ABSTRACT

During last few years, Safety culture principles and Human performance aspects of NPP operation were areas of special interest throughout the nuclear industry. Krško NPP has also focused its attention onto this topic and introduced several initiatives to address specific expectations and standards. For example, overall Krško NPP approach to Safety culture was described in internal management programs, while at the same time more specific guidance related to the area of Safety culture and Human performance improvement, including tools to be used, were defined in specific plant procedures.

Krško NPP has defined the following human error prevention tools:

- Self-checking,
- Pre-job briefing,
- Use of operating experience,
- Effective communication,
- Questioning attitude,
- Observation and coaching,
- Use of procedures,
- Peer checking,
- Independent verification,
- Post-job critique.

The internal training programs are continuously utilized to introduce above mentioned principles and tools aimed to establish expected standards in the area of human performance. Human error prevention tools were introduced through operations and maintenance personnel continuing training, while at the same time the expectations were reinforced through simulator and hands-on training.

Starting from February 2007, the new tool was introduced into use for the conduct of technical training programs. It represents a flow loop simulator, developed by the plant personnel with the aim to be used as practical hands-on training tool. The flow loop consists of hydraulic system involving tanks, pumps, valves and other mechanical equipment, electrical support systems, and instrumentation. The flow loop simulator was already effectively utilized as a tool to practice human error prevention tools through training of operations personnel.

For the future, it is planned to extend the use of the flow loop simulator to training programs for other technical personnel at the plant.
1 SAFETY CULTURE AND HUMAN PERFORMANCE

During the years of operation the nuclear industry has established the wide consensus that human performance has a great influence on its safety and reliability of operation. Due to this, several international initiatives were undertaken to assess the human performance aspects and to find ways to reduce the frequency and consequences of human errors.

One of the most important developments in this area was the increased focus on Safety culture, the approach, where we require from each nuclear power plant worker to perform all work activities and make all work-related decisions with great respect to the safety of operation. Definition of Safety culture, as provided by IAEA is [1]: Safety culture is that assembly of characteristics and attitudes in organizations and individuals which establish that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance. Other international organizations like WANO and INPO have also issued several documents providing in-depth guidance how to deal with this matter.

Human performance is a special area of before mentioned initiatives that was given additional attention and investigation. The nuclear industry is using power plant operational experience and operational events analysis results to progressively develop tools that can help individuals to improve in performing activities and to avoid making mistakes. Human performance research initiatives were focused on two major areas; to understand the principles of human behavior, their influence on work performance, reasons for making errors, and to develop simple tools that each individual can use to prevent from making mistakes. WANO – an international organization of nuclear power plant operators has defined basic principles of Human performance to promote behaviors throughout the organization that support safe and reliable operation of the plants [2]. To achieve excellence in human performance, following underlying principles were defined:

- Even the best people make mistakes,
- Error-likely situations are predictable, manageable and preventable,
- Individual behavior is influenced by organizational processes and values,
- People achieve high levels of performance based largely on the encouragement and reinforcement received from leaders, peers and subordinates,
- Events can be avoided by understanding the reasons why mistakes occur and applying the lessons learned from past events and not from asking "who made the mistake?".

Nuclear Power Plant Krško has defined its standards and expectations related to Safety culture and Human performance in several internal documents. From the highest level of plant programs to lower level procedures, the following three major plant goals are defined, that support long-term plant operation: Safety and reliability of operation, Competitiveness of power production, Public acceptability. Safety culture principles are in more details elaborated in an internal procedure [3] that defines responsibilities of each plant worker at different levels of organization and explanation of principles – methods to be used to reinforce strong nuclear safety culture (leadership, training, performance indicators, self assessment, …).

Additional and detailed guidance for application of various practical methods – tools for prevention of human errors were defined in the internal procedure [4].
2 HUMAN ERROR PREVENTION TOOLS

Based on various international reference documents and experience, Krško NPP has decided to implement a set of human error prevention tools that are applicable in variety of situations while performing operating, maintenance, surveillance testing or other activities within nuclear power plant. It is expected, that these tools are consistently applied by all workers that perform activities that have the possibility to influence safe or reliable plant operation. Set of defined human error prevention tools at Krško NPP is presented in Figure 1 below.

![Figure 1: Krško NPP Human error prevention tools](image)

**Self-checking** is a basic tool for human error prevention, because it increases our attention prior to, during and after performance of the assigned task. The application of self-checking is divided in three steps (POP):
- PREMISLI – Stop and Think – time to prepare for activity,
- OPRAVI – Perform – act in accordance with expectations,
- PREVERI – Check – review results / outcome of the activity.

**Pre-job briefing** is a basic tool for human error prevention for group activities. It supports quality preparation for performance of a planned activity, consideration of possible problems that could arise, reinforcement to prevent possible mistakes, and involves everybody, who is assigned to take part in the activity. Pre-job briefing is covering the following areas:
- Purpose and scope of the activity,
- Roles and responsibilities of group members,
- Work conditions,
- Safety requirements,
- Group members qualifications,
- Operating experience…
**Use of operating experience** means learning from past events and errors, own ones as well as those from others. International cooperation and exchange of relevant information within the industry leads to reduction of number and significance of events. This has direct positive influence on safety and reliability of plant operation. The key is in providing applicable information related to a task at hand at the right moment to the right people. There are different methods that can be used for operating experience exchange:

- Training,
- Including information in procedures,
- Including information in work packages,
- Pre-job briefing,
- Observation and coaching…

**Effective communication** plays important role in any activity, where more persons are involved and where is a need for coordination, exchange of operating instructions or other information. The principles and methods of effective communication are as follows:

- Clear, understandable and specific communication,
- Three-way communication,
- Use of phonetic alphabet,
- Personal identification,
- Use of appropriate devices…

**Questioning attitude** is the behavior when it is expected from each person involved to raise questions when in doubt and to actively participate in clarification to understand fully all aspects of the activity to be performed. It can be effectively used during conduct of any activity at the plant or during preparation prior to work. Each activity has to be approached to with the right amount of caution and suspect. Awareness shall exist that it is never too late for a question, even if it requires work to be stopped.

**Observation and coaching** it the tool that helps to improve quality of work / safety culture and can be used by those, who are involved in supervision or management of activities. Goals of coaching are to provide useful feedback in a timely manner, to improve quality of observed activity, to help assuring safe work performance, to transfer knowledge, and to exchange operating experience. Different aspects of a task performance observation are:

- Worker behaviors,
- Work environment,
- External factors,
- Work processes.

**Use of procedures** is one of basic tools for human error prevention that enables assigned tasks to be performed in a safe manner, consistently and in accordance with high standards. Strict adherence to procedures is a team value, founded by following principles:

- Hierarchy of procedures are respected,
- Steps are performed in correct sequence,
- Steps are performed completely,
- Performed steps are documented…

**Peer-checking** is an error prevention tool where two equally qualified workers work together in a manner that one worker executes expected sequence of steps while the other one
(his peer) observes the sequence execution and would intervene in case of error likely action of the first worker. This method involves simultaneous self-checking of both workers. Following are examples of activities that require peer-checking to be used:

- Activities that affect reactivity,
- Activities that involve changes of power,
- Operation of important equipment,
- Calibration of important instrumentation channel...

**Independent verification** is a method where the second person that was not directly involved in the performance of the activity, independently verifies its outcome after it is already completed, by checking status of the equipment like valve lineup, power supply, instrument setting etc. In case of identified discrepancies actions are taken to establish correct configuration. Independent verification is performed after:

- Surveillance testing,
- System lineup changes,
- Equipment tagging,
- Maintenance...

**Post-job critique** is a tool for learning and process improvements, used as an effective way to collect feedback - information about performed activity. It is used for comparison between planned vs. performed work, to collect and store information / experience that can be used during future work performance. It is performed immediately after work is completed, gathering information from everybody that was involved in the activity.

### 3 TRAINING PROGRAMS

In nuclear industry, Training was recognized as very important process utilized for improvement of personnel performance through various activities. Still, the overlying purpose of training is to provide workers with knowledge and skills needed to perform their work in safe and efficient manner.

Training activities at Krško NPP are coordinated by the Training department. Main training programs that also define internal training organization are as follows: Operations training, Maintenance training, and General training, covering Radiation protection and other areas. In general, the programs are divided in initial and continuing training. Usually, requirements for training and qualification are defined in regulatory documents, while additional and more specific guidance is provided by internal procedures.

Operations training includes training of Licensed operators and Field operators, the groups that play important role in plant day to day operation. Initial training programs are conducted in phases that provide operators with knowledge of fundamentals of NPP operation, systems and operation, practical training and on-the-job training. Continuing training is organized in two-year cycles, consisting of four training segments per year. Both, initial and continuing training of licensed operators use full scope simulator as most important training tool for operators to gain practical skills in operation of the power plant. Field operators perform practical training partially in the classroom that is connected through graphical interface to the full scope simulator, and partially in the technological area of the plant as shown on the Figure 2 below.

Maintenance training starts with fundamentals of nuclear technology and plant systems. Further specialist training is organized for groups that belong to different Maintenance departments: mechanical, electrical, instrumentation, etc. Continuing training is organized to
ensure that knowledge and skills of workers are kept at required level and further improved. Maintenance practical training is conducted in Maintenance training facility, where laboratories with necessary equipment, mock-ups, and tools are available. The training facility is also equipped with flow loop simulator, described in chapter 4 in more details.

![Practical training of local operators](image)

**Figure 2: Practical training of local operators**

General training programs are used to provide training to Krško NPP or subcontracted workers about plant standards, expectations and work practices. Special attention is given to regulatory- required training programs in the area of Radiation protection, Industrial safety, Fire protection, etc.

All of above described training programs have been utilized to provide training in the area of Safety culture and Human performance. The safety culture principles and human error prevention tools were introduced through theoretical training, while their application was continuously reinforced through practical hands-on training. For example, training on the full scope simulator focuses mainly on operating procedures and practices, but important portion of attention is also given to the use of mentioned tools. Other types of hands-on training are also recognized as effective setting to reinforce human error prevention tools in parallel to other program-specific objectives.

4 **FLOW LOOP SIMULATOR**

The first idea to obtain a flow loop simulator was raised in 2000, when the maintenance training facility was built. At that time, the group of maintenance engineers, responsible to establish training programs, has visited several NPP Training centers in US, where they became aware that this kind of tool can be effectively utilized to conduct practical training of Maintenance personnel. During the following years, the project involving plant personnel from various departments was performed in steps: flow loop design, build-up and testing. The flow loop was ready for training in February 2007.

The flow loop simulator is an active tool that enables hands-on training of technical plant personnel, and others. It can be used to demonstrate and train in following areas:

- System operation,
- Components operation,
- Maintenance of equipment,
- Surveillance testing,
- Safety at work practices,
- Administrative processes related to operation and work performance.

The flow loop simulator, shown on Figure 3 below, is a real functional system, consisting of two interconnected hydraulic loops and supported by electrical and instrumentation subsystems. It’s equipped with components that are similar to those in the plant.

![Flow loop simulator](image)

**Figure 3: Flow loop simulator**

Major portions of the flow loop simulator, together with important equipment are:
- Mechanical equipment: 2 tanks, 4 different pumps, different valves, compressor, console crane…
- Electrical equipment: 400 V AC bus, 125 V DC bus, 118 V AC instrumentation bus, breakers, inverter, batteries, charger, heat tracing, protection devices…
- Instrumentation equipment: pressure, level, flow and temperature measurement devices and instruments in the loop, instrumentation cabinets, control board with alarms, indications, controllers, positioners…

Similar training loops are being used at several NPPs in United States and Europe. Krško NPP training staff has gathered some of these experiences and took them into account while designing own training loop. A lot of thought was put in to install equipment identical or similar to that installed in the plant, and to simulate a system with functionalities that closely represent behavior of real plant systems. Another important fact is that the loop is situated in our training facility and that all related processes (tagging, maintenance) follow the same procedures as for a real technological system at the plant.

The flow loop simulator has already been effectively introduced into our training programs. Maintenance personnel have used the flow loop to perform training on electrical inverters, motor operated valves, air operated valves, pumps, heaters, etc. On the other side Operations personnel was trained on system operation, electrical manipulations, and in practical application of human error prevention tools. The simulator flow loop was also used
for industrial safety training on safe work at heights and on protection of surrounding equipment while performing welding or cutting.

5  HUMAN PERFORMANCE TRAINING USING FLOW LOOP SIMULATOR

Up until now operations personnel has been continuously trained in the use of human error prevention tools through scenarios on the full scope simulator or hands-on training in the field. Having the flow loop simulator available, additional possibilities were recognized for training and reinforcement to take place. The human performance training can now be organized in realistic environment, by using and operating real equipment.

The human performance training exercise starts with pre-job briefing, where planned activities are discussed, procedures reviewed and roles defined. During the second part of the exercise, trainees perform operating activities while acting in their roles: field operator, operator at the control board, shift foreman, etc, as shown on Figure 4 below.

Figure 4: Use of low loop simulator for operations personnel training

The main emphasis of training is provided to following human error prevention tools:
- Use of procedures,
- Self-checking,
- Peer-checking,
- Effective communication.

The exercise is concluded by the post-job critique, where performed activities are explained, problems discussed and future actions assigned. The final remarks are used to reinforce the rules related to the use of human error reduction tools.

Trainees that were involved in this kind of training for the first time have provided very positive feedback about possibilities and the applicability of simulator flow loop for their continuing training. The most appreciated characteristic of the facility and the equipment is that it is still a training environment, where additional explanations can be provided, questions raised and discussions undertaken. As other training tools, the flow loop simulator enables
trainees and instructors to repeat specific actions, to restore initial conditions, and even to make mistakes without affecting plant operation.

In future, it is planned to use the flow loop simulator in a similar manner for other plant training programs. Future plans are to include practical training on operation of the simulator flow loop in the initial training of licensed and field operators to help them gain basic operator knowledge and develop feeling for operating the equipment. Also, there are plans to provide mechanical maintenance specialists with in-depth training on pumps operation and their characteristics. Similar plans are being developed for instrumentation maintenance personnel training in form of equipment testing and troubleshooting, etc.

6 CONCLUSIONS

Safety culture principles and Human performance aspects are receiving increasingly important attention in nuclear industry during last years. Training of nuclear power plant personnel plays an important role in establishing and reinforcing these new standards. Krško NPP has adapted its training programs to include these topics into initial and continuing training of operations, maintenance and other plant personnel. While practical training plays a very important role in technical training, the tools used for this purpose can be different. The new tool that is used at Krško NPP is the flow loop simulator, active hydraulic system designed for training purposes. The flow loop can be a very effective tool to provide training also on the use of human error prevention tools.

REFERENCES


