Ceramic UO_2 Powder Production At Cameco Corporation

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ABSTRACT

This paper describes the various aspects of ceramic grade UO_2 powder production at Cameco Corporation's Port Hope conversion facility. It discusses the significant safety systems, production processes and plant monitoring and control systems. It also provides an insight into how various support groups such as Quality Assurance, Analytical Services, and Technology Development contribute to the consistent production of high quality UO_2 powder. The ability of Cameco to identify, measure and control the physical and chemical properties of ceramic grade UO_2 has resulted in the production of uniform quality powder that has consistently met customer requirements

1.0 INTRODUCTION

In 1988 the federally owned Eldorado Resources Ltd. merged with the Saskatchewan Mining and Development Corporation to form Cameco Corporation. Today Cameco is the world's largest low cost uranium producer and a growing supplier of clean electricity. Cameco delivers shareholder value by using its unique assets, employee experience and industry knowledge to meet the world's rising demand for clean, safe and reliable energy.

Cameco accounted for 20% of world uranium production in 2004. The company's position as a global leader is backed by 553 million pounds of proven and probable uranium reserves and a successful exploration program. Cameco has controlling ownership of the world's largest high-grade reserves and low-cost operations in northern Saskatchewan, with the McArthur River mine having average ore grades of 25% U_3O_8, which is more than 100 times the world average.

By focusing on a safe and healthy workplace, a clean environment, supportive communities and strong financial performance, Cameco will achieve its vision of being a dominant nuclear energy company producing uranium fuel and generating clean electricity.

Cameco is also an integrated uranium fuel supplier with refining facilities at Blind River, Ontario and a conversion plant at Port Hope, Ontario. Uranium trioxide (UO_3) from Blind River is processed at Cameco's Port Hope conversion facility, one of only four commercial suppliers of uranium hexafluoride (UF_6) in the western world with capacity to meet 20% of annual world requirements.

Port Hope is also the world's only commercial supplier of natural uranium dioxide (UO_2), the fuel used by all Canadian-designed Candu reactors. In February 2000, the Port Hope site became registered to and remains compliant with ISO 14001 International Environmental Standard. UO_2 production is the focus of this paper.

2.0 URANIUM PRODUCTION AT CAMECO'S ONTARIO OPERATIONS

2.1 Blind River Refinery

The Blind River Refinery is the world's largest and most modern commercial uranium refinery and is licensed to produce 18,000 tonnes of uranium per year.

The refinery receives drums of uranium ore concentrates from mines around the world including Canada, Australia and the United States. Uranium is separated from impurities contained in the mine concentrates in a refining process using digestion, solvent extraction, and denitration. The result is a nuclear grade uranium product known as uranium trioxide (UO_3). The uranium trioxide produced at Blind River is delivered to the Port Hope Conversion Facility in specially designed bins which hold approximately 9.5 tonnes of uranium. The UO_3 production matches the requirements for the Port Hope facility and Springfields Fuels Limited (SFL), located in the United Kingdom, where toll conversion to UF_6 takes place. The UO_3 supply to SFL has enabled the refinery to utilize unused production capacity.

2.2 Port Hope Conversion Facility

Cameco's Port Hope operation is the only uranium conversion facility in Canada and one of only four conversion facilities in the western world. It includes uranium dioxide (UO_2) and uranium hexafluoride (UF_6) processing plants, uranium metal production and casting facilities, technology development and analytical laboratories and a powerplant that supplies steam and compressed air requirements.

2.2.1 UF6 Production

In Port Hope, approximately 80% of the UO_3 received is converted to UF_6 which is exported to enrichment plants abroad as an intermediate product for the production of enriched uranium. The UO_3 is reduced to UO_2 by reaction with hydrogen in fluid bed reactors. This UO_2 is then hydrofluorinated to uranium tetrafluoride (UF_4) by reaction with hydrofluoric acid (HF). The UF_4 is fluorinated to UF_6 by reaction with fluorine gas. This facility is the only uranium conversion facility which uses a wet process to make UF_4, which has a very high efficiency for HF consumption.

2.2.2 UO_2 Production

The remaining 20% of the UO_3 received in Port Hope is converted to ceramic uranium dioxide. The licensed production capacity of the plant is 2,800 tonnes U per year as UO_2. This plant is the only supplier of UO_2 for Candu reactors. Ceramic UO_2 is produced through the ADU (ammonium diuranate) process. Both natural and depleted UO_2 powders are produced using this method which is described in more detail in the following section.

3.0 CERAMIC UO_2 POWDER PRODUCTION

Cameco's practice when generating reports is to report safety and environmental information ahead of other data such as production results, product quality etc. This practice continues in the following sections.

3.1 Safety Systems

Cameco places safety at the top of its priorities at all of its operations. In addition to the many plant wide safety and emergency response systems, the following are some of the safety systems in place in the UO_2 plant.

Hydrogen detectors are located in all areas where hydrogen gas is in use. If hydrogen is detected in the ambient air the system is shutdown and purged with nitrogen.

Ambient ammonia detectors are located in areas where there is a potential for aqueous ammonia leaks, they provide alarms to operators.

Level sensors and alarms are located in almost all storage tanks and a plant control system automatically shuts down the process to prevent upsets.

Heat stress monitoring is carried out in the plant from May to September, this data is logged into the plant computer system and provides a guide to operators on the degree of work that can be performed in a specific area of the plant.

A plant wide voice alarm system notifies personnel over the P.A. system of process upsets or other potential plant problems.

Safety is stressed continuously throughout the year and safety meetings covering a variety of topics are held every month.

3.2 Environmental Monitoring Systems

As mentioned previously Cameco's Port Hope operation is presently registered and compliant with ISO14001. To obtain this registration the site went through a detailed process of identifying all environmental aspects to ensure the appropriate controls and safeguards were in place. The following are some of the environmental monitoring systems presently in place in the UO_2 plant.

Dust collection systems are used throughout the plant to ensure all uranium dust is contained. These systems generally consist of four baghouses operated in series. A primary baghouse collects most of the dust while a secondary system collect dust leaking by the primary baghouse. A prefilter and absolute filter are used for final cleaning. Both the prefilter and absolute filter are HEPA type (High Efficiency Particulate Air filter). Downstream of the secondary filter and before the prefilter a bag leakage detector is installed in the duct. This electrostatic device detects even minute amounts of particulate and provides alarms to plant personnel if dust leaks by the secondary system. All the baghouse systems are equipped with differential pressure transmitters that provide indication and alarms on high filter bag loading or failure. All systems are inspected regularly as part of a preventative maintenance system.

Sintered metal filters are used to remove particulate from the kiln off-gas system. A primary system collects UO_2 dust and recycles it back to the kiln while a secondary system in series ensures complete cleaning of the off-gas. These filters are both of HEPA quality.

Liquid scrubber systems in the ADU drying area and fume collection system ensure the off-gas from these areas is scrubbed before release to the main plant stack. The liquid scrubber flow through these systems is monitored and interlocked to shut down the scrubbers on low flow.

The main stack mentioned above is continuously sampled and analyzed for uranium, nitrates and ammonia. The results of this monitoring have indicated that the stack emissions are well below regulatory action levels and internal action levels (which are set at a fraction of regulatory levels).

Cooling water, pumped from Lake Ontario, is used as an indirect source of cooling in a few areas of the plant. Before being returned to the lake it flows across a conductivity probe which alarms on high conductivity and a MISA (Municipal Industrial Strategy for Abatement) sampler. The sample is analyzed for uranium, ammonia, nitrates and TSS (total suspended solids). As part of the plants licensing requirement all the information from the above sampling systems is reported quarterly and annually to the CNSC (Canadian Nuclear Safety Commission) and is available as public information.

3.3 Process Monitoring and Control

Throughout the Port Hope facility many buildings are interconnected on a production network computer system. This system enables personnel with the appropriate security clearance to view operations in many areas.

The monitoring and control of the UO_2 plant is comprised of two main systems. The first system is composed of programmable logic controllers (PLC's) which receive analog and digital information from instrumentation in all areas of the plant. These controllers are programmed to enable the plant to be started up and operated safely. By using many series of interlocks they prevent plant upset conditions and help control product quality. Because they are programmed using lines of logic, the information they contain is not always discernable to plant operators and a second system, a graphical user interface (GUI) is employed. This interface, also referred to as an HMI (human machine interface), receives information from the PLC's and immediately converts it to a display that is easily understood, e.g. tank level, vessel pressure, temperature etc. These displays enable operators to monitor and control the plant process from the computer system. This information coming from the PLC's can also be historically trended and stored into files that contain many years of data.

3.4 Ammonium Diuranate (ADU) Process

Ceramic UO_2 powder has been produced at the Port Hope Conversion Facility since 1958. Production of UO_2 started in May of that year when about 4.5 tonnes of U as UO_2 was produced. Today the plant has a licensed production capacity of 2,800 tonnes U.

To obtain a UO_2 powder with physical properties suitable for sintering to a high density the following steps are taken.

UO_3 from the Blind River Refinery is dissolved in nitric acid to form a uranyl nitrate solution. In large reaction tanks aqueous ammonia is added to the uranyl nitrate solution . The precipitation reaction results in the formation of ammonium diuranate (ADU), a yellow precipitate and ammonium nitrate, a clear solution. The ADU is allowed to settle for a period of time after which the clear ammonium nitrate is removed by decanting. The ADU is discharged to a holding tank and pumped to centrifuges where the residual ammonium nitrate is removed.

After centrifuging the ADU is in the form of a wet cake. An automatic scraper blade removes the ADU from the centrifuge filter cloth after which it is discharged to a continuous tray dryer. The dry ADU powder is conveyed to one of two parallel kilns where it is reduced to UO_2 at high temperature in a counter current hydrogen flow.

The ammonium nitrate solution that was removed after precipitation is concentrated and treated to remove residual traces of uranium. After a suitable batch size has been produced it is certified and sold to a local fertilizer distributor.

The UO_2 powder from the kiln reduction system is conveyed to a large twin cone blender where it is homogenized, usually in 7.5 tonne U batch sizes. After blending the UO_2 is conveyed to a packaging station where it is sampled and drummed inside an enclosure. The resulting blend is given a unique lot number and is subjected to testing for certification purposes, typically Cameco Specification 1, (CS1). To meet this specification the UO_2 powder lot must have certain physical and chemical properties (appendix 1) and be capable of sintering to higher than 96.5 % theoretical density.

4.0 TECHNICAL SUPPORT TO UO_2 PRODUCTION

4.1 Analytical Capabilities

The analytical laboratory at the Port Hope Facility provides analysis of product to ensure that it meets customer specifications. A wide range of equipment is used to perform this work including the following: Inductively Coupled Plasma - Mass Spectrometer (ICP-MS); a Wavelength Dispersive X-ray Fluorescence Spectrometer (WDXRF); Atomic Absorption Spectrophotometer (AAS) and scanning electron microscope (SEM). The laboratory is able to analyse impurities in the product down to sub part per million levels. Other analytical equipment is used to determine physical characteristics of the UO_2 powder such as particle size, surface area, bulk, green and sintered density and the oxygen to uranium ratio (O/U). The equipment is located in a process control laboratory in the UO_2 production area. The location of the physical lab is beneficial because it enables the quick exchange of information on product quality between the lab and plant personnel, thus providing the ability to recognize production trends and implement process changes before unacceptable product has been produced.

4.2 Quality Assurance

Cameco has a Quality Assurance Manual that describes how the Quality Program is designed to ensure that the customer's quality requirements are recognized and that consistent and uniform control of these requirements is adequately maintained. The Quality Program is designed to satisfy the requirements of the CSA Standard Z299.2 (1985) and other equivalent standards.
At this time Cameco has not sought ISO 9000 certification as this certification is not recognized by the Canadian nuclear utilities which audits Cameco's quality program through CANPAC. There is some activity currently underway at CSA to develop a sector guide in support of an ISO 9000 quality program. Cameco will monitor the situation and assess the ISO 9000 certification option.

4.3 Technology Development

Research and development activities are an important part of strategic and production planning for Cameco. Characterization of ceramic UO_2 powders and the development of new processing techniques have always been an important part of Cameco's success.

The ongoing research programs on ceramic UO_2 at Port Hope are conducted by a group of highly qualified scientists and experienced technologists. Efforts in recent years have included: fundamental research into developing methods for effective characterization of ceramic UO_2 powder products, assisting in the correlation of powder characteristic data with final properties of sintered UO_2 fuel pellets and providing technical support to the customer. A recent example of technology development's contribution was their development of an x-ray diffraction method to analyze UO_2 powders. This method assisted UO_2 personnel in troubleshooting a plant processing problem. The database of information that has been developed over the years has greatly assisted the recent research and development of SEU (slightly enriched uranium) and BDU (blend of dysprosium and uranium) powders.

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1. R.T. Tanaka and T.W. Kennedy, "History of UO2 Production at Port Hope", International Conference on CANDU Fuel, October, 1986.

2. Cameco Website , www.cameco.com

Appendix 1

Symbol	Name	Maximum Level in ppm U, Basis	EBC
Al	Aluminum	25	0.0025
B	Boron	0.3	0.3000
C	Carbon	200	0.0010
Ca	Calcium	50	0.0100
Cd	Cadmium	0.2	0.0621
Cr	Chromium	15	0.0120
Cu	Copper	10	0.0090
Dy	Dysprosium	0.15	0.0122
F	Fluorine	30	0.0002
Fe	Iron	75	0.0525
Gd	Gadolinium	0.10	0.4438
Mg	Magnesium	10	0.0004
Mn	Manganese	5	0.0170
Mo	Molybdenum	2	0.0008
Ni	Nickel	20	0.0220
Si	Silicon	30	0.0030
Th	Thorium	500	0.2150
P	Phosphorus	35	0.0035
Na	Sodium	20	0.0060
K	Potassium	20	0.0160