PROGRESS REPORT (NYO 910-3)
TO
THE UNITED STATES ATOMIC ENERGY COMMISSION
ON
PROPOSAL # 3

RADIATION STUDIES: METABOLIC STUDIES WITH CALCIUM-47 AND OTHER RADIOACTIVE ISOTOPES

CONTRACT NO. AT(30-1) 910:
BIOLOGICAL EFFECTS OF RADIATION AND RELATED
BIOCHEMICAL AND PHYSICAL STUDIES

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Period of Report: May 1, 1963 - May 1, 1964

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July 1, 1964

Proposal #3 METABOLIC STUDIES WITH CALCIUM-47 AND STRONTIUM-85

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1. Clinical Studies

a) Total Body Retention (TBR)

The measurement of administered tracer dose by scanning the entire body and totalizing the counts accumulated by each detector has proven to be a reliable determination of TBR. In 14 carefully controlled studies with collection of stools and urines using different isotopes (Ca-47, Sr-85, I-131, Fe-59), the HEG scanner gave results which were within 5 per cent of the retention measured by radioactivity assay of excretions (Fig. 1). The ten calcium-47 studies were measured at numerous times and followed for a maximum of 22 days; the two strontium-85 studies were followed for 16 days; the three iodine-131 patients up to 10 days and the iron-59 patient up to 4 days.

Outpatients have been checked for strontium-85 retention with the HEG scanner for as long as one and a half years. Monthly 24 hour urine collections and body point measurements on these patients have indicated the TBR measurements to be accurate presentations of Sr-85 turnover in the body.

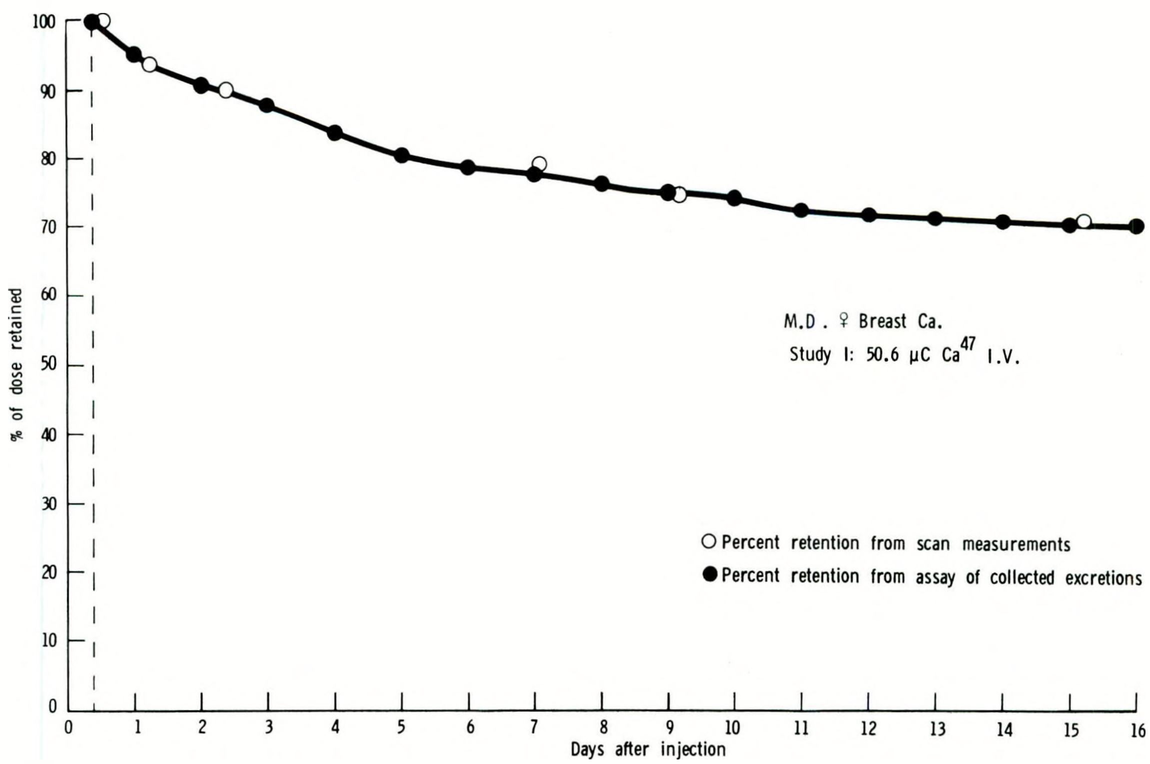

Fig. 1. Comparison of the retention of calcium-47 for patient M.D. as measured by scanning and by collection and assay of excretions. First study.

The first phase of the development of the total body retention measurements with the HEG scanner is now complete, and the method is routinely used for the determination of accretion rate in patients. Further work is needed to evaluate the importance of the interesting, but small, differences observed between HEG-scanning and the collection of excretions; these differences might indicate loss of calcium in the sweat.

The HEG-scanning techniques were published in the April issue of the British Journal of Radiology and reprints are enclosed.

b) Localization Studies in Patients and Kinetic Studies

Forty-four studies of intravenous injections of calcium-47 and strontium-85 in 38 patients were made during the period from May 1, 1963 to May 1, 1964. Seventeen studies were conducted with calcium-47 and 27 studies with strontium-85. Serial measurements of urine, feces and saliva were taken in ten patients for kinetic studies. Measurements of isotope uptake at selected anatomical points were taken on each patient at various times following injection.

Mathematical analyses of these data have been carried out. It was found that with the assumptions originally used by Bauer for the single compartment system, a simple derivation of the accretion rate could be done which holds for any mammillary compartment system. This was presented at a symposium on "Dynamic Clinical Studies with Radioisotopes in Man" in Oak Ridge, Tennessee (K.R. Corey, "Calcium Turnover in Man"). The computation of accretion rate and of the other parameters of the single compartment were programmed. This technique was used for the calculations submitted to the International Atomic Energy Agency at Vienna ("Comparative Calculations of Calcium Kinetics," to be published in Technical Report Series).

c) Digital Scanning of Liver and Other Organs

Liver scans have been performed on 13 patients injected with rose bengal tagged with iodine-131. Digital and photographic readout has been employed to display the data.

The digital scan is interpreted by plotting the isocount contours on the scan. Each contour is labeled numerically with the ratio:

$$\frac{\text{Number of counts at each scan point}}{\text{Number of microcuries injected} \times e^{-\lambda t}}$$

where λ is the decay constant and t the time elapsed since the injection. The resulting activity map is both easily interpreted and quantitative in terms of administered dose. The accuracy is great since it is based on 600 point readings. Figure 2 illustrates one set of contours taken from

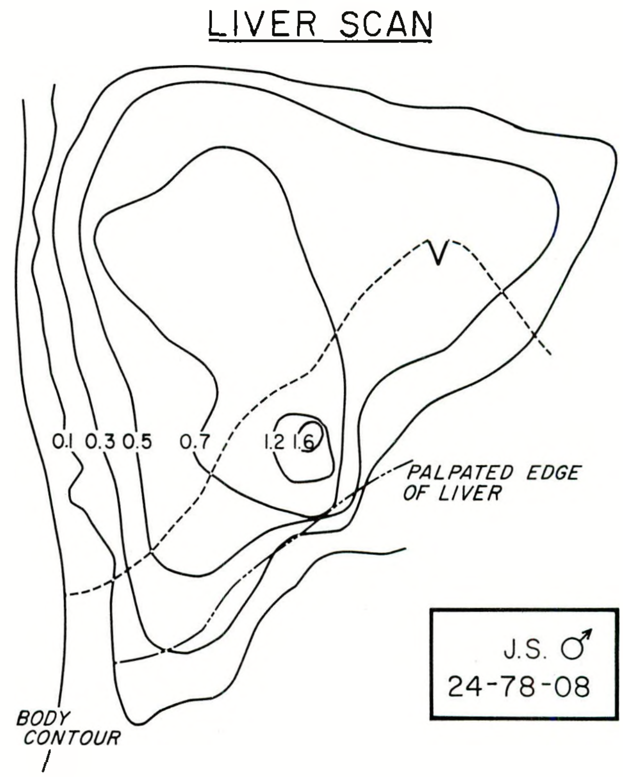

Fig. 2. A tungsten, 19 hole focusing collimator was used to measure the iodine-131 rose bengal uptake at discrete points with 3/8 inch spacing between individual measurements. Counting time was 5 seconds/position. The numbers noted on the individual contours correspond to counts per μc injected. A small Riedel's lobe appears to be present. The 1.2 and 1.6 contours indicate the position of the gall bladder.

the digital scan. A tungsten focusing collimator was used to measure the iodine-131 rose bengal uptake at discrete points with 3/8" spacing between individual measurements. Counting time was 5 seconds per position. The numbers noted on the individual contours correspond to counts per microcurie injected. The extension of the right inferior lobe contour of the liver, as shown by the scan, indicates the presence of a small Riedel's lobe. Medial from the mid portion of the costal margin, the elevated small closed contours indicate the gall bladder.

Liver scans handled in such a manner have been found to be diagnostically helpful and accurate in delineating liver abnormalities. The immediate available picture with the numerical level of the contours indicated provided new insight into the interpretation and quantitative comparison of liver scans.

A few scans of a variety of organs have been done in order to evaluate the best application of the digital readout. Brain scans have been done on two patients following the injection of mercury-203 neohydrin; one spleen scan was made with chromium-51 (heated, chromated red blood cells), and mercury-203 neohydrin was employed for one kidney scan. One study was done with a tracer dose of chromium-51 (chromated red blood cells) for determining cardiac volume of a patient before and after compensation.

d) Antibody Localization in Tumors

It has been shown by Dr. W.F. Bale that I-131 labeled antibody to human fibrinogen becomes localized in tumors. In an effort to determine quantitatively the antibody deposition in tumor and correlate it with the nature of the lesion, a collaborative project between Dr. Bale of the University of Rochester and Dr. McNeer of Memorial Hospital has begun. The technical help is supported by an AEC grant to Dr. Bale. The I-131 labeled antibody supplied from Rochester will be injected into patients before surgical removal of tumor. Counting of specimens as well as quantitative scanning with the HEG scanner will be done. During the period of this report, preliminary work has been carried out and the technician trained.

2. Animal Studies

Radiation Modification of Bone Metabolism in Dogs

Five adult male beagle dogs (three approximately one year old and two approximately three years old) have been injected with tracer doses of strontium-85 and retention of the isotope has been measured by whole body scanning with the High Energy Gamma-ray (HEG) scanner. At different times following strontium-85 injection (2,3,5 or 12 weeks) one foreleg (radius-ulna) and one hind leg (tibia) of each dog have been irradiated externally with 15 mev electrons from a betatron. Dosages have ranged from 1800 to 2750 rads in the forelegs and from 800 to 1500 rads in the hind legs. At regular intervals following irradiation, strontium retention in irradiated and control legs is measured externally at three points in each leg with the HEG scanner using a 1" x 1-1/2" rectangular collimator. Tracer doses of calcium-47 are also administered at intervals and the retention of the isotope at 24, 48 and 96 hours is measured at the same three points in each of the dog's legs. Total body retention of the calcium isotope has also been measured with the HEG scanner.

External point counts of strontium-85 retention in irradiated and control legs have shown a suppression of the catabolic process in legs expressed to 1800 rads or more. A cyclic suppression of bone anabolism, measured by calcium-47 retention in legs exposed to 800 rads or more, is observed: the maximal effect occurs at 40 to 60 days post-irradiation.

A 289 day study on the first dog has been completed. This dog received 50μc of Sr-85, 86 days before irradiation. The results of the Ca-47 uptakes and the Sr-85 measurements on the foreleg are illustrated in Table I. This leg had been given a dose of 1885 rads. It was found that the irradiated wrist lost 8 per cent of the dose or half as much Sr-85 as the control site during the 203 days following the irradiation.

Table I

Ratio of count rate in the irradiated wrist to the count rate in the control wrist.

Days post irradiation	Ca-47 ratio 24 hrs. after dose	Sr-85 ratio
1	.98	1.00
36	.89	1.01
63	.92	1.03
84	.95	1.03
113	1.00	1.04
144	.81	1.06
203	.90 (48 hrs.)	1.10

3. Technical Studies

a) Evaluation and Comparison of Scanner Performance

A method has been developed to establish a quantitative basis for intercomparison of different counters. This method does not depend on scanning of experimental phantoms, where the number of variable parameters is very large and difficult to standardize. It employs a computer program to calculate the percentage change in count rate that occurs when an arbitrary volume of higher or lower specific activity than the surrounding medium is scanned. The input of the program is a matrix of numbers, experimentally determined, which specify the response of the detector to a point source of the isotope being scanned. By appropriate interpolation and integration, the counting rate for an entire cylindrical volume of activity of dimensions equal to or less than those covered by the point source measurements is computed, and the effect on count rate of decreasing or increasing the concentration can be computed. The method has been used to compute the percentage change in count rate on the HEG scanner when cylindrical voids of various dimensions are created in a uniform specific activity phantom containing iodine-131.

b) Theoretical Computation of Detector Performance

A computer program has been written and run in a number of test cases to predict the response patterns and sensitivity of sodium iodide scintillation detectors to point sources in air for various values of parameters such as crystal and collimator dimensions and gamma ray energy. The first results of these computations show good agreement with values published elsewhere for selected cases. The computed efficiencies for an on axis point source of 1.33 mev gamma radiation at various distances from a 4" x 4" sodium iodide crystal are compared below, for a few values, with the results of similar computations made at Argonne National Laboratory.*

Table II

Source-crystal Distance (in.)	Sloan-Kettering Institute Computation	Argonne Computation
6	2.85×10^{-2}	3.13×10^{-2}
12	9.44×10^{-3}	9.44×10^{-3}
18	4.50×10^{-3}	4.53×10^{-3}

* MILLER, W.F., REYNOLDS, J. and SNOW, W.J., Efficiencies and photofractions for gamma radiation on sodium iodide (thallium activated) crystals, Argonne National Laboratory, ANL-5902

c) Comparison of Digital and Photographic Readouts

The HEG scanner's digital and photographic data presentations were evaluated by taking focusing collimator scans of small cylinders containing Sr-85 placed in a large medium of lower specific activity. The data accumulated are sufficient to predict the probability of detecting the sources for any combination of source specific activity and background specific activity used in the phantom. These results were included in the presentation of our work at the Symposium on Medical Radioisotope Scanning,April 20-27, 1964, Athens, Greece.

For example, it was found that a 0.4 by 0.4 cm cylindrical source in the focal plane with a 10 to 1 specific activity ratio above a background solution in the phantom of 1 microcurie per cc, can be detected with 95 per cent confidence with counting times of 5.1 seconds at each position. The difference between the mean background count and the mean source plus background count of 2.9 per cent would be masked completely on a photographic display.

Apart from the limitation of a short dynamic range which, at most, is two orders of magnitude, the photographic representation suffers from the further drawback that the sensitivity of the human eye to detect small variations in optical density is not constant over the visible optical density range of 0.2 to 2.0. Tests on fifteen individuals to determine their abilities to detect density differences from 0.01 to 0.2 over the range of absolute densities from 0.3 to 1.8 showed that there is a marked decrease in sensitivity with increasing absolute density, and indicated that even in the range of 0.3 to 1.0 the density variations would have to exceed 0.10 (or 10 per cent) for reliable detection. It is clear that this response phenomena places an additional and unnecessary limitation on the ultimate sensitivity of scanning. Work is under way to evaluate old scanning techniques and to determine precisely in which applications the digital readout gives a significant improvement in the number of correctly detected lesions. Such evaluation is coupled with consideration of the time spent in evaluating.

d) Digital Data Display with Continuous Scanning

This system was designed to simultaneously record on punched paper tape data from four six decade scalers as well as data regarding the distance and direction of movement of the scanner heads during the time the data accumulated. The system is also capable of recording "X Marks" used to locate anatomical positions of interest in the area scanned. Data are recorded at preset increments along the scan which, as well as the spacing between scan lines, may be set at 3/16", 3/8", 9/16", 3/4", 1-1/8", 1-1/2", 2-1/4", or 3". "X Marks" may be recorded at 3/32" intervals along the scan line. In addition to recording data at preset increments, the system may be operated in a mode wherein two scalers accumulate over the whole scan line and print out at the end of the line while the other two scalers operate as before. A third mode of operation allows all four scalers to accumulate data over the scan line and print out at the end of the line.

Once the data are recorded on paper tape, the tape is fed into a tape reader where the positional information is used to control the motion of a typewriter carriage and platen. The data from the scalers are then printed out. "X Marks" are printed out as they are recorded, that is between data points with a resolution of 3/32". If the data was recorded in the second mode described, the data may be printed out with the line totals appearing at the end of and directly below the scan line. If recording was done in the third mode described, the data will be printed out as a single column of figures, representing line totals and will require two passes of the tape to print data from all four scalers.

This system of data recording allows the scanner to be operated independently of the typewriter and in a continuous mode, that is the scanner heads move without interruption and data is accumuated over a finite increment of the scan. This system will record data at the rate of five complete cycles (positional information and data from four scalers) per second. Thus, with the scan increment set at 3/16" the maximum scanning speed is limited to 15/16" per second, 56"/minute. At all other scan increments the maximum scanning speed is limited by the motor drives used on the HEG scanner.

e) Bremsstrahlung Measurements

A specially constructed detector,using a 3 cm thick sodium iodide crystal and both straight bore and focusing collimators,has been used with phosphorus-32 and yttrium-90 sources in a polystyrene-scattering medium to evaluate the possibility of detecting these sources at various depths by counting their bremsstrahlung radiation. Spectral and spatial resolution measurements have been made and figures for the sensitivity for detection of point sources at various levels have been obtained. These measurements have established a quantitative basis for bremsstrahlung scanning of phosphorus-32 and yttrium-90 with this particular counter. This work has been presented as a thesis and accepted by the faculty of Cornell University Medical College in partial fulfillment of the requirements for the degree of Master of Science.

f) Adjustable Focus Counter

Four tapered-hole tungsten collimators have been provided for use with this counter and calibrations of the isocount patterns for various combinations of the adjustable parameters and various energies are being carried out.

Publications and Presentations During the Report Period

1. LAUGHLIN, J.S., KENNY, P., COREY, K.R., GREENBERG, E., WEBER, D.A, Localization and total body high energy gamma ray scanning studies in cancer patients. Symposium on Medical Radioisotope Scanning, International Atomic Energy Agency, Athens, Greece, April 20-24, 1964 (to be published in 1964)

2. KENNY, P., LAUGHLIN, J.S., WEBER, D.A., COREY, K.R., GREENBERG, E., High energy gamma ray scanner. Progress in Medical Radioisotope Scanning, Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee, 1963, pp. 236-250

3. LAUGHLIN, J.S., WEBER, D.A., KENNY, P.J., COREY, K.R., GREENBERG, E., Total body scanning, Brit. J. Radiol. 37:287-296, April, 1964

4. COREY, K.R., The retention of strontium-85 in healthy and diseased bones of patients with breast cancer. Presented at the 10th annual meeting of the Society of Nuclear Medicine, June 26-29, 1963; J. Nucl. Med. 4:200, 1963

5. GREENBERG, E., MERLINO, M., WEBER, D., KENNY, P., COREY, K.R., and LAUGHLIN, J.S., Kinetic studies of calcium based on saliva and total body retention measurements of Sr-85 and Ca-47, J. Nucl. Med. 4:194, 1963 (Abstract)

6. COREY, K.R., Member of the Panel on "Research Applications of Ca-47" held by the International Atomic Energy Agency, Vienna, September 9-12, 1963. The assay of urine and blood samples. International Atomic Energy Agency, Vienna (to be published in 1964 in the Technical Reports Series)

7. COREY, K.R., Member of the Panel on "Research Applications of Ca-47" held by the International Atomic Energy Agency, Vienna, September 9-12, 1963. Results of Kinetic Analyses and External Counts. International Atomic Energy Agency, Vienna.

8. COREY, K.R., Member of the Panel on "Research Applications of Ca-47" held by the International Atomic Energy Agency, Vienna, September 9-12, 1963. The Turnover of Ca-47 and Sr-85 in Bone Lesions. International Atomic Energy Agency, Vienna (to be published in 1964)

9. COREY, K.R., Member of the Panel on "Research Applications of Ca-47 held by the International Atomic Energy Agency, Vienna, September 9-12, 1963. Total Body Retention. International Atomic Energy Agency, Vienna (to be published in 1964)

Publications and Presentations (cont.)

10. COREY, K.R., Calcium Turnover Studies in Man. Presented at the 8th Symposium In Medicine entitled: Dynamic Clinical Studies with Radioisotopes. Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee, October 21-25, 1963 (to be published)

11. LAUGHLIN, J.S., High Energy Gamma Ray Localization and Total Body Scanning. Presented at the Society of Nuclear Medicine, Local Chapter, April 4, 1964

12. GREENBERG, E., Kinetic Studies with Bone Seeking Isotopes. Presented at the Society of Nuclear Medicine, Local Chapter, April 4, 1964

13. GREENBERG, E., KENNY, P., COREY, K.R., WEBER, D., LAUGHLIN, J.S., Detection of Bone Lesions with Ca-47 and Sr-85. Presented at Radium Society Meeting, White Sulphur Springs, West Virginia, May, 1964

Appendix

Punched Paper Tape Data Recording System for HEG Scanner

The system is housed in a 28 inch enclosed rack (see Fig. 3) which also supports the output typewriter. A considerable amount of relay logic and switching circuitry is used and is mounted on a swinging gate (see Fig. 4) at the rear of the machine. The bulk of these relays are plug-in units used to facilitate servicing. The transitorized circuitry and data storage relays are on plug-in cards (see Fig. 5) mounted behind the hinged front control panel. The tape punch and reader combination is a commercial unit (Tally Model 1477), mounted directly below the control panel. Power supplies, the typewriter positioning motors, and transmitting selsyns occupy the lower half of the rack. The power supply voltages are monitored by a front panel meter and selector switch. Hinged or removable panels on all sides of the rack expose all parts of the system for servicing or adjustment. The following is a sequential description of the data recording system operation.

Two block diagrams (Figs. 6 and 7) follow which illustrate the configuration of the entire system. Figure 6 shows the data recording portion. During the course of the scan, at periodic intervals determined by the scan increment chosen, a switch contact closure activates the "Record Data and Increment" line and starts the recording cycle. The "Count Gate" line to the scalers is closed to prevent the scalers from accepting counts during the time data on the output lines is being sampled. The opening of the "Count Gate" line is followed by a "Sample" signal to the "High Order Zero Detection Circuits." Here the three high order digits from each scaler are examined and a zero detected in any of these digits results in a sixteen pole relay associated with that digit being closed and latched through one of its own contacts. Twelve such relays (three for each scaler) constitute the "Input Data Switching Circuits." The six digits (twenty four lines) from each scaler are switched so that only the three most significant digits plus an exponent for a multiplier are sent to the "Data Storage Register." Eight milliseconds are allowed for this operation. At the end of the "Input Data Switching" operation a "Store" signal is sent to the "Data Storage Register" which holds the scaler data in the form of contact closures necessary to operate the paper tape punch. After the data are stored a "Reset" signal is sent to the scalers to clear them of data. The "Reset" line remains active for approximately four milliseconds. At the end of this time the "Reset" is dropped simultaneously with the opening of the "Count Gate" line. The total dead time of the scalers from closing to opening of the "Count Gate" line is approximately eighteen milliseconds which constitutes a nine per cent dead time at the maximum data recording rate of five cycles per second. While the input data are being switched and stored the paper tape punch is recording position increment and direction information through the output scanner "Home" contacts. The position increment information is in the form of contact closures on a deck of the rotary switch used to select the increment size. The direction information is in the form of contact closures of

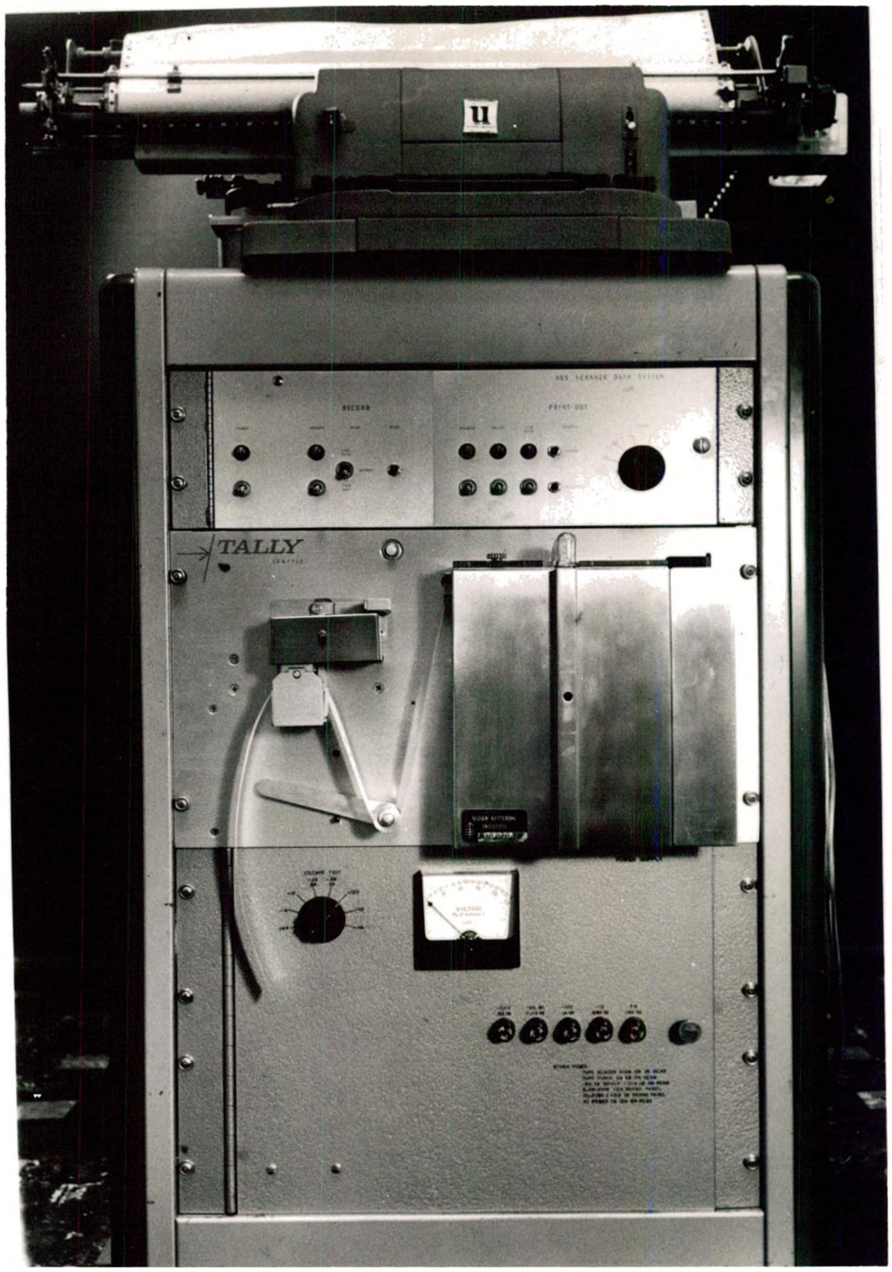

Fig. 3. This view of the system shows the output typewriter, control panel, tape punch and reader, and power supply monitor panel. Both the control panel and monitor panel are hinged to allow access to the circuit cards and power supplies respectively.

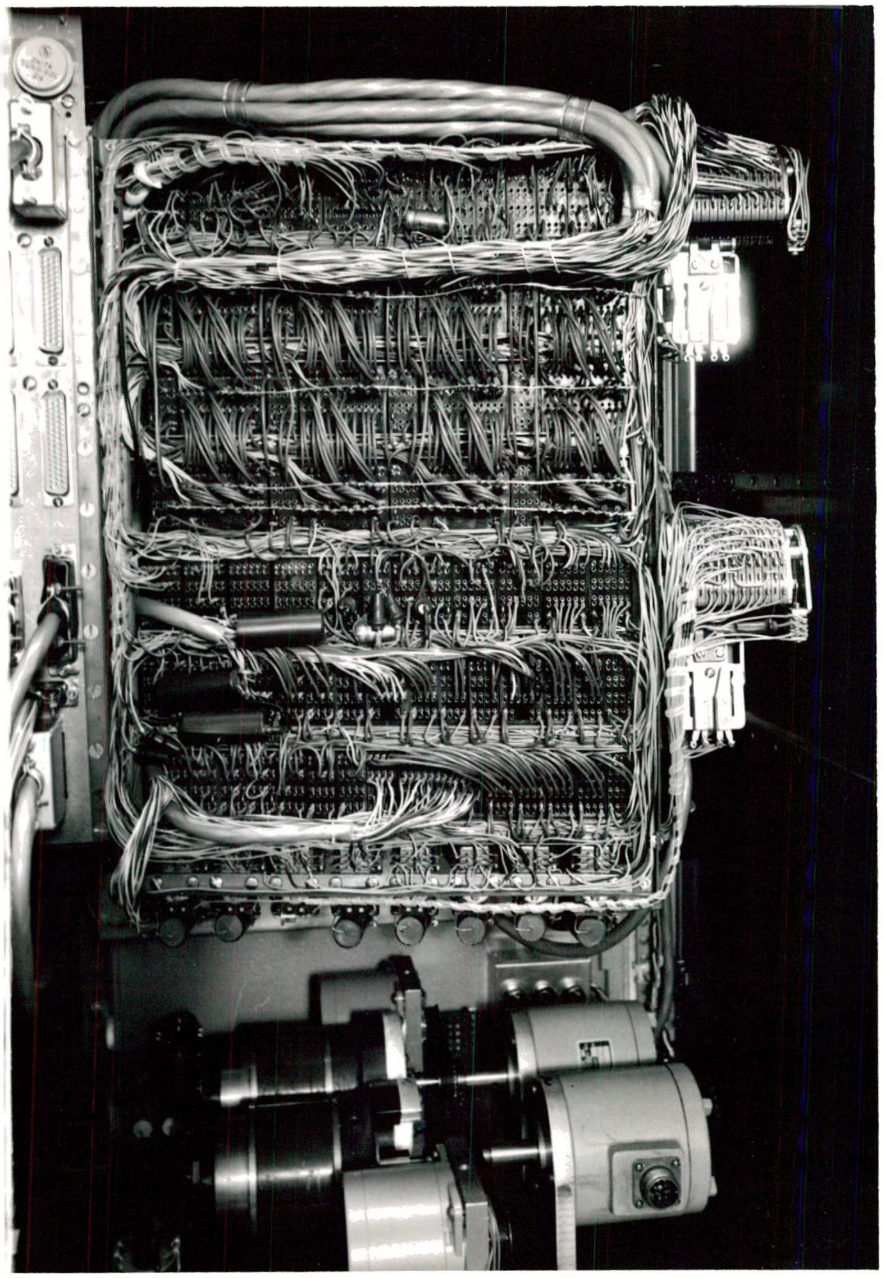

Fig. 4. The system is shown here with the rear door removed and the wiring side of the relay gate exposed. The gate is hinged at the left to allow access to the relays and to the rear of the circuit card cage.

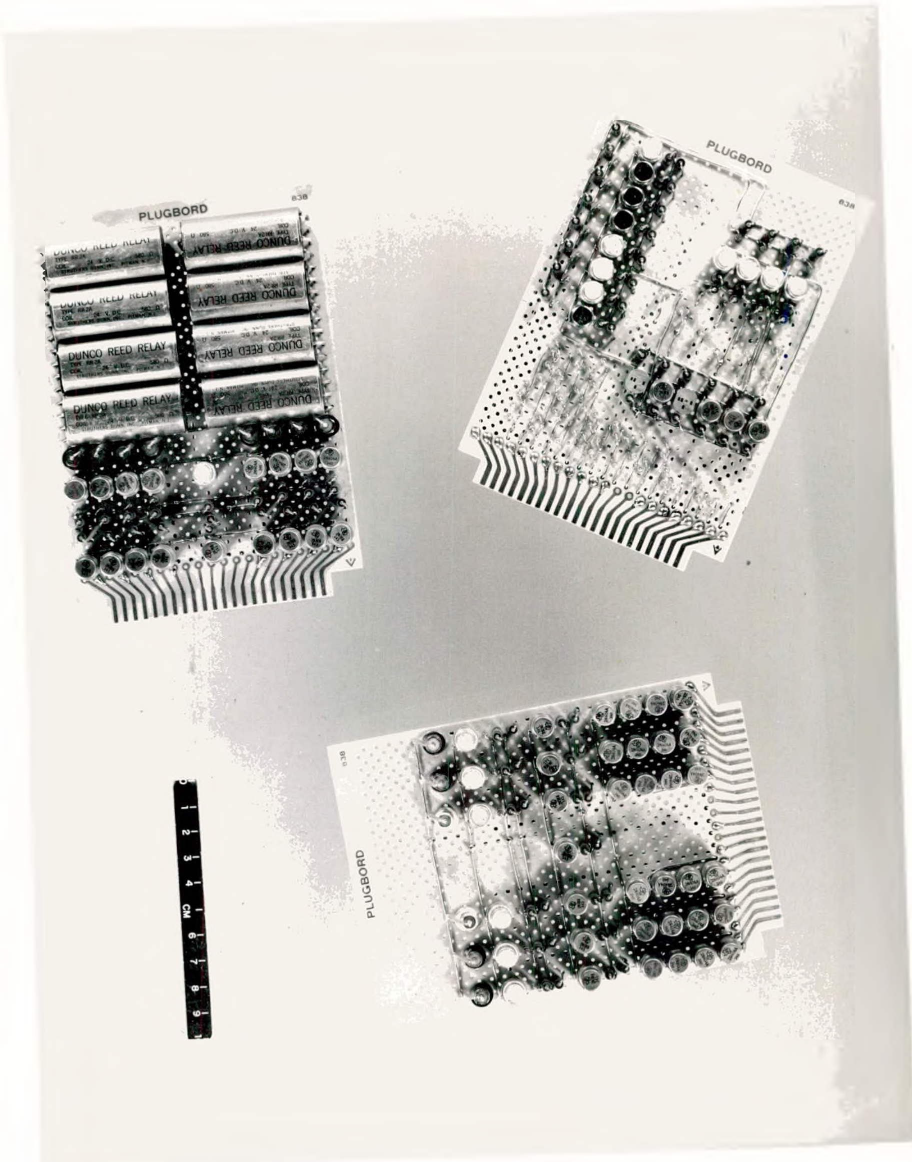

Fig. 5. Above are shown three of the circuit cards used in the system. The card at the upper left of the picture is part of the Data Storage Register. Directly to the right is part of the Counter Decoder used in positioning the typewriter carriage. Below is a card used in the High Order Zero Detection circuit. A centimeter scale is included to illustrate the size of the cards.

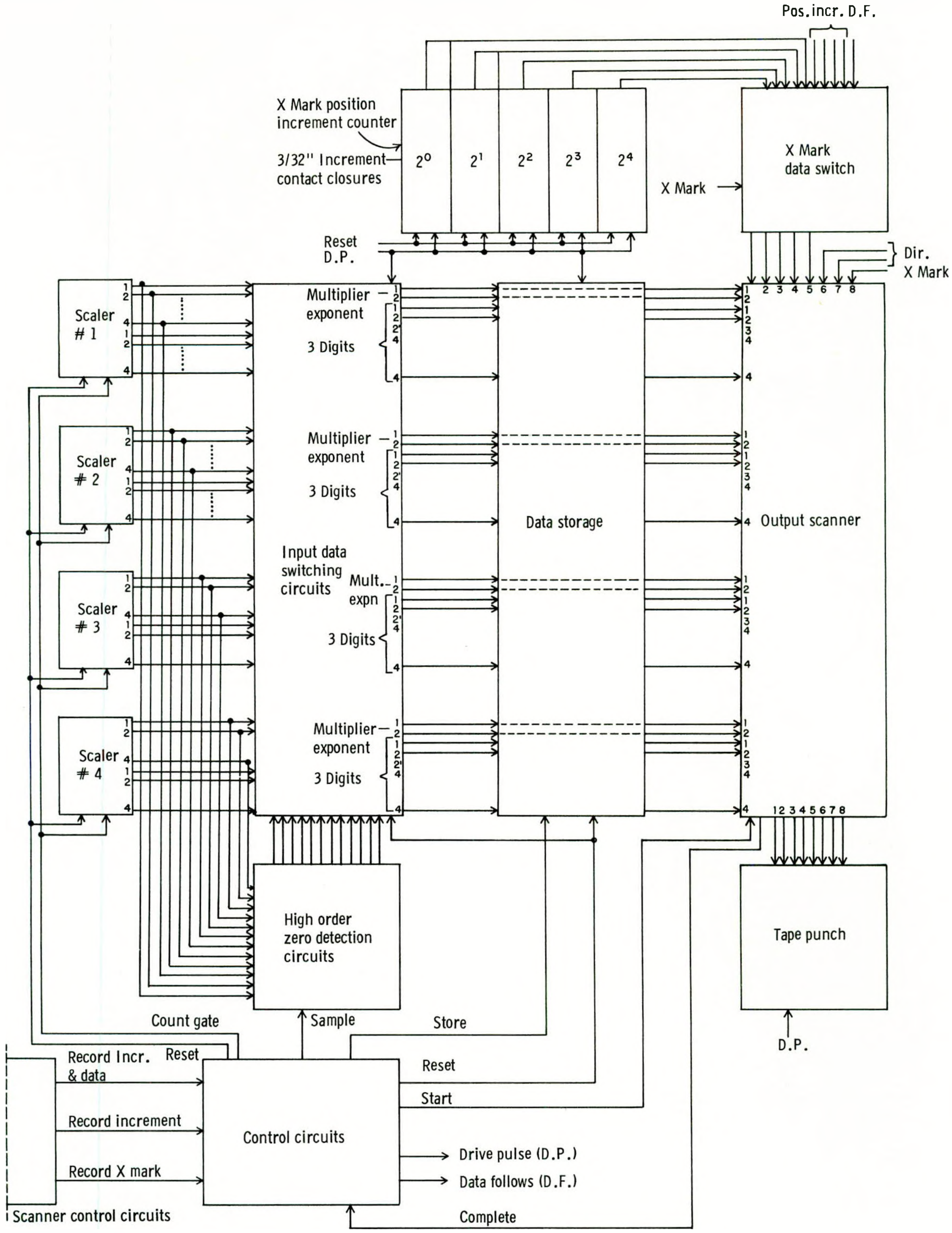

FIG. 6 SYSTEM BLOCK DIAGRAM (RECORDING)

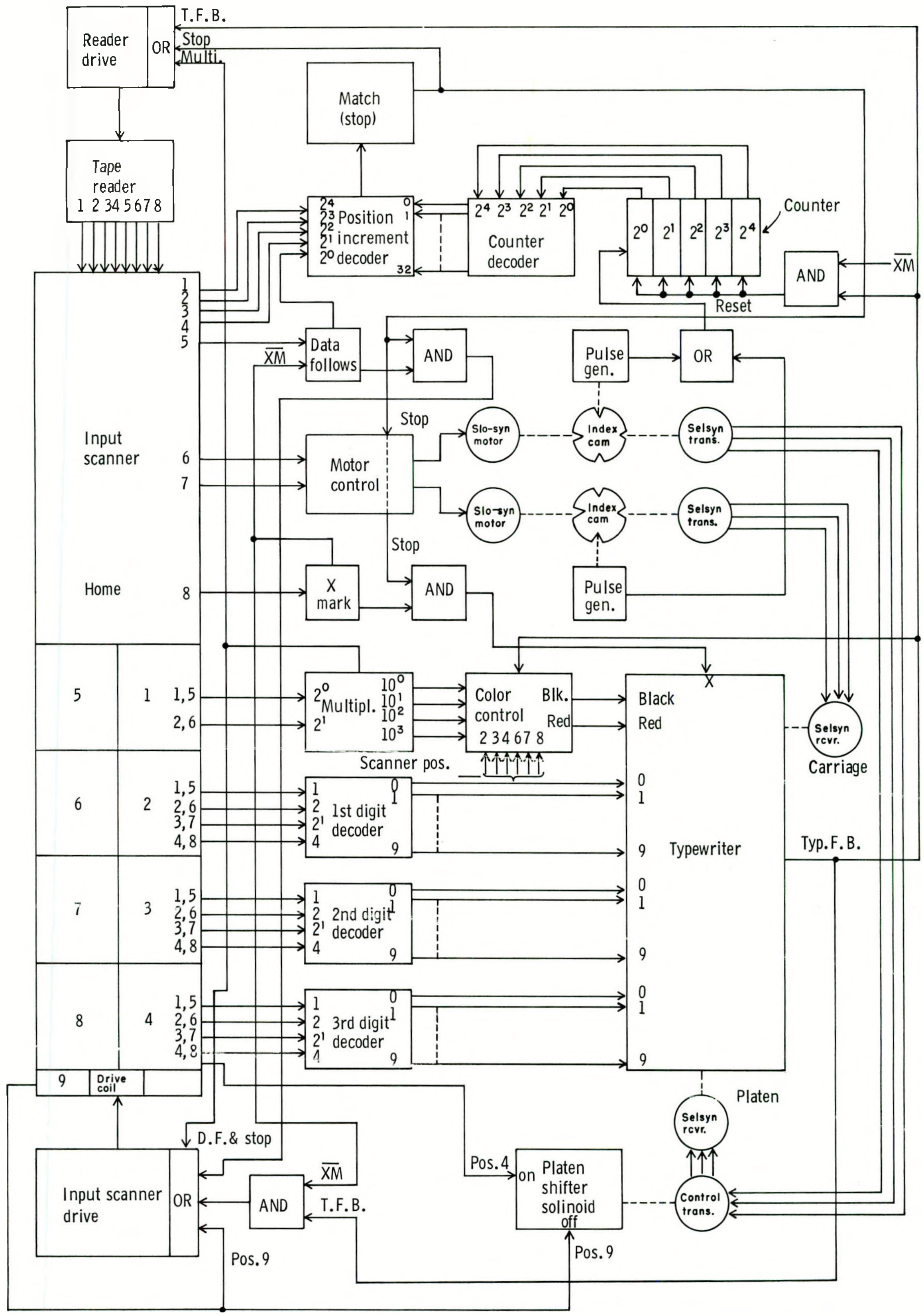

FIG.7 SYSTEM BLOCK DIAGRAM (PRINT OUT)

two latching relays which are slaved to the main motor control relays of the scanner. The axis (N-S or E-W) from which the information is chosen is controlled by the mode in which the scanner is operated. The "Output Scanner" then connects the paper tape punch in turn to data from scalers one and three followed by data from scalers two and four. The exponent for the data multiplier is punched first, followed by three digits of data. After the punch has recorded the last digits of scalers two and four, the "Output Scanner" steps to the ninth position where reset signals for the "Data Storage Register" and "Input Data Switching Circuits" are generated. The "Output Scanner" then advances to "Home" position and the recording cycle is completed.

At the end of a scan line the scanner moves a preset increment to the next line. A "Record Increment" signal to the "Control Circuits" indicates the recording of position increment and direction information from the appropriate scanner axis but does not cause any data to be stored or the "Output Scanner" to cycle. The "Data Follows" bit is not punched in the output character. The count gate lines are closed and the scalers reset during this time to prevent any electrical noise from the motor control circuits from being counted by the scalers. (Note: If the Recording system is being operated in the "line total" mode, scalers three and four are not reset at this time but are interrogated on the following "Record Increment and Data" cycle to provide the total counts for the previous line of the scan.) A "Record Increment" signal also causes the following "Record Increment and Data" cycle to record a position increment of zero. This prevents the offsetting of alternate lines of data on print out.

"X Marks" are recorded after the "X" switch on the scanner control box has been depressed. The recording does not take place unless the "X Mark Position Increment Counter" is in a stable state and the "Output Scanner" is at "Home" position. Five bits of positional information are carried with the "X Mark," giving it a resolution of 3/32". Two direction bits are carried as before. The eighth bit is punched identifying the character as an "X Mark." Again no data are stored and the "Output Scanner" does not cycle.

Before the scan is started an eighteen-inch leader of tape is prepared by depressing the buzz switch on the tape punch. This leader is fed into the tape reader and the tape loop between reader and punch goes below the tape tension switch arm. Initially, the "Counter" is set to zero by momentarily depressing the "Position Reset" switch and the print out is started by throwing the "Operate" and "Selsyn" switches to "On."

The following discussion refers to Figure 7. Since the "Counter" is in the zero state the "Counter Decoder" will detect this and send a "zero" signal to the "Position Increment Decoder" which also is in a zero state since no bits are sensed on the blank tape leader in the reader.

Since the two decoders match, a "Stop" signal is generated which prevents the selected motor from operating and generates a "Reader Drive" pulse which causes the Reader to advance the tape to the next character. Since no bit was present in the "Data Follows" position (Bit 5), the "Input Scanner Drive" is not actuated and the next tape character will be treated as a positioning command. As long as blank tape leader is sensed the above cycle will be repeated, interrupted only by the operation of the tape tension switch which prevents the reader from advancing tape until sufficient tape has been supplied by the punch.

When a non-zero position command is sensed by the "Position Increment Decoder" the match signal will not be generated. After a short delay the "Motor Control Circuit" gates AC power to the selected Slo-Syn Motor (Bit 6) in the proper phase for the selected direction (Bit 7). The motor turns the "Index Cam" and the transmitting selsyn which moves the typewriter carriage or platen in the proper direction. The "Index Cam" operates the associated "Pulse Generator" four times per revolution corresponding to 3/32" travel per pulse. The pulses are totaled by the "Counter" while the counter outputs are continuously decoded by the "Counter Decoder" and compared to the state of the "Position Increment Decoder." When the two decoders match, a "Stop" signal is generated which stops the motor, resets the counter, and signals the "Reader Drive" to advance the tape one character. If the "Data Follows" bit (Bit 5) was not present the following character will be interpreted as another positioning command and the above sequence of events will be repeated. If the "Data Follows" bit was present the input scanner will be stepped to position one and the following eight characters will be treated as data to be printed out on the typewriter. If the "X Mark" bit (Bit 8) was present, bits 1 through 5 will be decoded in the "Position Increment Decoder" and the typewriter carriage or platen positioned as before but with a resolution of 3/32". On receipt of the "Stop" signal an X is printed by the typewriter and the "Reader Drive" advances the tape one character but the "Counter" is not reset to zero. Therefore the next positioning command moves the typewriter only that fraction of the increment not involved in the proceeding "X Mark" command.

As noted before, a data cycle starts on the character following a positioning command with the "Data Follows" bit present. Two bits (Bits 1 and 2, or 5 and 6) are interpreted as the exponent for the multiplier. The combination 00 allows the following three digits to be printed out with the color control in "Black" indicating a number between 000 and 999 ($XXX.10^{0}$). The combination 01 causes the color control to shift to "Red" and to be set to black at the end of step 2, indicating a number between 1000 and 9999 ($XXX.10^{1}$). Likewise 10 and 11 shift the "Color Control" to "Red" and cause the reset at the end of steps three and four, respectively, indicating numbers ranging from 10,000 to 99,999 ($XXX.10^{2}$) and ($XXX.10^{3}$). Once the multiplier exponent is set, a signal is returned to the "Reader Drive" which advances the tape to the next character.

This signal also steps the "Input Scanner" to position two where four bits (Bits 1 through 4 or 5 through 8) are decoded and the selected digit is printed on the typewriter. The printing of any digit on the typewriter causes a typewriter feedback signal triggering the advance of the input scanner and the paper tape. At the end of step 4 the "Platen Shifter Solenoid" is energized which causes the platen to rotate enough to allow a second three digits to be printed directly below the first. Steps five through eight repeat steps one through five, and the number from scaler two or four is printed. The "Input Scanner" then steps to position nine where the "Platen Shifter Solenoid" is turned off and the "Input Scanner" is driven one more position to return to "Home." The system is then ready for the next positioning command.

Note:

A front panel rotary switch selects the scalers or scaler to be printed out. In normal operation either scalers one and two or three and four are chosen. It is also possible to select scaler one, two, three or four to be printed out alone. In this case the companion to the selected scaler is ignored and the "Input Scanner" is stepped past those positions. Example: selected scaler; number one. Scaler two is ignored (steps 5 through 8); however, the scanner is stepped through these positions and the tape is advanced for each step.

I. Publications During the Report Period
(including those in press)

1. LAUGHLIN, J.S., KENNY, P., COREY, K.R., GREENBERG, E., WEBER, D.A., Localization and total body high energy gamma ray scanning studies in cancer patients. Symposium on Medical Radioisotope Scanning. International Atomic Energy Agency, Athens, Greece, April 20-24, 1964 (to be published in 1964)

2. KENNY, P., LAUGHLIN, J.S., WEBER, D.A., COREY, K.R., GREENBERG, E., High energy gamma ray scanner. Progress in Medical Radioisotope Scanning. Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee, 1963, pp. 236-250

3. LAUGHLIN, J.S., WEBER, D.A., KENNY, P.J., COREY, K.R., GREENBERG, E., Total body scanning, Brit. J. Radiol. 37:287-296, April, 1964

4. COREY, K.R., GREENBERG, E., KENNY, P., LAUGHLIN, J.S., MERLINO, M. and WEBER, D.A., Presented by K.R. Corey as a member of the Panel on "Research Applications of Ca-47" held by the International Atomic Energy Agency, Vienna, September 9-12, 1963. The Assay of Urine and Blood Samples. International Atomic Energy Agency, Vienna (to be published in 1964)

5. COREY, K.R., GREENBERG, E., KENNY, P., LAUGHLIN, J.S., MERLINO, M., and WEBER, D.A., Presented by K.R. Corey as a member of the Panel on "Research Applications of Ca-47" held by the International Atomic Energy Agency, Vienna, September 9-12, 1963. Results of Kinetic Analyses and External Counts. International Atomic Energy Agency, Vienna.

6. COREY, K.R., GREENBERG, E., KENNY, P., LAUGHLIN, J.S., MERLINO, M., and WEBER, D.A., Presented by K.R. Corey as a member of the Panel on "Research Applications of Ca-47" held by the International Atomic Energy Agency, Vienna, September 9-12, 1963. The Turnover of Ca-47 and Sr-85 in Bone Lesions. International Atomic Energy Agency, Vienna (to be published in 1964)

7. COREY, K.R., GREENBERG, E., KENNY, P., LAUGHLIN, J.S., MERLINO, M., and WEBER, D.A., Presented by K.R. Corey as a member of the Panel on "Research Applications of Ca-47" held by the International Atomic Energy Agency, Vienna, September 9-12, 1963. Total Body Retention. International Atomic Energy Agency, Vienna (to be published in 1964)

8. COREY, K.R., WEBER, E., MERLINO, M., GREENBERG, E., KENNY, P., and LAUGHLIN, J.S., Presented by K.R. Corey at the 8th Symposium in Medicine: Dynamic Clinical Studies with Radioisotopes. Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee, Oct. 21-25, 1963 (to be published)

II. Presentations During the Report Period

1. COREY, K.R., The retention of strontium-85 in healthy and diseased bones of patients with breast cancer. Presented at the 10th Annual Meeting of the Society of Nuclear Medicine, June 26-29, 1963, J. Nucl. Med. 4:200, 1963

2. GREENBERG, E., MERLINO, M., WEBER, D., KENNY, P., COREY, K.R., and LAUGHLIN, J.S., Kinetic studies of calcium based on saliva and total body retention measurements of Sr-85 and Ca-47, J. Nucl. Med. 4:194, 1963, (Abstract)

3. LAUGHLIN, J.S., High energy gamma ray localization and total body scanning. Presented at the Society of Nuclear Medicine, Local Chapter, April 4, 1964

4. GREENBERG, E., KENNY, P., COREY, K.R., WEBER, D., LAUGHLIN, J.S., Detection of bone lesions with Ca-47 and Sr-85. Presented by E. Greenberg in Symposium on "Cancer Detection by Radioisotope Scanning." Radium Society Meeting, White Sulphur Springs, West Virginia, May, 1964