HUMAN RESOURCES
FOR INNOVATIVE NUCLEAR ENERGY SYSTEM

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INPRO Dialogue Forum 8.
Toward Nuclear Energy System Sustainability:
Economics, Resource Availability, and Institutional Arrangements
26-29 August, 2014
Contents

1. INPRO Architecture Related to HR Issues
2. Innovative Nuclear Energy System (the case of SVBR)
3. Training Solutions
4. Conclusions
Obninsk- cradle of the NPP development

Central Institute for Continuing Education & Training
Since 1967
(SAEC “ROSATOM”)

2009- branch of National Research Nuclear University MEPhI
1985- Obninsk Institute for Nuclear Power Engineering
1953- branch of Moscow Engineering & Physics Institute
(Ministry of Education & Science)

The-First-in-the-World Nuclear Power Plant
27 June, 1954
Objectives:

Rosenergoatom, CICE&T and IAEA reached understanding that enhancing interaction between them requires cooperation in the following areas:

• Exchange and dissemination of information, including release of joint publications;

• Mutual support in establishing **training courses to develop human resources** for countries embarking on the way of developing nuclear power;

Organizing joint missions to evaluate requests from recipient-countries
NKM Issues in Training Course Development

WWER – THE LOWEST OCCUPATIONAL EXPOSURE

<table>
<thead>
<tr>
<th></th>
<th>man·Sv/reactor</th>
<th>2011 average</th>
<th>3-year roll</th>
<th>All reactor types, incl.</th>
<th>GCR and LWGR</th>
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</thead>
<tbody>
<tr>
<td>WWER</td>
<td>0.51</td>
<td>0.54</td>
<td></td>
<td></td>
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<tr>
<td>PWR</td>
<td>0.65</td>
<td>0.69</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BWR</td>
<td>1.18</td>
<td></td>
<td>1.3</td>
<td></td>
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</tr>
<tr>
<td>PHWR/</td>
<td>1.18</td>
<td></td>
<td>1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CANDU</td>
<td></td>
<td></td>
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</table>

Data from “Twenty-first Annual Report of the ISOE Programme 2011”

EXPERTS INVOLVEMENT and the course team

Solovyev A.A.
Expert of the course
Head of the training center
“Nuclear and radiation safety” Rosatom CCE&T, former Deputy Director for Safety of Busudain NPP

Vaizer V.I.
The course reviewer
Head of Radiation safety department of A.I. Leypunsky Institute for Physics and Power Engineering, member of Radiation Safety Methodological Board of Rosatom

Filipyev I.S.
The course developer
Specialist of International Center for NPP Personnel Training, Rosatom CCE&T

Obninsk - 2014
Professional (left) and educational (right) background of national nuclear infrastructure personnel visited Rosatom-CICET in 2011-2014
1. INPRO Architecture Related to HR Issues
1. National position
2. Nuclear safety
3. Management
4. Funding and financing
5. Legislative framework
6. Safeguards
7. Regulatory framework
8. Radiation protection
9. Electrical grid
10. Human resources development
11. Stakeholder involvement
12. Site and supporting facilities
13. Environmental protection
14. Emergency planning
15. Security and physical protection
16. Nuclear fuel cycle
17. Radioactive waste
18. Industrial involvement
19. Procurement
Links Milestones and INPRO Methodology

1 National position
2 Nuclear safety
3 Management
4 Funding and financing
5 Legislative framework
6 Safeguards
7 Regulatory framework
8 Radiation protection
9 Electrical grid
10 Human resources development
11 Stakeholder involvement
12 Site and supporting facilities
13 Environmental protection
14 Emergency planning
15 Security and physical protection
16 Nuclear fuel cycle
17 Radioactive waste
18 Industrial involvement
19 Procurement
Personnel for Nuclear Programme

- Nuclear Energy Program Implementing Organization (NEPIO) – 50 persons
- Regulatory body (RB) – 70 persons
- Operating organization (OO) – 150 persons

Total: 270 persons/country – training in Russia

NPP Staffing options (person/MW)

- Training in Russia
  - (1.1)
  - (0.7)
  - (0.49)
  - (0.37)

- Training in TC of recipient country – up to 900 persons

Key personnel

(operating personnel, mid-level and top managers):

- up to 200 persons per 1 unit
- up to 300 persons per 2 unit
**Staffing for NPP Construction (2 Units)**

Example for Novovoronezh NPP-2 (by design documentation)

<table>
<thead>
<tr>
<th>Jobs</th>
<th>1 yr</th>
<th>2 yr</th>
<th>3 yr</th>
<th>4 yr</th>
<th>5 yr</th>
<th>6 yr</th>
<th>7 yr</th>
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<tbody>
<tr>
<td>Construction workers</td>
<td>1085</td>
<td>2374</td>
<td>5341</td>
<td>5178</td>
<td>1625</td>
<td>209</td>
<td>10</td>
</tr>
<tr>
<td>Tele-equipment fitters</td>
<td>193</td>
<td>397</td>
<td>1451</td>
<td>1783</td>
<td>695</td>
<td>36</td>
<td></td>
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<tr>
<td>Ventilation equipment installers</td>
<td>35</td>
<td>51</td>
<td>106</td>
<td>64</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction electricians</td>
<td>283</td>
<td>1440</td>
<td>1700</td>
<td>600</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulation workers</td>
<td>7</td>
<td>82</td>
<td>182</td>
<td>228</td>
<td>184</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td>1085</td>
<td>2609</td>
<td>6154</td>
<td>8357</td>
<td>5400</td>
<td>1700</td>
<td>46</td>
</tr>
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</table>
Architecture of INPRO: The Area of Infrastructure

UR1 Legal and institutional infrastructure
An adequate legal framework should be established to cover the issues of nuclear liability, safety and radiation protection, environmental protection, control of operation, waste management and decommissioning, security, and non-proliferation.

UR2 Industrial and economic infrastructure
The industrial and economic infrastructure of a country with a NES should be adequate to support the project throughout the complete lifetime of the nuclear power programme, including planning, construction, operation, decommissioning and related waste management activities.

UR3 Political support and public acceptance:
Adequate measures should be taken to achieve and maintain public acceptance of a nuclear energy system being planned or in operation to enable a government policy commitment to support the deployment and operation of the system.

UR4 Human resources
The necessary human resources should be available to enable all responsible parties involved in a nuclear power programme to achieve safe, secure and economical operation of the NES during its lifetime.

UR5 Minimization of infrastructure
The nuclear energy system should be designed to minimize the necessary infrastructure for a nuclear power programme.

UR6 Regional and international arrangements:
Regional and international arrangements should provide options that enable a country with a NES to minimize the infrastructure for a nuclear power programme.

Indicator IN4.1: availability of human resources
Acceptance limit AL4.1: human resources are sufficient according to international experience.
EP4.1.1 — educational and training system in nuclear power projects
EP4.1.2 — attractiveness of nuclear power sector
EP4.1.3 — capacity to accept additional load of nuclear power programme

Indicator IN4.2: attitude to safety and security in nuclear organizations
Acceptance limit AL4.2: a safety and security culture prevails in all nuclear organizations confirmed by periodic safety and security reviews.
Infrastructure basic principle: A country shall be able to adopt, maintain or enlarge a NES for the supply of energy and related products without making an excessive investment in national infrastructure.
Indicator IN4.1: availability of human resources  
Acceptance limit AL4.1: human resources are sufficient according to international experience.  
EP4.1.1 — educational and training system in nuclear power projects  
EP4.1.2 — attractiveness of nuclear power sector  
EP4.1.3 — capacity to accept additional load of nuclear power programme  

Indicator IN4.2: Attitude to safety and security in nuclear organizations.  
Acceptance limit AL4.2: a safety and security culture prevails in all nuclear organizations confirmed by periodic safety and security reviews.

UR4 Human resources 12: The necessary human resources should be available to enable all responsible parties involved in a nuclear power programme to achieve safe, secure and economical operation of the NES during its lifetime.

Criterion CR4.1 — availability of human resources
Criterion CR4.2 — safety and security culture
Indicator IN4.1: availability of human resources

Acceptance limit AL4.1: human resources are sufficient according to international experience.

EP4.1.1 — educational and training system in nuclear power projects

In Belarus, the National Training Programme, and the Programme of Scientific Support were developed and adopted. In February 2008, a mission by the IAEA was conducted in Belarus on staff training for future NPPs. The decision to create a national training system for nuclear power was taken.

EP4.1.2 — attractiveness of nuclear power sector

In the available data taken for the calculation of economic parameters, wages at the nuclear power station were found to be comparable with the average wages in Belarus for workers of the same qualifications. Also, a sensitivity analysis on wages was performed. Wages in Belarus for nuclear power related jobs are not competitive with similar jobs outside the country, i.e. EP4.1.2 has not been met.

EP4.1.3 — capacity to accept additional load of nuclear power programme

In 2008, students started to take courses relevant to nuclear power in the four metropolitan universities;
There are ongoing activities to invite nuclear specialists with experience in operating NPPs;
There is a screening programme of Belarusian energy specialists to retrain them for the most important positions at the NPP.
The number of workers at NPPs depends on the project and is expected to be about 2000 people. During peak demand, it is expected that approximately 10,000 employees will be used to build the power plant and associated infrastructure.
2. Innovative Nuclear Energy Systems (the case of SVBR)
Стадии развития технологии быстрых свинцово-висмутовых реакторов NS-705 Series (1976-1996гг.)

SVBR-100

NS-705 (1971г.)

NS 645 (1963г.)

NS 705 Series (1976-1996гг.)

Pb-Bi Technology: Towards Innovative Fast Reactors
Prototype nuclear plant is to be constructed in Dimitrovgrad, Ulyanovsk region near the Russian State Atomic Reactor Research Institute.

**NPP KEY PARAMETERS:**
- Co-generation mode
- Installed electric capacity: 100 MW(e)
- Heat capacity: 100 Gcal/h
- Efficiency factor: ~36%
- Working time: 50 years
- ICUF*: ~90%

**EVENTS BEHIND:**
- Public hearing
- Authorized site (signed rental agreement)
- Signed collaboration agreement between Dimitrovgrad government
HRD Phases for NPP Operation (General Requirements in Russian Federation)

- Independent work admission
- Obtaining a permit
- Duplication
- Examination
- On-the-job training

NPP - site

- Practical training (Analytical simulators, etc.)
- Theoretical training

Training centers
### Roadmap of SVBR Implementation and HRD Issues

<table>
<thead>
<tr>
<th>Training material Development: General courses</th>
<th>Training implementation</th>
<th>Development of AS</th>
<th>Task Order and Scope of Work development for Analytical Simulator (AS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training material development: NPP Systems &amp; Equipment</td>
<td></td>
<td></td>
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</tbody>
</table>

#### AS start-up

- Training start-up:
  - Plant Shift Supervisor (14)
  - Unit Shift Supervisor (14)

- Training start-up:
  - Reactor hall shift supervisor (14)
  - Turbine hall shift supervisor (14)
  - Senior reactor operator (14)
  - Senior turbine operator (14)

- Training modules:
  - SVBR Physics (8 AH)
  - Thermal Hydraulics (8 AH)
  - Coolant Technology (2 AH)

#### Full scope simulator start-up

#### Commissioning personnel

#### Workforce analysis & Staffing Plan development

- Training start-up

#### Personnel training schedule & Information System development

#### Fuel load

#### Road Map of SVBR -100 Implementation & HRD Issues

<table>
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<tr>
<th>$T_{0-5}$</th>
<th>$T_{0-4}$</th>
<th>$T_{0-3}$</th>
<th>$T_{0-2}$</th>
<th>$T_{0-1}$</th>
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<tbody>
<tr>
<td>$T_0$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- $T_0$: Commissioning personnel
3. Training Solutions
IAEA Documents Concerning the Training Process

- IAEA Safety Standards
  - The Management System for Facilities and Activities
    - Safety Requirements
      No. GS-R-3
  - Application of the Management System for Facilities and Activities
    - Safety Guide
      No. GS-G-3.1

- IAEA SAFETY STANDARDS SERIES
  - Recruitment, Qualification and Training of Personnel for Nuclear Power Plants
    - SAFETY GUIDE
      No. NS-G-3.3

- IAEA-TECDOC-1354
  - A systematic approach to human performance improvement in nuclear power plants: Training solutions

- IAEA-TECDOC-1597
  - Experience in the use of systematic approach to training (SAT) for nuclear power plant personnel

- IAEA-TECDOC-1084
  - Selection, competency development and assessment of nuclear power plant managers

- IAEA-TECDOC-1179
  - Analysis phase of systematic approach to training (SAT) for nuclear plant personnel
Phases of Training Courses’ Development (based on SAT)

- Analysis
  - List of competences
  - List of tasks

- Design
  - Plan of subjects (standard training programme)
  - Goals of training
  - Questions for verification
  - Lesson plans
  - Trainee’s textbooks
  - Technical aids, computer training aids, models, posters…

- Development
  - To be done once then to be adjusted, is related to a specific position

- Planning based on training needs and tasks analysis
  - Initial control, training programme, individualization, harmonization, approval

- Training implementation, theoretical, practical, on-the-job training

- Test of knowledge and skills

- Internship, duplication, obtaining a permit (if required)

- Evaluation of the whole training process in order to improve all SAT phases
  - Questionnaires for trainees
  - Questionnaires for executives
  - Qualification analysis during accident investigations

Admission
Training Materials’ Design and Development in ROSATOM CICE&T

Methodological control

Expertise

Lecture Content

Training materials in Russian

Language control

Team Work

Slide Design

TM in English

Methodological control

Language control
Developing of Training Materials in Russian

1. Developer
2. Reviewer in-house
3. Final Methodological Control

- Customer
Developing of Training Materials in English

1. Approved Training Materials in Russian
2. Translation
3. Translation Quality check: lexis, grammar
4. Translation Quality check: terminology
5. Final Methodological Control
6. Customer

Customer and Final Methodological Control are connected as feedback loops.
Training Programme Description (1/2)

Course structure:
1. Course objectives
2. Course description
   - Prior level of competence required
   - Course modules
   - Modules and training objectives description
   - Requirements for the course implementation
3. Prerequisites
   - Work experience
   - Education
   - Additional training
   - Health requirements
4. Training evaluation
5. Competencies
Training Programme Description (2/2)

Curriculum

1. Module PR.11.01
   - Lesson PR.11.01.1
     - Characteristics of radiation sources
   - Lesson PR.11.01.2
     - Radiation-spectrum characteristics of radioactive sources
   - Lesson PR.11.01.3
     - Primary interaction of ionizing radiation with matter: Radiation energy transfer
2. Module PR.11.02
   - Biological effects of ionizing radiation and health effects
     - Lesson PR.11.02.1
       - Modern view on biological effects of ionizing radiation. Health effects
     - Lesson PR.11.02.2
       - Acute and chronic radiation syndromes
     - Lesson PR.11.02.3
       - Biological effects of radionuclides intake and internal exposure dose
3. Module PR.11.03
   - Decision and assessment of risks associated with doses
     - Lesson PR.11.03.1
       - 0.5

List of competencies

Glossary
International Training Courses in Innovative NS

Training COURSE:
«HEAVY LIQUID METAL COOLED FAST SMR TECHNOLOGY»

The course is adjacent with the 4-th conference:
«HEAVY LIQUID METAL COOLANTS IN NUCLEAR TECHNOLOGIES», CICE&T, 30 September – 4 October

Challenge of Training to Support Implementation of SMRs

According to the IAEA estimates, the world demand for small and medium-sized reactors (100-400 MW) by year 2040 will be about to 500-1000 plants. The aggregate capacity of this market segment is evaluated as – 600 billion US$. SVBR is considered as a promising candidate to meet this international market.

To prepare for this, 07.06.2011 CICE&T hosted Special International Workshop on The Development of Curricula for Training of Foreign Specialists in Russian SMR technology.

The Workshop was attended by the representative from IAEA Dr. M. Hadid Subki, Technical Lead, SMR Technology Development, Division of Nuclear Power, Department of Nuclear Energy, the representative from Singapore Energy Studies Institute Mr. Hooman Peimani (Head, Energy Security & Geopolitics).
# Introductory Training Schedule

<table>
<thead>
<tr>
<th>No</th>
<th>Training modules</th>
<th>Ac. Hours</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Potential of SVBR Technology in Sustainable Power Development</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>SVBR Reactor Core Physics</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>SVBR Heat Transfer</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>Coolant Technology</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>SVBR Operation &amp; Control (Practice with Analytical Simulator)</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>SVBR HRD Issues</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>34</td>
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</table>
Training Course Evaluation

Average course rating: 9.00 points

Number of International Participants

<table>
<thead>
<tr>
<th>Country</th>
<th>Participants</th>
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</thead>
<tbody>
<tr>
<td>Russia</td>
<td>7</td>
</tr>
<tr>
<td>Indonesia</td>
<td>3</td>
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<td>Malaysia</td>
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<td>Belgium</td>
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<td>Italy</td>
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<td>China</td>
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<td>Turkey</td>
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<tr>
<td>Czech Rep.</td>
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<td>Slovakia</td>
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<tr>
<td>Finland</td>
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</tr>
<tr>
<td>Singapore</td>
<td>1</td>
</tr>
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</table>
Conclusions & Challenges

HRD Challenges for innovative nuclear energy systems:

- Lack of reference staffing options
- Uncertainties in scheduling
- Lack of reference Education & Training trajectories
- Training material development for innovative nuclear energy system requires high level expertise from R&D side
Thank You for Your Attention!
Welcome to Rosatom CICET

http://rosatom-cicet.ru/

http://rosatom-cicet.ru/?page_id=98