National Center for Nuclear Research (NCBJ)





RESEARCH REACTOR MARIA

NCBJ avtivities in the research reactor field

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THE MAIN NUCLEAR FACILITIES SWIERK - OTWOCK



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MARIA RESEARCH REACTOR Facility description



- MARIA reactor (1974) is Poland's second research nuclear reactor and the only one still in use; it was Polish design;
- Reactor is located at Świerk-Otwock, near Warsaw and named in honor of Maria Skłodowska–Curie;
- MARIA is a multifunctional research tool, with a notable application in production of radioisotopes, research with utilization of neutron beams (mainly in the condensed matter physics), neutron boron therapy (BNCT), and industrial applications (e.g. neutron activation analyses), as well as facility for training groups;
- Reactor operates about 4100 hours annually, usually in blocks of 98 up to 267 hours (mostly 100-120 hours).



MARIA RESEARCH REACTOR Otwock - Świerk

General view





- * Nominal power: 30 MW
- * Type: pool type reactor
- Thermal flux: 2.5*10¹⁴ n/cm²s

Operated since December 16, 1974 Upgraded 1992

MARIA RESEARCH REACTOR Facility description



- The high flux research reactor MARIA is a water and beryllium moderated reactor of 30 MW power level;
- Pool type reactor with pressurized fuel channels containing concentric tube assemblies of fuel elements;
- Fuel channels are situated in matrix containing beryllium blocks surrounded by graphite reflector:
 - nominal power
 - thermal neutron flux density
 - moderator
 - reflector
 - cooling system
 - expected operation

30 MW(th) 2.5*10¹⁴ n/cm²s H₂O, beryllium (70% & 30% of the moderation, respectively) graphite in Al channel type 2030 & >







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22 FE / P=22MW

MARIA RESEARCH REACTOR Facility opportunities





MARIA RESEARCH REACTOR Vertical cross-section of reactor pools





MARIA RESEARCH REACTOR verical & horizontal cross section





- 1. control rod drive mechanism
- 2. mounting plate
- 3. ionization chamber channel
- 4 . ionization chamber drive mechanism
- 5. fuel and loop channels support plate
- 6.plate support console
- 7. horizontal beam tube shutter drive mechanism
- 8. beam tube shutter 9. fuel channel 10. ionization chambers shield 11. core and support structure 12. core and reflector support plate 13 . reflector blocks
- 14 . beam tube compensator joint.



core and reflector support plate
multiple graphite block
reflector support structure
heam tube compensator joint

5. graphite reflector block 6. beryllium block 7. ionization chambers shield

MARIA RESEARCH REACTOR General view of reactor pool





MARIA RESEARCH REACTOR Facility opportunities



- Expected operation time of reactor: 2030
- Experienced reactor operation staff;
- Guaranteed delivery of fuel for the next years: MARIA has two suppliers of LEU fuel:
 - (a) AREVA (CERCA), France (FEs are used)
 - (b) TVEL, Russian Federation (FEs past test in reactor core);
- MARIA RR according to RERTR Initiative converted nuclear fuel from HEU to LEU

19.75% / 485 g U-235 per FE / density of 4.8 g/cm The first LEU type FE made by CERCA was loaded to the core on Sep'12

• **Program of reactor utilization:** radioisotopes production, utilization horizontal channels (neutron beams), support of nuclear power plant program (trainings)

MARIA RESEARCH REACTOR Fuel conversion history



- Following preparation (started in 2004), MARIA was converted to use LEU fuel by 2012, with assistance from the U.S. DOE's National Nuclear Security Administration (NNSA),
- MARIA as a civilian research reactor in Poland was converted based on principles of the Global Threat Reduction Initiative,
- The GTRI Reactor Conversion Program was established in 2004 by NNSA as a continuation of the Reduced Enrichment for Research and Test Reactors Program (established 1978),
- Argonne National Laboratory has provided technical support since the inception of RERTR and among its current GTRI responsibilities provides technical leadership for the conversion of foreign reactors to LEU fuel.

MARIA RESEARCH REACTOR Fuel conversion history



Туре	Operation period	Fuel	Enrichment %	Mass of ²³⁵ U	Density of U g/cm ³	Clad mm
MR	1974 ÷ 1999	UAI	80	350	1.2	0.8
MR	1999 + 2005	UO ₂	36	540	2.3	0.5
MR	since 2005	UO ₂	36	430	2.8	0.75
мс	since 2012 (tests 2009 ÷ 2011)	U ₃ Si ₂	19.75	485	4.8	0.6
MR	since 2014 (tests since 2012)	UO2	19.7	485	3.8	0.6

MR – Fuel Elements manufactured by TVEL (Russian Federation) MC – Fuel Elements manufactured by CERCA (France)

MARIA RESEARCH REACTOR

5000



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MARIA reactor operation time 1993-2013



MARIA RESEARCH REACTOR General reactor applications





Neutron Beam Applications

RI Production



Education & Training

Fuel Management

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MARIA RESEARCH REACTOR General research applications



- Safety analysis
- Reactor materials
- Radiological monitoring
- Analysis of nuclear accidents
- Spent fuel
- Radioactive waste



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RESEARCH APPLICATION:

- Radioisotopes production
- Material modification
- NTD of silicon
- Neutron-boron therapy
- Neutron radiography





MARIA RESEARCH REACTOR

IRRADIATION SERVICES

MARIA RESEARCH REACTOR Facility capabilities



Radioisotope production:

- Major irradiated target material are : TeO₂, Lu₂O₃, LuCl₃, Yb₂O₃, S, KCl, Cu, Se, SmCl₃, Co, NiO.
- Irradiation of target materials for radioisotopes production for medicine and industry purposes:
 - Radioisotope production: 635 TBq (annually in 2013 year),
 - Irradiation HEU targets for Mo-99 production: 9 300Tq (2013 y),
 - Irradiation Ir/Pt seeds for Intravascular Therapy and low activity Ir-192 source ribbon for Oncology Application,
 - "Molibden-Świerk" Program: feasibility study for Mo-99 processing facility planned to locate on Świerk (based on LEU targets irradiation).
- Wide range of irradiation positions: vertical channels & channels with hydraulic transfer system; irradiation position under safety rods (considered for production of the high activity radioisotopes).

MARIA RESEARCH REACTOR In-core irradiation facilities



- Irradiation channels
- * Channels with hydraulic transport system
- ***NTD** irradiation facility
- ***Irradiation position for minerals modification**





MARIA RESEARCH REACTOR Radioisotope Production



Specification of irradiated targets & produced activity 2011-2014

Target material	radioisotope	2011	2012 Total acti	2013 vity [TBg]	2014 / Q1-2
TeO ₂	I-131	561.7	585.2	610.0	555.0
KCI	S-35	8.9	4.5	10.5	3.7
S	P-32	7.6	17.7	4.2	12.0
Со	Co-60	2.8	3.0	3.7	0.9
LuCl₃ / Lu(NO₃)₃	Lu-177	1.1	2.6	3.5	9.0
SmCl₃ / Sm₂O₃	Sm-152	3.6	min	min	1.5
other	Yb-169, Cu-64, Sr-85, Fe-89, Br-82, Ir-192	3.1	2.1	2.0	1.6

ΤΟΤΑΙ	TDa	E00 0	615 1	622.0	E02 7
TOTAL	твү	500.0	615.1	055.9	202.7

MARIA RESEARCH REACTOR Radioisotope Production (1978-2013)





Rok



MARIA RESEARCH REACTOR NTD Silicon Program



The project presented on 10th Edition of the Polish Product of the Future (PPP) the competition organized by the Polish Agency for Enterprise Development (PAED) under auspices of the Prime Minister of the Republic of Poland

The project awarded Distinction in Category "Technology of Future"





Reactor MARIA pool (up) NTD Test Facility installed outside reactor pool (left)

MARIA RESEARCH REACTOR NTD of Silicon Program







RESEARCH REACTOR

NAPPLICATIONS

MARIA RESEARCH REACTOR HORIZONTAL CHANNELS







REGIONAL LABORATORY of NEUTRONOGRAPHY

Operates six horizontal channels for investigations of internal structure of condensed matter

MARIA RESEARCH REACTOR HOP IZONTAL CHANNELS UTILIZATION



H3



High resolution diffractometer (Si monochromator)



Small angle diffractometer double-crystal PG monochromator λ = 2.37 Å,Q > 0.01 Å⁻¹



H4

Very small angle double-crystal diffractometer Si (111) monochromator and analyzer scattering angle 0.5" - 3' λ = 1.5 Å



H5 High resolution diffractometer Double-crystal monochromator Cu(200) λ < 1 Å

MARIA RESEARCH REACTOR HOP IZONTAL CHANNELS UTILIZATION





H8 Neutron radiography station

H6, H7 Triple-axis spectrometers (PG or Zn monochromator and analyzer set)



RESEARCH REACTOR

RADIOACTIVE WASTE MANAGEMENT & DECOMISSIC NING

MARIA RESEARCH REACTOR SPENT FUEL MANAGEMENT



- More than 400 spent fuel assemblies were collected during many years of MARIA reactor operation;
- These assemblies (mainly MR-6 type fuel assemblies with 36% enrichment and 430g ofU-235 isotope contents) have been stored under water in the special pool (adjacent to the reactor pool);
- Starting from 2010 year fuel assemblies were sent to Russian Federation under the *Global Threat Reduction Initiative* (GTRI);
- The shipments was realized using special transport casks named TUK-19; each transport contained 80 fuel assemblies was loaded into 20 TUK-19 transport casks;
- In near future shipment of the rest Russian origin fuel is planned and due to this, problem of highly enriched spent nuclear fuel storage in reactor MARIA will be resolved.

MARIA RESEARCH REACTOR SPENT FUEL MANAGEMENT







TUK-19 container placed on the transport cart



Operation of entering set of four spent fuel elements into the disassembly cell



Operations carried out in the disassembly cell monitored with the use the TV system



Transport of the TUK-19 container from the reactor facility to the forwarding point



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IA REACTOR

EDUCATION & TRAINING

TRA MARIA RESEARCH REACTOR INING COURSES IN THE FIELD OF REACTOR PHYSICS & TECHNOLOGY



- Specialized experiments offered as educational exercises for university level students:
- Training courses cover the field of reactor operation issues:
 - Dynamics of nuclear reactor (reactivity measurements),
 - Neutron flux detection (spectrum of neutrons),
 - Release of activity into environment (measurement of release of noble gases via reactor ventilation system),
 - Poisoning of reactor (training on reactor simulator),
 - Basic critical experiments.
- Training courses for students from TU of Warsaw
- Advanced Training Courses for students from Postgraduate Studies of Nuclear Energetic of Technical University of Warsaw (MEiL) and for all other levels of academic study.

NARIA RESEARCH REACTOR TRAINING & DISSEMINANTION OF THE KNOWLEDGE ON ATOMIC ENERGY



- Program of visits and presentations for: high school students, university students, engineers and scientists visitors (up to 4000/y)
- The lessons on the field reactor physics and technology for students of Physics and Chemistry Faculty (universities and technical universities from Warsaw, Lublin, Silesia, etc);
- Summer practice trainings for university students (experimental neutron and reactor physics);
- Commercial Trainings organized by Laboratory of Dosimetry Measurements for government institution and participants from different industry branches: on the field radiological protection;
- Training Courses on the field radio-measurements in the Nuclear Medicine for medicine doctors and technicians.

