Criticality Safety And Fuel Segregation At Zircatec – Past Present And Future – Part I

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Abstract

In response to the Power Uprate program at Bruce Power, Zircatec has committed to introduce, by Spring 2006 a new manufacturing line for the production of 43 element Bruce LVRF bundles containing Slightly Enriched Uranium (SEU) with a centre pin of blended dysprosia/urania (BDU). This is a new fuel design and is the first change in fuel design since the introduction of the current 37 element fuel over 20 years ago.

Zircatec has been involved with the manufacture of enriched fuel for at least 30 years. In the recent past (~ 20 years) enriched manufacture at Zircatec has been limited to small special orders for test purposes; this has included the major development work conducted to support the evolution of the current design. This presentation will discuss methods that have been used for small scale manufacture of special fuels including those with multiple enrichment. Specific examples will be given as pertaining to the manufacture of 26 LVRF Demonstration Irradiation bundles.

1. Introduction

Zircatec has been involved with the manufacture of enriched fuel for over 30 years. Since 1986 the work has included small scale manufacture of enriched fuel pellets and bundles for various out-reactor tests. Enriched manufacture has been conducted within the scope of the existing Facility License Manual – the facility is licensed for up to 5% enriched uranium with up to 20% allowed upon obtaining a Special Project License from CNSC. The license allows up to 5 Smallest (spherical) Critical Masses (5SCM) (the on site of which 3 SCM can be in process under conditions that will be described.

The existing Criticality Control Program falls under the jurisdiction of a Criticality Control Committee (CCC) which operates according to the ZPI Criticality Control Manual (CCM). The chairman of the CCC reports to the Facility Licensing Committee on issues pertaining to criticality.

The set-up of the Criticality Control Program follows established ANS guidelines adopted for the small scale production that has been usual to date at ZPI. The philosophy is that "no single credible failure can cause a criticality event" and is embodies in the so-called "double contingency" principle – "..process designs to incorporate sufficient factors of safety to require at least two unlikely, independent and concurrent changes in process conditions...".

The implementation involves ensuring that passive and administrative controls are incorporated into each project that is undertaken. The work is done as "special project" similar to past work in special fuels (thorium, 20% EU etc.) which has included "mixed enrichment" 37 element and canflex type fuel. The project is conducted under the authority of a Project Leader and all manufacture is conducted according to the Criticality Control Manual (CCM). This governing document establishes policies, standards and regulations specific to nuclear criticality safety for special material and specifies material control procedures etc.

2. Critical Mass and Process Batch Size

As is usual in laboratory scale processing, the primary control mechanism adopted is one of limiting the batch size that can be present at any one location. The Zircatec CCM requirement is that no more than 0.45SCM may be present in any processing zone. Since in almost all cases the material is not present in spherical form during processing, this condition is conservative. If a second 0.45 SCM worth of material needs to be processed, this has to be done in a second zone which is more than 3.7m distant.

In practice the batch size is thus controlled by material enrichment – some typical batch sizes are shown in Table 2.1.

Table 2.1: Batch Sizes for Various Enrichments

1%	788 kgUO_2
2%	82 kgUO_2
4%	26 kgUO_2
5%	18 kgUO_2

Control elements of the CCM include the requirement that material transfers between designated processing zones can occur only under the supervision of individuals designated as Nuclear Material Control Technicians (NMCT). These individuals are trained in the overall principles embodied in the CCM as well as the limits established for each project.

3. Process Set-up

Production of laboratory scale enriched production is authorized by the CCC. The designated NMCT is required to analyze the project and determine the appropriate batch sizes allowed. The processing areas are then broken up into Criticality Control Zones (CCZs) which are physically marked or otherwise delineated. These are predefined areas of the plant with geometric boundaries clearly defined by solid walls, floor tapes and/or stanchions and ropes and each CCZ is separated by a minimum distance of 3.7m. A Criticality and Material Control Plan is then written which describes the process flow and material control procedures in detail. This is approved by the CCC.

Prior to receipt of enriched material at site it is established that the site limit of 5SCM is not exceed. Received material is stored in areas designated as storage areas for enriched material – no processing is allowed in these areas.

Prior to release of enriched material for manufacture a material balance is produced to ensure that the processing limit of 3SCM is not exceeded and authorization is obtained from the CCC.

Material transfer to and between CCZs is done only in the presence of an NMCT and each transfer is logged both in a database maintained by the NMCT as well on display boards at each CCZ – material that is not actually being worked on is locked in designated and secured storage areas located within the CCZs.

Only one enrichment can be processed at any one time and co-processing of different enrichments is forbidden. The CCM requires a cleandown of all process areas followed by an inventory mass balance of incoming, outgoing and scrap materials prior to the start of a second enrichment.

4. Projects conducted under current CCM

The described methodology has been successfully used for:

Table 4.1: Summary of Enriched Projects

Enrichment Level %	Time Frame	SCM	Project
1%	Continuing	~0.3	DI Bundle build
1%	Continuing	< 0.03	SEU/BDU test/scale-up work
1.75 and 1.2	~ 1997/1998	~ 0.3	Downblend of 2.26% material to two enrichments and manufacture of mixed enrichment bundles for out reactor tests
19.89	1997	~1.2	Slowpoke reactor fuel for Ecole Polytechnique

2.26	1994	~0.5	Test bundles for out reactor tests
2.28	1993	~0.75	Test bundles for out reactor tests
19.89	1986	~1.2	Slowpoke reactor fuel for RMC

5. Demonstration Irradiation Bundles for Bruce

ZPI is currently producing 26 LVRF bundles for the Demonstration Irradiation at Bruce currently targeted for December 2005. The project is being conducted within the scope of the current license and criticality aspects are being done according to the procedures set out in the existing CCM. The fuel involves two separate materials and is similar to other mixed enrichment fuels that have been manufactured at ZPI. The philosophy being adopted is to treat the BDU material as a second enrichment for material control purposes and use the same controls as for SEU. Thus, the Criticality and Material Control Plan forbids the co-processing of the two materials until the product is in sealed element form and a material balance has been obtained. It can be understood that the two materials are segregated in time (during routine production of this fuel the two materials will be segregated in space).

To further identify the two materials, until the bundle is assembled all BDU and SEU product is identified using distinct colour coding – this colour coding extends to the signs on the equipment being used as well as the units used to transfer the product between process areas. In addition, as per the CCM, product that is not under actual processing is kept in designated (and colour coded) locked and secured storage areas.

6. Training

Although the DI bundle manufacture is a small scale project, it is seen as a precursor to the full LVRF production. With this is mind, all supervisory staff have been trained in basic criticality safety concepts as well as in specific mass and segregation issues related to the DI project.

7. Summary

The currently existing criticality and material control methods are robust and have been used in the past for small scale manufacture of specialty fuels without incident. The many years of experience with the manufacture of these fuels is being applied to the manufacture of the Bruce LVRF Demonstration Irradiation bundles.