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The Value of and Need for International Nuclear Criticality Safety Standards – A Report on ISO TC 85/SC 5/WG 8 Activities

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ABSTRACT

Recent initiatives and developments of nuclear criticality safety standards for nonreactor nuclear facilities by the International Organization of Standards (ISO) have highlighted some differences that exist in administrative and technical practices among different countries. This paper will review the current ISO 1709 standard, those ISO standards that are currently under development, and proposed standards for development and maintenance by ISO on the subject of criticality safety. The author brings his perspectives as the Convener of ISO TC85/SC 5/WG 8. The current standard in maintenance is ISO 1709: 1995, "Nuclear energy – Fissile materials – Principles of criticality safety in handling and processing." This standard is very generic and global in nature with few specifics about what to do to ensure subcriticality and nuclear criticality safety. Two standards under working draft (WD) development by ISO TC 85/SC 5/WG 8 are:

- WD 14943, "Nuclear energy – Fissile materials – Administrative criteria related to Criticality Safety" and
- WD 14941, "Nuclear energy – Fissile materials – Nuclear criticality control and safety of plutonium-uranium oxide fuel mixtures outside of reactors."

These working drafts are characteristic of administrative and technical differences among countries in the implementation of nuclear criticality safety. Though nuclear fuel cycle facility managers, safety managers, regulators, and auditing/compliance inspectors have identical objectives (e.g., the prevention of nuclear criticality accidents) there are industrial and national cultural perspectives and practices that influence the implementation of safety. Standard development will be discussed as it may relate to industrial and national differences.

A new proposed work item (PWI) is a standard for the estimation of nuclear criticality accident fission yields. The development of this standard will likely reveal philosophical, administrative, and technical differences among participating countries regarding the what and how to perform these estimates. The value of and need for international standards will be highlighted with respect to the opportunities that are available from these differences.

INTRODUCTION

In the arena of international trade, there are obvious reasons for the "harmonization" of national standards into international standards. Obvious examples include worldwide progress in trade liberalization, interpenetration of business activities, worldwide communications systems, impact of emerging international technologies, and evolution of developing world countries and their economics, regarding:

- enhanced product quality and reliability at a reasonable price;
- improved health, safety and environmental protection, and reduction of waste;
- greater compatibility and interoperability of goods and services;
- simplification for improved usability;
- reduction in the number of models, and thus reduction in costs;
- increased distribution efficiency, and ease of maintenance.

The scope of ISO standards covers all technical fields except electrical and electronic engineering, which is the responsibility of the International Electrotechnical Commission (IEC). There are approximately 180 ISO Technical Committees that range over technical fields like screw threads, technical drawings, product definition and related documentation, tractors and machinery, agricultural food products, applications of statistical methods, fire safety, quality management and quality assurance, and many others.

The technical field of nuclear criticality safety is addressed by Working Group 8 (WG 8), *Standardization of calculations, procedures and practices related to criticality safety*, which is within the purview of Subcommittee 8 (SC 8), *Nuclear fuel technology*, of Technical Committee 85 (TC 85), *Nuclear energy*. This paper provides information and the status regarding the extent and developing standards of the working group, ISO TC85/SC 5/WG 8, from the perspective of the author.

The only current WG 8 standard in maintenance is ISO 1709: 1995-11-01, "Nuclear energy – Fissile materials – Principles of criticality safety in handling and processing." This standard is very generic and global in nature with few specifics about "what" and "how" to ensure subcriticality and nuclear criticality safety. Two standards under working draft (WD) development by ISO TC 85/SC 5/WG 8 are:

- WD 14943, *Nuclear energy – Nuclear fuel technology – Administrative criteria related to Criticality Safety* and
- WD 14941, *Nuclear energy – Nuclear fuel technology – Nuclear criticality control and safety of plutonium-uranium oxide fuel mixtures outside of reactors*.

Issues and diversities impacting the development of WG 8 standards are addressed. These issues and diversities relate to:

- the character of the specifications for a nuclear criticality safety standard, that is "what-to-do" versus "how-to-do"
- the cultural/regulatory balance of expectations for "knowledge-based" versus "procedure-based" operations, safety evaluations, and safety analyses,

- the cultural/regulatory balance regarding standardized "critical" versus "safe" reference values, and
- the expected variations in language and organizational differences among ISO member countries.

Resolutions of these issues and diversities through the development and issuance of an ISO standard provide a broader perspective for each member body to consider in the development and implementation of their own national practices, procedures, standards, and regulations. The issuance of an ISO standard forms the obvious basis for maximum international concurrence with minimum expectations and specifications. In today's world of increased international commerce/services (e.g., the cooperative venture of Duke, SGN-COGEMA, and Stone and Webster to build a mixed plutonium-uranium oxide fabrication plant in the United States, the design, fabrication or sale of nuclear reactor fuel among international bodies) such international concurrence is evermore important for cost reduction with safety.

Brief descriptions of the status of these standards are addressed below.

STATUS OF ISO 1709: 1995, *NUCLEAR ENERGY – FISSILE MATERIALS – PRINCIPLES OF CRITICALITY SAFETY IN HANDLING AND PROCESSING*

ISO 1709: 1995-11-01 is the fundamental standard for nuclear criticality safety. As indicated by the document number, the standard was revised and issued November 1, 1995. The standard is applicable to operations with fissile materials outside nuclear reactors but within the boundaries of nuclear establishments for which the unique properties and quantities of these materials could support an uncontrolled nuclear chain reaction under normal or foreseeable abnormal conditions. The standard contains reference to the normative ISO 7753 standard, *Performance requirements and testing procedures for criticality detection and alarm systems.* It provides specifications for required (1) procedures, (2) technical criteria, (3) equipment control, (4) material control, (5) dispatch and receipt of material, (6) monitoring of procedures, and (7) need for criticality alarms.

(1) Procedural requirements by ISO 1709 include:

- the clear definition and assignment of operational responsibility for criticality safety to operations management throughout the normal chain of command,
- the incorporation of criticality safety considerations, to a practicable extent, in design of equipment and plant facilities (the approval of equipment design/use by appropriate authority is optional),
- the performance of criticality assessments to demonstrate, with the help of processing supervision, that processes will remain subcritical in the event of unforeseen circumstances,
- the use of written procedures for governing operations involving fissile material in excess of threshold quantities defined by management (availability of these procedures in the operating areas is optional),
- the review of procedures by persons skilled in the interpretation of experimentally validated criticality data and familiar with criticality safety practices and processing

operations (the administrative independence of these skilled persons from operations under review is optional),
- the reporting, analysis and consideration of processing violations and unusual occurrences for possible improvements to criticality safety practices, and
- the training of processing operators to the extent necessary to provide confidence that the operator can conduct activities without undue risk to himself, his co-workers or the facility (sufficient supervisory technical knowledge to provide guidance to operators concerning the safety of operations is optional).

(2) Technical criteria requirements include:

- the incorporation of safety features in equipment, or instrumentation, rather than on administrative control where practicable,
- the consideration of multiple factors in combination affecting criticality (i.e., moderation, reflection, interaction, neutron absorbers, geometry),
- examples of reasonably foreseeable abnormal conditions that are to be considered in safety assessments,
- the use of experimental measurements, or alternatively validated calculations, to form the basis of subcriticality for assessments, and
- the consideration of the probability of procedural violations, the seriousness of the consequences from the potential criticality accident, and the uncertainty in the basis of the assessment for establishing specifications defining margins of operational safety.

(3) Equipment control criteria includes the verification of equipment dimensions and materials upon which the safety assessment is predicated.

(4) Material control criteria includes:
- fissile material movement,
- the labeling of materials, and
- the marking of operating areas with material identification and parametric limits for control of criticality safety.

(5) Dispatch and receipt of material includes:
- the concurrence of the consignor and consignee before fissile material is transferred, and
- the provision for receipt of damaged packages.

(6) Monitoring of procedures includes:
- the periodic verification of operational conduct with written procedures,
- the verification by persons not directly involved with operations, and
- the issuance of a written monitoring findings report to management and directsupervision.

(7) Need for criticality alarms includes:
- the evaluation in accordance with ISO 7753, and
- the preparation of emergency procedures for alarmed areas.

ISO standards require a review for withdrawal or revision every five years. That is to say that the ISO 1709 standard is to be withdrawn or revised and approved by November 1, 2000. It was the consensus of WG 8 members at the 1999 and the 11 May 2000 WG 8 meeting that the standard is current, should not be withdrawn, but should be reaffirmed as issued in 1995. That recommendation is committed to ISO TC 85/SC 5 for action by ISO TC 85 international vote.

STATUS OF ISO WD 14943, *NUCLEAR ENERGY – NUCLEAR FUEL TECHNOLOGY – ADMINISTRATIVE CRITERIA RELATED TO CRITICALITY SAFETY*

The ISO working draft WD 14943 was initiated about five years ago as a supplement to the limited administrative criteria provided in ISO 1709 as discussed above. The WD has been finalized by WG 8 and is committed to be submitted to ISO TC 85/SC 5 for action by ISO TC 85 international vote as a committee draft (CD). The specifications of the draft standard are more definitive with regard to (1) personnel responsibilities, (2) operating procedures, (3) process evaluation/assessment for nuclear criticality safety, (4) materials control, and (5) planned response to nuclear criticality accidents. The WD has been through at least four WG revisions. The greatest obstacles to the consensus for the WD were the various concepts regarding organizational and operational structure and responsibilities of corporate management, supervisors, and operating personnel relative to regulatory and oversight responsibilities. The WD required modifications to avoid conflicts in individual national concepts for the interaction and oversight among the regulated organizations and the regulators. It is judged that with the latest WD being submitted as a CD for international vote, WG 8 has successfully completed this task. Issues and concepts of the standard that may reach consensus in the future revisions may include:

- the periodicity of management program effectiveness reviews,
- the need for verification of supervisory and nuclear criticality safety staff knowledge,
- the need for readily available and approved operating procedures for operators in their job areas,
- the periodicity of supervisory procedural reviews (operations are to be reviewed at least annually for compliance with procedures), and
- the degree for which procedures are supplemented by posted limits, incorporation of limits in check lists, flow sheets, or automated control systems.

STATUS OF ISO WD 14941, *NUCLEAR ENERGY – NUCLEAR FUEL TECHNOLOGY – NUCLEAR CRITICALITY CONTROL AND SAFETY OF PLUTONIUM-URANIUM OXIDE FUEL MIXTURES OUTSIDE OF REACTORS*

The ISO working draft WD 14941 was also initiated about five years ago. The working draft (WD) continues to evolve through the development of the specifications bases document for the standard, generation of bases documents, and will ultimately conclude in the consolidation of information into critical specifications for selected conditions with plutonium-uranium oxide (MOX) fuel mixtures and water. The development specifications included the detail of what and how much specific information will be provided in the standard and what will be used as the basis of the standard. Much work has been expended on the development of the bases documents. Tens of hundreds of computational evaluations have been performed by participating ISO member subject-matter experts to define the critical condition of the many considered mixtures.

This work will result in the issuance of a significant international reference standard for MOX. Currently, the perceived shortcomings of the intended standard are:

- the current limitation to homogeneous MOX systems, and
- the limitations of critical experiment benchmarks relative to the computed mixtures.

The intent of the WG is to establish computational variations and uncertainties among various internationally computed results from indigenous methods and data of each member. Based upon the resulting variations in critical values and associated uncertainties, the WG will evaluate the information to provide "best professional estimates" of minimum critical conditions (i.e., those parametric conditions that may barely permit a critical condition for the considered materials and configurations).

Materials and configurations that are considered for this standard are:

A. 1 maximum oxide (UO_2 + PuO_2) **powder** material density,
   3.50 g (UO_2 + PuO_2)/cm^3
   at 2 plutonium weight fractions of (g Pu)/(g U + g Pu) expressed as percentages
      35.0 wt %
      12.5 wt %

B. 1 maximum oxide (UO_2 + PuO_2) **green pellet** material density
   5.50 g (UO_2 + PuO_2)/cm^3
   at 2 plutonium weight fractions of (g Pu)/(g U + g Pu) expressed as percentages
      35.0 wt %
      12.5 wt %

C. 1 maximum oxide (UO_2 + PuO_2) **sintered pellet** material density
   11.03 g (UO_2 + PuO_2)/cm^3
   at 1 plutonium weight fractions of (g Pu)/(g U + g Pu) expressed as percentages
      12.5 wt %

All of the above oxides at

D. 3 plutonium isotopic weight percentages

^{239}Pu,	^{240}Pu,	^{241}Pu,	^{242}Pu
100 wt %,	0 wt %	0 wt %	0 wt %
95 wt %	5 wt %	0 wt %	0 wt %
65.883 wt %	20.000 wt %	12.941 wt %	1.176 wt %

and

E. 2 uranium isotopic weight fractions of ^{235}U, (g ^{235}U/g U) expressed as percentages
   0.718 wt %
   0.300 wt %

F. with 30 different H_2O weight fractions expressed as percentages
   0.33 wt % $\leq$ (100)(g H_2O)/(g H_2O + g UO_2 + g PuO_2) $\leq$ 97.09 wt %

[30 corresponding H/(U + Pu) atom ratios and 30 corresponding metal densities, g (U + Pu)/cm^3]

G. Critical parameters for all of the above materials are to be determined for
2 full density water reflector thicknesses,
2.5 cm
30.0 cm

Parameters that are to be determined for each of the above combinations include:

k_∞ (verify minimum critical fissile material/oxide concentration, g/cc)

Critical (k_{eff} = 1.0000) dimensions and sensitivities of k_{eff} with respect to critical dimensions to include

B_m^2
Sphere
Radius, cm
Volume of fissile material, cm^3
Mass of fissile material, g (U + Pu)
Mass of fissile material oxide, g (UO_2 + PuO_2)
Volume density, g (U + Pu)/cm^3
Volume density of fissile material oxide, g (UO_2 + PuO_2)/cm^3
Plane
Thickness, cm
Surface density of fissile material, g (U + Pu)/cm^2
Surface density of fissile material oxide, g (UO_2 + PuO_2)/cm^2
Cylinder
Radius, cm
Linear density of fissile material, g (U + Pu)/cm
Linear density of fissile material oxide, g (UO_2 + PuO_2)/cm

A quick perusal of the above parameters and their many combinations reveals the significance of the computational effort. It is expected that all results from the various WG members will be completed by September 2000. Consolidation and subsequent review of the information will occur shortly thereafter.

An interesting observation for the United States of America (USA) participants is the international desire to establish "best estimate" critical values, and associated uncertainties, from which the user is then expected to establish their own margins of subcriticality for safety applications. It then becomes the users' responsibility to convince their regulatory authority about the adequacy of the selected margins of subcriticality for safety. Within the USA nuclear criticality safety standards are developed through the Nuclear Criticality Safety Division (NCSD) Subcommittee 8 and the N16 Consensus Committee of the American Nuclear Society (ANS) for the American National Standards Institute (ANSI). The ANSI/ANS Subcommittee 8 standards strive to establish the consensus (including regulatory authority participation) subcritical or "safe" values for implementation by the user. The consensus within ISO TC 85/SC 5/WG 8 is that the independent national implementation of an ISO standard will still require regulatory concurrence of applied margins of subcriticality for safety.

STATUS OF PWI 199910-1, *NUCLEAR ENERGY – NUCLEAR FUEL TECHNOLOGY – ESTIMATION OF NUCLEAR CRITICALITY ACCIDENT FISSION YIELDS*

This work item was suggested at the 27-28 September 1999 meeting of ISO TC 85/SC 5/WG meeting. A member of WG 8 has accepted an appointment as the "Leader" for the project and a scope of work was defined at the 10-11 May 2000 WG 8 meeting. The PWI scope is:

> Standardization of objectives and example methods to estimate the power spikes and fission yields anticipated during a criticality accident and specifies procedures to substantiate these values in the case of a hypothetical criticality accident.

The purpose and justification for the work, as described by the Project Leader, is provided below.

> For any nuclear fuel facilities, for example fuel enrichment and fabrication facilities or spent fuel reprocessing facilities in which a criticality accident might happen due to inadvertent treatment of fissile materials, it is essential to estimate power spikes, especially the first power spike, to properly design and install criticality detection and alarm systems in order to minimize exposure of workers and to initial evacuation. It is also vital to estimate fission yields anticipated during the criticality accident to assess the effects on the environment and public health for and integral design of the facilities.
>
> Furthermore, although the possibility of a criticality accident would be restrained to be very low, if a criticality accident occurred, there might be a need to take quick response to estimate the power spikes together with fission yields to assess the exposure of workers and the health effect of the general public.

Upon ISO TC 85 registration of the Accepted Work Item, WG 8 will pursue the development of a Working Draft for the standard.

SUMMARY

As can be observed from the above, WG 8 is relatively active for a working group of limited membership participation. The WG is responsive to inquiries and suggestions for standard development. Though the development and issuance of an ISO standard can require substantial work and time there is a process by which individual national standards can be "fast tracked" for adoption as an ISO standard following an ISO affirmative vote. Also, extent national standards can be adapted through ISO TC 85/SC 5/WG consensus to reduce the developmental time and effort.

Differences in international perspectives relative to the implementation of nuclear criticality safety provide a resource to member nations for consideration in their own implementations. Because of the valuable resources and need for additional assistance, other ISO member countries are encouraged to sponsor their own subject matter experts to participate in ISO TC 85/SC 5/WG 8 standards development.

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