Manufacture of Nuclear Fuel Elements in Chile
Fabricación de Combustible Nuclear en Chile

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RESEARCH REACTOR

Nuclear Research Reactors are devices in which a controlled, self-sustained fission chain reaction can be maintained. Differs from power reactor by its low power level and purposes. Uses: basic or applied research, training, testing of materials, radioisotopes production for nuclear medicine and Industry

The Chilean Nuclear Energy Commission - CCHEN have two Nuclear Research Reactors: RECH-1 (5 MW) located at La Reina Nuclear Center and RECH-2 (10 MW) located at Lo Aguirre Nuclear Center
RECH-1 CHILEAN RESEARCH REACTOR - 5 MW
CONTENTS

- NUCLEAR FUEL FOR RESEARCH REACTORS AT THE CCHEN
  - Fuel Fabrication Plant
  - Major Milestones

- NUCLEAR FUEL FABRICATION PROCESS
  - Processes & QC diagram
  - Operation Licensing
  - Local Qualification
  - International Qualification
  - Fabrication Summary
  - Fabrication Pictures

- ACTIVITIES OF RESEARCH AND DEVELOPMENT OF NUCLEAR FUELS AT CCHEN

- CONCLUSIONS
NUCLEAR FUEL FOR RESEARCH REACTORS AT THE CCHEN Fuel Fabrication Plant

- CCHEN is the owner and operates a Nuclear Fuel Fabrication Plant for Research Reactors (MTR) in Lo Aguirre Nuclear Center.

- Design and construction: 1985-1986

- Total Constructed Surface: 1137 m² approximately

- Facility and Fabrication Process licensed in 1998 by the Chilean Nuclear Regulatory Authority

- The fuel fabrication process is being developed at CCHEN in accomplishment of international specifications and under a Quality Management System certified since 2003 under ISO 9001 standard
NUCLEAR FUEL FOR RESEARCH REACTORS AT THE CCHEN Fuel Fabrication Plant
NUCLEAR FUEL FOR RESEARCH REACTORS AT THE CCHEN

Major milestones


• 2012: Reception of 33 kg of US Origin LEU metal uranium

LEU from Russia was used for fuel elements previously fabricated for RECH-1
NUCLEAR FUEL FOR RESEARCH REACTORS AT THE CCHEN

Major milestones

• 2005: End of International Qualification, started at 2001 (CHI/4/021 TCP Production and Irradiation Qualification of Fuel Elements for research reactors)

• 2004: 46 fuel elements have been fabricated and delivered to the RECH-1, since 1998

• 2002: RECH-1 officially converted from HEU to LEU (reference core 32 LEU FA)
NUCLEAR FUEL FOR RESEARCH REACTORS AT THE CCHEN
Major milestones

• 1998: Fabrication and delivery of 4 leaders fuel elements to RECH-1 reactor

• 1997 – 1995:
  • Fabrication process development
  • Licensing of processes and facility
  • Development of the fuel technical specs.

• 1987: Inspection and re-manufacturing of RECH–2, HEU Fuel Elements
CONTENTS

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  ○ Major Milestones

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  ○ Processes & QC diagram
  ○ Operation Licensing
  ○ Local Qualification
  ○ International Qualification
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  ○ Fabrication Pictures

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Fuel element is a grouping of fuel plates held together by structural components to form a complete fuel unit which is maintained intact during fuel transfer and irradiation operations in the reactor.
Fuel plates: Are the main components of fuel element containing nuclear material encapsulated in Al alloy cladding.

- Compacting of an homogeneous blend of fuel and aluminium powders.
- Assembling of fuel core (compact), covers and frame of Al alloy (TIG welding).
- Co-Rolling process: Plastic deformation until obtain fuel plate with fuel core encapsulated by Al cladding.
Nuclear material: Usually a particulate system of uranium compound (aluminide, oxide, silicide) or uranium alloy (U-Mo)
Fissile material: Usually $^{235}\text{U}$ isotopes present up to 20wt% in metal uranium
Four fuel elements (leaders) were fabricated and loaded into the core of reactor at the end of 1998.

Some of them were instrumentalized with thermocouples in order to control the inlet and outlet temperatures of coolant flow.

The goal was to know and register the behavior of the leaders fuel elements under irradiation. For that, the reactor staff implemented a follow-up program.

The leaders fuel elements were unloaded from the reactor in 2010, with an estimated burnup of about 50% and behavior according to expected.
NUCLEAR FUEL FABRICATION PROCESS
Local Qualification program (1998 - 2010)

- Visual inspection of fuel element into the RECH-1 pool
NUCLEAR FUEL FABRICATION PROCESS

International Qualification Program (2001-2004)


- Signature of tripartite contract IAEA-CCHEN-NRG (Petten)

- Fabrication of test fuel element LCC-01
  - Density 3.4 gU/cm³ (fuel plates RECH-1 inner type)
  - Design of fuel assembly adapted to HFR
  - Inspections by NRG inspector before, during and after fabrication of LCC-01 test fuel
NUCLEAR FUEL FABRICATION PROCESS

International Qualification Program (2001-2004)

Picture of the test fuel element
• Test fuel element finished, during inspection by part of NRG in CCHEN
NUCLEAR FUEL FABRICATION PROCESS
International Qualification Program (2001-2004)

Shipping of test fuel element

Fuel element into special cask for fuel transport
NUCLEAR FUEL FABRICATION PROCESS
International Qualification Program (2001-2004)

Irradiation in HFR Petten during 16 cycles from May 2003 until December 2004
NUCLEAR FUEL FABRICATION PROCESS
International Qualification Program (2001-2004)

Post Irradiation Examination in Petten Hot Cell Lab

Visual inspection of LCC-01 inside the hot cell
NUCLEAR FUEL FABRICATION PROCESS

International Qualification Program (2001-2004)

• Neutronics calculations given $^{235}\text{U}$ burnup level of 64.5% ± 8.4%, this value is greater than 55%, expected at the beginning.

• The PIE results show proper behavior of fuel element. No deviations were detected during and after irradiation.

• According to the results of inspections before, during and after fabrication and to the performance of the test fuel element under irradiation in HFR Petten, the irradiation qualification concluded successfully and qualify CCHEN as an international manufacturer of LEU fuel elements based on $\text{U}_3\text{Si}_2$. 
From 1999 to 2004, 46 fuel elements have been fabricated and delivered to the RECH-1.

In 2005, the LR-82 standard fuel element was delivered to RECH-1. The last one of the manufacturing campaign started in 1998.

In 2011 the fabrication of fuel elements was restarted, with 2 fuel elements delivered in 2011, 3 in 2012 and 3 fuel elements under fabrication for 2013.
FUEL FABRICATION PROCESS AT CCHEN - Pictures

General View of Fuel Fabrication Plant at CCHEN
Induction furnace for melting and synthesis of $\text{U}_3\text{Si}_2$
FUEL FABRICATION PROCESS AT CCHEN - Pictures

Glove box room G-3 used for powder preparation
Glove box room G-5 used for compact fabrication
Hydraulic uniaxial press inside glove box in G-5 room
Rolling machine and forced air annealing furnace
X-ray system for core (meat) control in fuel plates.
Core location, core metrology and homogeneity
Eddy current system for cladding thickness measurement
UT scanning system used for bonding test in fuel plates
Gamma scanning system for U-235 measurements in fuel plates
Metrology for structural components
Assembling of fuel element - swaging process
Finished fuel box
Metrology of fuel box and components
Metrology of assembled fuel element
Final visual inspection and cleaning of fuel element
Different design of fuel elements fabricated at CCHEN
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  - Operation Licensing
  - Local Qualification
  - International Qualification
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  - Fabrication Pictures

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ACTIVITIES OF RESEARCH AND DEVELOPMENT ON NUCLEAR FUELS AT CCHEN: $U_3O_8$ - Al System

- **1988 - 1990**
  R&D of miniplates based on $U_3O_8$ – Al

- **1991**
  Dispersion type fuel plates based on $U_3O_8$ - Al (full size)

The project end with a trial run, manufacturing two full size fuel elements with natural uranium.
ACTIVITIES OF RESEARCH AND DEVELOPMENT ON NUCLEAR FUELS AT CCHEN: $\text{U}_3\text{Si}_2$ - Al System

• 1992
Application and approval of FONDECYT project “Development of uranium silicides for use as high density nuclear fuel. Obtainment and Sintering of molybdenum silicides”

• 1993 – 1995: Main Results of $\text{U}_3\text{Si}_2$ R&D Project
  • Technology for Synthesis and Characterization of $\text{U}_3\text{Si}_2$
  • Fabricating of $\text{U}_3\text{Si}_2$ powder under International Specs
  • Manufacturing technology of miniplates $\text{U}_3\text{Si}_2$ - Al (Uranium densities: 3.4 - 4.8 gU/cm³)
  • Interaction study of $\text{U}_3\text{Si}_2$- Al at high temperature
    (Paper published at Journal of Nuclear Materials)
Main Activities 2003 – 2014...

- Melting and homogenization of UMo alloys (7,8 and 10wt% Mo)
- Study of Phase transformation in U-Mo system
- UMo Powder production by several methodologies
- Out of pile swelling test (thermal treatment)
- Fabrication of dispersion type fuel miniplates
- UMo powder production by centrifugal atomization
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• After 30 years of studies, research and development, local technology development, qualification, fabrication and irradiation of fuel produced at CCHEN is possible to assure the supply of these devices to Chilean Research Reactors, accomplishing international specifications and with a Quality Management System certified under ISO 9001:2008.

• The main challenge for CCHEN will become an international provider of fuel for research reactors.
THANKS YOU FOR YOUR ATTENTION