

**A Method for Determining the Content of
Knowledge Training for Nuclear Professionals**

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Abstract

A developer of knowledge training materials for nuclear professionals is faced with the challenge of determining the appropriate scope and depth of training. This paper presents a method for establishing the content starting from overall objectives of the activity and breaking it down into the job and task level of an individual's specific jobs and tasks. Nuclear safety training is used as an example. In this case there are four stages of break down in the knowledge base before its implementation in jobs and tasks of the station's work processes. This process also satisfies the training principles for enabling effective operational decision making.

1. INTRODUCTION

This paper is the third in a series of papers [Ref. 1, 2] addressing training programs for the professional development of engineers and scientists working in the nuclear industry. Its purpose is to describe a method for determining the content of specific training modules needed for professional development. It is applied to training for the ultimate goal of '*safe and reliable operation*' of a nuclear power plant. This knowledge training is a subset of the professional development that would lead to the designation of a Professional Nuclear Engineer where such a certification exists.

The need to improve the training and development of nuclear professionals as is driven by several factors including:

1. The need to improve the commercial performance of power plants while maintaining a high level of safety.
2. The ageing of today's cadre of professionals and the erosion of the tribal knowledge base due to the high influx of less experienced professionals as replacements.
3. The globalization of expected performance standards and the need for continuous improvement promoted through the efforts of the IAEA and WANO.

4. The use of a systematic approach to training (SAT) to address the needs for skills and for effective decision making.
5. The introduction of Management Systems incorporating total quality and continuous improvement which make the organization the 'keeper' of the knowledge rather than the individual professionals who are 'users'.

References 1 and 2 address aspects of drivers 3 and 4. The first looked at the contribution of professional development culture to a successful nuclear industry. This requires mutual recognition of the common interests of the employer, employee and professional associations. The critical element is linking the improvement in job performance with the employee's development and maintenance of their professional accreditation.

Reference 2 examined the relationship between the management system, the professional's performance and their professional classification regarding effective decision making. Of particular interest was the design of training to assure competence in decision making regarding safe and reliable operation.

This paper continues the work in Reference 2 and looks at driver # 5. It looks at the training program as an integrated component of the management system and links the training directly to the business management model. The challenge for developing the training in a systematic way is illustrated by the example below.

As an example, nuclear safety is an area of knowledge that has concepts and principles that apply across different work processes and activities. It has been used to develop the methodology described in this paper. Considering a specific job function, the following are the first four levels of development in knowledge training for safety analysts listed as terminal learning objectives.

Knowledge - Learned and retained knowledge of the licensed design basis and the resulting safety analysis principles used to validate the safety design of the plant. Examples include the Siting Guide, design basis accident analysis, probabilistic safety assessments, the role of the Safety Report and its content.

Comprehension - Developed an understanding of the licensed design basis and safety analysis principles and their use in assessing the safety of the plant design. Examples of topics include, the safe operating envelope, risk assessment, design basis accident analysis methodology.

Application - Developed the ability to apply knowledge of safety analysis in the solution of routine work place problems. Examples would include safety reviews of design changes, assessment of the safety significance of system impairments, performing safety analysis for altered configurations or degraded safety margins.

Analysis - Developed the ability to analyze complex plant configurations and determine the safety analysis needed to demonstrate the licensed design basis is met. Examples include technical operability evaluations, safety reviews of design changes, etc.

The above objectives would be typical output from a 'needs analysis' for the training of safety analysts. The specific enabling objectives can then be developed based on an analysis of jobs, tasks and performance expectations. However, there are three issues that have to be addressed in developing the training material.

The systematic approach to training is effective in identifying the training needs for specific jobs. However, it is less effective in defining

- the depth of knowledge needed for an effective job performance; and
- the scope and depth of prerequisite enabling knowledge.

Ultimately, it is the work place supervisor who judges the performance of the employee in executing specific tasks. However, this is a closed loop and the supervisor's ability to judge is determined by the same training program.

Some enabling knowledge training should be decoupled from the training for specific jobs. This includes the body of knowledge that prepares the professional to work at different jobs within the organization. That is, it is common enabling knowledge for all professional development within the organization.

An approach has been developed for addressing the above issues in preparing training course materials. The knowledge requirements are categorized by a break down structure that parallels the business process model. This approach provides a natural separation between knowledge that is required for professional development and that required for performing a specific task. For example, a knowledge of the purpose and methods of design basis accident analysis is necessary knowledge across many jobs and tasks. However, knowledge of the input file preparation for a specific accident analysis code is only needed by the code user.

The approach to developing the knowledge base is described in Section 2. Section 3 then describes the scope and depth of knowledge required in the breakdown.

2. PRINCIPLES FOR TRAINING IN NUCLEAR SAFETY

The training in nuclear safety for technical support staff at operating nuclear power plants has two objectives.

1. To develop the knowledge and skills required to successfully perform the jobs and tasks that affect nuclear safety.
2. To develop the capability to be effective in making operational decisions related to nuclear safety.

The training program can achieve these objectives by applying the following principles in developing the training.

Principle 1 – *To make correct decisions affecting nuclear safety, the decision maker has to be able to assess the safety significance and success of the intended outcome from the decision.*

To be able to assess the safety significance of outcomes requires training on the implementation of nuclear safety in the design and operation of the plant. The decision maker has to have the capability to analyze and evaluate the different options that are available. The required capability depends upon the role and responsibilities of the decision maker.

Principle 2 – *A correct decision is based on accurate assessment of the risks associated with each of the possible outcomes.*

The inputs to the decision making process are developed by staff trained for the jobs and tasks of safety assessments and risk evaluation. The decision maker has to have the capability to determine that the inputs are complete and accurate.

Principle 3 – *The intended outcome of a decision includes the management system's effectiveness in implementing and maintaining the conditions the decision was based upon.*

The decision maker must fully understand the management system as it affects the inputs to the decision making and the outcome. The effectiveness of the management system is fundamental to ensuring correct decisions are made. This is illustrated in Figure 1.

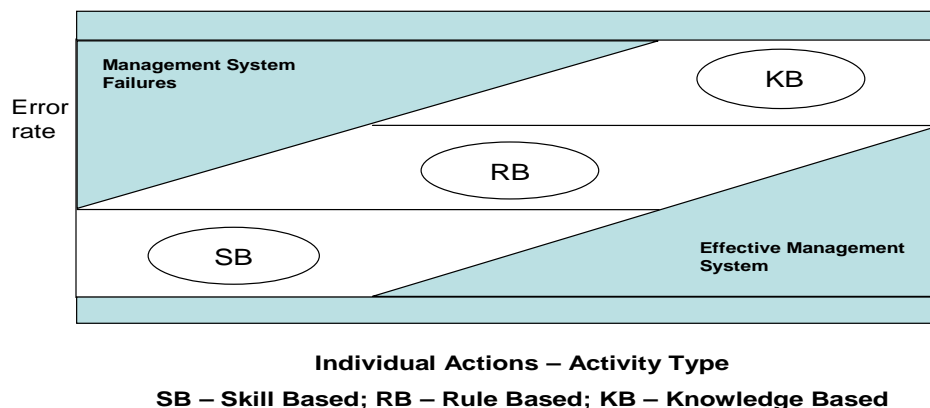


Figure 1. Human performance vs work skills

At the management level, operational decisions are primarily knowledge based. At the working level there is a combination of rule based and knowledge based decisions. An example of this is having knowledge of a standard and applying its 'rules' to a work activity. The error rate in knowledge based activities is reduced to an acceptable level if the management system is effective [Figure 1].

Seen from the perspective of a management system process model, the knowledge requirements can be categorized according to

- needed across work processes; or,
- needed for a single work process or even a specific activity.

The next section describes a breakdown of the nuclear safety objective into the knowledge requirements needed for its implementation in design and operation.

3. DEVELOPING THE KNOWLEDGE BASE

The overall nuclear safety objective for a nuclear power plant is

....to protect station staff, the public and the environment from harm by establishing and maintaining effective defenses against the radiological hazard.

To achieve this objective it must be broken down into the jobs and tasks that are required to provide and maintain the defenses. That exercise is equivalent to answering the question "How do I know the facility is safe?" That is, what has to be done by designers and operators to ensure the plant is built and operated safely?

Five stages in the breakdown of the safety objective are shown in Figure 2. The first four stages develop the approach and methodologies used to achieve the nuclear safety objective. The last stage is breakdown of the resulting work activities into jobs and tasks of the business process model. The knowledge content of each of these stages is discussed below.

3.1 Nuclear Hazard

To be able to build and maintain defences against the radiological hazards requires a thorough understanding of the hazards. This enabling knowledge includes

- the origin and location of the hazards;
- the type, magnitude and physical characteristics (solid, liquid, gas);
and
- the health and environmental effects.

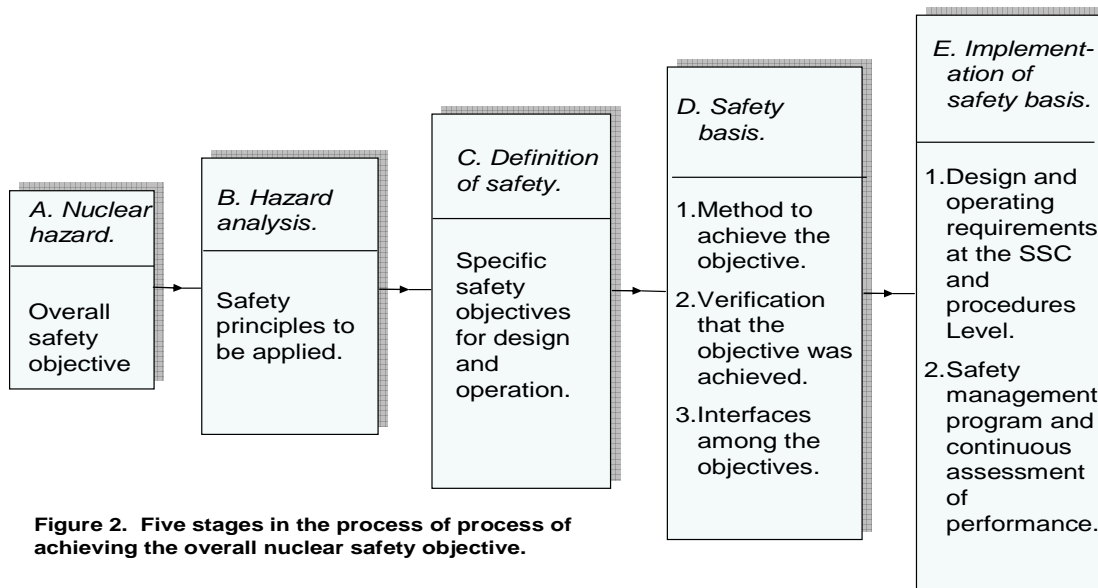


Figure 2. Five stages in the process of process of achieving the overall nuclear safety objective.

A second aspect of understanding the overall nuclear safety objective is the performance in achieving the objective. The station's management and the regulator have different achievement goals. The regulator defines an acceptable level of defence against the radiological hazards through the licensing process. To achieve business objectives of operating safely and efficiently, management sets a higher goal for performance than is needed for compliance alone.

3.2 Hazard Analysis

Given the nature of the hazard, five fundamental safety principles are used to build and maintain the defences against it. The five principles apply across all activities at the station.

1. Be able to control reactor power, cool the fuel and contain the radioactivity for all operating states.
2. Incorporate defence in depth provisions to manage the risk to the public.
3. Notwithstanding specific limits, keep radiation exposures as low as reasonably achievable.
4. Incorporate quality assurance into the management system so that the performance of work ensures safety expectations are met.
5. Perform safety reviews to confirm the licensing basis of the operating plant and to assess its safety against current standards.

3.3 Definition of Safety

The nuclear safety objectives can be made more specific by applying the safety principles to design and operational activities. There are four sets of specific safety objectives for radiation protection, safety design, operational safety and human performance.

*The **radiation protection objectives** are*

- *to ensure that radiation exposure within the plant, or due to planned radioactive releases from the plant are kept below prescribed limits and as low as reasonably achievable (ALARA) for all operational states; and,*
- *to mitigate the radiological consequences of accidents*

This objective implements the requirement to meet prescribed limits to protect the staff and the public and to apply the ALARA safety principle.

*The **safety design objective** is to keep the risk from the operation of the plant as low as reasonably achievable. This includes:*

- *defence in depth taking all reasonably practical measures to prevent accidents and to mitigate their consequences should they happen;*
- *that, for all possible accidents taken into account in the design ensuring, any radiological consequences would be below prescribed limits; and,*
- *to ensure the likelihood of accidents with serious radiological consequences is extremely low.*

The approach to safety design is based on the Siting Guidelines for a power reactor as set by the CNSC. These guidelines set out the accidents that have to be considered and requirements for the risk to the public.

*The **operational safety objectives** are*

- *to maintain the safety level of the plant as provided for by its design; and,*
- *when possible, to reduce the risk to the public in accordance with the ALARA principle and regulatory requirement.*

To maintain the safety level requires a configuration control program to ensure equipment condition, performance and plant procedures meet design requirements. Key programs in this are system health monitoring, testing, etc.

*The **safety culture objectives** are*

- *the organization and staff give nuclear safety an overriding priority in all activities: and,*

- *plant safety issues receive the attention warranted by their significance.*

The management system is a major component of the implementation of a safety culture for the organization. It supplements the other three objectives, which are passive, by bringing human performance into the achievement of the nuclear safety objective.

3.4 Safety Basis

To implement each of the safety objectives there has to be an approach that includes three elements.

- the method(s) that will be used for the specific work activities;
- verification that the work activities achieved the desired results; and
- the necessary links are made between work activities.

The safety basis breakdown, as described above, is shown in Figure 3.

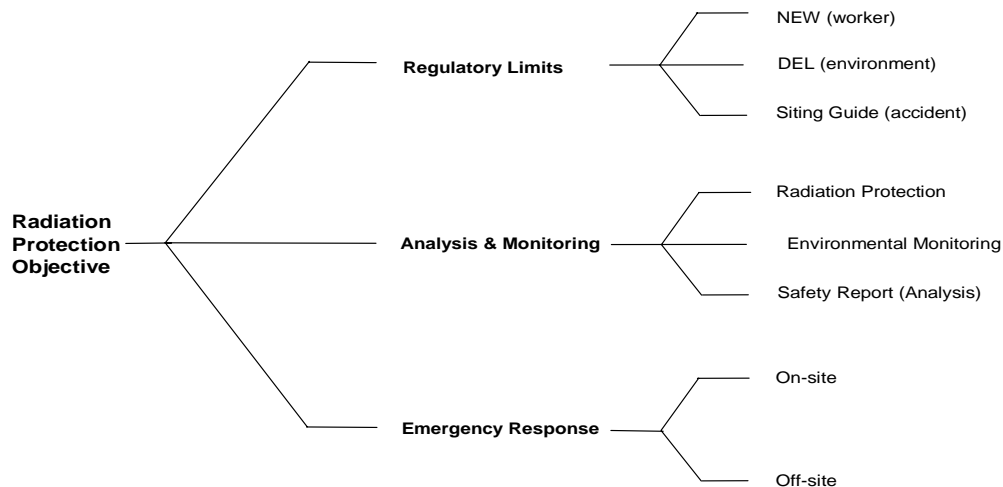


Figure 3. Break down of the radiation protection objective.

3.5 Implementation of the Safety Basis

The implementation of the safety basis is the final stage in achieving the nuclear safety objective. It breaks down the safety basis into the design and operating requirements

from which the job and task analysis can be performed. The first step in this breakdown stage is shown in Figure 3 for radiation protection. This stage includes the definition of work processes to monitor and maintain the safety basis.

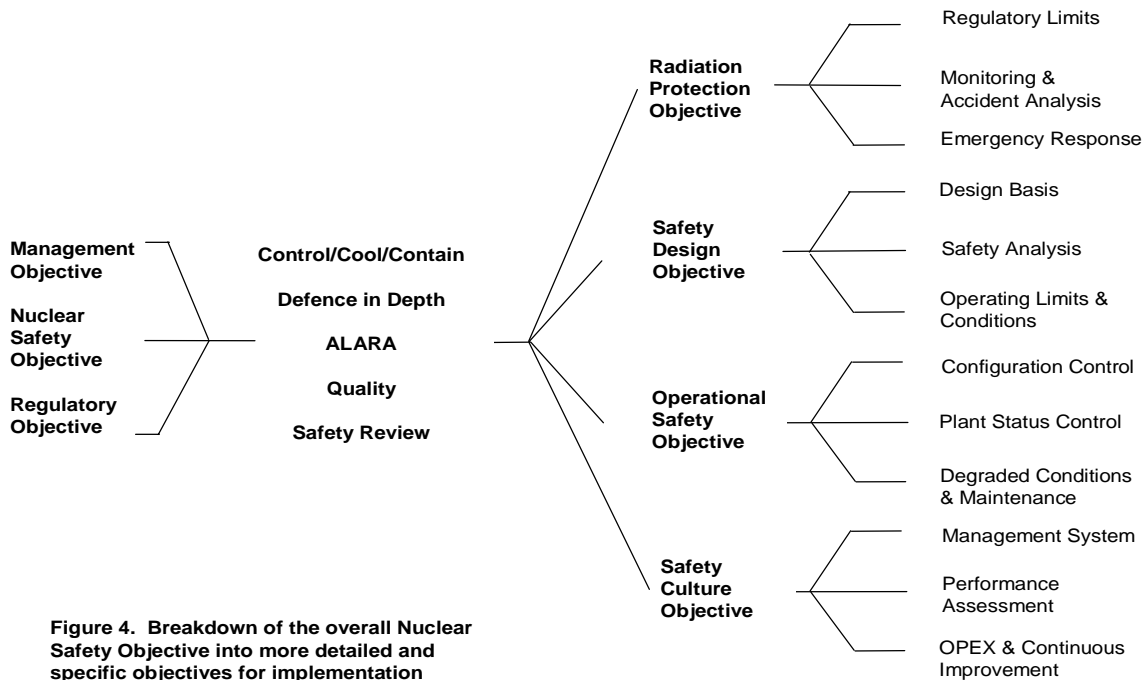
4. SUMMARY AND CONCLUSIONS

The break down of the nuclear safety objective as a knowledge base is summarized in Figure 4. The next stage of break down is the implementation via specific jobs and tasks as defined by the business process model.

Knowledge of the first four stages of the break down is common across all station work processes for technical support staff. At the next stage of break down the knowledge requirements can be limited to specific jobs and tasks.

Training modules can be prepared according to the break down shown in Figure 4. However, the ‘common’ knowledge to the end of stage 4 is the required basis for training at the job and task level. At each stage the depth must be sufficient to enable the next stage.

The analysis of nuclear safety training as presented satisfied the three nuclear safety training principles for enabling effective operational decision making.



REFERENCES

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