LA-UR -84-1726

CONF

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

LA-UR--84-1726

DE84 012578

TITLE: LITTLE BOY REPLICATION: JUSTIFICATION AND CONSTRUCTION

AUTHOR(S): R(ichard) E. Malenfant, S-4

SUBMITTED TO: 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

LITTLE BOY REPLICATION: JUSTIFICATION AND CONSTRUCTION

R. E. Malenfant
Los Alamos National Laboratory
Los Alamos, New Mexico 87544

ABSTRACT

A reconstruction of the Little Boy weapon allowed experiments to evaluate yield, leakage measurements for comparison with calculations, and phenomenological measurements to evaluate various in-situ dosimeters. The reconstructed weapon was operated at sustained delayed critical at the Los Alamos Critical Assembly Facility. The present experiments provide a wealth of information to benchmark calculations and demonstrate that the 1965 measurements on the Ichiban assembly (a spherical mockup of Little Boy) were in error.

INTRODUCTION

"Given this unique experience at Hiroshima...it really is appalling to think that we stand here, 36 years later, debating orders of magnitude in the doses" (Jablon 1981). Indeed, as Marshall (1981) pointed out some time later,

> We know very little about the long-term health hazards of human exposure to neutron irradiation--certainly less than we thought we knew a year ago. The painstaking follow-up of the Hiroshima and Nagasaki survivors has provided our only extensive data on human neutron exposure. A joint Japanese-American effort has for more than three decades attempted to keep track of the medical history of every person within a few kilometers of Ground Zero who survived the cataclysm and its immediate aftermath in these two ill-fated cities.

Nearly all evaluations of the long-term effects of exposure to radiation for a human population are derived from observations concerning the survivors of Hiroshima and Nagasaki. Although the medical history is well documented, the radiation exposures are still uncertain. Fat Man, the Nagasaki weapon, is well understood and has been subject to numerous comparisons between calculation and observation. Little Boy is not understood; it was unique, never tested, and, until recently, never duplicated. Reconstruction of Little Boy and the performance of the measurements are particularly important because a comparison of the radiation effects allows (in principle) determination of the neutron relative biological effectiveness (RBE) and the detailed evaluation of dose standards such as the Health Physics Research Reactor. The RBE derivation is possible because Little Boy was predominantly a neutron leaker and Fat Man a gamma-ray source. The evaluation of dose standards is of consequence because the leakage spectrum of Little Boy is unlike any of the so-called standards. Previous attempts to duplicate Little Boy have failed to represent significant features that affect the external radiation. The present attempt represents not only the first time that a weapon-like system was operated at sustained delayed critical (to represent the fissioning source fully), but it is also the first time that the original archives were exhaustively researched to truly replicate the original. It is noteworthy that the system was not compromised by such features as extraneous material or control rods.

CONSTRUCTION OF THE REPLICA

With this background, a program was devised to answer those questions that could be answered. Three basic types of experiments were done at Los Alamos: critical separation measurements to establish limits on the yield for the Hiroshima explosion, output spectra and dose measurements for direct comparison with calculations, and phenomenological experiments involving exposures of diverse in-situ dosimeters to validate the techniques.

The source for all of the experiments used the nonnuclear components of a Hiroshima-type bomb that had been retired from stockpile and stored at Los Alamos. This real atomic bomb configuration was mounted on the Comet Assembly Machine at the Los Alamos Critical Assembly Facility (Figure 1). To bring the assembly to critical, nuclear components were carefully inserted into the bomb by means of a hydraulic lift and the precision screw mechanism of the Comet Assembly Machine. By clever design of the system, operational safety was achieved without the use of control rods or other extraneous material. For the critical separation measurements, fissile parts were fabricated using the

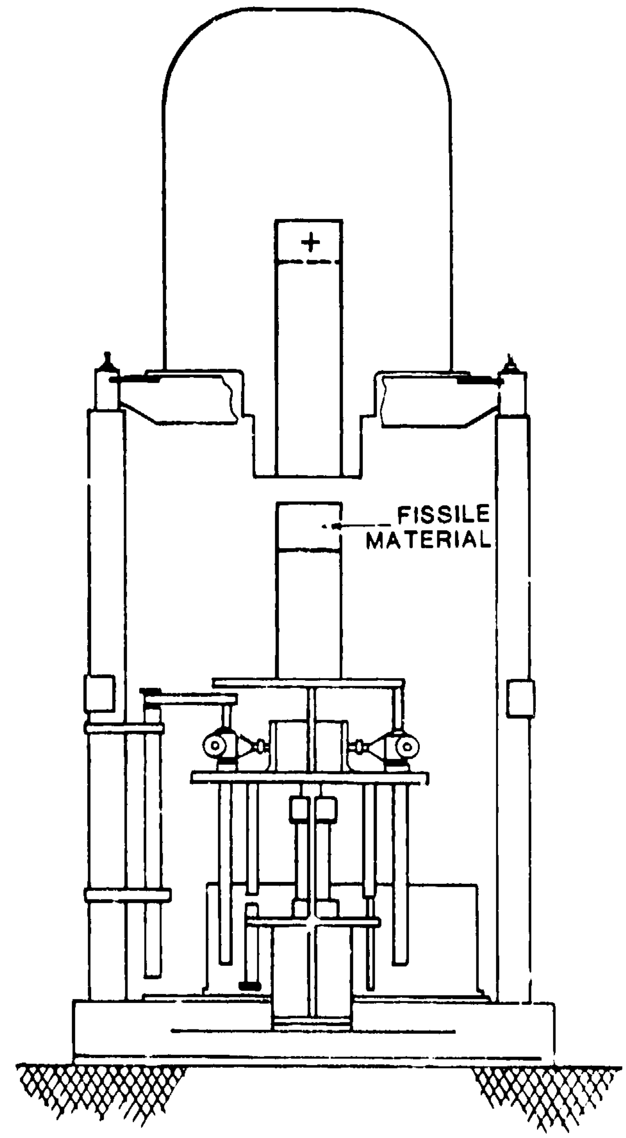

Figure 1. The replica of Little Boy on the Comet Assembly Machine.

original Hiroshima bomb drawings and specification sheets. For the spectra and phenomological measurements, an amount of fissile material just sufficient to allow sustained operation at delayed critical was used. Measurements were made both with the assembly inside the assembly building and on a stand outside the building (Figure 2). The program of experiments included several firsts, including the first operation of a bomb-type assembly at sustained delayed critical to allow measurements to be analyzed and, where necessary, repeated under carefully controlled conditions.

The only concessions that had to be made to allow the experiment to be done were the shortening of the gun barrel and the use of dummy initiators. Shortening the gun barrel allowed the use of a shorter stroke on the hydraulic ram and screw mechanism and contributed to safety. Another safety-related factor, the use of dummy initiators, eliminated the requirement to use extraneous radioactive material. Neither of these approximations compromised the experiment in any way. As Little Boy was truly unique, the only previous opportunity to conduct critical separation measurements was on Tinian Island in 1945. Neither time nor facilities at that time permitted the measurements. An attempt was made in 1965 to evaluate the leakage through use of a depleted uranium "core" and a ^{252}Cf source (Auxier 1977). The present configuration more closely represents reality in that spatial distribution of the source is preserved and a correct representation of capture gamma-rays is produced.

Obviously, we cannot produce all the effects of the actual explosion. However, the prompt radiation is adequately represented in that most of the fissions in Little Boy were produced before the weapon disassembled in the explosion. As such, the angular distribution, neutron-to-gamma-ray ratios, and spectra are accurately replicated.

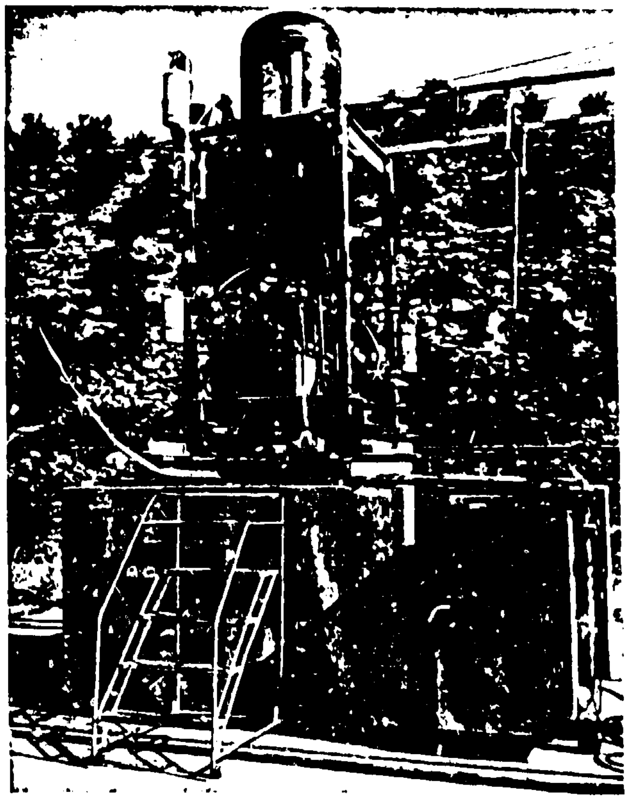

Figure 2. Replica of Little Boy set up outdoors on the Comet Assembly Machine to minimize the effect of scattering from surrounding material and to eliminate the effects of building walls and ceiling.

MEASUREMENTS

Comparisons of calculated and measured neutron spectra at the waist of the assembly indicate excellent agreement in neutron spectra from 0.6 to 10 MeV. If this result continues to be supported by other experiments, the long-standing disagreement between the calculations and measurements on the Ichiban critical assembly (Thorngate et al. 1960) (Auxier 1977) can be laid to rest: the 1965 measurements were in error.

Comparisons of calculated and measured neutron spectra at the nose of the assembly where the neutron exit path is longer are not in good agreement. This result was not unexpected. The disagreement in spectral shape is similar to that observed in deep penetration problems in other materials.

The replica measurements will be of immense value in resolving uncertainties in the calculations of the output from the Hiroshima device. Currently, Los Alamos and Livermore calculations of the sulfur fluence neutrons from the Hiroshima explosion differ by a factor of two. The major fraction of this discrepancy is due to the different yields of the calculated explosion, but 20% effects are due to the choice of cross sections and cross-section representation. The critical separation measurements will allow the calculated yields to be brought together and the spectral measurements will allow the choice of the best cross-section sets and representations to be used for a final calculation of the nuclear emission from the Hiroshima explosion (Whalen et al. 1983).

REFERENCES

Auxier, J. A. 1977. Ichiban: Radiation Dosimetry for the Survivors of the Bombings of Hiroshima and Nagasaki. TID-27080, Technical Information Center, U.S. Energy Research and Development Administration.

Marshall, E. 1981. "New A-Bomb Data Shown to Radiation Experts." Science 212(19 June 1981):1364.

Schwarzschild, Bertram M. 1981. "Studies Revise Dose Estimates of A-Bomb Survivors." Physics Today (September 1981):17.

Thorngate, J. R., D. R. Johnson, and P. T. Perdue. 1960. Leakage from the Ichiban Critical Assembly. Report CEX-64.7, U.S. Atomic Energy Commission.

Whalen, P. P., P. D. Soran, R. E. Malenfant, and H. M. Forehand. 1983. "Experiments at Los Alamos with the Replica of the Hiroshima Bomb." Presentation at Second US-Japan Workshop on A-Bomb Dosimetry Reassessment, Hiroshima, Japan, November 8-9, 1983.