INTRODUCTION TO CRITICALITY SAFETY MANAGEMENT

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What is criticality safety?

- The **prevention of an unintended critical excursion.**
- The protection against the consequences of an inadvertent nuclear chain reaction, by preventing the reaction. This is achieved by controlling one or more factors of the system within subcritical limits.
- Nuclear criticality safety for uranium facilities involves both preventive measures to maintain process conditions and mitigative measures to reduce the overall risk of nuclear criticality.
- The achievement of nuclear criticality safety depends on controlling either the mass of the fissile material or neutron behavior.

What is criticality safety?

- It differs from reactor physics because its **scope** deals with assemblies, facilities, or situations where fissile materials are encountered **outside** of a conventional nuclear reactor core.
- The ‘tools’ used to assess the critical state of a system are essentially the same as those used for reactor physics but their successful **application** requires some knowledge of the nuclear fuel cycle, chemistry, plant design and processes, regulations and standards, etc.
- Criticality safety management is an applied subject for managing the risks inherent in handing fissile materials.

Nuclear Criticality Safety is a mature discipline that was established over 50 years ago as a result of several accidents that occurred in nuclear weapons related research and development. The number of accidents over this period is well over 50, taking into account previously unreported accidents in the former Soviet Union. It is estimated that about 10% of these accidents occurred in working nuclear reactors, 20% in production plants and 70% in critical facilities where the properties of the assemblies were being investigated.

Although the rate of such accidents has decreased dramatically over the decades, the reactor accident at Chernobyl (1986) in Russia and the reprocessing accident at Toki Mura (1999) in Japan demonstrate there is never room for complacency.

The importance of the safe handling of all fissile materials was recognized at early stage both by the scientific community and the responsible authorities. At the beginning, intensive experimentation with large variety of configuration and material took place in order to establish a basis of knowledge of such systems. At the time, computational methods and basic nuclear data were either not yet properly developed or had not reached sufficient sophistication to reliably predict the critical status of fissile materials

Over the years, substantial experience has been gained in both experimentation and in data and code development. This state-of-the-art knowledge in criticality safety also has an economic impact. The reduction of uncertainties in safety margins allowed improved and more economical designs for manipulation, storage and transportation of fissile materials. New fuel cycles, handling of excess fissile materials from the weapons programmes and its possible use for civil energy applications make new demands on method development, experimentation and regulations

Working Party on Criticality (WPC)

- Due to the changing face of the UK nuclear industry, the WPC recognised that a national framework (such as that used by the US Department of Energy) would allow the competence of organisations working in criticality safety management to be assessed.

- The WPC noted that there were four key areas in which competence must be demonstrated by a criticality safety professional:

Professional Competences

1. Professional skills.

2. Plant and process knowledge.

3. General technical criticality.

4. Specialised technical criticality.

Criticality Competence Framework

- It was realised that as plant and process knowledge is very specific to the plant or process in question, and as certain specialised aspects of criticality are not widely used (or have national security considerations), only general technical knowledge could be assessed.

- The general technical knowledge of a criticality safety professional forms the basis of the criticality competence framework.

General Technical Criticality

- A criticality safety professional should have knowledge and understanding of:
  - Criticality physics.
  - Methods used for criticality control.
  - Criticality accidents and incidents.
  - Methods for estimating sub-criticality.
  - Computational codes and the nuclear data.
  - Sources of uncertainty in criticality assessment and the necessity for methods validation.

General Technical Criticality

- A criticality safety professional should have knowledge and understanding of:
  - Anomalies of criticality and hazards from plutonium, MOX and highly enriched fuels.
  - Criticality incident detection and response.
  - Criticality hazards during decommissioning, storage and transport.
  - Regulatory requirements and standards applicable to criticality safety.
  - Criticality assessment methodology.

LEARNING OUTCOMES

- By the end of this course you should be able to:
- Have an holistic overview of nuclear criticality accidents
- Understand and be able to apply a simple ab initio calculation (the six factor formula) to asses nuclear criticality.
- Be able to use classical methods to assessing sub-critical limits.
- Apply specific numerical methods (buckling and surface density) to estimating criticality limits.

- Appreciate the deterministic methods (neutron transport and diffusion theory) that may be applied to criticality calculations.
- Understand the probabilistic approach (Monte-Carlo method) to criticality assessment and be aware of the computational methods used.
- Have a broad knowledge of the guides, principles and standards applied to nuclear criticality safety management.
- Understand the lessons learned from previous criticality accidents and appreciate the expected understanding required of criticality engineers.

THANK YOU