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Title: **American National Standard ANSI/ANS-8.6: Safety in Conducting Subcritical Neutron-Multiplication Measurements 'In Situ'**



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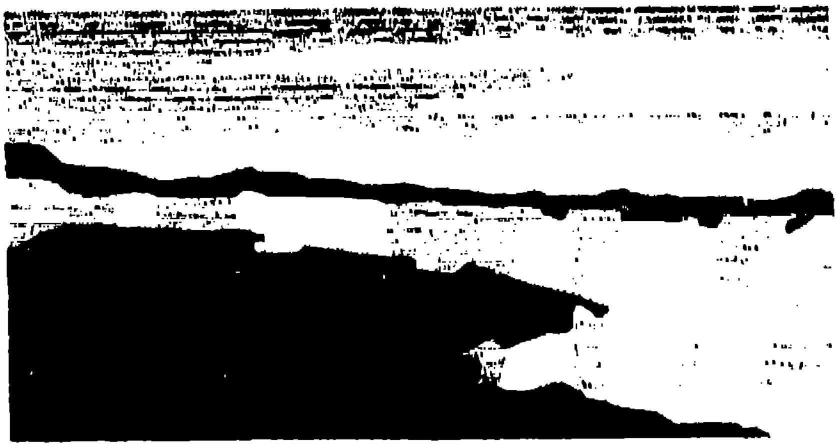

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**American National Standard ANSI/ANS-8.6:**
**Safety in Conducting Subcritical Neutron-Multiplication Measurements *In Situ***

Thomas P. McLaughlin, LANL

**Introduction**

Safe and economical operations with fissile materials require knowledge of the subcriticality of configurations that arise in material processing, storage, and transportation. Data from critical experiments have been a principal source of information with which to establish safety margins. However, the lower cost and the expediency of performing confirmatory subcritical measurements on the process floor or in the storage vault resulted in much of the early criticality safety guidance being based on subcritical *in situ* experiments (Refs. 1,2).

The *in situ* standard, ANS-8.6, was developed in the mid-1960s. While reported applications of this potentially valuable standard in the last 30 years are scarce, a few examples from the past ten years are presented. This scarcity is probably driven by the difficulty in providing well-characterized conditions (suitable for validations) in the process areas as well as a hesitancy among regulatory personnel to permit "approach-to-critical" experiments at work sites even though there is no intention of going beyond accepted hands-on practices at critical experiment facilities and process facilities.

Although the early subcritical measurements provided valuable data, to take advantage of refinements in safety margins that may be afforded by the application of current computer codes, it is necessary to have more accurate measurements of the subcritical state than may be readily available today. The criticality specialist routinely bases safety margins for far subcritical operations on validations made against data gathered at the critical point.

*In situ* measurements, in addition to possibly providing more expeditious and less costly information about safety margins than may be available from experiments at critical, may also be applied to the task of providing identification information. Finally, with the increasing interest in site restoration and the possible desire to exhume material that may have been buried for decades, *in situ* techniques may offer the only practical means of characterizing a situation before it is disturbed.

**Early Applications**

Extensive critical measurements were performed at the several critical experiment facilities that existed from the 1940s into the 1960s. The majority of these experiments were with single units, partly because of the cost, time, and complexity of large array measurements. However, guidance for storage of weapons and weapons components and early reactor fuel storage configurations was based largely on subcritical measurements in the field. The major reason was that it was not always practical to perform critical experiments since necessary facilities did not always exist where the bulk of the material of interest was stored.

Subcritical *in situ* measurements made in 1945-1955 on weapons and weapons components at Rocky Flats and at weapons assembly and storage sites provided criticality safety guidance that is still valuable today.[1] C. L. Schuske of Rocky Flats and H. C. Paxton of Los Alamos National

Laboratory (LANL) were instrumental in the instigation of these measurements, an example of which is illustrated in Fig. 1. The safety guidance from most of these early subcritical experiments was derived from inverse multiplication plots with the limit for safe storage chosen as, for example, a cross multiplication of two.

Exemplifying the efficiency and timeliness of *in situ* measurements for unique applications is the proof test conducted on a compact, poisoned fuel storage rack for the PM-2A reactor (Ref. 3). This portable, medium-power reactor was located at Camp Century, Greenland, and the multiplication measurements were conducted on site.

## ANSI/ANS-8.6

The standard development effort leading to ANS-8.6 was largely due to the efforts of Schuske. He was associated with many beneficial *in situ* measurements on process vessels and storage configurations within the facility, and he participated in or instigated many others at sites within the U.S. Atomic Energy Commission and the military.

While this standard should facilitate the application of measurements that can better define safety margins and hence enhance the safety and economy of operations, few reported *in situ* measurements have been noted since the 1960s. Perhaps the difficulty and expense of critical experiments as well as developments in subcritical measurement techniques will reverse this trend. On the other hand, as stated in Sec. 4.1 of the standard, "primary responsibility for safety shall be assigned to one individual experienced in the performance of subcritical or critical experiments.[8] Such personnel are becoming as scarce as critical facilities.

The correct interpretation of data gathered with well-understood techniques is clearly dependent on knowledgeable, experienced personnel. Indeed, the incorrect interpretation of data was a factor in the confusion and misunderstanding associated with reactivity measurements of the Z-9 Crib at Hanford (Ref. 4). These *in situ* pulsed neutron experiments were performed to provide confidence in the expected high degree of subcriticality of the plutonium-bearing liquid waste disposal site. Interpretations of initial data, however, did not confirm the expected result and indicated a system possibly near critical. Analyses of subsequent data led to the conclusion that the system was indeed highly subcritical, and there were no criticality safety concerns. Perhaps noise analysis techniques currently being refined might have enabled a more accurate estimation of how far subcritical the Z-9 Crib really was.

## Recent and Future Applications

Two applications of *in situ* measurements and the ANS-8.6 standard at LANL in the past decade come to mind. The first is a one-of-a-kind operation calculated to be subcritical by ~10% Δk when fully assembled, which included thick reflection. Appropriate counting equipment and knowledgeable personnel from the critical experiments facility were brought into the plutonium facility to monitor the assembly operation. The inverse multiplication data coupled with calculational results provided confidence during the assembly process that the unit was subcritical by about the degree predicted, and the final multiplication factor was also nearly as expected.

The second application involves inverse multiplication measurements on boiling water reactor and pressurized water reactor assemblies with loadings and enrichments typical of commercial reactors. These assemblies are used by the Safeguards Assay Group at LANL for instrumentation development purposes. Following the administrative and operational practices stated in the standard provides confidence that no surprises will be encountered, even though it is known that individual assemblies in water cannot be made critical for expected loadings and enrichments.

Recently developed measurement methods permit more quantitative subcriticality measurements (Ref. 5) and have been applied to determine the subcriticality of a storage vault containing metric tons of highly enriched uranium metal at the Oak Ridge Y-12 Plant (Ref. 6). Measurements are now in progress to provide data for validation of calculational methods for criticality safety of production items at the Oak Ridge Y-12 Plant.

As U.S. Department of Energy environmental restoration activities escalate, situations will undoubtedly arise in which the degree of subcriticality of buried material will be desired knowledge prior to its disturbance. The advancement of technologies to handle such situations is certainly a necessary item, but adherence to the *in situ* standard and other professional practices will also provide the necessary confidence that acceptably large margins of subcriticality are maintained.

## Summary

There are many examples of expeditious and cost-effective *in situ* measurements dating from the 1940s and 1950s. These subcritical experiments, on which the safety of operations were based, were paralleled by numerous critical experiments, which provide most of the bases for computer code validations today. As the capability to expeditiously and cost-effectively perform critical experiments withers, *in situ* subcritical measurements may provide the information necessary to further reduce uncertainties and biases in safety margins and thus incorporate more safety and efficiency into process operations. This type of measurement has recently been performed for a storage vault containing highly enriched uranium metal at the Oak Ridge Y-12 Plant. Finally, certain site restoration activities may demand knowledge of the subcritical state before disturbing the buried material. *In situ* subcriticality measurements may offer the only practical means to this knowledge.


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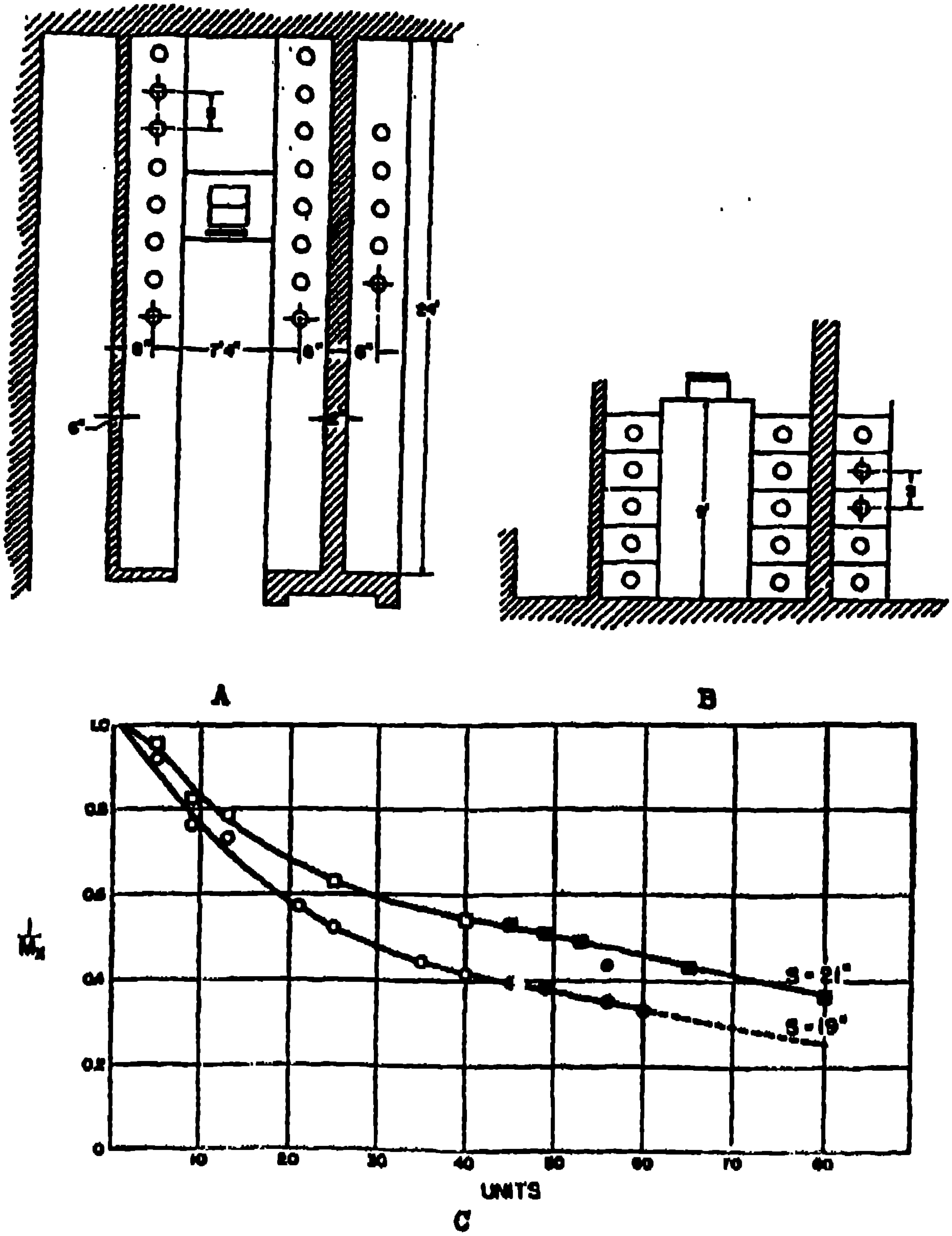


Fig. 1. Change of reciprocal cross multiplication as large capsules were positioned in a storage vault at spacings of 19 and 21 in. One side was filled before the other was started. The lonesome point, for 19-in spacing, shows the apparent effect of four persons in the corridor