A PRACTICAL GUIDE TO BUYING SPECIALTY METALS

Speed up the ordering process and get the right materials exactly as you need them.

What Purchasers Need to Know About How to Buy Exotic & Refractory Metals

Purchasing specialty metals for various applications can be a complex process, so it's important to know how to buy before you get started.

That's why we're introducing a 3-part series on how to buy exotic and refractory metals, culminating in a handy downloadable guide that aims to simplify, streamline, and optimize the specification and purchase journey by highlighting key considerations for buyers.

PART 1
Applications, related exposures, machining, and standards

PART 2
Metal properties, conditions, and surface conditions

PART 3
Formats and other considerations

It all starts with the application, the metal's properties, and established industry standards. Let's get into the nitty-gritty on how to buy specialty metals

PART 1

Exposures, Machining, and How to Buy for Your Application

It may seem obvious, but before starting an order, you need to be clear on the purpose, environment, and standards for the specific metal you're ordering. The details will help you determine how to buy it. The more information you (and therefore we) have, the more precise your order will be and the better your exotic or refractory metal materials will perform.

What's Your Application?

Every customer order starts with a specific application. That means where and how you'll use the material, which varies greatly across industry sectors. We work with many industries, but the most common are:

> **Aerospace & Defense** – Common applications include missile and rocket components, counterbalance weights, jet and turbine engines, sensors, armor and protective gear, and advanced communication systems.
>
> **Electronics** – Common applications include semiconductors, thin-film resistors, electrodes, integrated circuits, microelectromechanical systems (MEMs), displays, connectors, and contacts.
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> **Energy** – Common applications include fusion reactors, nuclear reactor components, heat exchangers, chemical process equipment, turbine blades, oil/gas drilling equipment, solar panels, batteries, and hydrogen production.
>
> **Medical** – Common applications include implants and prosthetics, surgical instruments, imaging equipment, pacemakers and defibrillators, stents, dental applications, radiation therapy equipment, and biocompatible coatings.
>
> **Research and National Laboratories** – Common applications include analytics equipment, cryogenics, high-temperature vacuum systems and furnaces, nuclear materials research, particle accelerators, beam collimators, superconducting magnets, and high-pressure studies.

What Are Your Exposure Conditions?

Understanding the environmental exposures the metal will face also helps in determining the right production practices. The choice of metals and how to buy them depend on the properties of the metals and their ability to endure the conditions they will be exposed to during their service life. Exposures include factors such as:

Temperature – How high of a temperature can the material withstand? Consider factors like thermal conductivity, thermal expansion, melting point, creep resistance after prolonged exposure to stress and high temperatures, oxidation, and thermal shock resistance in the face of rapid temperature changes.

Corrosion Resistance – Can it withstand damage from oxidizing or reducing environments or chemical reactions? Oxidation is a reaction that leads to rust and deterioration. For corrosion resistance, we look for metal properties of inertness, or low reactivity with environmental chemicals that it will be exposed to.

Formability – Capacity for shaping, bending, stretching, drawing, stamping, etc. without damage? These metal properties include ductility, malleability, tensile and yield strength, elasticity, and work hardening.

Biocompatibility – Properties of the metal that enable it to perform as intended without adverse effects, especially for applications like medical implants and instruments. Key metal properties include non-toxicity, corrosion resistance, fatigue life and surface properties like roughness.

Radiation Resistance – Especially important in environments with high radiation levels like nuclear reactors, space exploration, and medical imaging equipment. Key considerations in how to buy include the ability to shield or focus the radiation while maintaining structural integrity and minimizing radiation-induced hardening, cracking, and deformation.

Exposures like these play crucial roles in determining how to buy the materials you need. For instance, metals used in the fusion reactor industry must withstand extremely high heat and thermal expansion, and meet conductivity requirements. Every detail is essential in the specification process.

Machining/Fabrication Requirements

The final component relative to the application is any machining or fabrication needed to meet the specific application's requirements. These specifications are highly dependent on the customer's procuring document and may require a machinability test to confirm that the metal properties are sufficient for the unique case.

One key consideration is magnetic permeability, or the extent to which refractory and exotic metals can become magnetized in response to an external magnetic field occurring during machining, fabrication, or welding. Depending on the application, this can be something necessary, or something to avoid, and that also helps determine which material is needed.

Standards and Minimum Requirements

Several organizations publish standards for how to buy and specify exotic and refractory metals (and other materials) by industry and application. The authoritative organizations on standards for properties of metal include:

> **American Society for Metals (ASM International)**
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> **American Society for Testing and Materials (ASTM International)**
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> **American Society of Mechanical Engineers (ASME)**
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> **Department of Defense (DoD) Military Standards or Military Specifications (MIL) on the Defense Logistics Agency (DLA) ASSIST Database**
>
> **SAE Aerospace Material Specifications (AMS, formerly known as the Society of Automotive Engineers or SAE)**

One quick way to cut to the chase on the standards is to **visit our materials pages**. There, you will find the applicable standards for the properties of the metal.

These standards ensure that materials meet the minimum requirements set by industry guidelines. When we say minimum, we mean it, and it's important to understand. Industry specifications may be influenced by the capabilities of the producing mill or the requirements of the end user. Your application could require higher-level specifications or tolerances than those "required," and we can help you determine the right level beyond the standards.

PART 2

Conditions and Properties of Metal

Let's dig into the properties of metal, conditions and surface conditions, and how they relate to the purchasing process.

Essential Properties of Metal Explained

The properties of metal encompass specific characteristics that define how metals behave under various conditions. These characteristics are categorized as physical, chemical, mechanical, electrical, and thermal properties. Here's a brief overview of what falls under each category of metal properties:

> **Physical Properties:** The important characteristics of ***density*** (mass per unit volume), ***melting point*** (the temperature where it changes from solid to liquid), and ***color*** (visual appearance) fall into the category of physical properties. Our customers don't worry too much about color, but density and melting point are mission-critical in their specifications.
>
> **Chemical Properties:** Chemical properties include the very important characteristics of ***corrosion resistance*** (ability to resist oxidation and degradation) and ***reactivity*** (how easily it reacts with other substances).
>
> **Mechanical Properties:** There's a lot covered in this category. It includes ***hardness*** (resistance to scratching, cutting, or deformation), ***tensile strength*** (maximum stress before breaking), ***ductility*** (ability to be drawn into wires), ***malleability*** (ability to be hammered or rolled), and ***toughness*** (ability to absorb energy and deform without fracturing).
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> **Electrical Properties:** This category is all about ***electrical conductivity***, or the ability of a metal to conduct electric current. Sometimes that's important to have, other times it's important to avoid, depending on your application of course!
>
> **Thermal Properties:** Thermal properties of metal include ***thermal conductivity*** (ability to conduct heat) and ***thermal expansion*** (the extent to which it expands upon heating). These properties tend to be ones you need to account for in your application.
>
> **Magnetic Properties:** Finally, as touched on above, magnetic properties of metal (ability to be ***magnetized or attract a magnet)*** can be a very important factor in specifications both in the machining process and for the end-use application.ace finish and increased strength through strain hardening.

These properties define how metals behave in different environments and applications, allowing metallurgists to select the appropriate metal for specific purposes. That selection process does not stop with the properties listed above. It also takes into account elements like conditions, surface conditions, and tolerances.

Metal Conditions Defined

Although properties of metal are inherent, they are not fixed. There are several treatments that the metal undergoes to achieve certain states or conditions that influence the properties. Understanding the interplay between the properties and the conditions listed below allows engineers and metallurgists to design metals that meet specific performance requirements, enhancing the functionality and longevity of metal components in your applications. Below are the key conditions that are important in the specification process.

Annealed: Heated to a specific temperature and then cooled slowly to soften the metal, improve ductility, and relieve internal stresses.

Centerless Ground: Ground without a center, resulting in a very smooth and precise surface finish, often used for rods and shafts.

Cold-Rolled: Rolled at room temperature, resulting in a smoother surface finish and increased strength through strain hardening.

Drawn: Pulled through a die to reduce diameter and increase length, improving surface finish and mechanical properties. Often used for wire.

Forged: Shaped by compressive forces, typically using a hammer or press, resulting in improved mechanical properties and structural integrity. Typically performed at elevated temperatures.

Heat-Treated: Subjected to a specific heat treatment process, such as quenching, tempering, or aging, to alter its mechanical properties like hardness, strength, and ductility.

Hot-Rolled: Rolled at high temperatures, typically above the recrystallization temperature, which makes the metal easier to shape and form.

Normalized: Heated to a high temperature and then air-cooled to refine the grain structure and improve toughness.

Quenched: Rapidly cooled from a high temperature to harden the metal by locking in a specific microstructure.

Stress-Relieved: Heated to a temperature below the recrystallization point and then cooled to reduce residual stresses from prior processing without significantly altering the metal's structure.

Tempered: Heated to a temperature below the critical point after quenching to reduce brittleness while retaining hardness. Tempers range from fully hard to fully annealed.

Surface Conditions

Surface conditions can also vary and must be included in the specification. Here are the most important surface conditions to know:

Anodized: Electrochemically treated to form a thick, protective oxide layer, often used for aluminum to enhance corrosion resistance and dye retention.

As-Cast: Resulting directly from the casting process, often characterized by a rough texture and potential surface impurities.

As-Forged: Resulting from the forging process, typically exhibiting scale and roughness due to high-temperature deformation.

As-Rolled: Resulting directly from the rolling process, typically characterized by a relatively smooth finish but with visible scale and minor surface irregularities from the rolling mill.

Blasted: Treated by abrasive blasting (e.g., sandblasting, bead blasting) to remove scale, rust, and surface contaminants, providing a clean, roughened surface ideal for further coating or finishing.

Brushed: Finished with a brushed appearance, characterized by fine parallel lines created by brushing with an abrasive.

Coated: Covered with a protective or decorative layer, which can include paints, polymers, or other metal coatings to improve resistance to environmental factors or wear.

Electropolished: Smoothed and brightened through an electrochemical process that removes a thin layer of material to enhance corrosion resistance and cleanliness.

Etched: Chemically or electrochemically treated to create patterns or textures, often used for decorative or functional purposes.

Extruded: Resulting from the extrusion process, where the metal is forced through a die to create long shapes with a consistent cross-section, typically exhibiting a smooth finish with directional lines along the length of the extrusion.

Ground: Finished using abrasive techniques to achieve a fine surface finish, improving dimensional accuracy and surface texture.

Machined: Finished through mechanical cutting processes, providing a smooth and precise texture with visible tool marks.

Passivated: Treated to remove surface contamination and enhance the formation of a protective oxide layer, improving corrosion resistance. Primarily used on stainless steels.

Plated: Coated with a thin layer of another metal (such as chromium or nickel) through electroplating or other deposition methods to enhance properties like corrosion resistance or appearance.

Polished: Treated to achieve a high level of smoothness and shine, often used for aesthetic purposes or to reduce friction.

Sanded: Smoothed using abrasive materials such as sandpaper, resulting in a fine, uniform texture free from significant surface imperfections.

Exotic and Refractory Metal Tolerances

Understanding tolerances is another crucial component when buying exotic and refractory metals. Here are definitions for key tolerances:

Concentricity: Specifies the allowable deviation of the center of a cylindrical feature from a common axis, ensuring uniform wall thickness and balance.

Diameter: The permissible variation in the diameter of cylindrical components, ensuring that the parts fit correctly within their intended applications.

Flatness: The maximum allowable deviation from a perfectly flat surface, which is critical for components that require tight contact with other surfaces.

Roundness: The allowable variation in the roundness of a cylindrical component, which affects the part's ability to rotate smoothly and fit properly.

Surface Finish: The acceptable roughness or smoothness of a surface, which affects the material's performance, aesthetics, and wear characteristics.

Thickness: The allowable variation in the material's thickness from its specified dimension, ensuring uniformity and consistency across the entire surface.

These tolerances are essential in ensuring the precise manufacturing and performance of exotic and refractory metal components, particularly in high-precision applications like aerospace, medical devices, and high-temperature industrial processes. Understanding and adhering to these tolerances helps in achieving the desired fit, function, and longevity of metal parts.

PART 3

Metal Properties, Formats, and Other Ordering Considerations

There's still more to consider when buying exotic and refractory materials and specifying metal properties. One of the most important things you need to tell us is in what format you need the metal.

Material Formats

Metals come in several formats. Overall, the format is determined by the metal properties and the necessary thickness or diameter of the product. Here are the primary formats our customers require in order by their typical dimensions, from the thinnest and smallest to larger, more substantial forms:

Foil: A very thin sheet of metal, typically less than 0.2 mm (0.008 inches) in thickness, used in applications requiring lightweight and highly flexible metal properties.

Wire: A long, thin strand of metal with a small diameter, typically used in electrical applications, binding, and structural reinforcement.

Sheet: A flat piece of metal with a thickness greater than foil but typically less than 4.75mm (0.187 inches), commonly used in fabrication and construction.

Plate: A flat piece of metal with a thickness typically greater than 4.75 mm (0.187 inches), used in structural applications and heavy machinery.

Rod: A solid cylindrical piece of metal with a larger diameter than wire, used in various structural, manufacturing, and engineering applications.

Bar: A solid piece of metal with a rectangular, square, or circular cross-section, used in construction, manufacturing, and engineering applications.

Tube: A hollow cylindrical piece of metal with a relatively thin wall, used for transporting fluids and gasses or as structural components with robust metal properties.

Pipe: A hollow cylindrical piece of metal with a thicker wall than a tube, used primarily for conveying fluids and gasses under pressure.

Billet: A solid, semi-finished piece of metal with a circular or square cross-section, typically used as a starting material for rolling, forging, or extrusion.

Ingot: A large block of metal cast in a specific shape for convenient handling and further processing into sheets, bars, or other forms.

Extrusion: A process where a material with metal properties suitable for machining is pushed through a die to create long shapes with a consistent cross-section, such as rods, tubes, or complex profiles.

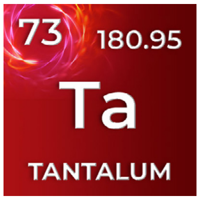
Other Considerations for Specifying Metal Properties

Chemistry: While we sell most materials in their pure form, some are available as alloys to enhance certain metal properties. You might need certain specialty chemistry for your application, and we can make that happen based on the details you share in your specifications.

Testing: You may also require testing for factors such as machinability or magnetic permeability. Standard tests include tensile, mechanical, hardness, bendability, pressure, Charpy impact, and fracture toughness as required by the applicable specification. Specialty tests may also be required based on specific metal properties needed.

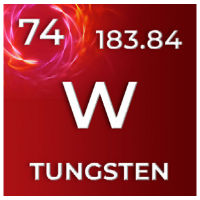
Nuanced Metal Properties and Ordering Information to Get What You Need

Now we're really getting down to it. Below is just a taste of the metal properties you'll be looking for per each exotic or refractory metal we sell. Click on the link to each individual materials page to see the relevant ASTM specifications and AMS specs for that metal.



Tantalum

Tantalum products, such as rod, bar, foil, sheet, and plate, are produced to ASTM B365 and ASTM B708 standards. They are available in various alloys, such as R05200 (Pure Ta) and R05252 (Ta2.5%W).



Tungsten

Pure Tungsten foil, sheet, and plate are produced to ASTM B760 standards. They are available hot or cold-rolled and are often supplied stress-relieved.

Tungsten Alloys

Heavy metal Tungsten Alloys are produced per ASTM B777 or AMS 7725. Depending on the Tungsten content and required density, these materials are available in various classes. Nominal Tungsten content can range from 90-97.5%, and densities range from 17-18.5 g/cc.

42 95.94 Mo MOLYBDENUM

Molybdenum and TZM

Flat Molybdenum products are produced to ASTM B386, while round products are to ASTM B387. Common grades include Molybdenum 360 (pure Arc-Cast), 361 (pure standard powder metallurgy grade), 363 vacuum arc-cast TZM), 364 (powder met TZM), and 365 (vacuum arc-cast Mo30%W).

41 92.906 Nb NIOBIUM

Niobium and its Alloys

Niobium products are produced according to ASTM B392 (Bar, Rod, and Wire), B393 (Strip, Sheet, Plate), and B394 (Seamless and Welded Tubes) standards, as well as various AMS specs when needed. It is known for its high melting point and resistance to most acids.

26-28-27 Fe-Ni-Co KOVAR

KOVAR®

KOVAR materials, produced to ASTM F15, are available in various formats and tempers, making them suitable for deep drawing applications.

26-28 Fe-Ni INVAR 36

INVAR 36®

INVAR 36 is typically produced per ASTM F1684. It is essential to specify the required temper for the application.

22 47.867 Ti TITANIUM

Titanium

Titanium products, like Ti 6Al-4V, are produced to ASTM B265 and AMS 4911 standards. They can be heat treated to improve strength.

28 58.693 Ni NICKEL

Nickel

Nickel 200 and 201 are produced per ASTM B162, B160, and B161 standards. They are available in various tempers and surface conditions.

40 91.224 Zr ZIRCONIUM

Zirconium

Pure Zirconium products are produced to ASTM B551 and ASTM B352 standards. Round products are produced to ASTM B550 and ASTM B351 standards.

The Easiest Thing is to Talk to Our Pros

Contact us to discuss specialty, refractory, and exotic metals, or **request a quote** to cut right to the chase. **Sign up** to receive our monthly newsletter, and join the conversation on **LinkedIn**.

We compiled this information and developed this article meticulously under the watchful eye of our Chief Metallurgist, Bob Desberg. Except for our Chief Morale Officer Bonzo, who had no paw in this article, we are human. If you see anything missing or incorrect, please advise us and we'll be sure to update or correct it!