the $^{23}Na(n\gamma)^{24}Na$ reaction (σ = 530 mb), while the fast neutron flux will be measured by the $^{27}Al(n,\alpha)^{24}Na$ (σ = 115 mb), the $^{55}Mn(n,2n)^{54}Mn$ (σ = 1000 mb), and the $^{56}Fe(n,p)^{56}Mn$ (σ = 105 mb) reactions. The reaction product yields will be determined from the γ-ray activity of the decay products. The $^{27}Al(n,\alpha)$ reaction permits the measurement of the fast-to-thermal ratio independent of detector efficiency and of uncertainties in the nuclear decay scheme properties. The use of the $^{55}Mn(n,2n)$ reaction (threshold = 10.41 MeV) permits the measurement of the contribution of the Li^6D-produced neutron flux, independent of the reactor fission neutron flux.

The possible use of Li^6D as a source of 14-15 MeV neutrons for activation of products for nuclear spectroscopic studies is very much dependent on the fast-to-thermal ratio we obtain. With a projected thermal flux of 10^{14} n/cm^2·sec and a conversion ratio of 10^{-4}, we should be capable of competing with accelerator-produced DT neutrons (maximum: 10^{10}n/cm^2·sec at the target) using Ti-T targets for producing activities with halflives below 10 hours and arising from reactions with $\sigma \approx 10$ mb. However, if the conversion ratio is only about 10^{-5}, we will be limited to the study of activities with $T_{1/2} \leq 1$ hour and with $\sigma \approx 100$ mb. (C. Papanicolopulos and R. A. Braga)

4.0 X-RAY AND ELECTRON SPECTROSCOPY WITH RADIOACTIVE SOURCES

4.1 L_1-subshell x-ray fluorescence and Coster-Kronig yields

Preliminary work on the measurement of the mean L_1-subshell x-ray fluorescence yield ν_1 of Gd (Z = 64) through the decay of 1.81 year ^{155}Eu was attempted with our cooled, windowless Si(Li) electron detector in coincidence with a second Si(Li) x-ray detector. This experiment consists of gating L x-ray spectra with L_1-subshell conversion electrons. It failed from several experimental difficulties, primarily the inability of our electron detector to detect electrons below about 50 keV and the low coincidence geometry. We then made a survey of all possible radioactive sources that might be suitable for L_1-subshell measurements using this method, and found that for one or more reasons, such as excessive nuclear cascading in the decay scheme, low energy L_1 electrons, poor true/chance coincidence ratio, or low counting rates, none would give a successful experiment. Cases considered include ^{155}Eu, ^{233}Pa, ^{201}Tl, ^{195}Au, ^{159}Dy, ^{139}Ce, ^{191}Os, ^{175}Hf, and ^{181}Hf. Cases which would work (low nuclear cascading) but where the L_1 conversion electrons lie below 50 keV where our detector has inadequate sensitivity are ^{201}Tl, ^{191}Cs, ^{195}Au. Cases which would offer some good

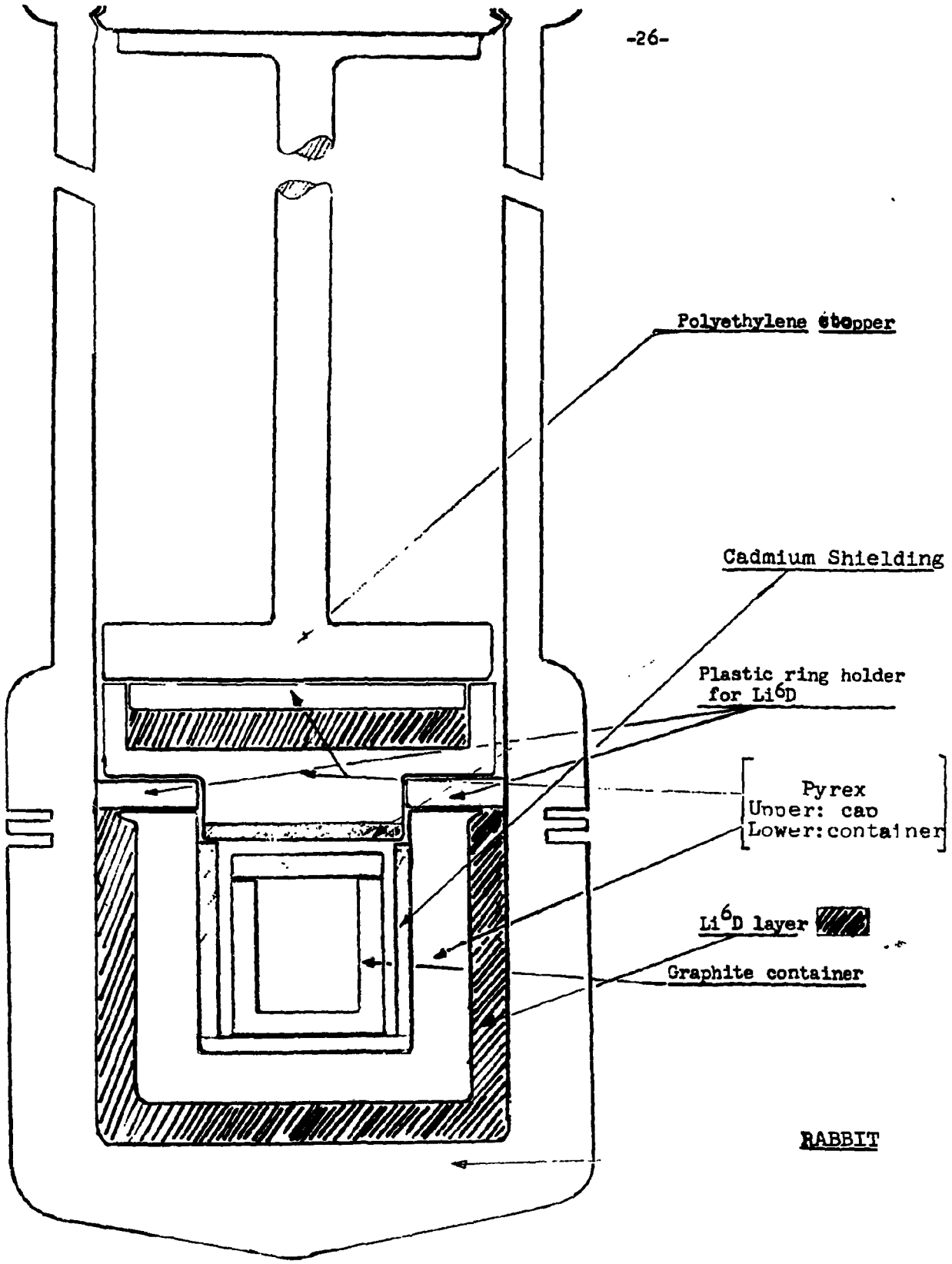

Fig. 9

D R A W I N G : Front side of the Rabbit

possibilities for this measurement also are ^{243}Cm, ^{245}Cm, and ^{247}Bk, but we are unable to obtain thin, vacuum-deposited, or isotope-separated sources of these nuclides. For these reasons, the program of measurement of L_1-subshell quantities with our electron detector has been abandoned. We are using this detector for higher energy conversion electron spectroscopy instead. (W.S. Lewis and M.S. Rapaport)

In general, conversion electron spectroscopy requires the preparation of very thin sources to avoid self-absorption problems. In addition, point sources (< 2 mm dia) are required for precise comparison of detector efficiency obtained with different sources. We therefore have investigated a method for preparation of thin, point sources which involves the carrier-free micro-electroplating of the radioactive isotope from an organic solvent. This "molecular plating" technique, first described by Parker[34], involves the formation of a metal complex with the solvent at a high voltage gradient (1000 volts/cm). The metal complex migrates to the cathode and precipitates, the rate of deposition being a function of the current. We used low currents which increased the source homogeneity at the expense of longer plating times.[35] Currents and voltages were continuously monitored during the plating.

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[34] W. Parker, et al. Nucl. Instr. & Meth. 26, 255 (1964).
[35] N. Getoff, et al., Nucl. Instr. & Meth. 46, 308 (1967).

Such plated sources were prepared from solutions of $^{241}Am(NO_3)_3$, $^{57}CoCl_2$, and $^{137}CsNO_3$ in isopropanol solvent. Some 10 to 15 microliters of aqueous radioactive solution was injected into 2 ml of solvent in a Teflon plating cell. The plating was done on 2 mil (0.002-inch) Be cathodes at 1000 volts/cm and currents ranging from 0.4 to 10 milliamps. The plating time was from 2 hours for ^{241}Am to 5.7 hours for ^{137}Cs. The microplating cell consisted of a thermostated Teflon cylinder tapered to a cylinder 2 mm high and 1.5 mm dia. near the cathode. The plating solution was coaxed into this capillary by applying a piece of dry ice to the bottom of the cathode backing material. The small diameter plated source resulted in extremely poor plating efficiency for the amount of time required for source preparation. Typical efficiencies were 8%, 0.8%, and 0.3% for Am, Cs, and Co, respectively. However, this technique could be quite useful when extremely high specific activities are to be deposited as a "point" source. This work constitutes a section of the PhD thesis of Mr. W. S. Lewis. (W. S. Lewis)

4.2 Measurement of Mean L-Fluorescence Yields from Double Vacancy States in Indium

The electron capture (EC) decay of ^{113}Sn (115 days) is a very convenient source of double vacancy atomic states in indium (Z = 49). Vacancies in the K shell are created both in K-capture decay (P_K = 0.75) to the 392 keV level in indium, as well as in the internal conversion of the 392 keV transition (α_K = 0.44). Thedecay of these K-shell vacancies through K-Auger electron emission leads to final atomic states in In characterized by double (LL)- and (LX)-vacancy states.

The principle is to measure L x ray spectra in coincidence with K-shell conversion electrons, the counting rate of the coincidence spectra being $C_{L(e_K^-)}$ and to compare them with L x rays in coincidence with K_α x rays, $C_{L(K_\alpha)}$. The ratio of these two coincidence rates is related to the average L x-ray yields in the following way,

$$C_{L(e_K^-)} / C_{L(K_\alpha)} = (C_{e_K^-} / C_{K_\alpha}) [n_{KL}(A)(\bar{\omega}_L(2)/\omega_{KL}) + n_{KL}(R)$$

where $C_{e_K^-}$ is the number of K-shell conversion electron gate counts, C_{K_α} is the number of K_α x-ray gate counts, $n_{KL}(A)$ is the number of L-shell vacancies present in the double vacancy states per K-shell vacancy, $n_{KL}(R)$ is the number of L-shell vacancies present in single vacancy states (created by the emission of a K_α x ray) per K-shell vacancy decay, $\bar{\omega}_L(2)$ is the mean L x-ray fluorescence yield of the double-vacancy atomic states, and ω_{KL} is the mean L x-ray fluorescence yield following K_α x-ray emission.

The values of $n_{KL}(A)$ and $n_{KL}(R)$ can be calculated from experimental data on Auger electrons and x rays for Z = 49 published in the literature. If there is a substantial increase in the mean L-fluorescence yield of double vacancy atomic states as compared to that of single vacancy atomic states, as had been expected from studies at lower Z in charged particle bombardment studies, this experiment should give results to an accuracy in the range of 10 - 20 percent, the main limitation in accuracy being our knowledge of the quantity $n_{KL}(A)$ at Z = 49.

A microCurie drop-evaporated source of ^{113}Sn was prepared on a thin Mylar film. High resolution, cooled Si(Li) detectors are employed to detect indium L x rays (≈ 3.5 keV), K x rays (24-28 keV), 392 keV K-shell conversion electrons, and 392 keV L,M,N··shell conversion electrons. A fast-slow coincidence system in conjunction with a Nuclear DAta ND-4420 multiparameter analyzer is employed

to measure the coincidence rates. The amplifiers (TC-205 and TC-205A) are adjusted so that one ADC unit accepts L x rays and K x rays, while the other ADC unit accepts K x rays, K-shell conversion electrons, and L,M,N···-shell conversion electrons. The prompt coincidence events are selected by gating the ADC units with pulses derived from a TAC unit which correspond to prompt coincidence events. A special feature of the decay of ^{113}Sn is that the 392 keV level lies between atomic states created in the EC decay and those created by internal conversion (ie, there is no nuclear cascading).

In addition to the experiment on the double vacancy yields currently in progress, an attempt will be made to find answers to some of the remaining questions concerning the EC decay of ^{113}Sn. For example, a better experimental value for P_K, the total K-capture probability, or the ratio P_L/P_K, the ratio of probabilities for L and K capture, can be obtained using the fluorescence yields measured in the present experiment, if one can obtain an accurate value for the ratio of the L and K x-ray intensities, I_L/I_K, in this decay.

Plans are underway to modify the geometry of the windowless, gate-valved, cooled Si(Li) electron detector housing to improve the coincidence geometry, which is too low to permit the L_1-subshell measurements described in Sect. 4.1. This modification also will permit its use as an x-ray detector.

(Drs. P. Venugopala Rao and D. W. Nix)

5.0 EQUIPMENT ADDED DURING 1975

Our Nuclear Data Dual-parameter ND-4420 computer-based analyzer was expanded this year with a third ADC unit and an additional 4K of buffer memory at a cost of $3950 in non-ERDA funds. The analyzer now has a total of 11,288 words of memory available for data storage. This expansion allows the simultaneous acquisition of data from two detectors and a time-to-amplitude (TAC) converter to be stored in three 2000-channel groups. All energy events and their time relationship can be recorded on the magnetic tape while displaying selected portions of the spectrum. During August, 1975, the analyzer was returned to the factory near Chicago for a thoroughgoing repair of the multiparameter unit, and is now operating well. (W. S. Lewis)

We have on order a new Ge(Li) γ-ray and x-ray detector which has state-of-the-art specifications: 1.65 keV FWHM or better guaranteed resolution at 1332 keV at 1000 counts/sec (^{60}Co source) and deadlayer shaved to less than 200 microns for good x-ray detection down to 22 keV (^{109}Cd source). The efficiency is 6% or better at 1332 keV of that for 3 x 3-inch NaI(Tl). A 3000-volt Tennelec TC-941 bias supply and a Canberra Model 1412 spectroscopy amplifier,