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CRITICALITY ALARM SYSTEM VERIFICATION AT THE LOS ALAMOS CRITICAL EXPERIMENTS FACILITY: PAST EXPERIENCE AND PRESENT CAPABILITIES

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ABSTRACT

The Los Alamos Critical Experiments Facility (LACEF) has been involved in the testing and evaluation of criticality accident alarm systems since 1980. At that time we designed and built the solution critical assembly SHEBA for this purpose. The response of the alarms to neutron pulses was done using the GODIVA-IV Burst Assembly. Currently, SHEBA and a new fast assembly, SKUA, are being modified for burst operation.

PAST EXPERIENCE

Early in 1980 the LACEF was funded by the Oak Ridge Operations Office of the Department of Energy (DOE) to design, construct, and operate a solution critical assembly to evaluate nuclear accident alarm dosimetry. This evaluation was to benefit the proposed Portsmouth, Ohio, gaseous diffusion plants. As a result, the SHEBA Critical Assembly (Fig. 1) was built. The acronym stood for the Solution High Energy Burst Assembly, although there were no immediate plants for burst operation. It is interesting to note that construction time for this assembly, from concept to first critical, was only four months--a noteworthy record for Los Alamos. The solution used is $U(4.8)O_2F_2$ at an H/U ratio of about 550, and the

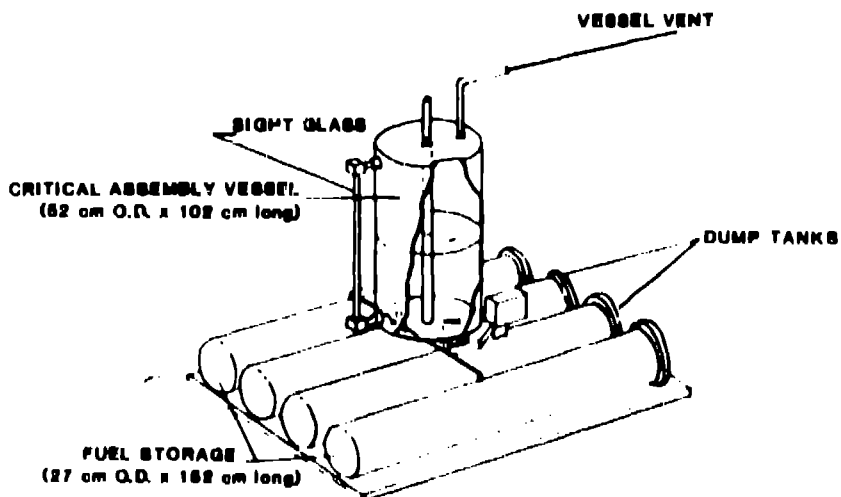


Fig. 1. Schematic of SHEBA Solution Critical Assembly.

critical height in the 54.6-cm (21.5-in.) i.d. assembly vessel is 36.5-cm (14.4-in.) at 25°C, which corresponds to 85.5 liters of solution. SHEBA is located in a thin-walled steel Butler-type building situated about 400 meters from its associated control room. Thus, measurements in its radiation field can be accomplished at considerable varying distances from the assembly. Furthermore, shields of different materials such as steel, concrete, or polyethylene can be erected between the assembly and radiation detector locations. A series of experiments, including steady-state and ramp operation, were completed in September 1980 to test equipment brought by Goodyear Atomic Corporation and Oak Ridge Gaseous Diffusion Plant personnel. In addition, seven detector vendors participated in evaluations of their products and the Lawrence Livermore National Laboratory was involved with spectrum and dosimeter measurements. These runs were continued in 1984, with a week of irradiations in June, for the alarm systems chosen by Goodyear Atomic. Several reports and presentations were made on the results of these experiments.¹⁻⁷ One interesting problem that resulted from these detector evaluations was their response to extended excursions (Fig. 2) generated with the SHEBA Assembly.

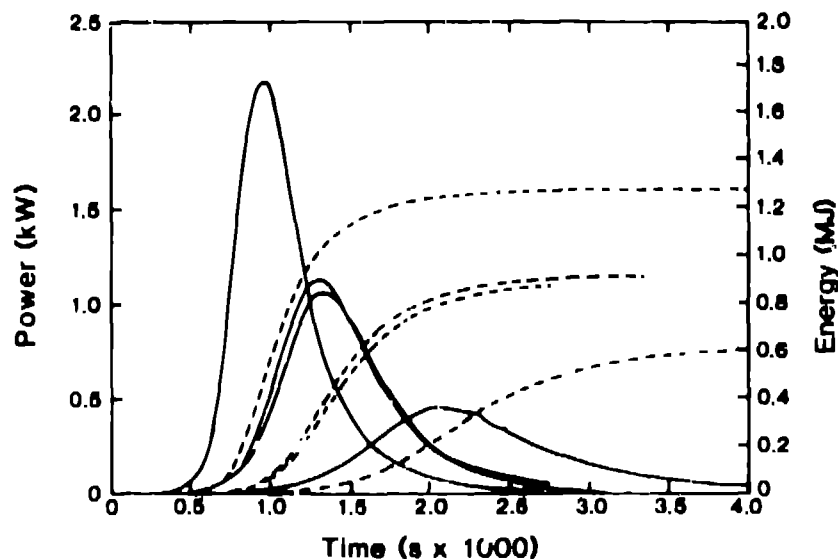


Fig. 2. SHEBA Free Evolution Excursions.

In addition, we have used the GODIVA-IV Fast Burst Assembly (Fig. 3) for further tests of criticality alarm systems. GODIVA-IV is a bare metal, U(93) alloyed with 1.5% molybdenum, system that is capable of fast burst yields up to 1.1×10^{17} neutrons/burst and sub-prompt excursions with yields about a factor of 1.5 higher. Bursts can be tailored within limits; experiments with moderating neutron reflectors have demonstrated some control of pulse profile. These alarm evaluations, using the GODIVA IV Assembly, started in 1983 on Eberline Corporation detectors developed for the Lawrence Livermore National Laboratory. The Goodyear Atomic criticality alarm systems tested in the SHEBA radiation fields in 1984 were also evaluated for response to GODIVA-IV bursts at varying distances from the assembly and through the different shielding materials. More recently, in 1987, we used GODIVA IV to test several alarm systems supplied by the Oak Ridge National Laboratory.

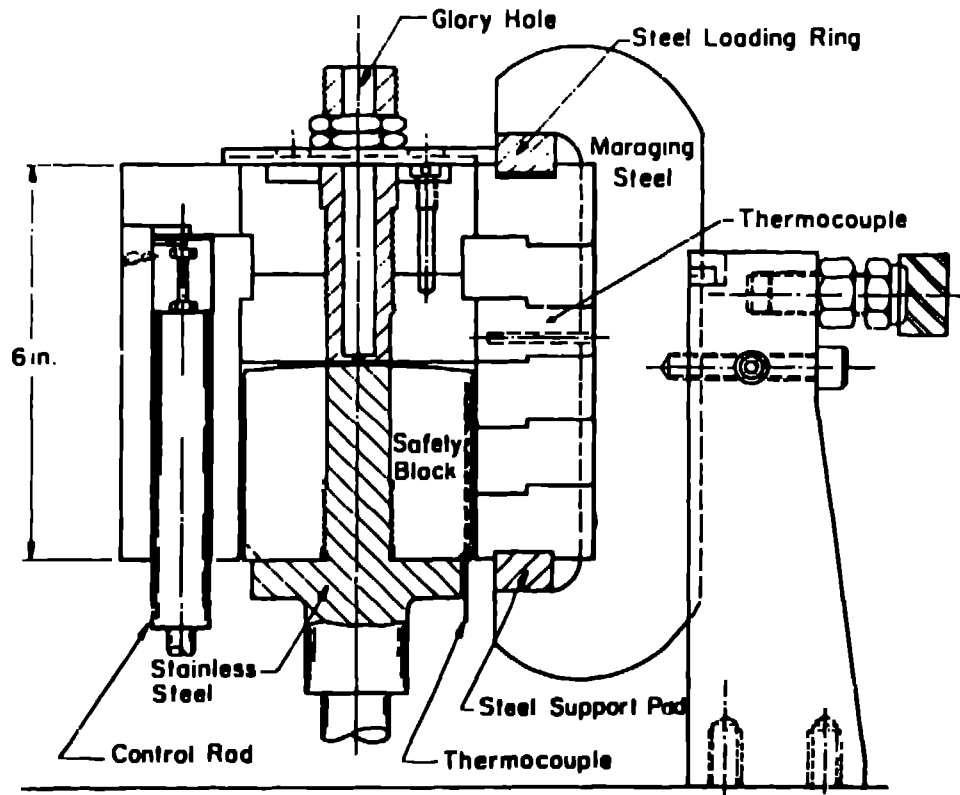


Fig. 3. GODIVA-IV Fast Burst Assembly.

PRESENT CAPABILITIES

At present, the Los Alamos Critical Experiments Facility has six operating benchmark critical assemblies that can be used for dosimetry experiments. Neutron fluxes and fluences available with these assemblies are listed in Table I. These values were calculated⁸ for a one hour

TABLE I

NEUTRON FLUXES AND FLUENCE AVAILABLE FROM LACEF ASSEMBLIES

(Calculated for one-hour irradiation with 200°C/h initial core heating rate)

	Power (kW)	Central Flux	Central Fluence (n/cm ²)		Flux at 1 m from Center
		(n/cm ² s) x 10 ⁻¹⁵	(1 h) x 10 ⁻¹⁵	(10 h) x 10 ⁻¹⁵	(n/cm ² s) x 10 ⁻⁸
FLATTOP Pu	0.1	12	6.4		0.60
FLATTOP U(235)	5.6		2.0	0.26	
BIG TEN	5	14		5.1	13
GODIVA	1	17		6.0	6.0
NEVA	1	5.6		1.9	3.6
NEUBA	2	1.1	0.38		2.7

irradiation at a power level that produces a core temperature rise rate, at start, of 200°C per hour.

The SKUA Fast Burst Assembly (Figs. 4 and 5) is a recent addition to our capabilities. The fuel is enriched uranium metal, again U(93) alloyed with 1.5% molybdenum, in the form of a hollow right circular cylinder made up of a stack of 12 annular rings. This fuel stack is 30.5-cm (12-in.) high, with a nominal 24.1-cm (9.5-in.) and 31.8-cm (12.5-in.) inside and outside diameters. Reactivity control is achieved with copper reflectors. The three segments that move by hydraulic actuators in the radial direction provide the independent major shutdown or SCRAM mechanisms. Then there are three rotary drums, two for vernier reactivity control and one for burst insertion. The neutron spectrum at the center of the core can be altered by inserting a flux trap into the central void. Table II gives a comparison of the SKUA burst characteristics with those of GODIVA-IV. These are listed for a burst temperature rise of 300°C. SKUA has not yet achieved burst operation, however, we believe that temperature rises up to 600°C will be possible.

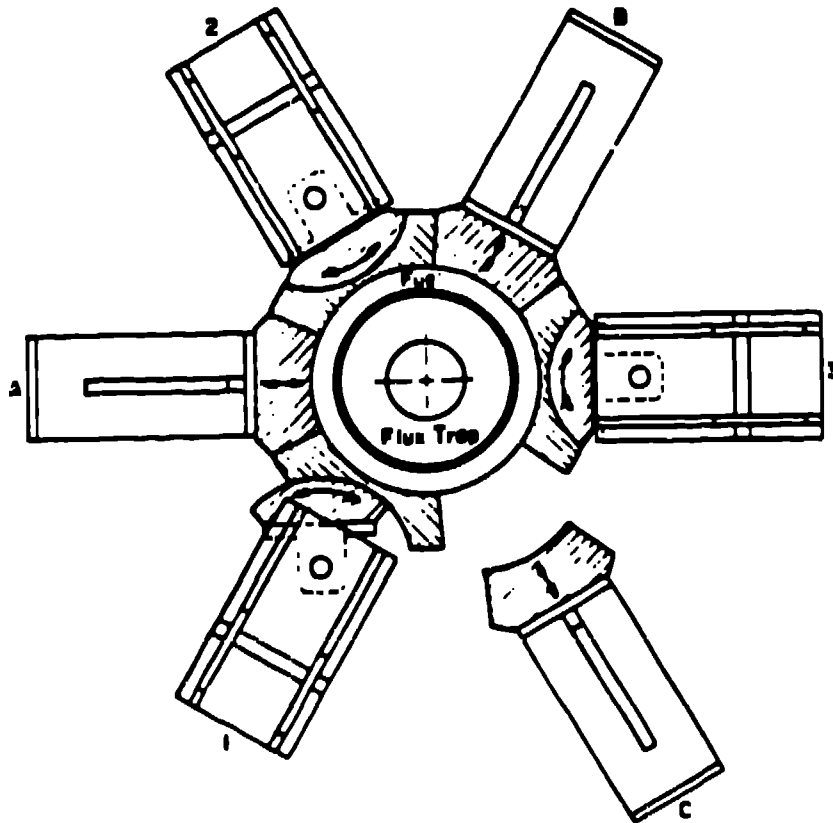


Fig. 4. Top schematic view of the SKUA Assembly.

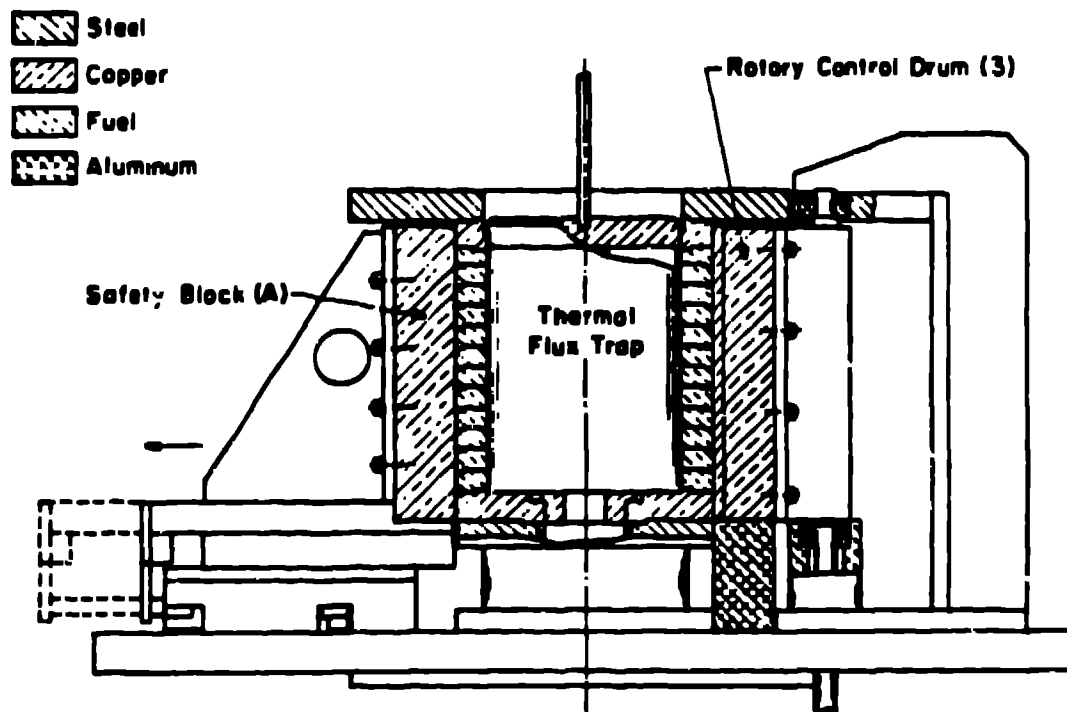


Fig. 5. Cross section of the SKUA Assembly.

TABLE II

COMPARISON OF BURST CHARACTERISTICS ($\Delta T = 300^\circ\text{C}$)

	<u>GODIVA IV</u>	<u>SKUA (estimated)</u>
Burst width (μs)	30	400
Joules/burst	1.8×10^6	5.4×10^6
Leakage neutrons	8.9×10^{16}	2.67×10^{16}
Flux at 1 m ($\text{n}/\text{cm}^2\text{-s}$)	2.35×10^{16}	5.3×10^{16}
Central fluence (n/cm^2)	3.3×10^{14}	3.3×10^{14}
Central flux ($\text{n}/\text{cm}^2\text{-s}$)		
average	1.1×10^{19}	8×10^{17}
peak	2×10^{19}	1.5×10^{18}

As a result of a recent Agreement between the French-CEA and the US-DOE for an Exchange of Criticality Safety Data, we are planning superprompt burst operation with SHEBA, and extensive modifications (Fig. 6) are currently under way. This involves replacing the old core vessel with a new one capable of withstanding the anticipated pressure shocks. In addition, the external solution pumping system will be rearranged into a more compact geometry beneath the vessel. This newer configuration will allow SHEBA to be lowered into a shielding pit (Fig. 7) following high power operation, thus allowing access to the irradiation area immediately following shutdown. Although the fuel in SHEBA is currently enriched to 4.8%, one of our plans is to gradually increase this enrichment to about 20%. This will extend its experimental capability by being able to study the pulse characteristics as a function of fuel enrichment.

The LACEF is thus in an excellent position to continue verification studies of criticality alarm systems, as well as providing dosimetry irradiations to satisfy future experimental requirements.

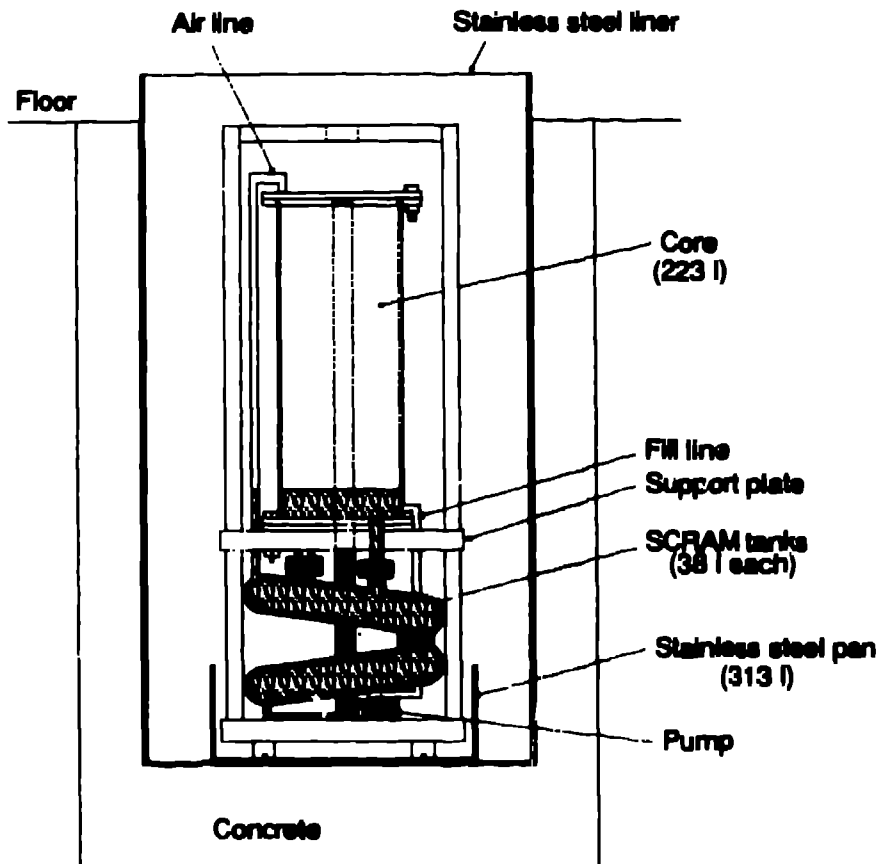


Fig. 6. SHEBA Modification Proposal.

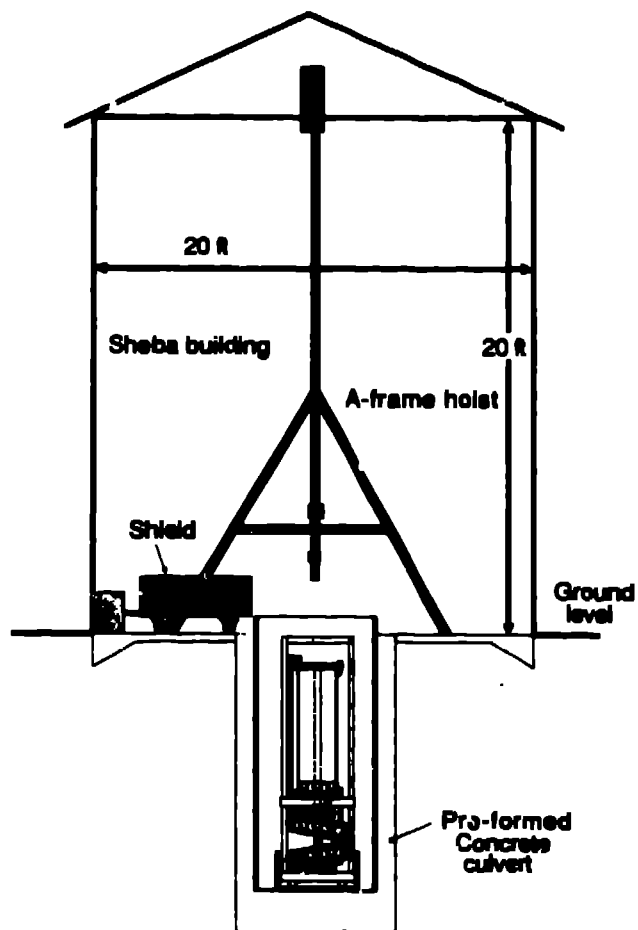


Fig. 7. SHEBA Building Modification Proposal.

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