weight Standards

International tungsten alloy weight standards are developed by the International Organization of Legal Metrology (OIML) to achieve global consistency in measurement values and are widely used in international trade and scientific research.

international tungsten alloy weight standard

is primarily based on OIML R111-1:2004 Weights, applicable to weights from E1 to M3, covering materials such as tungsten alloy and stainless steel. Guided by the International Bureau of Weights and Measures (BIPM), this standard is linked to the International Prototype Kilogram (IPK) or its replica, ensuring traceability.

Main content

- **Quality grade** : divided into E1, E2, F1, F2, M1, M2, M3 grades, with tolerance range from 0.003 mg (E1) to 10 g (M3). Tungsten alloy weights are commonly used in grades E1 to F2.
- **Material requirements** : Tungsten alloy weights must have high density (17-19 g/cm³), low magnetic susceptibility (≤ 0.001 SI units), and corrosion resistance. The coefficient of thermal expansion must be less than 6 $\mu\text{m}/\text{m}\cdot\text{K}$.
- **Manufacturing process** : Precision machining is required, with surface roughness $R_a \leq 0.1 \mu\text{m}$, and anti-corrosion coating or polishing treatment is used to prevent environmental impact.
- **Verification requirements** : The weights must pass mass deviation, magnetism, surface condition, and density uniformity tests. The calibration environment must be controlled at $20^\circ\text{C} \pm 0.5^\circ\text{C}$ and 40%-50% humidity.
- **Marking specifications** : The quality value, grade, serial number and manufacturing year must be indicated. The marking material must be corrosion-resistant to ensure long-term readability.

Scope of application:

This international standard is applicable to global laboratories, international trade, aerospace, and medical equipment calibration. It is particularly suitable for high-precision scenarios such as microbalances and scientific research experiments.

Implementation requirements:

Calibration must be performed by an OIML-accredited body, traceable to the International Kilogram Standard. Records must be retained for at least 10 years, and data must be verified for consistency through

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international comparisons. Manufacturers must meet ISO 17025 laboratory accreditation requirements.

Appendix 3 Tungsten Alloy Weight Standards in Europe, America, Japan, South Korea and Other Countries

The tungsten alloy weight standards in Europe, America, Japan, South Korea and other countries are based on international specifications and combined with local needs to form a regional standard system.

Standard system

- **Europe** : Follows OIML R111-1:2004 and combines with the EU EN 45501:2015 Non-automatic weighing instruments standard, emphasizing the use of weights in trade and industry.
- **United States** : Based on the National Institute of Standards and Technology (NIST) "NIST Handbook 105-1:2019 Specification for Weights and Mass-Measuring Equipment", suitable for high-precision and industrial scenarios.
- **Japan** : Refers to the "JIS B 7609:2009 Weights" standard, aligns with OIML, and focuses on high precision and scientific research applications.
- **South Korea** : Complies with the KS B 5503:2013 Weights standard and combines OIML requirements, making it suitable for industrial and trade use.

Main content

- **Quality Grade** :
 - Europe: Using OIML E1 to M3 grades, tungsten alloy weights are mostly used in E1 to F2.
 - United States: ASTM E617 grades (Class 0 to Class 7) are used, and tungsten alloy weights correspond to Class 0 to Class 2.
 - Japan: adopts JIS grade (grade 1 to grade 4), and tungsten alloy weights are mostly grade 1 and 2.
 - South Korea: Uses KS grade (E1 to M3), consistent with OIML.
- **Material requirements** : Tungsten alloy weights are required to have a density of 17-19 g/cm³, a magnetic susceptibility less than 0.001 SI unit, corrosion resistance, and a low thermal expansion coefficient ($\leq 6 \mu\text{m/m}\cdot\text{K}$).
- **Manufacturing process** :
 - Europe and the United States: Emphasis on nano-level polishing and antibacterial coating, roughness $R_a \leq 0.1 \mu\text{m}$.
 - Japan: Focus on precision processing and low magnetic susceptibility treatment, and the surface must be resistant to chemical corrosion.
 - South Korea: Requires high-gloss polishing or nickel plating to prevent moisture effects.
- **Verification requirements** : The calibration environment must be controlled at $20^\circ\text{C} \pm 1^\circ\text{C}$ and humidity 40%-60%. Test mass deviation, magnetism and surface condition.
- **Marking specifications** : Quality value, grade, and serial number must be engraved. Europe and the United States require additional environmental protection labels, while Japan and South

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Korea require the year of manufacture.

Scope of application

- Europe: Widely used in trade settlement, medical equipment and laboratory balance calibration.
- United States: Suitable for aerospace, semiconductor manufacturing and industrial weighing.
- Japan: Focuses on high-precision scientific research and calibration in the electronics industry.
- South Korea: Used in trade, pharmaceuticals and industrial production.

Implementation requirements

- Europe: Performed by a metrology institute accredited by the European Union and must comply with EN ISO/IEC 17025.
- United States: Calibrated by a NIST-certified laboratory, and records must be kept for 10 years.
- Japan: Verified by the National Metrology Institute of Japan (NMIJ) or authorized agencies, and subject to regular international comparison.
- South Korea: Supervised by the Korea Research Institute of Standards and Science (KRISS), data must be traceable to OIML.

Appendix 4 Material Terminology for Tungsten Alloy Weights

the term	definition
Tungsten Alloy	An alloy primarily composed of tungsten with added elements such as nickel, iron, or copper. Its density is typically 17-19 g/cm ³ and it is suitable for the manufacture of high-precision weights.
High density tungsten alloy	Tungsten-based alloys with a density close to that of pure tungsten (≥18 g/cm ³) offer excellent quality stability and compact size.
nickel	A common additive element in tungsten alloys to enhance toughness and corrosion resistance and reduce magnetic susceptibility.
copper	Auxiliary elements in tungsten alloys, enhancing ductility and corrosion resistance, and improving processing performance.
iron	A minor additive element in tungsten alloys to adjust hardness and cost, often used in low-precision weights.
Non-magnetic alloys	Tungsten alloys with extremely low magnetic susceptibility (such as those containing nickel and copper) are suitable for calibrating high-precision electronic balances.
Corrosion-resistant coating	Nickel or polymer coatings applied to the surface of tungsten alloy weights provide enhanced resistance to moisture and chemical corrosion.

Appendix 5 Technical Terminology for Tungsten Alloy Weights

the term	definition
Powder Metallurgy	tungsten alloy weights is done by mixing tungsten powder with other

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	metal powders, pressing and sintering at high temperature to ensure uniform density.
Precision Machining	Tungsten alloys are turned, milled or polished using CNC machine tools to achieve high-precision dimensions and surface finish.
High gloss polishing	Mechanical or chemical polishing is used to reduce the surface roughness of the weight to $Ra \leq 0.1 \mu m$ to reduce the adhesion of contaminants.
Nickel plating	Electroplating nickel on the weight surface enhances corrosion resistance and wear resistance, making it suitable for use in humid or chemical environments.
Laser marking	The weight's mass value, grade, and serial number are laser engraved on the surface for clear and durable marking.
Demagnetization treatment	The demagnetization equipment reduces the magnetic susceptibility of the weights to ensure compatibility with electronic equipment and is suitable for high-precision scenarios.
Ultrasonic cleaning	Use an ultrasonic cleaner with a neutral detergent to remove particles and grease from the weight surface to maintain measurement accuracy.

Appendix 6 Performance Terms of Tungsten Alloy Weights

the term	definition
Density uniformity	The density distribution inside the weight is uniform, without pores or segregation, ensuring quality stability and measurement accuracy.
Measuring stability	The ability of a weight to maintain its mass over time, affected by thermal expansion, wear and corrosion.
Low magnetic susceptibility	The weights have a magnetic susceptibility of less than 0.001 SI units, preventing interference with electronic weighing equipment and making them suitable for high-precision applications.
Corrosion resistance	The weights' ability to resist corrosion from moisture, salt spray, or chemicals ensures long-term performance.
Low coefficient of thermal expansion	The volume change rate of the weight during temperature changes (about $4.5-5.5 \mu m / m \cdot K$) ensures measurement accuracy.
wear resistance	The ability of the weight surface to resist friction and scratches affects the stability of mass during long-term use.
Impact resistance	The ability of a weight to resist deformation or damage during handling or dynamic loading, ensuring structural integrity.

Appendix 7 Application Terms for Tungsten Alloy Weights

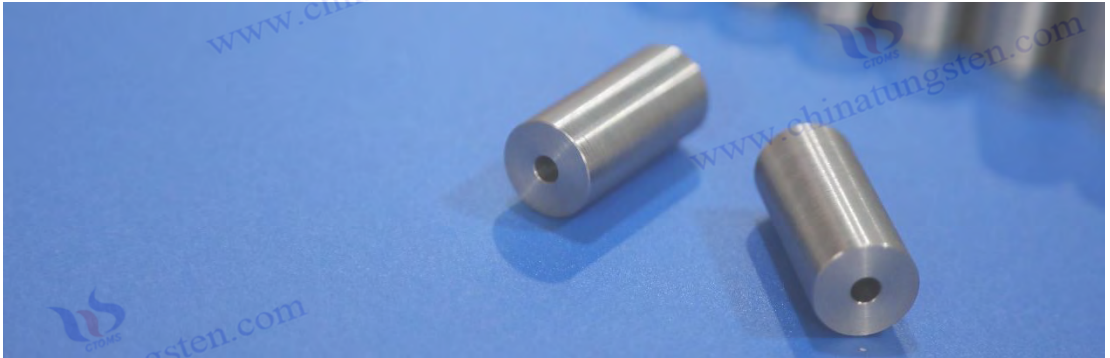
the term	definition
High-precision	Use tungsten alloy weights to calibrate microbalances or analytical

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calibration	balances for laboratories and semiconductor manufacturing.
Bulk weighing	Use heavy-duty tungsten alloy weights to calibrate floor or platform scales, ideal for ports and industrial trade.
Environmental simulation	tungsten alloy weights in climate chambers or ecological experiments to verify the stability of weighing equipment in temperature and humidity changes.
Radiation therapy weights	Tungsten alloy weights are used in linear accelerators or gamma knife to calibrate or balance equipment to ensure treatment accuracy.
Precious Metals Trading	Use high-precision tungsten alloy weights to calibrate jewelry scales to ensure fair transactions in precious metals such as gold and silver.
Material mechanics experiments	Use tungsten alloy weights as counterweights to simulate tensile, compressive, or bending loads to verify material properties.
Traceability	By comparing tungsten alloy weights with the benchmark, a mass value transfer chain is established to ensure the traceability of measurement results.



CTIA GROUP LTD Tungsten Alloy Weights

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