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## Nuclear Zirconium Alloy Market



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## Introduction & Overview

UxC, LLC (UxC) is pleased to present the seventh edition in its special report series on the *Nuclear Zirconium Alloy Market*.

For over a decade, UxC has been closely tracking the nuclear-grade zirconium alloy market and publishing updated reports given the ongoing need and desire for current information and analysis on this unique marketplace.

Nuclear-grade zirconium alloys and components are employed in the fabrication of fuel assemblies used in the vast majority of nuclear reactors currently operating, under construction, and planned around the world. Even as the nuclear renaissance has been derailed in many countries by the Fukushima accident in Japan in 2011, many aspects of the international nuclear fuel supply chain continue to be of interest.

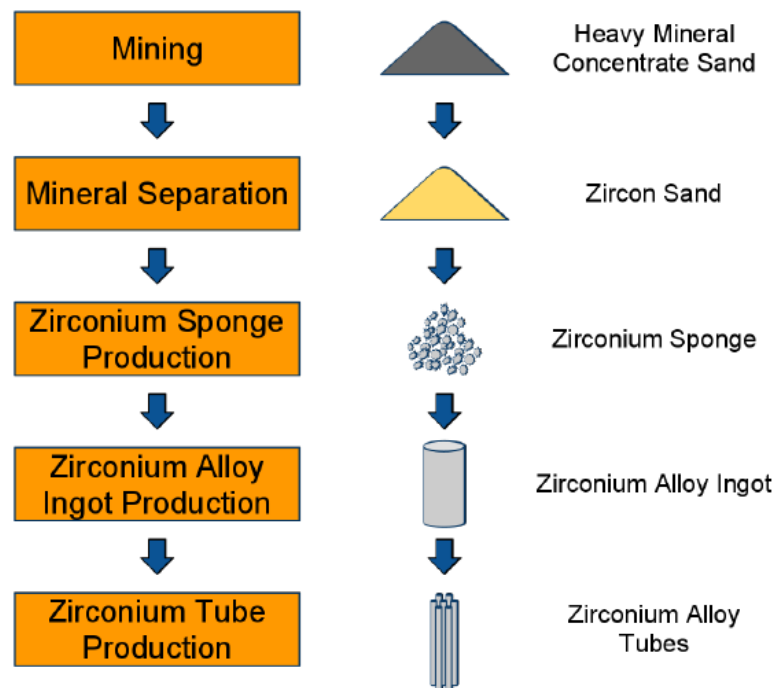
The supply of nuclear-grade zirconium alloys – from the mining of zircon mineral sand through the manufacture of cladding and other components used in finished nuclear fuel assemblies – has not escaped this scrutiny. Therefore, the primary objective of this report is to factually and analytically approach the current and expected future direction of the nuclear-grade zirconium alloy market with the aim of reaching some clear conclusions about how producers of fuel assemblies for nuclear reactors will obtain the necessary zirconium alloys for their finished products and at what cost.

This fully updated report, published in May 2019, offers UxC's most recent analyses and opinions of the various sectors that make up the nuclear-grade zirconium sponge, alloy, materials, and tubing markets. Additional details are included on the interplay of the nuclear fuel fabrication and zirconium alloy supply markets, and of the fabrication process itself. The report also assesses major trends in this unique industry by analyzing the global and regional supply and demand balances for nuclear-grade zirconium sponge, alloy, and tubing as well as the supply and demand situation based on reactor fuel types. We conclude with some final observations on the global market, recent emerging market trends, as well as the status and expectations for future price developments for zirconium alloy products.

## Comprehensive Coverage of the Global Nuclear Zirconium Industry

This report encompasses every aspect of the global nuclear zirconium industry. As such, it provides a detailed analysis and the associated market implications of the numerous steps that convert zircon mineral sand to finished nuclear fuel components. Figure 1 below provides a brief introduction to the principal steps currently employed in the nuclear zirconium industry.

**Figure 1. Nuclear Zirconium Manufacturing Overview**



Source: Lundberg (Uppsala University)

### Availability of Data

Since UxC prepared its first report on this topic in 2008, it has been evident that many of the various processors and fabricators of nuclear-grade zirconium sponge, alloys, and fuel assembly components are reluctant to publish, or even discuss, the details of their businesses. Much of their data is considered proprietary and information sharing is restricted.

Over the years, however, UxC has been able to identify additional sources of information allowing us to fill in a number of blanks on specific data. However, the majority of the participants in the industry remain reticent to share information, and some of them have actually reduced the amount of information presented on their websites and in their public pronouncements over the years.

To supplement our own data collection process for this 2019 edition, UxC reached out to principal zirconium processors and producers in order to gain insights into current and future operations. Generally, the best information available from public and

private sources was used to complete all supplier reviews. Where possible, we confirmed data from one source with another, independent source.

We believe that the information contained herein is accurate or, at a minimum, representative of the operations, production levels, expansion plans, etc. of the companies discussed in this report. However, the possibility still exists that there may be a few inaccuracies or that the information has changed since the data were obtained. In a couple of instances, there were no available non-proprietary data, and therefore the missing information is listed as “not available” in the affected data tables.

It should also be noted that all price and cost data is quoted in U.S. dollars (US\$) throughout this report unless otherwise indicated.

## What's New in the 2019 Report?

In this May 2019 edition of the *Nuclear Zirconium Alloy Market* report, we have continued to employ the format and content of the previous documents but have updated all the relevant information to reflect current circumstances. Other improvements to our market coverage and analysis have been made as well.

Beginning around 2010, the markets for zircon sand and some of the downstream zirconium products entered a period of great volatility. Shortages of zircon led to explosive increases in prices for raw materials and created substantial uncertainty as to the future performance of these markets. This was followed, during the latter half of 2012, by a collapse of demand, production, and prices, raising additional questions about the future of the zircon market. Despite optimistic pronouncements by zircon producers, the market did not recover and subsequently hit a bottom in late 2016. Since then, zircon producers responded by cutting back production and working off inventories, which, coupled with recent increases in demand, have led to a price recovery in the zircon market, which continues as of early 2019.

Consequently, we have substantially expanded our analysis of the zircon minerals market compared to previous reports and highlighted the role of China, both as the world's largest importer of zircon sand and the largest exporter of processed zirconium products, such as zirconium oxychloride, which is a major input product for nuclear zirconium sponge producers. Updates have been made on the latest status of the zircon market as of early 2019 and the outlook for zircon supply and demand as well as prices for the key raw input material to the nuclear zirconium alloy market.

This report also includes detailed descriptions of the zircon mining and refining process as well as the processes employed for the manufacture of nuclear-grade zirconium sponge and downstream zirconium alloy products.

The impact of the March 11, 2011 earthquake and resulting tsunami in Japan, which devastated the Fukushima Daiichi Nuclear Power Plant, continues to weigh on all aspects of the nuclear industry. Additional negative market and policy trends over the

past eight years have also weighed heavily on major nuclear power markets, especially in parts of Western Europe, Northeast Asia, and North America. All of the analyses in this report have taken account of the implications of the Fukushima accident and other nuclear power market developments and how they continue to influence the current status and future prospects of the nuclear industry.

Over the past decade, the prospects for future growth of nuclear power around the world have gone through major fluctuations, and therefore the demand for nuclear fuel assemblies and the zirconium alloy components that comprise them have also experienced significant shifts. The updated demand projections for zirconium sponge, alloys, and tubing described in this report have taken specific account of the post-Fukushima world as well as other major developments affecting nuclear fuel demand over the past few years.

The current demand projection incorporates UxC's detailed calculations of the zirconium weight and tube content in all the major nuclear fuel assemblies in the world, including improved estimates of the quantities of material used in various assembly designs. Moreover, the forecasts make use of UxC's recently refined *UxC Requirements Model* (URM) to forecast global reactor fuel loading requirements and the resulting demand for zirconium alloy materials and products. The URM projects demand on a reactor-by-reactor basis taking account of each plant's refueling schedule (and/or construction schedule for new plants), the specific fuel assembly design used in that plant, the size of the reload batch (or initial core), and the zirconium alloy content of the individual fuel assemblies.

Since 2013, we have included a supply-demand analysis for nuclear-grade zirconium sponge, in addition to those for alloys and tubing. In this 2019 edition, we continue to include market analyses for every step in the zirconium cycle from zircon sand through nuclear fuel tubing.

Given various recent developments in terms of trade and government policies affecting the zirconium sector, the evolution of accident tolerant nuclear fuels in the post-Fukushima world, and the growth in the hafnium market, a new section on emerging market trends has been added to this 2019 report to provide broader context to these key issues. Analysis of how each of these emerging issues may affect the nuclear zirconium market over the longer term is presented.

Finally, we have also noted that many of the subscribers to the previous editions of this report represented organizations that did not participate directly in the nuclear fuel fabrication market. Thus, for those not familiar with the technical aspects of the fabrication industry, we have again included a discussion of the design of BWR and PWR fuel assemblies, the zirconium alloy components of which they are constructed, and the fuel fabrication process itself.

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## Structure of the Report

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This report contains separate chapters for various aspects of the nuclear-grade zirconium alloy market, supply and demand, and other related areas. In addition to this **Introduction & Overview**, the report includes the following chapters:

**Chapter 1 – General Zirconium Overview & Zircon Market Review** provides a broad exploration of the zirconium mineral occurrence, resource base, and industrial applications, including the role of zirconium alloy production in the nuclear fuel industry. It describes the mining and refining of zircon sand, and most importantly, it addresses the current and projected supply, demand, and price of zircon in the international marketplace with emphasis on China’s critical role. This chapter helps to put the specific nuclear-grade zirconium alloy market analysis in perspective, as there are numerous applications for the zirconium mineral beyond nuclear reactor fuel.

**Chapter 2 – Manufacturing Processes for Nuclear Fuel Components** covers the processing steps from zircon sand through zirconium sponge and alloy production to the manufacture of nuclear fuel components, i.e., the overall “nuclear zirconium cycle” for production of the materials and components used in nuclear fuel assemblies.

**Chapter 3 – Nuclear Zirconium Alloy Materials & Product Suppliers** presents a profile of each of the companies involved in nuclear-grade zirconium alloy materials and product supply. This includes all the companies in the world involved in nuclear-grade zirconium sponge and alloy production and processing through manufacture of sheet, plate, bar stock, and tube-reduced extrusions (TREX), as well as tubing and other component manufacture.

**Chapter 4 – Nuclear Fuel Fabricators & Zirconium Components Supply** provides a brief overview of the global nuclear fuel fabrication industry and indicates the source of each fabricator’s fuel assembly tubing and other components. It also includes a discussion of the individual components that make up fuel assemblies and describes the fuel fabrication process.

**Chapter 5 – Nuclear Zirconium Supply & Demand Analysis** offers UxC’s most recent analysis of the global supply and demand balance for nuclear fuel-related zirconium sponge and alloy products as well as zirconium tubing. In addition, this chapter includes an analysis of zirconium supply and demand by region as well as by reactor type.

**Chapter 6 – Overall Conclusions & Market Analysis** summarizes our findings on the nuclear-grade zirconium market and offers some final thoughts on the current situation and forecast of future trends. Included in this chapter is also a review of new and emerging trends that could impact the nuclear zirconium market over the longer term. This chapter also provides UxC’s estimates of the current nuclear-grade zirconium alloy prices and expectations for future price developments.

Finally, the **Appendices** include the data and assumptions used in the analyses discussed in the body of the report as well as several additional reference materials.