

**Criticality Measurements for Control and Accountability of Fissile Materials
on Critical Assemblies**

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Introduction

Operational critical assemblies are subject to the same standards of materials control and accountability (MC&A) as other fissile materials. Typically these assemblies are not easily dismantled and the fuel components cannot be inventoried by traditional methods of destructive or non-destructive materials assay. Because of the large mass or unusual geometry of the fuel components these parts are often categorized as difficult-to-measure (DTM) items. The use of criticality to infer fissile inventory, in conjunction with physical security and two-person control procedures, provides accurate and cost-effective MC&A for these large critical assembly components. This method is being implemented at the Los Alamos Critical Experiments Facility (LACEF) and at several national nuclear research centers in Russia.

Description

The use of criticality to infer fissile inventory for MC&A verification measurement of large critical assembly fuel components is based on the documented sensitivity of critical assemblies to changes in the configuration and the demonstrated reproducibility of the assemblies from operation to operation. This is illustrated with reference to two applicable critical assemblies at Los Alamos.

Critical assemblies are very sensitive to changes in fuel loading. The Flattop fast critical assembly at Los Alamos is currently fueled with a uranium core (16.2 kg (~ 93.2% ^{235}U metal). In the core support pedestal there are cylindrical voids machined for the placement of mass adjustment buttons. A 44 gram U(93) button is typically worth 0.084 \$. Three buttons were recently added to the core adding 0.241 \$, where 1 \$ is the interval between delayed and prompt critical. The control rod positions changed approximately 6.70 in. between the two configurations. The sensitivity of the system was 0.127 cm (0.05 in.) of

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control rod position per gram of material in the mass adjustment buttons. Thus a 10 g discrepancy (in 16,300 g) would show up in a 1.27 cm (0.5 in.) position difference in the control elements. Such a discrepancy would be obvious to the operating crew and would have to be resolved prior to proceeding with operations. Other positions, such as the central glory hole, are more sensitive.

The other issue is machine assembly reproducibility. The Godiva-IV prompt-burst assembly is fueled with 1.5-wt% molybdenum-uranium ($\sim 93.2\%$ ^{235}U) alloy with a general configuration similar to that of Godivas II and III. When assembled, the core of six interlocking plates is 17.78 cm (7 in.) in diameter by 15.24 cm (6 in.) in height. Fuel components are all aluminum-ion-plated and have a total mass of ~ 65.4 kg. Three external C-shaped clamps, fabricated from high-strength maraging steel, fasten the stack of six stationary fuel rings.

Godiva reproducibility is on the order of 0.001 β during normal delayed critical operations and about 0.05 β from day-to-day due to temperature coefficient of 0.02 β /degree-C and room return sensitivity of 0.01 to 0.05 β . A central safety block has a reactivity worth of about 0.01 β / mil (25 β total) with the greatest sensitivity due to the top portion. Three control rods have a reactivity worth of ~ 0.03 mils / ϕ (1.40 β total worth). The inside of the rings will have a reactivity sensitivity similar to that of the safety block, while the outside of the rings are worth considerably less.

Results

Critical assemblies are assembled to a standard configuration as one of the first checks during any operation. This involves adjusting the position of the control elements to add a known amount of excess reactivity above delayed critical. The asymptotic reactor period is then measured and used to infer a reactivity from the Inhour equation of the system. Critical assemblies are typically reproducible to 0.005 to 0.01 β . The effects of temperature must be included since temperature differences affect the density and the neutron leakage. A series of these critical assembly operations for Godiva-IV is shown in Figure 1.

Figure 1 is used by MC&A specialists to verify the Godiva fissile inventory. If one of the Godiva fuel components is selected during a routine MC&A audit operational logbooks are inspected to examine recent operations. Period-temperature data for these operations must fall within the allowed discrepancy band. This band corresponds to an allowed discrepancy of 1 part in 10^4 or in the case of Godiva 6.5 grams of fissile material.

Summary

The above mentioned assemblies are illustrative of the process. Each critical assembly has a different configuration and sensitivity. Physical security measures coupled with the fact that these are large pieces provides constant MC&A assurance. One could not remove a "small" amount of material without extreme measures obvious to security or the operating personnel. Historically loss of reactivity on the order of 0.10 \$ is obvious to the operating crew and would be of serious concern. A 0.10 \$ reactivity difference represents approximately 1 part in 10^4 sensitivity in mass.

Using the critical configuration as a routine accountability check is being implemented as a standard MC&A procedure. Based on the critical control rod positions LACEF personnel, in conjunction with the nuclear materials custodian, and MC&A specialists, could help insure accountability of critical assembly fuel components.

Figure 1 - Period versus Average T for Godiva Critical Assembly

