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INSTRUMENTATION AT THE LOS ALAMOS CRITICAL ASSEMBLY LABORATORY*

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Summary

A summary is presented of the various types of electronic instrumentation used at the Los Alamos Critical Assembly Laboratory. Also discussed is automatic data handling equipment as well as the nature of command and readout signals used on remote control critical assembly machines. Equipment is described for performing prompt neutron lifetime measurements by the Rossi- α method, pile oscillator technique, and the power fluctuation experiment.

The critical assemblies facility at Los Alamos Scientific Laboratory is located several miles from the main technical area and is situated in the fork of two canyons which flow together forming Pajarito Canyon. Gross features of the installation are the main building containing offices and control rooms and three separate test area buildings called "Kivas," housing various remotely controlled critical assembly machines (Figure 1). Each Kiva is located approximately 1/4 mile or more from each other.

Electric motors, valves for pneumatic cylinders, hydraulic pumps, and valving for each critical assembly machine are operated by Kiva relays which are energized from the control room.

Position indicators are generally provided for transmitters (geared to control hydraulic lifts, etc.) which drive syn receivers via long line hard wire connections. Figure 2 shows a standard type of drive mechanism: a motor driven lead screw coupled to a rack and pinion gear providing motion for a rotary control rod.

Neutron detection instrumentation for monitoring critical or subcritical configurations is relatively standard commercial equipment. Each Kiva-control room complex contains the following basic units.

1. Low level for startup and sub-critical measurements: four BF₃ proportional counter channels in "Long Counter" geometry feeding into scalers in the

control rooms. Figure 3 shows these counters monitoring a typical experiment.

2. High level for critical operation: two ion chamber channels using linear amplifiers to drive strip chart recorders.

3. Safety monitors: three B¹⁰ lined ion chamber channels feeding log amplifiers which provide power level and period scrams. It is noteworthy that for these log channels the ion current is sent directly over 1/4 mile of RG63 cable to amplifiers in the control rooms. A linear and log ion chamber installation is shown in Figure 4.

A major portion of the instrumentation used at the Pajarito Critical Assembly Site has been tailored for specific experimental investigations. One such device is an oscillating control rod, synchronizing an RIDL 400 channel analyzer which stores counts from an internal fission chamber. Figure 5 diagrammatically shows the experimental setup for measuring the zero power transfer function of an assembly. The oscillator rod rotates continuously in one direction, alternately shading and unshading a set of poison-vanes in the core. This causes a change in the reactor reproduction factor of $\Delta K \approx A \sin \omega t$. A notched wheel rotating with the control rod (shown in Figure 6) interrupts a light beam 100 times per revolution causing the channel address of a 400 channel analyzer (operating in the externally synchronized time analyzer mode) to be advanced 100 channels. One of the notches is deeper and triggers a second light beam once per revolution, causing the channel address to be reset to zero, thus synchronizing the channel address with oscillator rod angle. Stored counts are then displayed as a function of time, since ω is held constant during the data accumulating period. Values of ω range from several seconds per cycle to about 20 cycles per second.

The Rossi- α method of determining the prompt neutron fission chain decay rate is based on a measurement of the average time distribution of pairs of

counts due to neutrons from a common ancestor in a neutron chain. Time analyzing equipment designed to measure β_{eff} is shown in the block diagram of Figure 7.¹ Counts are supplied to the input by an incore fission detector and the "first" count received initiates a sawtooth ramp which goes simultaneously to 11 discriminators. These discriminators are set in 15 volt increments to cover the major portion of the ramp height. Outputs of the discriminators provide gates to separate coincidence circuits and are designed in such a way that when a succeeding discriminator is triggered it turns off the preceding discriminator and coincidence circuit. The right hand side of all coincidence units are driven in parallel by a narrow pulse initiated for each input count. Thus only one coincidence unit is on at a time and its duration is determined by the length of time required for the ramp to rise through a 15 volt interval. Output pulses from the coincidence units are stored in 10 scalars giving a display of counts as a function of time from the sweep initiating counts. After the sweep has run out, a short "off" time is required before another count can initiate a second sweep. This ensures that the sweep circuitry has indeed recovered and the sweep will start from zero volts.

Sweep slope is selected on the front panel and channel times from 0.5 μsec to 3000 μsec are available in nine steps. The equipment is shown in Figure 8 where the center rack contains the time analyzer, the left rack holds the "Input" and "Sweeps" monitor and the right rack is an array of ten scalars with automatic readout instrumentation for the ten time channels.

An alternate scheme² of providing 10 time channels is shown in Figure 9 and has proven most useful for short channel widths (0.25 and 0.5 μsec). In this case the channel widths are determined by the duration of a square gate sent down a tapped delay line. Transit time between taps is identical to the width of the gate and hence only one coincidence unit is gated "on" at a time. Each input count, in addition, initiates a narrow pulse to drive the right side of all coincidence units simultaneously. Ten scalars driven by the outputs of the coincidence units show the time relationship between counts following counts provided they occur within the maximum delay time of the equipment.

Reactor statistical fluctuation measurements are made by the so-called "1/2" experiment which leads to determination of the prompt reactivity of a

critical assembly system. The "mean square deviation from the mean" of the number of counts in a time interval is a measure of the deviation of a chain reacting neutron source from a random source ($(\bar{N} - N)^2$ where N is the average number of counts in a fixed interval of time). The experiment consists of observing the number of counts from an incore fission counter during a constant and repetitive time interval ΔT . The expression $(\bar{N}^2 - \bar{N}^2)/\bar{N}$ is then a function of the prompt criticality of the system. Figure 10 is a block diagram and Figure 11 a photograph of the equipment³ which automatically records the number of ΔT cycles, the sum of N over all cycles (ΣN), and the sum of N^2 for all cycles (ΣN^2).

Counts from an incore counter are continually arriving at the "Input" and pass through the "count gate" for a time ΔT determined by the "Gate Generator." These counts are sent to the " ΣN " scaler, which keeps a running total of N ; they also go to a "Counts" storage register of 6 binary bit capacity. Squaring is produced by adding N to the " ΣN^2 " register N times. The value N is stored in the "Counts" register and the number of triggering pulses for the adding process are accumulated in the "Follow-Up" register. When "Follow-Ups" become equal to "Counts," the squaring process is stopped and both registers are cleared. The next counting cycle begins and a new N is stored in "Counts."

An Electronic Associates model TR10 analog computer is shown in Figure 12 with associated equipment and programming for solving the reactor kinetics equations. The computer is programmed to accept an input signal from a linear ion chamber channel and deliver reactivity in dollars as the output. Readout is obtained from a digital voltmeter display or an X-Y plotter. The X-Y plotter may display reactivity vs. time or control rod position and has proven to be of considerable assistance in calibrating control and safety rods. The instrument is scaled for $\pm 2.00\%$ from delayed critical and is accurate to approximately $\pm 1\%$ of indicated value of reactivity.

Figure 13 is a photograph of a gamma ray counting system utilizing an automatic timing and readout system. A NaI(Tl) scintillator and phototube are contained in the lead shield at the left and count samples placed on the shelf above. The rack at the left contains the high voltage power supply, linear amplifier and single channel pulse height analyzer. Output of the single channel analyzer goes to the printing scaler at the bottom of the right

rack. This rack also contains a timer for off-on time control and an identification chassis whose panel knobs are read out and recorded on the Victor printer and Friden eight track paper tape punch shown in the center of the picture. All of the equipment mentioned except the high voltage power supply is of Los Alamos design.

An automatic foil changer gamma counting system⁴ is shown in Figure 14. The changer mechanism is a Wurlitzer Juke Box with record selection determined by a punched paper tape reader. The automatic readout system which has been described earlier is used with the juke box and counting "on-off" times, as well as sample changing, are determined by the associated master clock. Tape loops may be used for unattended overnight counting while the versatility of the system is still maintained by the complete freedom one has in preparing the control tape. The records are replaced by steel discs which hold 1/2 inch diameter by 0.001 inch thick U-235 foils. The changer lifts a steel disc from the storage basket and positions it in front of a 2" x 2" NaI(Tl) scintillation crystal inside the lead shield. An extra disc and phototube-crystal assembly are shown outside the shield in the photo.

Figure 15 is a photograph of a time delay analyzer of Los Alamos design which is capable of automatically sequencing through time channels of different widths. Front panel selection is provided in units of 10, 20, 30, and infinity for the number of channels of each width (0.001, 0.01, 0.1, 1.0, and 10 seconds). The selected number of 0.001 second channels are used and then the instrument switches to 0.01 second channels, and so on, finally providing an infinite number of 10 second channels. Readout of the time channels is via electrostatic pens on sensitized strip chart paper.

Fine-structure fission distributions are measured by an autoradiographic technique based on transferring the record of fissions in a 0.001" U-235 monitor foil to X-ray film. A recording photographic densitometer for scanning this

is shown in Figure 16. It is equipped with a motorized "angular scan" device and also has a linear scan lead screw advance built into it. Automatic readout of position (either X or θ) and film density is provided for printed and punched paper tape. Potentiometric

position transducers and the output of the densitometer amplifier provide analog signals which are digitized by a Kin-Tel logical voltmeter, alternately reading position and density of the film. The

chassis shown in the photo interprets the voltmeter output and drives a Friden 8 track paper tape punch along with a Victor printer. Run identification knobs are provided on the front panel.

The critical assembly laboratory has recently acquired the pulsed neutron generator shown in Figure 17. It consists of a Cockroft-Walton accelerator at the right, beam analyzing magnet in the center with the target at the extreme left in the photo. Electrostatic deflection plates sweep the beam across a slit to produce a "pulsed" beam at the target. Neutron pulses resulting from d,T reaction on the target may be varied in width from 3×10^{-3} to 10^{-8} sec and the corresponding neutron yield per pulse is 6×10^8 to 2×10^3 . Repetition rate may be varied from 10 cycles/sec to 1 megacycle. The machine is the result of a joint venture by Applied Radiation Corporation, the parent company, High Voltage Engineering, and the Los Alamos Scientific Laboratory.

1, 2, 3 Designed by C. W. Johnstone presently of Schlumberger, Inc.

⁴ 100 Foil Sample Changer with Tape-Controlled Sequencing, C. G. Chazem and H. H. Helmick, Nucleonics, March 1963, Vol. 21, No. 3, p. 83.

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