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DESIGN AND PERFORMANCE OF THE SAVANNAH RIVER SITE BILLET ACTIVE WELL COINCIDENCE COUNTER (U)

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ABSTRACT

The Savannah River Site (SRS) has acquired, installed, and tested a custom-built Billet Active Well (neutron) Coincidence Counter (BAWCC). The BAWCC is used to make accountability measurements of the ^{235}U content of U-Al coextrusion billets in the SRS fuel fabrication facility. The instrument design incorporates a unique center-source configuration, with two moderated americium-lithium (AmLi) neutron sources located in a central spindle that inserts through the center hole of the U-Al billets. This configuration, a result of earlier experimental studies at SRS, yields improved response and precision for billet assay when compared to the standard AWCC source arrangement. Initial tests of the BAWCC at SRS have yielded one-sigma uncertainties of 0.8-1.0% for a fifteen-minute assay. This paper will describe the design, testing program and performance characteristics of the BAWCC.

INTRODUCTION

The Savannah River Site (SRS) 321-M fuel fabrication area produces reactor fuel tubes via a multi-step casting and coextrusion process. As the emphasis on nuclear material control and accountability programs has increased in recent years, it has become desirable to develop methods for making accountability measurements of the ^{235}U content at several stages in the fuel tube production process. These accountability measurements are needed to meet the inventory measurement requirements of DOE Order 5633.3, as well as to verify product quality in the fuel tube production process.

In 1988, as part of the effort to improve the accountability measurement capability in the fuel tube production process, the Analytical Development Section (ADS) and Reactor Materials Engineering & Technology Department (RME&T) of WSRC experimentally evaluated the use of an active well coincidence counter (AWCC) for the assay of ^{235}U in U-Al coextrusion billets (Fig. 1), an intermediate step in the fuel tube production process. The evaluation was a success (Ref. 1); as a result, ADS and RME&T subsequently pursued the design, development, and

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production of the 321-M Billet Active Well Coincidence Counter (BAWCC), a production instrument for U-Al billet assay. Many of the design details of the BAWCC are derived from the earlier experimental work with the standard AWCC and will be discussed in more detail in later sections of this paper. Although a Cf Billet Shuffler (Ref. 2) was also acquired to meet this measurement need, acquisition of the BAWCC was still desirable because it could be acquired very quickly (less than 7 months) and relatively inexpensively.

STANDARD ACTIVE WELL COINCIDENCE COUNTER

The standard AWCC (Fig. 2) is a commercially available neutron coincidence counter specifically designed to assay ^{235}U in metallic or oxide form (Ref. 3). The instrument operates on the principle of active neutron interrogation, in which random neutron sources induce fission events in the ^{235}U of the assay sample. The resulting fission neutron signal rate is then taken to be proportional to the ^{235}U content of the sample.

As shown in Fig. 2, the standard AWCC essentially consists of a polyethylene barrel surrounding a cylindrical sample cavity. Two $^{241}AmLi$ random neutron sources are mounted in polyethylene end caps immediately above and below the sample cavity to allow a uniform irradiation of the sample. Thin cadmium shielding between each source and the sample reduces the non-uniform irradiation from thermal neutrons. Forty-two ^{3}He-filled proportional counter neutron detectors, arranged in a double ring, surround the sample well. A junction box at the top of the neutron detectors contains the preamplifier/amplifier boards for the system.

Operation of the AWCC is controlled by an external shift register coincidence module. The shift register module provides: 1) high voltage for the detectors, 2) low voltage power for the preamplifier/amplifier boards, and 3) coincidence circuitry for processing the neutron signals. The counting circuitry provides front panel display of the scalers for accidental coincidence counts (A), real + accidental coincidence counts (R + A), and totals counts (T) for each counting period. The real coincidence rate (R) is the difference between the counts in the R + A and A scalers and is proportional to the fission rate (and thus the ^{235}U content) of the sample. A more detailed description of the AWCC and its operation can be found in Ref. 3.

The standard AWCC offers a great deal of flexibility in configuration: the sample cavity can be easily enlarged, the thermal neutron flux can be enhanced by removing the cadmium liners, and the sources can be easily removed or rearranged. In fact, in the 1988 SRS U-Al billet experiments, the AWCC was tested in both the standard configuration described earlier, and in a special center source configuration. The center source configuration, in which one of the AmLi sources was placed in a polyethylene capsule in the central hole of the billet, was clearly superior. Coincidence responses for the billets increased by almost a factor of five, while measurement uncertainties were reduced by a factor of three from 1.5% to 0.5% (one sigma). These improvements occurred for two reasons:

1) improved coupling between the AmLi source and the sample, and

2) increased moderation of the interrogation neutrons by the polyethylene source holder.

The experimental results with the center source configuration were promising enough to warrant further investigation into a Billet AWCC. Monte Carlo (MCNP) calculations were performed to validate the use of this center source arrangement and to further develop the design details.

DESIGN OF THE BAWCC

Incorporating the results of the experiments and Monte Carlo calculations, ADS and RME&T developed the design specifics for a dedicated Billet AWCC. To speed the design and construction and to reduce costs, the BAWCC specifications were based heavily on the basic design configuration and materials of the standard AWCC, with the following exceptions:

1) the AmLi neutron interrogation sources were placed in the central portion of the sample cavity, rather than in the end caps.

2) the sample cavity dimensions were sized to accommodate <u>all</u> U-Al billets of interest (something the standard AWCC cannot do).

The signal processing electronics, as well as the number, type and arrangement of the ^{3}He neutron detectors, were carried over from the standard AWCC design.

The BAWCC was built for SRS by Jomar Systems, Inc. in Los Alamos, NM. The BAWCC is shown in Fig. 3 and, in schematic form in Fig. 4. The instrument consists of essentially two parts: the well body, containing the sample cavity, neutron sources, and neutron detectors/electronics; and the elevator assembly, consisting of the elevator, support scaffold, and associated components (electric motor, counterweights, etc.). Major dimensions of the BAWCC are indicated in Fig. 4.

The two AmLi sources (each 0.50" OD by 5.00" length with a neutron activity of 5 x 10^4 n/sec) are encapsulated in tungsten containers and placed in a high-density polyethylene (HDPE) source holder mounted in the center of the sample cavity (see Fig. 4). The source holder is bolted in from the bottom and is easily removed from the BAWCC body.

Billets are loaded into the BAWCC from the top via the elevator assembly (Fig. 5). The elevator platform contains polyethylene shielding on top and bottom and a central hole on the bottom that allows it to drop over the AmLi source holder. Billets are manually placed on the elevator platform and centered with the use of special wedges (see Fig. 5). Once loaded, the elevator and billet are lowered electrically via a double-chain assembly with counterweights. For safety, the chain and counterweights are located in the 4" square steel channel tube support legs. An interlock bar with proximity switch is used to ensure that the elevator platform cannot be raised or lowered until the safety cage around the elevator has been closed (Fig. 6). Lowering (and raising) the elevator is accomplished by pressing and holding the appropriate buttons. Limit switches monitor the counterweight position to halt the elevator at the "load" (billet up) or "assay" (billet down) position. In the assay position, the billet elevator is just resting on the bottom of the well. A third, "maintenance" position, allows the elevator to be raised high enough to clear the BAWCC body. In this position the BAWCC body and the elevator scaffold can be unbolted and separated for service work.

ACCEPTANCE TEST RESULTS

Acceptance testing was performed in the SRS fuel tube production area with the actual U-Al fuel billet standards that are used for BAWCC and Billet Shuffler calibration. The U-Al billet standards consist of twenty-six billets, covering two billet types (inner (BI) and outer (BO)) and four different ^{235}U enrichments (50%, 59%, 68%, and 80%). ^{235}U mass ranges extend from 1000 to 1900 grams. Mass and enrichment values were determined by New Brunswick Laboratory (NBL) from analysis of drill samples taken from each U-Al core (the fabrication step directly preceding the coextrusion billet).

All BAWCC assays were 15 minutes (900 seconds) long, divided into 9 x 100 second collection intervals to reduce data loss in the event of system transients. Data acquisition through the Jomar JSR-11 shift register was controlled by a Digital Equipment Corp. MicroVAX II computer. The MicroVAX II ran a code called BAWCC, an SRS adaptation of AWCCUNCL (Ref. 4) and QUICK (Ref. 5). This program also serves as the control software for calibration and operation of the BAWCC during normal production use. The operation of the shift register also allows for stand-alone operation of the BAWCC without computer control, when necessary.

Two types of tests were made with the BAWCC: 1) a check of long-term stability, and 2) calibration-type measurements to determine the response and sensitivity of the instrument. The stability check consisted of repeated measurements of two billets over a period of more than five months. The response and sensitivity tests were made by assaying each of the twenty-six U-Al billet standards in order to determine the response of the instrument as a function of ^{235}U mass, enrichment, and billet type.

Results of the instrument stability measurements are plotted in Fig. 7. These results were obtained from repeated assays of BI WT3016 over a period of seven months. Results for the other standard billet, a BO, are almost identical. Assay frequency was variable; in some cases, the billet was assayed several times in a day; in other cases, several weeks passed between assays. Overall, the results indicate excellent stability, with no discernable variation or drift in instrument performance during the seven month period.

Results of the testing with the U-Al billet standards are plotted in Figs. 8 and 9. In these tests the BAWCC yields a count rate response that varies with the billet type (BO and BI), but, within the type and measurement uncertainty, is independent of the uranium enrichment. Typical measurement uncertainty for a 15 minute assay is slightly less than 1% (one sigma); this is identical to the target value in the purchase specification. Further details on calibration of the BAWCC and comparison of the results to those obtained with the Billet Shuffler can be found in Ref. 6.

SUMMARY

The SRS BAWCC has successfully completed all preliminary testing and is being incorporated into normal production use in the SRS reactor fuel fabrication area. The instrument functioned reliably during the test period and is quite simple to operate; it is completely capable of performing assays without any computer control, using only the shift register for data acquisition. Measurement uncertainty for the BAWCC matches the original specifications almost exactly: measurement uncertainty is slightly less than 1% (one sigma) for a typical billet. Testing with a set of standard billets revealed that the instrument response varies with billet type, but, within the type and measurement uncertainty, is independent of uranium enrichment.

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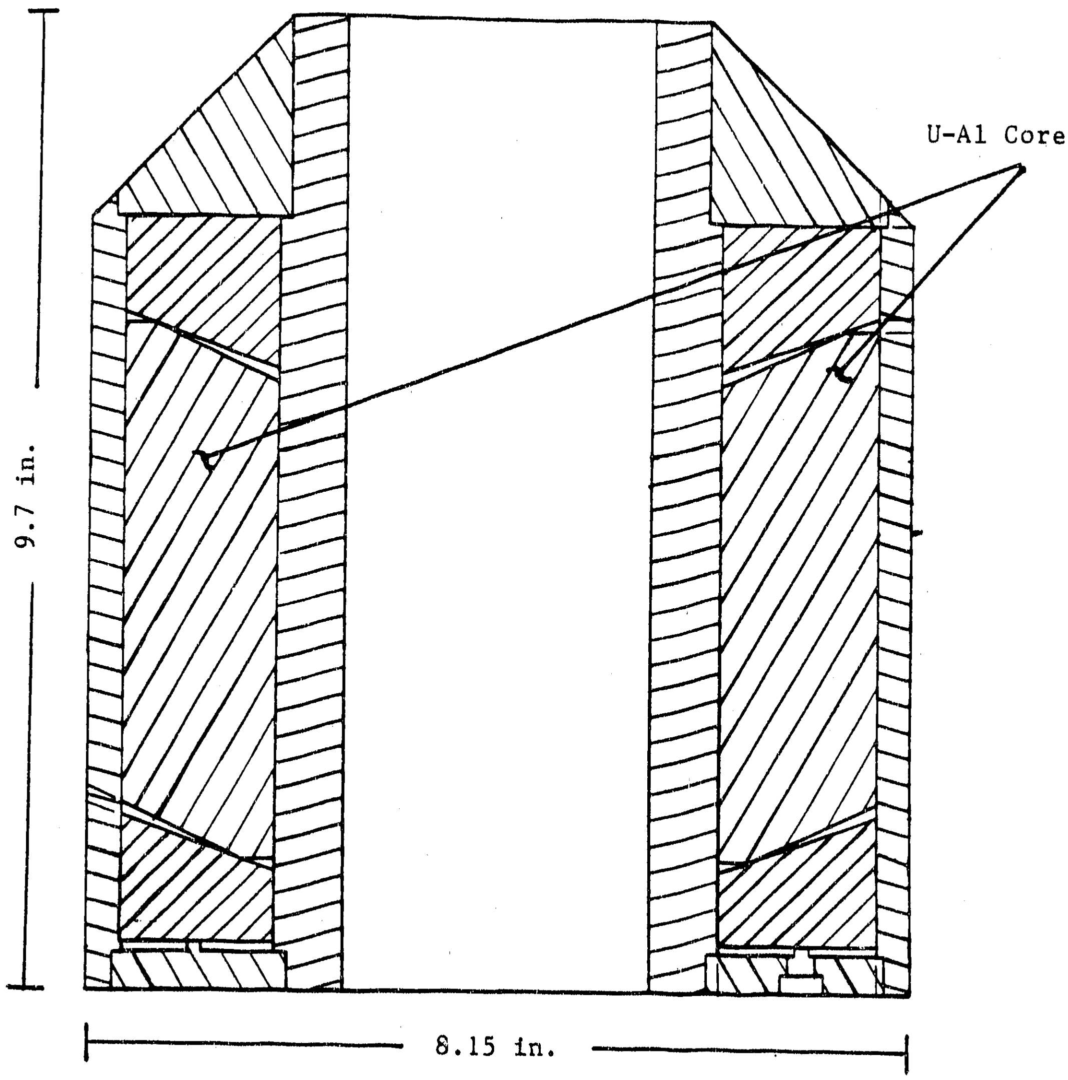

Figure 1. Cross-section of a typical SRS coextrusion billet

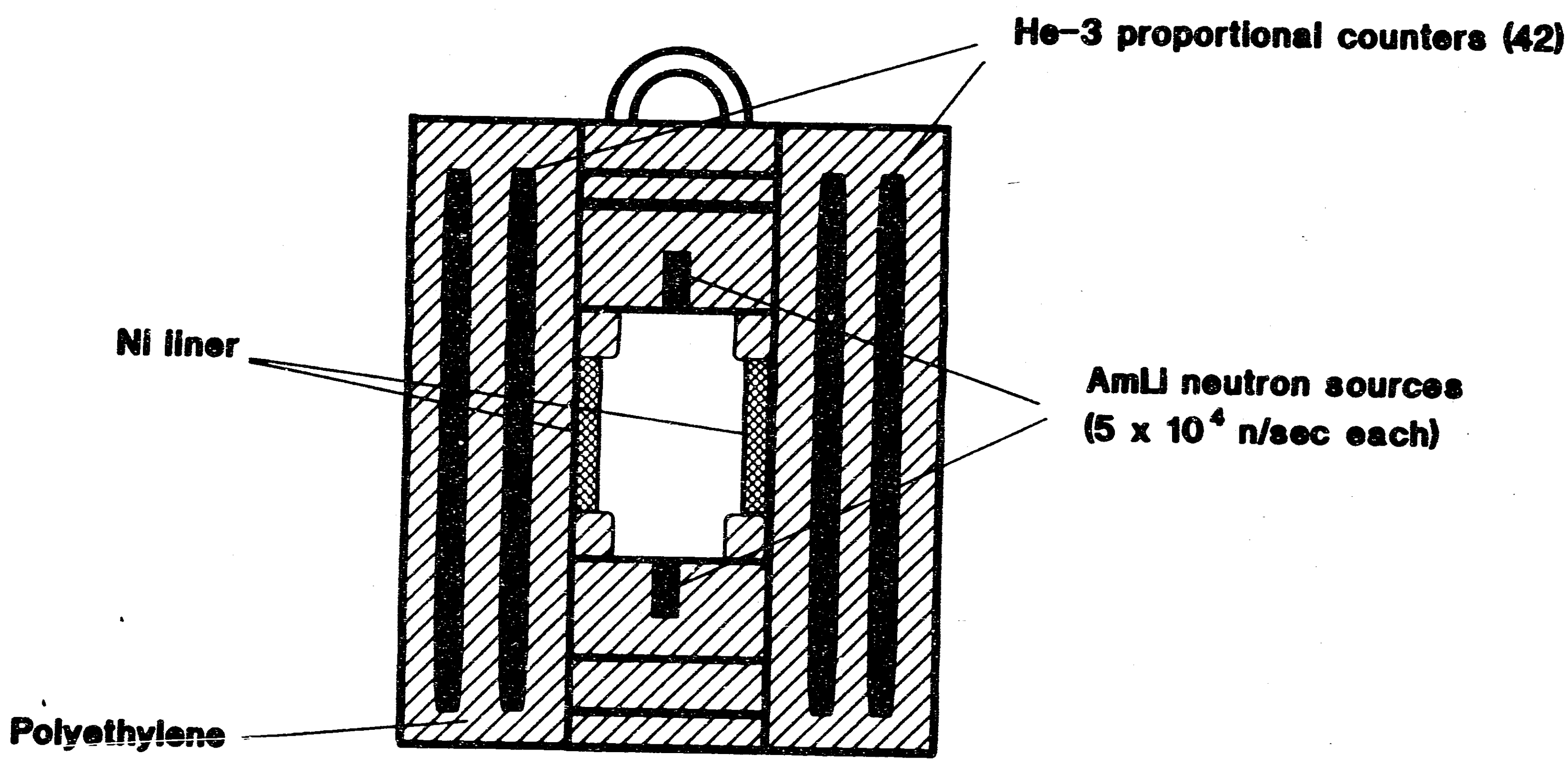

Figure 2. Standard configuration of AWCC (not to scale)

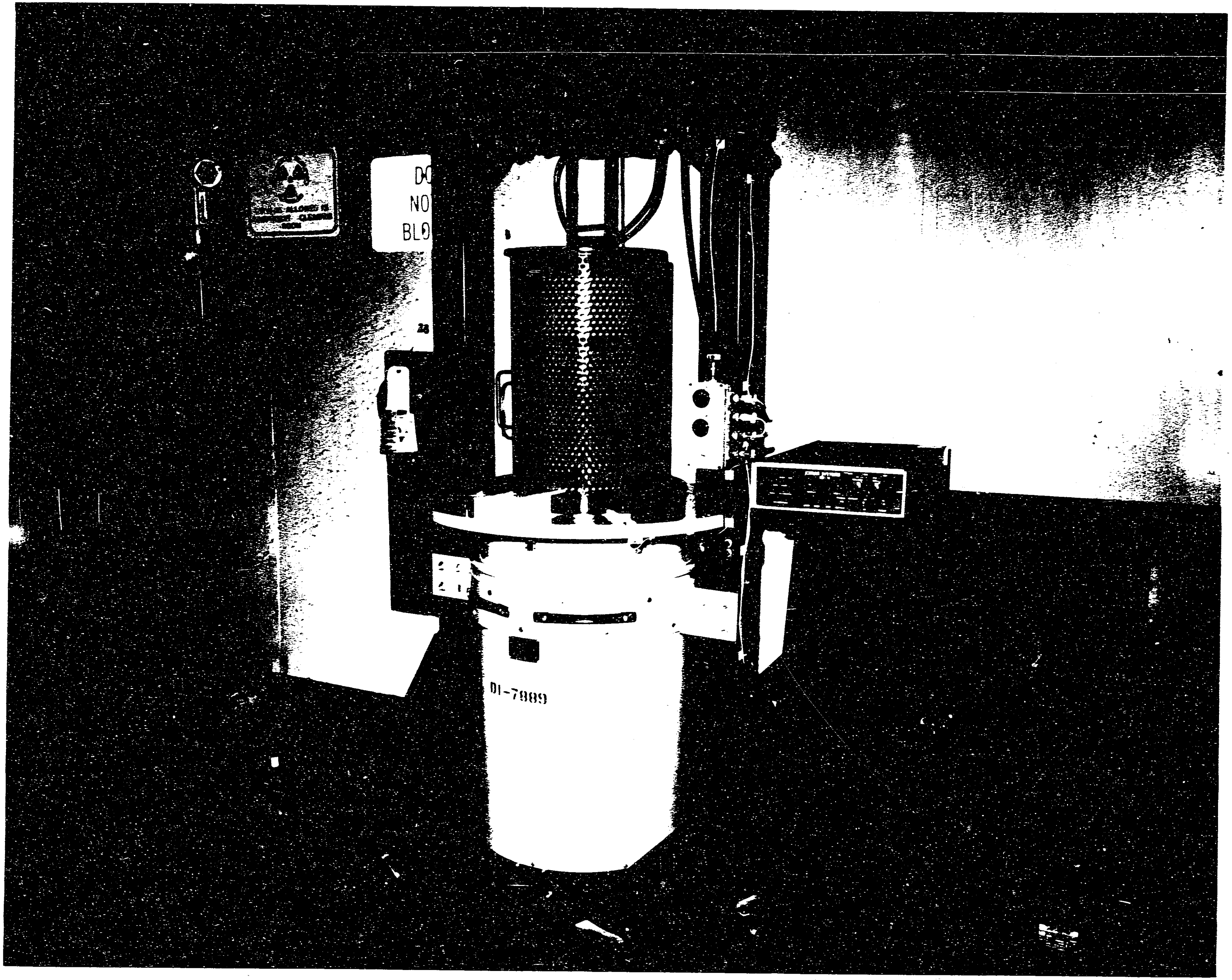

Figure 3. SRS Billet Active Well Coincidence Counter (BAWCC).

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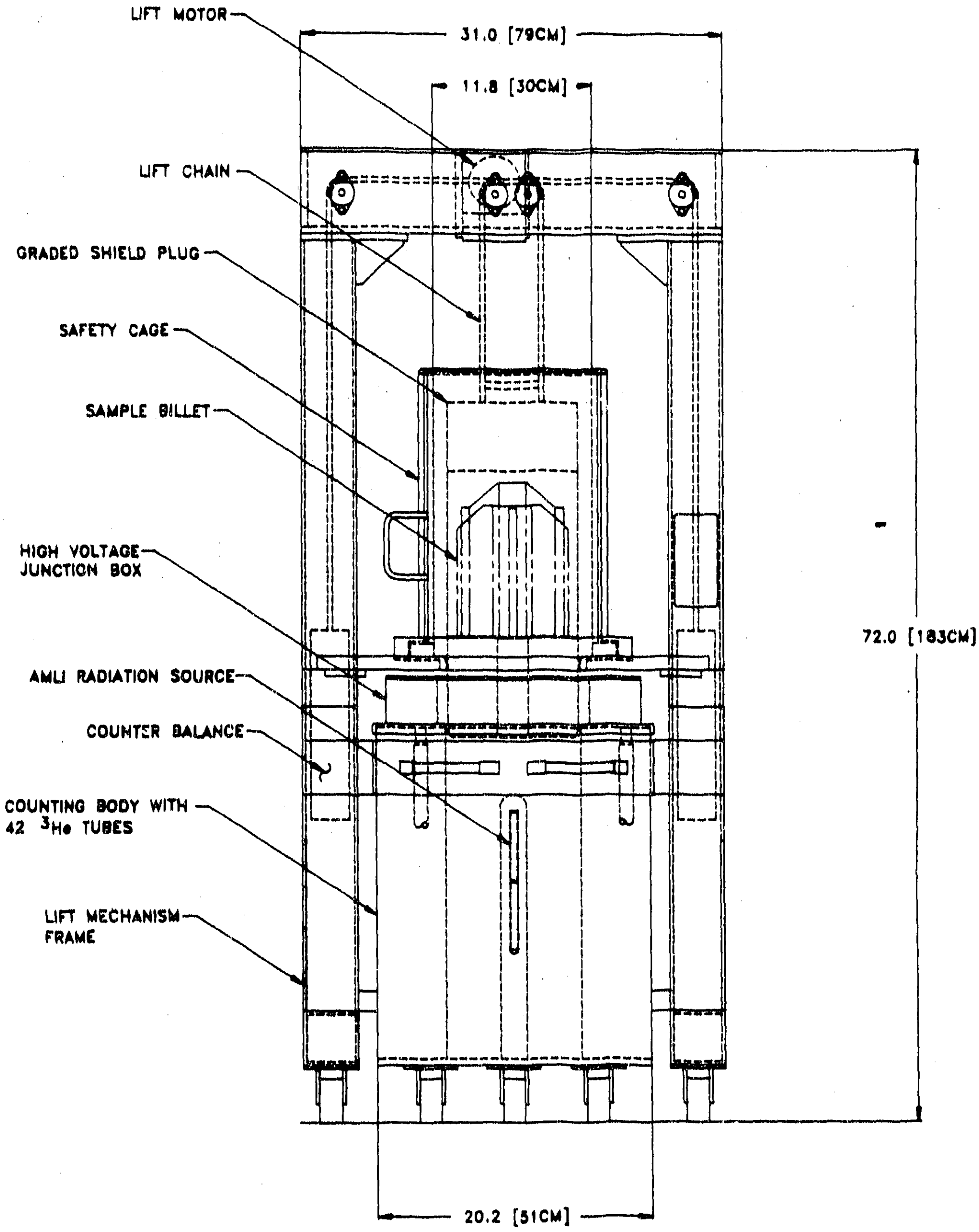

Figure 4. Schematic of Billet Active Well Coincidence Counter. Total weight is approximately 600 lbs. (Used with permission of Jomar Systems Division of Canberra Industries.)

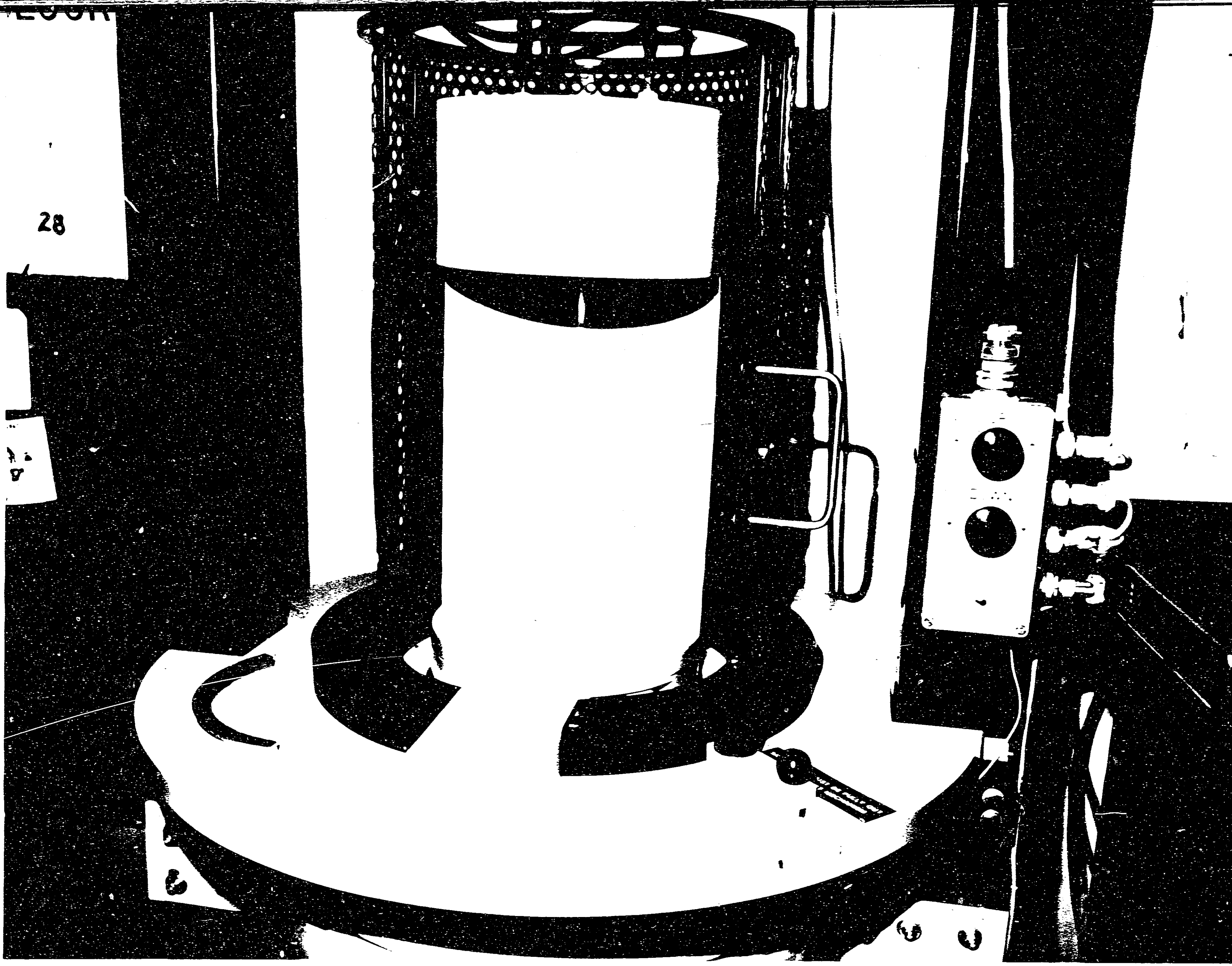

Figure 5. Elevator assembly for the BAWCC. The polyethlene block in the lower center is used to slide billets onto the elevator. Aluminum wedges for centering the billet types are shown: one on the elevator and one to the left of the elevator. Note the "up/down" buttons on the right.

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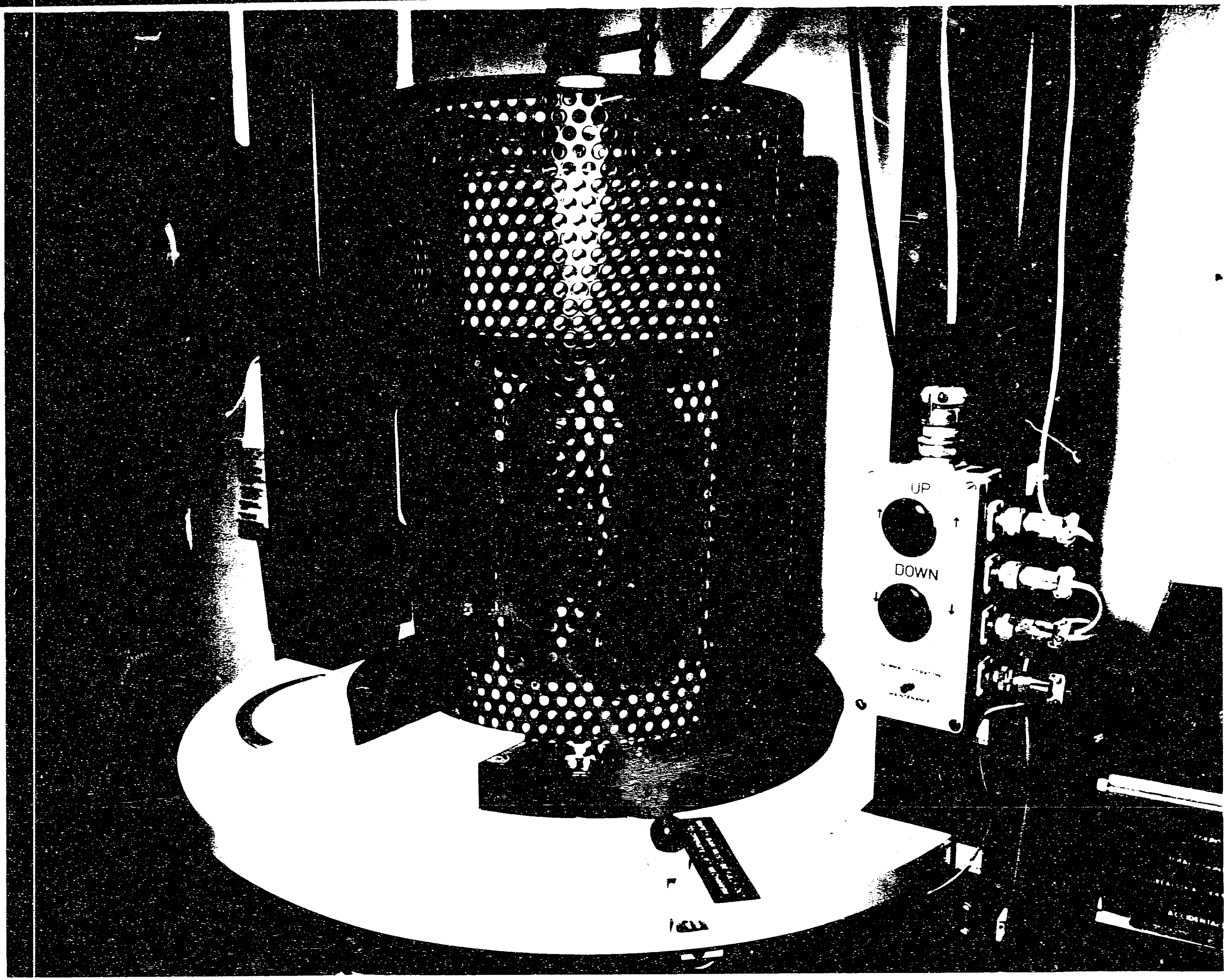

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Figure 6. Safety cage around BAWCC elevator assembly.

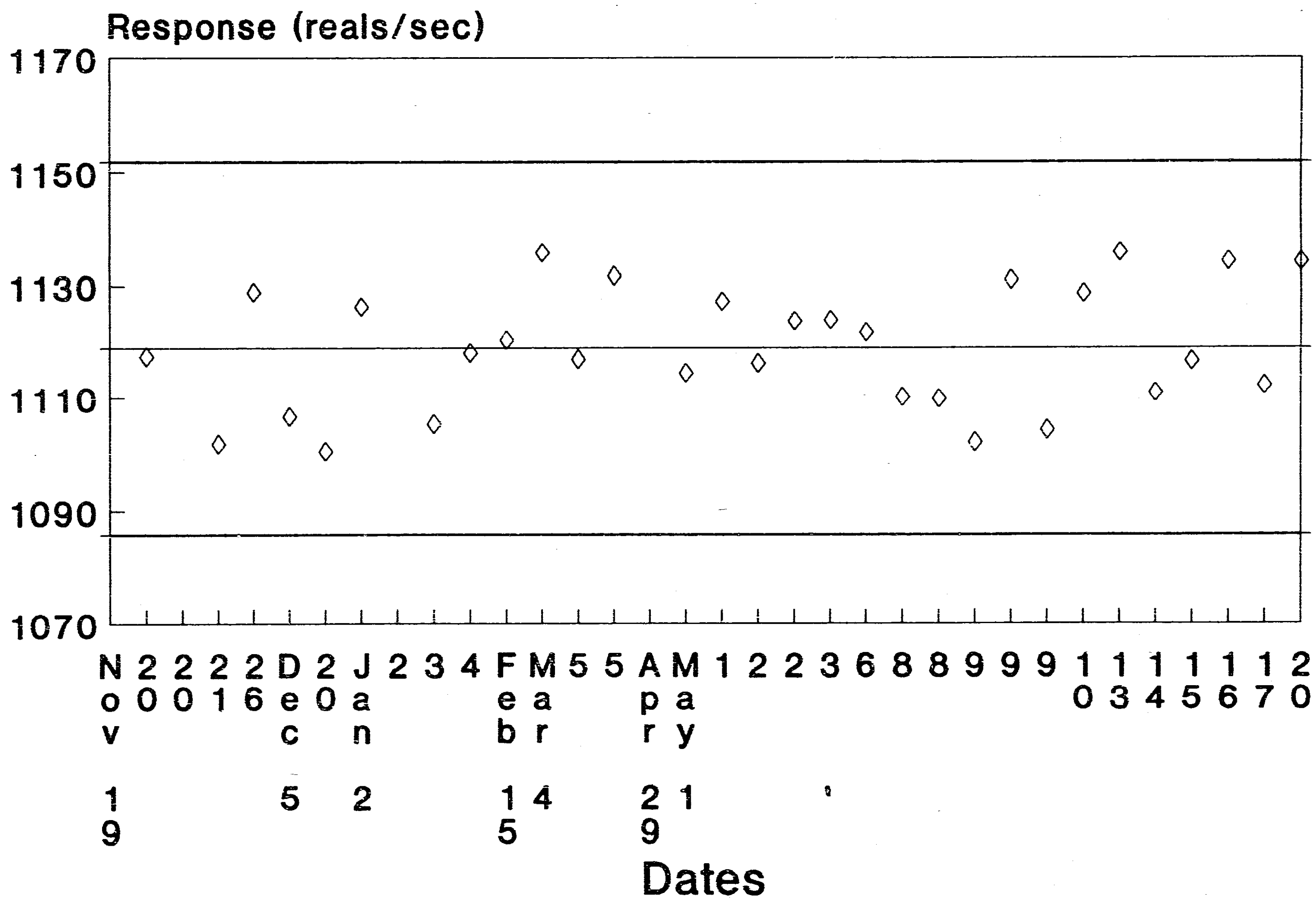

Figure 7. Plot of BAWCC stability check measurements on WT3016 over seven month period. The center line is the measurement average. The bold lines are the three-sigma control limits.

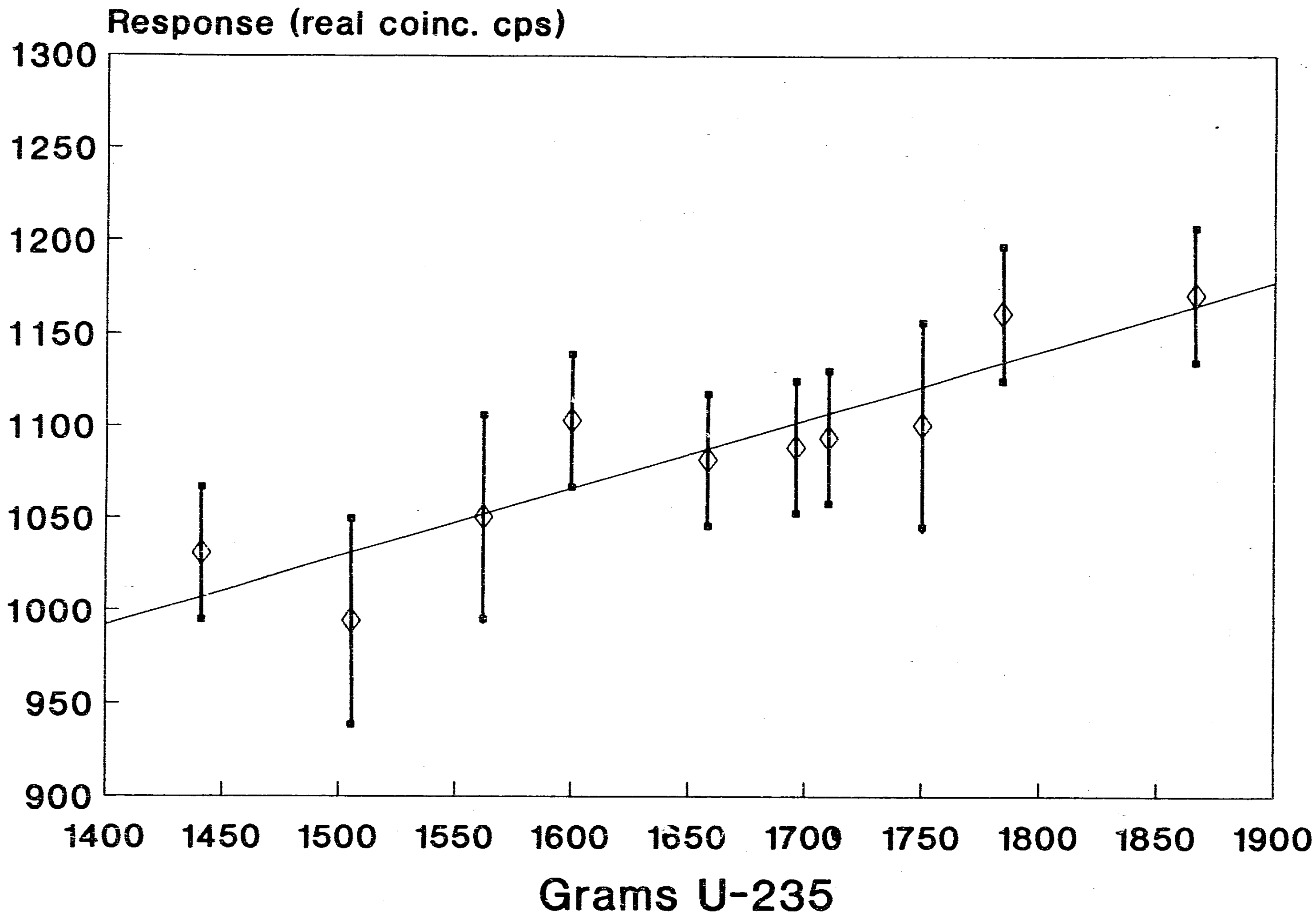

Figure 8. Least-squares fit of BAWCC coincidence response vs. ^{235}U mass for BO billets of various enrichments. Error bars are three-sigma uncertainties.

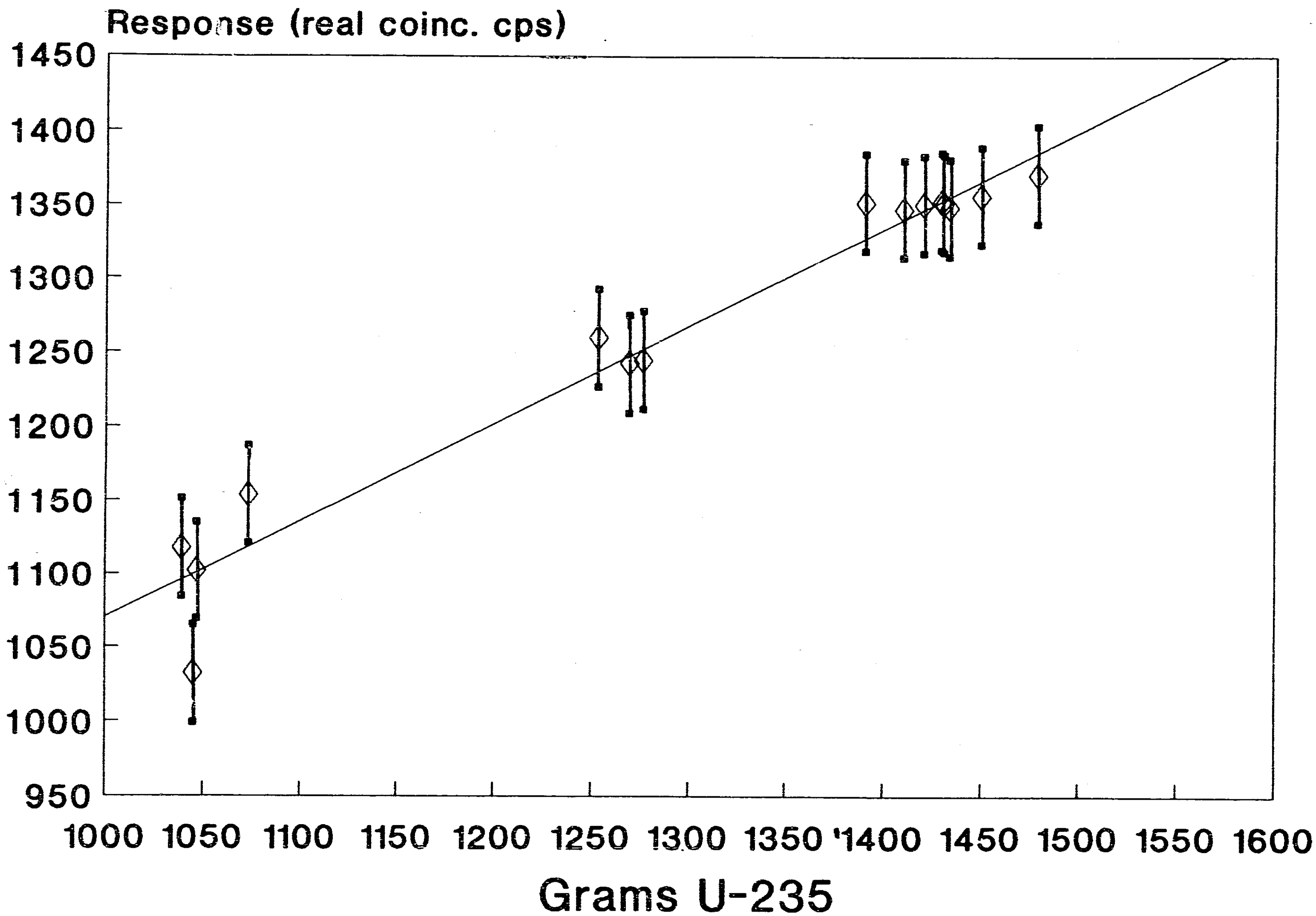

Figure 9. Least-squares fit of BAWCC coincidence response vs. ^{235}U mass for BI billets of various enrichments. Error bars are three-sigma uncertainties.

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