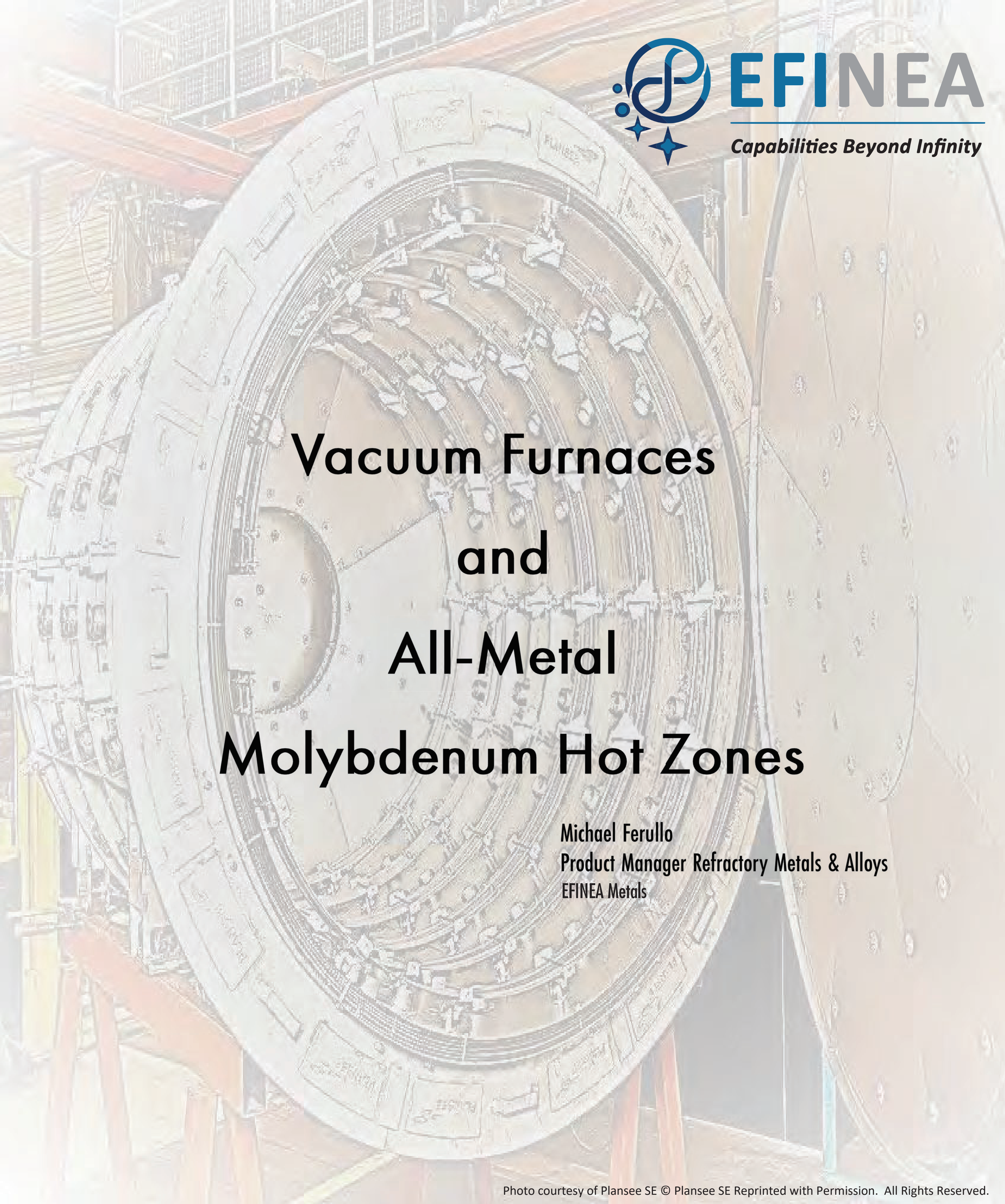

Capabilities Beyond Infinity

Vacuum Furnaces

and

All-Metal

Molybdenum Hot Zones

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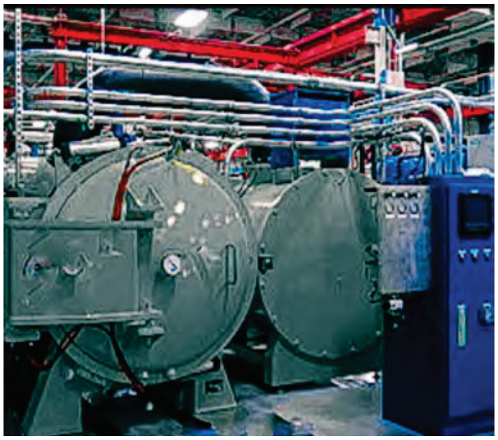
Vacuum Furnaces and All-Metal Molybdenum Hot Zones

Vacuum furnaces have been in existence for many decades now. In this type of furnace, the parts being treated are surrounded by a vacuum while they are being processed.



What is a vacuum? Basically stated, vacuum is a space devoid of matter; its gaseous pressure is much less than atmospheric pressure. There are different quality levels of vacuum and the ideal state of a perfect vacuum containing zero particles is usually not attained.

The vacuum furnace is constructed with a sealed chamber in which air or other gases are removed from the chamber by means of a pumping system. The furnace is capable of varying levels of vacuum. The removal of the air and gases prevents oxidation, heat loss from the products being treated and in addition removes sources that may have a contaminating effect on the final parts. Heating is performed in the chamber which therefore permits the processing to occur in a vacuum environment. The furnace can heat materials which are usually metals or ceramics to extremely high temperatures depending of course on the melting points and vapor pressures of the materials being processed as well as the temperature capabilities of the vacuum furnace itself. Inert gases, for example argon and nitrogen, are introduced and quickly cool the heat-treated products after the desired furnace procedure has taken place.

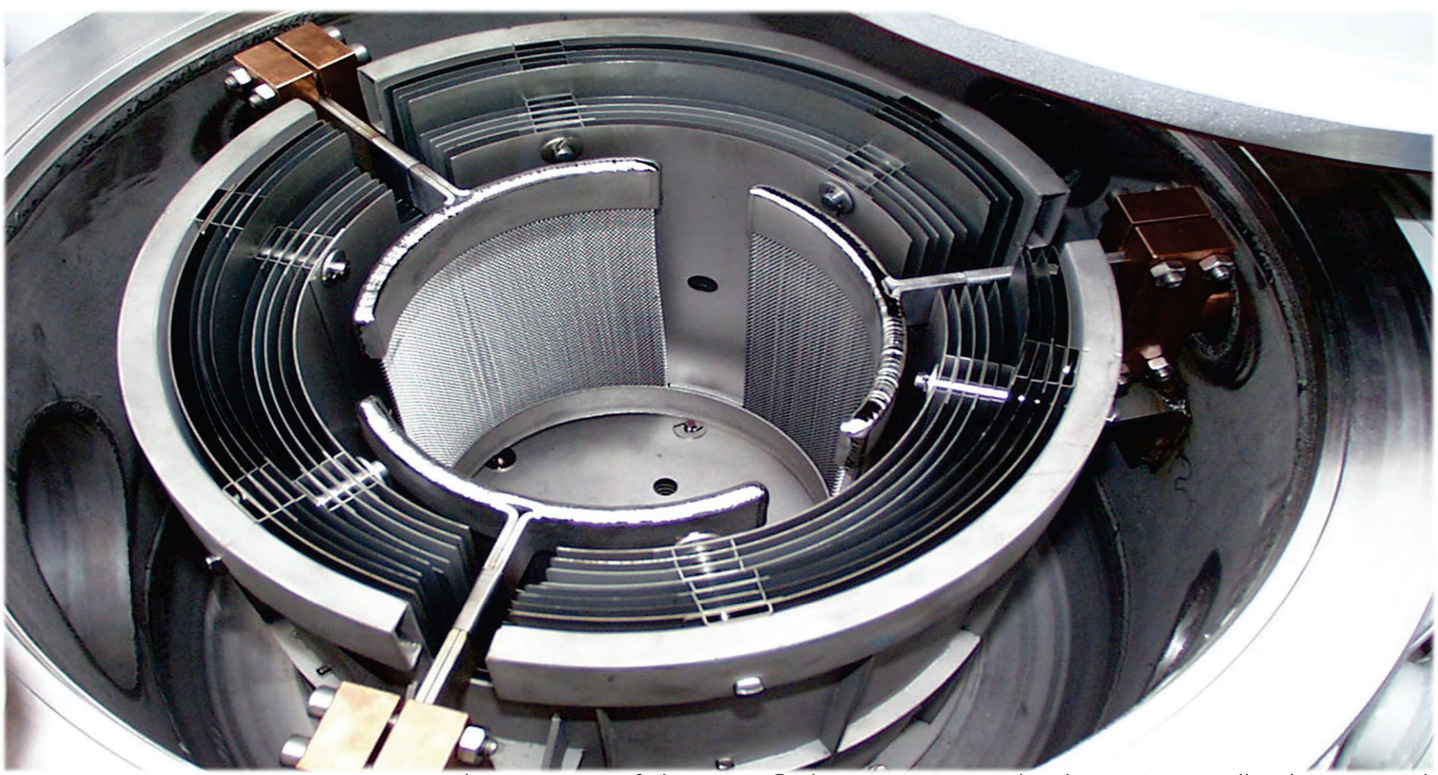
Key features of a vacuum furnace are its ability to maintain a controlled uniform temperature within a heated zone or zones providing for process repeatability, ability to reach high vacuum levels with removal of contamination resulting in high-purity end products, and quick cooling or quenching of parts which enables shorter cycle times.

Vacuum furnaces have uses in many industries for a broad range of applications and are commonly used for production level volume as well as in laboratories for research and development. Typical processes run in these furnaces include annealing, brazing, metal injection molding, degassing, sintering, nitriding, hardening and a variety of other heat treatments.

Low temperature vacuum furnaces running at approximately 1200°C / 2192°F and below are generally used for the heat treating of steel materials for the purposes of hardening, tempering and carburizing. Binder removal is also another application in the low temperature range.

High temperature vacuum furnaces employ temperatures of higher than 1200°C / 2192°F and are used for the most critical applications for parts requiring the highest levels of purity in the electronic, semi-conductor, medical, energy, lighting, crystal growth and aerospace industries, amongst others.

Many vacuum furnaces are round and are utilized in either a vertical or horizontal position. There are manufacturers who also produce non-cylindrical furnaces. In any case, the heart of the vacuum furnace is its hot zone, the internal component of the furnace in which the load is heat-treated. The types of hot zones utilized can be of a graphite insulated design, all-metal insulated or even hybrid varieties depending on the temperatures and conditions required as well as the budget available for its purchase. It is estimated that 25% - 30% of the hot zones being put into service today are of the all-metal variety. Of course, this can vary based on application demand at any given time.



Vacuum Furnaces and All-Metal Molybdenum Hot Zones

The typical all-metal hot zone is used for high temperature applications, generally up to 1350°C / 2462°F and is manufactured from Molybdenum. Higher temperatures up to 1649°C / 3000°F are possible depending on the design. For even higher temperatures Tungsten and Tantalum are utilized.

The plenum or outer shell of the Molybdenum hot zone is fabricated from stainless steel, normally 304L or 316L. It is also possible to use carbon steel to reduce cost.

Molybdenum sheet metal is used to fabricate the side shield pack, as well as the door and rear shield packs if so equipped.

Normally, there is a Molybdenum key shield and two Molybdenum inner shields backed by two layers of stainless steel. Alternate configurations are possible.

The thicknesses of these layers are specified by the furnace manufacturer to allow for proper operation. The designs can vary somewhat and can be subject to modification as agreed upon with the manufacturer to obtain a higher level of performance and a longer life if desired. Heating elements, again with specific dimensions, and the support structure as well as the gas nozzles are also fabricated from Molybdenum.

ML (molybdenum with lanthanum oxide) Alloy for hot zone components subjected to extreme thermal and mechanical load has been very successfully substituted for heating elements, gas nozzles and areas of structural support. Also, hearth post and hearth rail components can be upgraded to TZM Alloy (Molybdenum with Titanium and Zirconium) for improved performance and longevity. Recently, much work has been done with enhancements to all-metal Molybdenum hot zones for the purposes of energy efficiency. One must weigh the initial upfront cost vs. the total cost of ownership.

With respect to the various choices of metals for hot zones operating in the above temperature range, pure Molybdenum is the least expensive upfront option. Upgrading the components to ML or TZM Alloys as discussed can allow for a longer life as well as better performance and a higher level of energy efficiency when combined with enhanced hot zone configurations.

A brief description of the materials follows.

Pure Molybdenum

This material is the standard when considering options for furnace construction. This material is quite workable in terms of machining and fabrication. It has a high melting point, low vapor pressure and high strength at elevated temperatures as well as low thermal expansion properties. The recrystallization temperature of pure Molybdenum is 800-1200°C / 1472-2192°F. The maximum operating temperature of Molybdenum is approximately 1900°C / 3452°F. Its melting point is 2620°C / 4748°F.

ML Alloy (Molybdenum doped with Lanthanum Oxide)

The lanthanum oxide particles in this material create a structure which keeps it stable to temperatures in excess of 1850°C / 3362°F. ML is considered when avoiding embrittlement after recrystallization is necessary and when stability must be maintained at high temperatures. The creep resistance strength of ML is significantly higher than that of pure Molybdenum. Heating elements, radiation shields as well as stock for sintering boats are typical applications.

TZM Alloy (Molybdenum doped with Titanium and Zirconium)

The small quantities of finely dispersed oxides and carbides added to this material inhibit grain growth at high temperatures significantly increasing ductility and creep strength. TZM has a higher recrystallization temperature than pure Molybdenum. Recommended application temperatures are 1000-1400°C / 1832-2552°F. TZM is used for highly stressed parts subjected to both high thermal and mechanical loading such as components for hearth assemblies, furnace racks and fixtures.

Vacuum Furnaces and All-Metal Molybdenum Hot Zones

Material Property Charts

Molybdenum Typical Physical Properties		
Density	g/cm^3	10.22
Melting Point	°F	4748
	°C	2620
Specific Electrical Resistance	$(\Omega \cdot mm^2)/m$	0.056
Specific Heat @20°C	J/(gK)	0.254
*Recrystallization Temp		1100
Thermal Conductivity @20°C	W/(m-K)	142
Coefficient of Linear Thermal Expansion @20°C	m/(m-K)	$5.2x10^{-6}$
*Temp C for 100% recrystallization. One hour annealing time. Deformation level + 90%. Source: Plansee		

Molybdenum Lanthanum Oxide Typical Physical Properties		
Density	lb/in^3	0.376
	g/cm^3	≥10.1
Melting Point	°F	4748
	°C	2620
Electrical Resistivity	Microhm-cm	5.17
Thermal Conductivity	$Cal/cm^2/cm°C/sec$	0.35
Specific Heat	Cal/gm/°C	0.061
Recrystallization Temp.	°C (90% def)	1300
Coefficient of Linear Thermal Expansion	Micro-in/°F x 10^{-6}	4.90
	Micro-in/°C x 10^{-6}	2.70
Source: Plansee Brochures, www.plansee.com		

Molybdenum TZM Typical Physical Properties		
Density	lb/in^3	0.37
	gm/cm^3	10.22
Melting Point	°F	4753
	°C	2623
Thermal Conductivity @20°C	Cal/cm^2/cm°C/sec	0.48
Specific Heat	Cal/gm/°C	0.073
Coefficient of Linear Thermal Expansion	10^{-6} (°F) $^{-1}$	2.50
	10^{-6} (°C) $^{-1}$	5.20
Electrical Resistivity	Microhms-cm	6.85

To support the furnace industry, EFINEA maintains a full line of pure Molybdenum, TZM, ML, Tantalum and Tungsten materials in inventory. Product forms stocked are round bar, flat and coiled sheet, plate, threaded rod, nuts, wire and with our cutting facility quick delivery of hearth components. In addition, long rods for continuous rod furnaces are supplied. Specialty products can be furnished upon request.

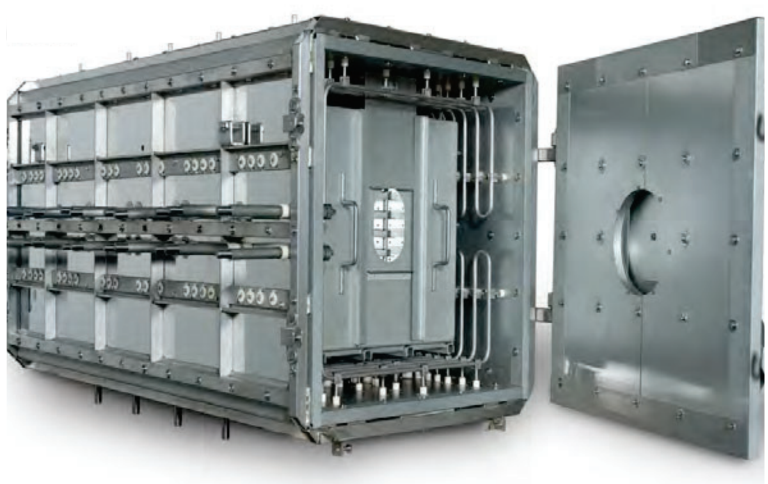


Photo courtesy of Plansee SE