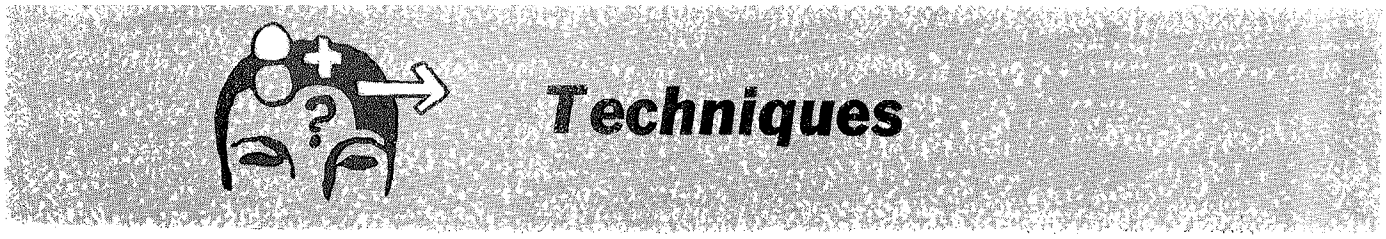

C. L. McCARTY, JR., Editor

Automation of the Radioisotope Accountability System

ELAINE L. LAHNERS
Veterans Administration Hospital, Omaha, Nebraska

The Radioisotope Service of the Veterans Administration Hospital, Omaha, Nebraska, used a manual system of radioisotope accountability for three years. The procedure which was satisfactory but time-consuming was converted from manual to a fully automated computer system in January, 1963. The program for purchased radioisotopes is written in FORMAT FORTRAN for the IBM 1620 Computer. A second program for maintaining accountability for reactor-created radioisotopes is written in the FORCOM programming language. A minimum amount of bookkeeping is required by the reactor operating staff. The United States Atomic Energy Commission regulations specify that records be kept. This system provides detailed records for each container of radioactive material purchased and/or created in the Triga reactor indicating the amounts received, used, and/or transferred to the health physicist for disposal. Consolidated records contain total amounts received, used, and/or disposed of for any specified period of time. Purchased radioisotopes are reported in millicuries; reactor-created radioisotopes in microcuries.

Introduction

The Radioisotope Service of the VA Hospital, Omaha, Nebraska, used a manual system of radioisotope accountability [1] for three years. The procedure which was satisfactory but time-consuming was converted from manual to a fully automated computer system in January, 1963. The program for purchased radioisotopes is written in FORMAT FORTRAN (Figure 1) for the IBM 1620 computer. A second program for maintaining accountability for reactor-created radioisotopes is written in the FORCOM programming language (Figure 2). A minimum amount of bookkeeping is required by the reactor operating staff. The United States Atomic Energy Commission regulations specify that records be kept. This system provides detailed records for each container of radioactive material purchased and/or created in the Triga reactor indicating the amounts received, used, and/or transferred to the health physicist for disposal. Consolidated records contain total amounts received, used, and disposed of for any specified period of time. Purchased radioisotopes are reported in millicuries; reactor-created radioisotopes in microcuries.

Methods and Results

When a radioisotope is purchased, the information shown on the container label and the User's Report (Figure 3), indicating use or disposal, is punched into cards and verified. All computations are done by the 1620 Computer thus eliminating human errors in arithmetic.

All manual posting is eliminated and all computations are printed by the IBM 1620 console typewriter. A complete detailed history of each container of radioactive material with remaining activity indicated is shown in the listing (Figure 4) which includes three types of entries; namely, receipt, usage and disposal.

Each purchased isotope is identified by name, lot number, assay and date of assay. The type of the isotope is also defined—Cr-51 and I-131 could be defined as 51 1 for Rachromate and 131 3 for Radiocaps, respectively. The "1" and "3" were arbitrarily assigned to these types of isotopes.

Receipt. The first entry of the detailed record represents the receipt of the isotope and the date it is received. The information from the isotope container label is recorded in column 1, the total amount in millicuries received in column 6, and the total amount in milliliters received in column 7.

Usage. The second type of entry represents information gained from the User's Report (Figure 3). The date and patient's identification number appear in column 1. The patient's name and the test performed is punched into the card and is available for listing purposes. The amount in millicuries used is indicated in column 4, and the amount in milliliters withdrawn in column 5. The previous milliliter balance (column 7) minus the milliliters used (column 5) gives a new milliliter balance (column 7), and the product of this multiplied by the assay is the new balance which is shown in column 6. In each entry the total of column 6 and column 8 subtracted from the previous entry of column 8 reveals the amount of decay, which is entered in column 3. It is possible to know at all times the amount on hand and the millicurie strength of that amount.

Disposal. When a radioisotope is kept in active status, the listing will indicate that updating of the record is complete up to the last entry date. When the remaining amount of radioactive material is sent to the health physicist for disposal, the User's Report is filled out by the user

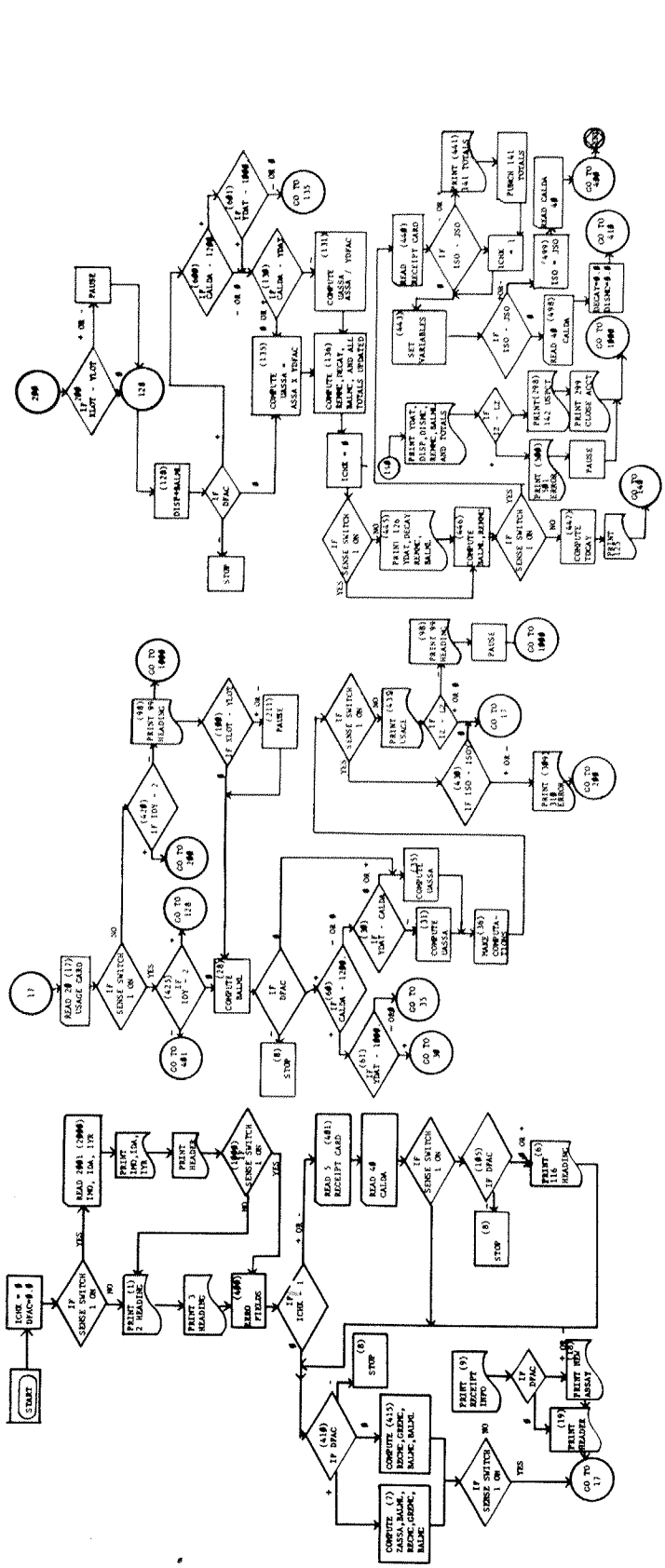

FIG. 1. Flowchart of Isotope Accountability (Purchased) program which is written in FORMAT FORTRAN

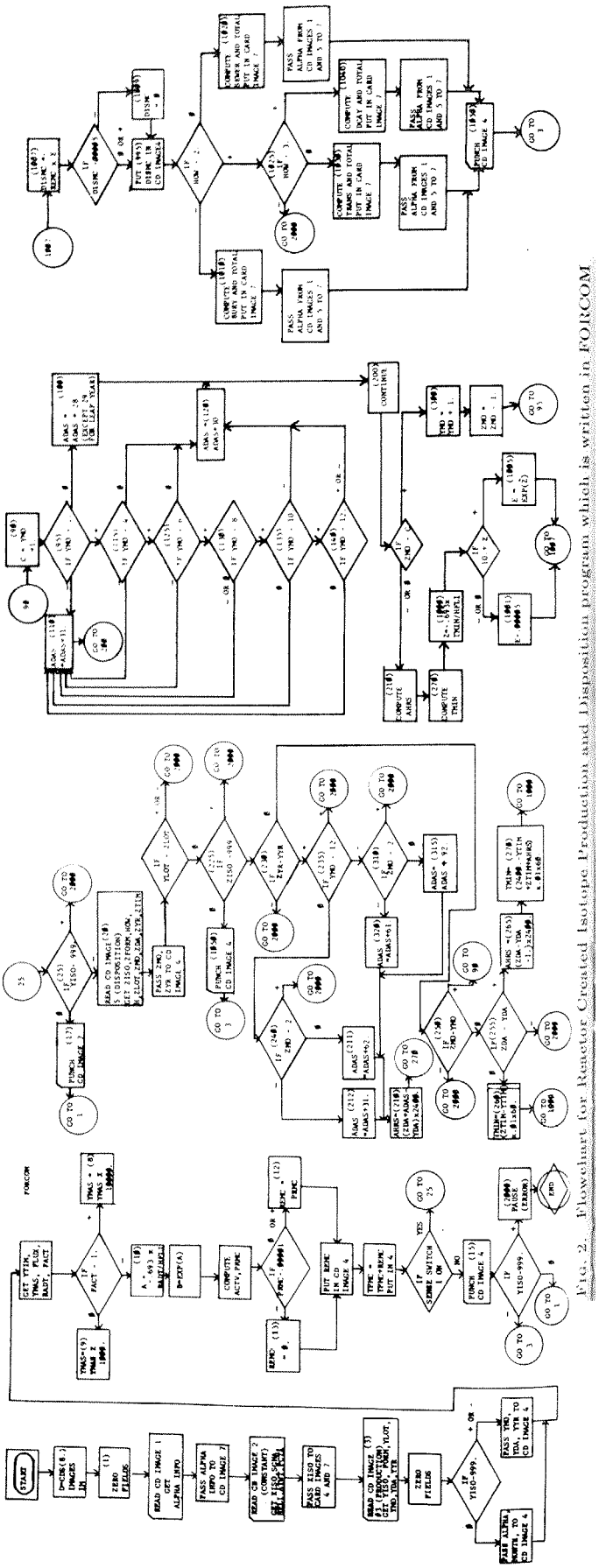

FIG. 2. Flowchart for Reactor Created Isotope Production and Disposition program which is written in FORCOM

and the words "for disposal" written on the form. The third type of entry indicates the date, the amount which has decayed since previous usage, the remaining amount in millicuries and remaining amount in milliliters. Then the next line of the record indicates the date the isotope was transferred for disposal, the milliliter amount, the microcurie amount, and the zeroing of columns 6 and 7.

The total of columns 3 and 4 must equal the first entry in column 6, i.e. the total of decay plus disposal plus used

USER'S REPORT

NAME OF ISOTOPE I-131 (cc 7-13)
LOT NO. RC 415-0 (cc 14-23)
ASSAY .048 mc/cap
DATE OF ASSAY 11-6-63
****
DATE USED 11-12-63 (cc 1-6)
DECAY FACTOR .5977 (cc 61-65)
ASSAY USED .0286896 mc/cap (cc 48-53)
ML REMOVED 1 cap (cc 54-60)
MC REMOVED .0286896
PATIENT'S U-NO 12598 (cc 24-29)
PATIENT'S NAME I. M. MALDEMER (cc 30-47)
EXPERIMENT OR TEST Thyroid Uptake (cc 73-80)
USED BY E. Elam Quick, MD.

FIG. 3. User's Report form is completed at the time an isotope is used for test or experiment. It is completed at the time remaining isotope sent to health physicist for disposal with words (FOR DISPOSAL) written on "Experiment or Test" line.

	1	2 DISP ML/CAP	3 DECAY MC	4 USED MC	5 USED ML/CAP	6 BAL MC	7 BAL ML/CAP
ISOTOPE PURCHASED MILLICURIES REPORTED.							
DATE	ISOTOPE						
1105.3	131	3 (1)				(2) .1045979E+01	20.000
LOT NO.	415.00						
SP ACT.	.00						
CONC.	.0000						
EXP DAT	0						
ASSAY .4883300E-01 AS OF 1106.3							
COST	17.00						
ASSAY .5229897E-01 AS OF, 1105.3 DATE RECD							
DATE	PT UNO						
1112.3	.12598		.4721875E-00	.2868960E-01	1.000	.5451024E-00	19.000
1118.3	.00000		.2193360E-00	.1714560E-01	1.000	.3086208E-00	18.000
1118.3	.12598		.0000000E-99	.1714560E-01	1.000	.2914752E-00	17.000
1119.3	.12356		.2399040E-01	.1573440E-01	1.000	.2517504E-00	16.000
1119.3	.08268		.0000000E-99	.1573440E-01	1.000	.2360160E-00	15.000
1120.3	.00000		.1936800E-01	.1444320E-01	1.000	.2022048E-00	14.000
1121.3	.12356		.1666560E-01	.2650560E-01	2.000	.1590336E-00	12.000
1121.3	.08268		.0000000E-99	.2650560E-01	2.000	.1325280E-00	10.000
1202.3	.00000		.8092800E-01	.1548000E-01	3.000	.3612000E-01	7.000
1231.3	DECAY		.3433920E-01			.1780800E-02	7.000
1231.3	FOR DISPOSAL	7.000	.1780800E-02			.0000000E-99	.000
1231.3	TOTAL (3)	7.000	.8685955E-00	.1773840E-00	13.000		

16.95 PERCENT OF RECD MC WAS USED.
ACCOUNT FOR THIS ISOTOPE IS NOW CLOSED.

(1) Arbitrary number assigned to I-131 Radiocaps
(2) .1045979E+01 = 1.045979 millicuries
(3) 1231.3 = 12-31-63

FIG. 4. Detailed history of one container or radioactive material.

TOTALS FOR PERIOD ENDING 12 31 63

ISOTOPE	COST	FOR DISPOSAL	DECAY	USED	RECD
51	23.50	.1519751E-00	.6484140E-00	.1219611E+01	.2020000E+01
131	17.00	.1780800E-02	.8668147E-00	.1773840E-00	.1045979E+01

FIG. 5. Consolidated record of radioisotopes purchased

VETERANS ADMINISTRATION HOSPITAL
Omaha, Nebraska

IRRADIATION REQUEST — RADIATION FACILITY

1. Isotope Committee Approval # 55 — Serial No. 00800
2. Charge To OCDM — Fee
3. Target Material NA_2CO_3 — K.W.H. 15.5
4. Target Form — Quantity
5. Flux Desired 1 X 10" — K.W. 15.5

INSERTION
6. Period of Irradiation 60 min — Date 27 Jan 64
NA_2CO_3 — Time 1130
10.4 mg (NA_2CO_3) = 4.513mg NA — Position
(ACTUAL FLUX 1.1166)

REMOVAL
Date 27 Jan 64
Time 1230
Storage Compartment # SC

DELIVERY
7. Delivery Date Preferred 27 Jan 64 — Date 27 Jan 64
Time 1300
8. Deliver to John Doe — To (Signature) John Doe
9. Method of Delivery Pick Up — By Sam Brown

10. Estimated Microcuries 10 (min) — container mrhm 1.5 at surface of transport
11. NA^{24} Major Isotope 900 Half Life — Date 27 Jan 64
12. Remarks — Time 1245
Instrument REAC (SB)

(Sig) John Doe Requestor — (Sig) Sam Brown Operator

User's License No. 12345
VA Accountability No. 800

TOTAL AMOUNT IN MILLIGRAMS
NA^{24} 4.513

FIG. 6. Radiation request form which is completed on the left side by requestor. This form allows scheduling of reactor time. The right side of this form is completed by radiation facility staff.

REACTOR PRODUCTION

Form Code: 1 - Liquid 2 - Serum 3 - Solid 4 - Container 5 - Gas

Isotope 1-5	Form 11	Lot 21-25	Prod Date 31-36	Prod Time 41-44	Mgm Mass 51-58	Flux	Irrad Time 71-76	Factor 80
NA 24	1	800	12764	1230	4513	11166	60	

FIG. 7. This form completed at the time isotope is produced. From this a card is punched, verified, and used for computation of the amount of activity produced.

CONSTANT CARDS FOR REACTOR CREATED ISOTOPES

ISOTOPE	CROSS-SEC	HALF-LIFE	ATOMIC WT	PCT AB
H 3 (n,γ)	945000	6440893	6940	752
H 3	5400	6440893	3	1
F 20	9	12	19000	10000000
NA 24	536	9000	22997	10000000
MG 27	27	95	24320	1129000
AL 28	210	23	26980	10000000
SI 31	110	1570	28090	305000
P 32	190	2066240	30975	10000000
S 35	260	12528000	32066	4215000
S 37	140	50	32066	1700
CL 38	560	375	35457	2460000
A 41	630	1090	39944	9960000
K 42	1100	179150	39100	691000

FIG. 8. This list represents "constant" cards which are used in the computation of the amounts produced and disposed of by using the activation analysis formula and/or the standard decay formula.

microcuries equals total received in microcuries. The total of column 5 (milliliters used) plus milliliters disposed of equals the first entry in column 7—milliliters received.

The consolidated record (Figure 5) is obtained for any period specified by using the switch option of the program. In this manner only the totals are printed on the 1620 console typewriter. These totals consist of disposal, decay, usage, receipt and cost for each specified isotope. The time spent in maintaining this system has been cut in half and human error possibility reduced.

Before any isotopes are manufactured in the reactor, the requestor is required to fill out the left side of the form shown in Figure 6. The right side is completed by the radiation facility staff and the actual flux entered. The production form (Figure 7) is completed with the following information: isotope identification number, lot number, form (liquid, gas, solid, serum or container), date, time, mass, flux, radiation time and factor. This information is punched in a card and verified.

For each isotope there must be a "constant" card which contains the isotope identification number, cross-section,

REACTOR DISPOSITION

Method of Disposal Code: 1 - Burial 3 - Transfer 2 - Sewer 4 - Decay

Isotope 1-5	Form 11	Lot 21-25	Disp Date 31-36	Disp Time 41-44	Method 48	Name 73-80
NA	1	800	12764	1300	3	OCDM

FIG. 9. This form is completed at the time the isotope is disposed of, and the method of disposal is indicated at this time.

```
DETAILED PRODUCTION LISTING
LISTING FOR PERIOD JAN 1 THRU JAN 31 1964

 ISO   DATE   AMT    TOTAL AMT                          FORM LOT NO
NA 24 10764 00000000 00000000                            1   791
NA 24 10764 00000000 00000000                            1   791
NA 24 10864 00001012 00001012                            1   792
NA 24 12164 00000001 00001013                            1   797
NA 24 12164 00000003 00001016                            1   797
NA 24 12164 00000002 00001019                            1   797
NA 24 12164 00000006 00001026                            1   797
NA 24 12764 00000862 00001889                            1   830
NA 24 JAN   00000000 00001889                                #
```

FIG. 10a. Detailed listing of each isotope produced

```
REACTOR CREATED ISOTOPES ACCOUNTABILITY SYSTEM
ACTIVITY REPORTED IN MICROCURIES.  TIME IN MINUTES.  MASS IN MILLIGRAMS.
AG 210 IS AG110 METASTABLE
BR 801 IS BR 80 METASTABLE
CODING SYSTEM 1 LIQUID 2 SERUM 3 SOLID 4 CONTAINER 5 GAS PRODUCTION
CODING SYSTEM  1 BURIAL 2 SEWER 3 TRANSFER 4 DECAY  DISPOSAL
2 DECIMAL PLACES
ISOTOPES  FORM 1, 2, 3, 5
LISTING FOR PERIOD JAN 1 THRU JAN 31 1964

 ISO   DATE  UC PROD  UC ACCUM  DATE      HOW DISP     UC DISP TOT DISP FOR
NA 24 10764 00000000 00000000 11364  FE DOSE SWR    00000000 00000000 1
NA 24 10764 00000000 00000000 11364  FE DOSE SWR    00000000 00000000 1
NA 24 10864 00001012 00001012 10864  OCDM     TRN   00000983 00000984 1
NA 24 12764 00000862 00001874 12764  OCDM     TRN   00000834 00001819 1
NA 24 JAN TRN 00001819 BUR 00000000 DCA 00000000 SWR 00000000 TOT 00001819
CL 38  1 764 00000003 00000003 11364  FE DOSE SWR    00000000 00000000 1
CL 38  1 764 00000001 00000005 11364  FE DOSE SWR    00000000 00000000 1
CL 38 JAN TRN 00000000 BUR 00000000 DCA 00000000 SWR 00000000 TOT 00000000
```

FIG. 10b. Detailed listing of each isotope disposed of

```
REACTOR CREATED ISOTOPES FORM 1, 2, 3, 5
TOTAL DISPOSITIONS FOR JANUARY 1964

 ISO MONTH    TRANS    BURY    DECAY    SEWER    TOTAL
NA 24 JAN     1819                                1819
              1819                                1819*
CU 64 JAN                                    1      1
                                             1      1*
```

FIG. 10c. Consolidated listing of total amounts of each type of isotope disposed of for any period specified.

half-life, atomic weight and percent abundance (Figure 8). The amount of each specific isotope is computed by the activation analysis formula

$$A_t = .602 F b_{act} N \left(1 - e^{-\frac{.693t}{T_{\frac{1}{2}}}}\right)$$

where

A_t = activity at time of removal from reactor (dis/sec)

N = number of atoms precursor

$$= \frac{\text{mass (mgm)} \times \text{percent abundance}}{\text{atomic weight}}$$

F = flux $\dfrac{n}{\text{cm}^2 - \text{sec}}$

b = cross-section (barns)

t = irradiation time (minutes)

$T_{\frac{1}{2}}$ = half-life (minutes)

At time of disposition, the health physicist provides the following information (Figure 9): isotope identification number, lot number, form, time, date, manner of disposition (burial, sewer, transfer or decay), and if transferred, to whom transferred. A card is punched and verified for each isotope listed on this disposition form and decay is computed by the standard decay formula. The amount which is being disposed of is also computed at this time.

Listings (Figures 10a, 10b, 10c) are made from the cards which are generated for production and disposition. The consolidated record (Fig. 10c) enables us to fulfill the record keeping requirement as indicated in Title 10, para. 20.401b, Code of Federal Regulations. At all times it is possible to know the amounts which have been produced as well as disposed of as required by U.S. Atomic Energy Commission.

Acknowledgment. I wish to thank Richard E. Ogborn, M.D., Chief, Radioisotope Service, and Alan J. Blotcky, Reactor Physicist, for their technical assistance.

RECEIVED SEPTEMBER, 1964

REFERENCE

1. OGBORN, R. E., DUNN, A. L., LAHNERS, E. L. A radioisotope accountability system. *Amer. J. Roentgen. 88* (Aug. 1962), 355-357.