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TITLE: BENCHMARK ASSEMBLIES OF THE LOS ALAMOS CRITICAL ASSEMBLIES FACILITY

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BENCHMARK ASSEMBLIES OF THE LOS ALAMOS CRITICAL ASSEMBLIES FACILITY

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Abstract Several critical assemblies of precisely known materials composition and easily calculated and reproducible geometries have been constructed at the Los Alamos National Laboratory. Some of these machines, notably Jezebel, Flattop, Big Ten, and Godiva, have been used as benchmark assemblies for the comparison of the results of experimental measurements and computation of certain nuclear reaction parameters. These experiments are used to validate both the input nuclear data and the computational methods. The machines and the applications of those machines for integral nuclear data checks are described.

INTRODUCTION

The Los Alamos Critical Assemblies Facility (LACAF) comprises three assembly buildings, called Kivas, and the machines within each one are operated from a remote control room associated with the respective Kiva.

Experiments designed to validate computational methods and input data sets for various configurations of fissile, reflecting, and moderating materials considered for both military and civilian applications are conducted. A recounting of these activities at Pajarito Site is available as Reference 1.

MEASUREMENT OBJECTIVES

The measurement data sought from these assemblies for the purpose of validation of calculations include the prompt and delayed neutron responce, and the cross sections of various materials within the assembly, integrated over the neutron energy spectrum. These data are usually obtained as: spectral indices, the ratios of fission rates of isotopes with significantly different integral response, such as $\sigma_f(^{235}U)/\sigma_f(^{238}U)$, $\sigma_f(^{239}Pu)/\sigma_f(^{238}U)$ and $\sigma_f(^{237}Np)/\sigma_f(^{238}U)$; the Rossi-$\alpha$ at and near delayed critical; the measurement of periods for small reactivity changes above delayed critical; the measurement of neutron population dieaway for large negative reactivity changes from delayed critical, the central reactivity coefficients of a wide variety of materials, and the spatial variation of the reactivity coefficients of these materials; and the differential leakage radiation spectra.

The assemblies have been built with simple, clean geometries, and with high mechanical precision to guarantee reproducibility and have been well characterized so that they can be considered benchmark assemblies[2] for the purpose of providing the experimental validation of the computational results.[3]

ASSEMBLY DESCRIPTION (See accompanying figures)

GODIVA IV is the latest in a line of unreflected enriched uranium metal critical assemblies. The original spherical "Lady Godiva" was constructed to determine the critical mass and neutronic behavior of a ^{235}U unreflected sphere, providing an accurate benchmark assembly. The cylindrical geometry was selected in the later Godiva machines, like Godiva IV, for structural strength and reduced thermal shock when these machines were operated in the fast burst mode.

JEZEBEL was constructed to determine the critical mass and neutronic behavior of an unreflected sphere of delta-phase plutonium metal. Jezebel has also been used to assemble unreflected metal spheres of ^{233}U and of plutonium with a significant ^{240}Pu enrichment (20%). Detailed neutronics measurements were made with each of these spheres. Comparisons of the measurement results from the three spheres provide a more precise understanding of the neutronic behavior of each of them separately.

FLATTOP is an assembly consisting of a spherical core of either uranium (93.2% ^{235}U or 98.1% ^{233}U) or plutonium (5% ^{240}Pu) metal, and a thick spherical natural uranium reflector. Flattop assembly spectra are characteristically hard at the center and degraded in the reflector. This position-varying neutron spectrum is particularly useful for neutron activation studies and reactivity coefficient measurements. Intercomparisons with the results of the same measurements in the other benchmark assemblies provide integral reaction rate information over a very broad range of neutron energies. Jezebel and Godiva have hard spectra, Big Ten has an intermediate spectrum, and Flattop has a spectrum that is position variable from hard to intermediate.

BIG TEN is a normally fueled version of a split table critical assembly made of uranium metal. The core is composed of a central section of homogeneous 10% enriched uranium enclosed in a region of alternating 93% enriched and natural uranium plates simulating an overall 10% enrichment. The outer reflector is depleted uranium. The central neutron spectrum is comparable to that of the Liquid Metal Fast Breeder Reactor so that verification of cross-section sets in Big Ten would validate them for LMFBR calculations. The reaction rate comparisons for Big Ten complement the same comparison for Jezebel, Godiva and Flattop, and together these form an impressive integral test of cross-section sets and computational methods.

INTERCOMPARISON METHODS

Typically, ratios of reaction cross sections and ratios of reactivity worths are measured and calculated because these are more accurately obtained than the corresponding absolute values. As an example[4] of these, the following table gives the values of the criticality parameter, k_{eff}, the ratios of fission cross sections f28/f25, f37/f25, f49/f25 and reactivity worths w28/w25, w37/w25, w49/w25 for ^{238}U (28), ^{235}U (25), ^{237}Np (37) and ^{239}Pu (49), for Godiva, and for two experimental measurement sets, one prior to 1981 and one subsequent, and for two data files ENDF/B-V and ENDF/B-V Revision 2.

LOS ALAMOS DATA TESTING RESULTS: 1981–1984
(Calculated/Experimental C/E Ratios Only)

Assembly Parameter	ENDF/B-V 1981 C/E	ENDF/B-V Recalc. 83–84 New E	Revision 2 1983–84 New ^{239}Pu
GODIVA			
k_{eff}	0.9987	0.9990	
f28/f25	1.037	1.037	
f37/f25	1.064	1.044	
f49/f25	0.994	0.985	0.985
w28/w25	1.024	1.024	
w49/w25	1.020	1.019	1.011

CONCLUSION

The benchmark critical assemblies at the Los Alamos Critical Assemblies Facility continue to provide the capability to validate cross-section sets by comparing measured and calculated integral reaction rates in these assemblies, and for confirming the suitability of computational methods. Because of the variety of machines that are available at the LACAF, and their precision construction, these validation experiments can provide a much more stringent test than would be possible with a single assembly. This can be attributable to the differences in neutron spectrum in the different machines, and the variation of spectra even within a single machine.

REFERENCES

1. H. C. Paxton, "A History of Critical Experiments at Pajarito Site," Los Alamos National Laboratory report LA-9685-H (March 1983).
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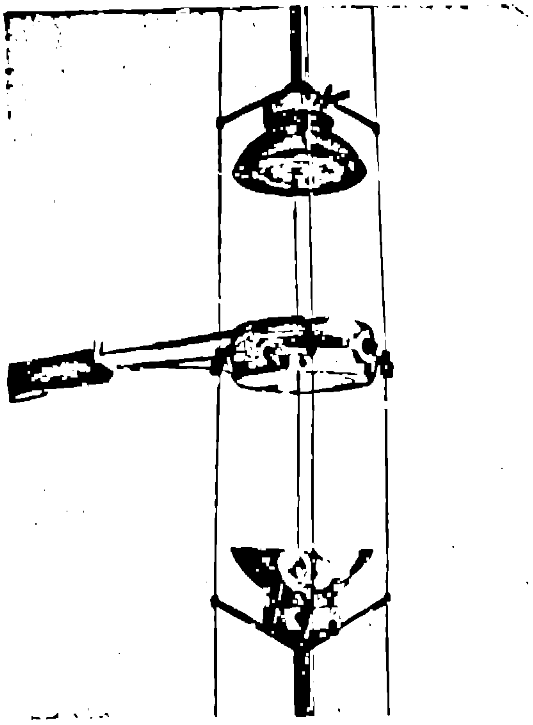
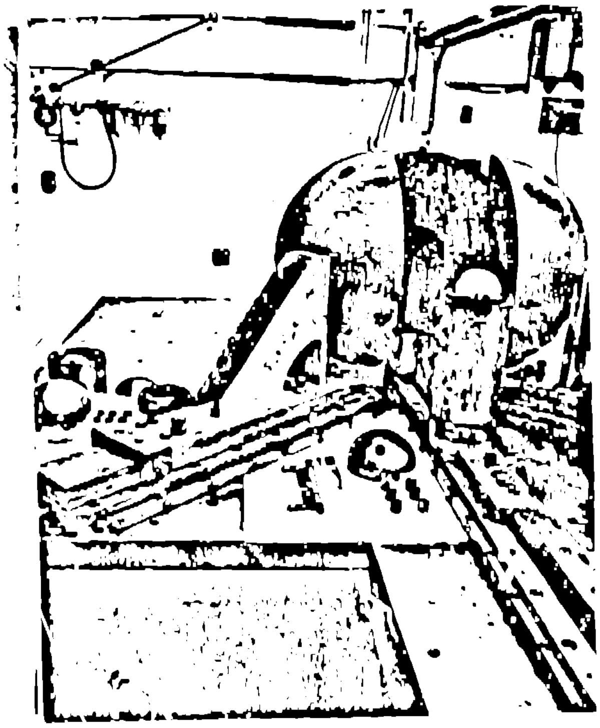
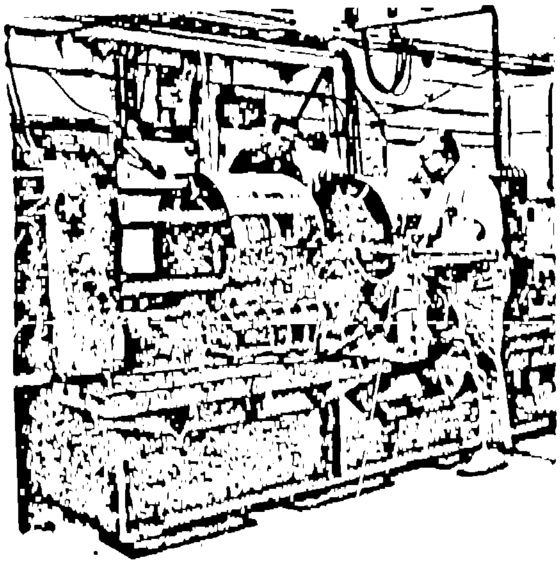
3. D. W. Muir, "Analysis of Central Worths and Other Integral Data from the Los Alamos Benchmark Assemblies," Los Alamos National Laboratory report LA-10203-MS (ENDF-340), 1984.
4. E. D. Arthur, A. D. Mutschlecner, "Applied Nuclear Science and Development Semiannual Progress Report, October 1, 1983 - May 31, 1984," Los Alamos National Laboratory report LA-10288-PR, 1985.



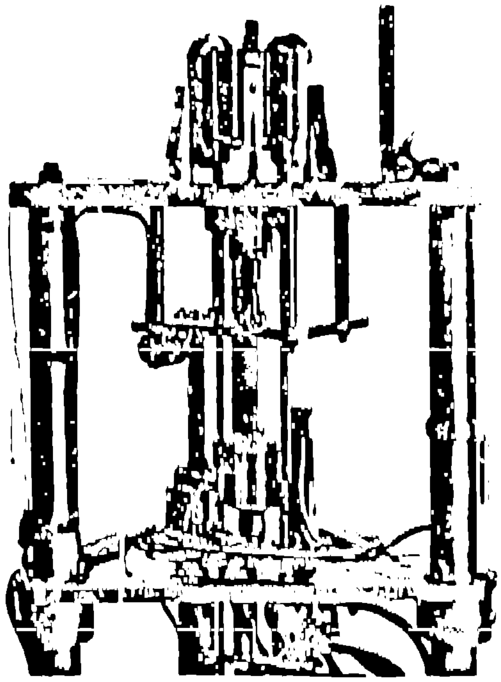
Jezebel



Flattop



Big Ten



Godiva IV