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LOVELACE FOUNDATION

for Medical Education and Research

Albuquerque, New Mexico

DATA PROCUREMENT AND PROCESSING FOR THE FISSION PRODUCT INHALATION PROGRAM USING AN AUTOMATIC READ OUT COUNTING SYSTEM

by

R. M. GOODRICH AND R. G. THOMAS

December, 1963

ATOMIC ENERGY COMMISSION-
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FISSION PRODUCT INHALATION PROJECT

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DATA PROCUREMENT AND PROCESSING FOR THE FISSION PRODUCT INHALATION PROGRAM USING AN AUTOMATIC READ OUT COUNTING SYSTEM.

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Lovelace Foundation for Medical Education and Research

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ABSTRACT

Data processing primarily concerned with studying experimentally the distribution and excretion of inhaled mixed fission products, has been "streamlined" and automated considerably. An automatic read out counting system is in use which allows the radioactivity information from the scaling system to be transmitted directly to punch tape and/or typewriter. Additional sample information, such as tissue identification and weight, counting time, experiment number, etc., is preset with thumbwheel switches into a data input box. Read out of the data input box just precedes scaler read out, the signal for which is given by the end of preset counting time.

The punched-tape is converted to cards which are stored until completion of an experiment. At this time the information is used in a program to compute the necessary parameters for final distribution and excretion analysis. When desired, the computer plots the radioactivity data from any given series of tissue or whole body determinations and yields the constants of the least squares equations. Integration of the function may also be performed for dosage determination.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contributions of Dr. Bruce B. Boecker and Miss Randi Lie during the early planning of the data processing requirements for the computer format. Mr. Ray W. Albright of the Biomathematics Department provided invaluable assistance in establishing system requirements to yield data essential to the computer program. Also, personnel in the Health Division of the Los Alamos Scientific Laboratory, particularly Dr. Chester Richmond, gave us valuable advice on many phases of this work.

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INTRODUCTION

This report describes the pertinent equipment and procedures used to obtain the quantitative experimental data necessary for correlation with the biological effects of inhaled mixed fission products. Although the major emphasis in this Program may eventually be placed on the "effects" studies pertaining to biochemistry, pathology, and microbiology, the Radiobiology Department has been and will continue supplying certain required information to these clinically oriented Departments. These, in general, are data pertaining to the type of compound and level of radioactivity initially in the exposed animal, plus the doses which various organs receive. To facilitate the collection and processing of these data, all methods and associated equipment items have been "streamlined" to the limit of current feasibility. The major items involved are electronic in nature.

Information pertaining to the above may be of interest to those associated with allied Programs and certain pieces of locally employed equipment may not be in common use. Also, in future publications, a reference to this report will aid in writing and also give the interested reader a detailed reference source.

RADIOACTIVITY DETERMINATION

General Considerations

1. Pulse Height Analysis

The Program in its early stages is dealing only with individual isotopes introduced into an animal. One advantage of this is that the amount of radioactivity in an organ or the whole body can be obtained from an integral count, the result ultimately being used to calculate radiation dose. However, with the use of multiple isotopes, an emission energy separation is mandatory to obtain dosage. The problem this poses is one of good energy resolution, which in turn depends on the effectiveness of the degradation medium used for a detector (type of scintillator) and the intimacy of the photo-peaks. With a few isotopes of widely spaced photon energy, a liquid scintillation system is applicable and will also give high counting efficiencies. However, with energies which are not widely separated, a suitable crystal system is required. Sodium iodide (NaI) is the most common crystal detector and when used with the proper associated electronics will provide adequate resolution for all of the anticipated biological experiments.

The types of detection media decided upon are discussed in detail below, accompanied by brief reasons for their choice. It is impossible to arrive at one system which will meet all specifications without encountering insurmountable costs for the number of detectors required.

2. Configuration of the Detector

The shape and size of the detector depends almost exclusively upon the sample to be counted. Some samples are in liquid form (urine) and have to be placed in a position which will prohibit leaking. On the other hand, whether the positioning is vertical or horizontal is of little consequence for the solid and/or frozen specimens.

The biological studies will be done on four species of animals, namely mice, rats, guinea pigs and dogs. Knowing this, it is easy to understand the wide range in size and nature of the samples to be counted in one detector. These may vary from the equivalent of a sphere of 1/8" diameter to one of 3". Since it is not economical to have a suitable detection unit designed to meet each sample specification, it is obvious that the system must be geometry insensitive within acceptable limits. Judicial placement into the well (or other configuration) is also important in counting such inhomogeneously sized samples.

Tissue Counting

Only detectors utilizing NaI have been used to date (July, 1963) in small animal studies and no radioactive studies with dogs have been performed. These counters were constructed by Sharp Laboratories, Inc., and are referred to as their "Lowgamma Bulk Spectrometer Detector". The general construction consists of three, 2" diameter x 6" length, NaI crystals triangulated in the horizontal position giving a separation of 120° center to center. Both ends of each crystal are optically coupled with an EMI 6097 phototube and the signals from each pair are added and sent to a pre-amplifier and mixer. The space between crystals is such that a 2 1/2" diameter by 6" length sliding tubular well, which will accept samples up to 300 cc in volume, will just pass between. The energy resolution for cesium-137 gamma rays is specified as 10% typical and 12% maximum.

The nature of the tissue samples from small animals as pointed out above, is such that the size can vary from that of a mouse adrenal to a bulky muscle sample from a guinea pig. In the detector just described, changing the volume counted from less than 1 cc to 250 cc gives a change of $\approx$ 2% in integral counting efficiency for cesium-137 ($\approx$ from 24 to 22%). This offers the advantage of allowing a whole body count on mice, rats and smaller guinea pigs, prior to dissection. Thus, when all tissues from one animal are counted and the results summated and compared to the pre-dissection count, a percent recovery is obtained and serves as a check on the various procedures employed (dissection, counting, computing). The average recovery on 40 rats, determined in this manner, was 109 per cent with a standard deviation of 7.4. This figure could be tolerated experimentally, but these pre-dissection whole body counts are used only for a check on the procedures and not as a quantitative part of the data, per se. This result is in line with the 2% change just mentioned and does indicate a higher efficiency for individual tissues compared to the composite, in the form of an intact animal. Much more consistent results are obtained if care is taken to center each of the smaller samples in the well, thus giving a slightly higher efficiency as well as a better geometry.

Excreta Counting

Feces counting presents fewer considerations regarding geometry than perhaps any other biological sample. The day-to-day collections are roughly of equal size and therefore the sample (in the container) can consistently be placed in approximately the same geometrical configuration in a given type of detector. In the case of small animals these collections are placed into pill boxes and may be counted in the same units as used for the tissues.

Urine probably represents a greater counting problem than any of the biological samples, primarily because of its liquid state. A horizontal well, such as described above, is not feasible unless tightly sealed containers are used in collection. However, it is much more convenient to utilize something like a wax-coated conically shaped milk carton, and count in an upright position. The lids on these are simple to fit onto and remove from the top, and the conical shape gives much more stability in collection, storage and counting. A major consideration in attaining constant counting geometry with urine samples is to always bring the level of liquid to the same height following collection and cage cleaning. Ordinary tap water is currently being used as an additive to dilute the sample to the proper mark for counting. Only rarely will a container overflow due to a malfunctioning drinking water dispenser and cause loss of sample.

To date, the urine samples have been counted in the small animal whole body counter which is comprised of two NaI crystals, 5" diameter x 3" length, mounted horizontally and facing each other.* The urine sample stands in an upright position between the two and is counted at approximately 6% efficiency for cesium-137.

Future Counting Units for Tissues and Excreta

In the near future two liquid scintillation counters will be obtained, suitable for spectral separation of certain isotopic mixtures and for detecting Bremsstrahlung radiation. These will be upright and have a vertical well of approximately 5" diameter x 8" depth, surrounded by more than four inches of liquid scintillator. These counters are suitable for determination of the radioactivity in any of the samples we obtain but their primary use will be for dog tissues and excreta and for small animal urine. The specifications on these call for 1) a 50% efficiency for integral counting of cesium-137, using a 50 kev discriminator base line, 2) a half-width resolution of at least 25% for cesium-137, and 3) a capability of detecting 0.05μc of yttrium-91 with an accuracy of ± 4% at the 95% confidence level for a five minute count. These detectors are being constructed by the Packard Instrument Co., Inc.

DATA ACQUISITION

General Considerations

In distribution and excretion studies there are innumerable calculations to be performed before attaining the end result. In fact, for the simplest small animal experiment of 20 mice, rats, or guinea pigs (one exposure-day), an average of ≈ 12,000 individual data manipulations is required. Considering the possibility of three exposure-days per week, this amount of computation is extremely burdensome and, if done by

*This counter has been described in LF 11 entitled "Procedures and Equipment Used in Inhalation Studies on Small Animals" by R. G. Thomas and R. Lie, September, 1963.

hand, would introduce human errors into the analyses.

To help delete or reduce the numbers of these errors, it was decided to automate the radiation detection process and to use computers for the mathematical manipulations. This requires a system into which as much available information as possible regarding the sample to be counted can be conveniently and automatically punched on paper tape along with the automatic read out from the radiation detectors. This, along with other manually punched information, is acted upon by the computer to give the necessary results. The chances of error are reduced and the time for processing is shortened considerably.

The Automatic Read Out Counting System

1. Block Diagram of all Components

The simplified block diagram shown in Figure 1 demonstrates the over-all counting system. In its simplest form, as shown, there is one scaler for each detector. However, the system in its final form is constructed to enable several scalers and single channel analyzers to operate off one detector and one data input box. The Demand Programmer and Scanner Units sequentially interrogate the scalers and input boxes until a unit has finished a count and is ready to dump all of its information. This is fed through to the tape punch and/or typewriter and the scaling unit is automatically reset. When the tissues from one animal are sequentially being counted on one detector (generally > 50 samples), the data input box need only be changed to indicate the numerical code and the weight of the next tissue.

The system as described above was submitted for competitive bidding and the contract for manufacturing was let to the Radiation Instrument Development Laboratory, Inc. For a detailed description of the system as delivered, see APPENDIX I.

2. The Scalers

There will be many very highly radioactive samples to be counted in the Inhalation Program, so having a fast scaling system is imperative. Because of the high counting rates expected and the choice to

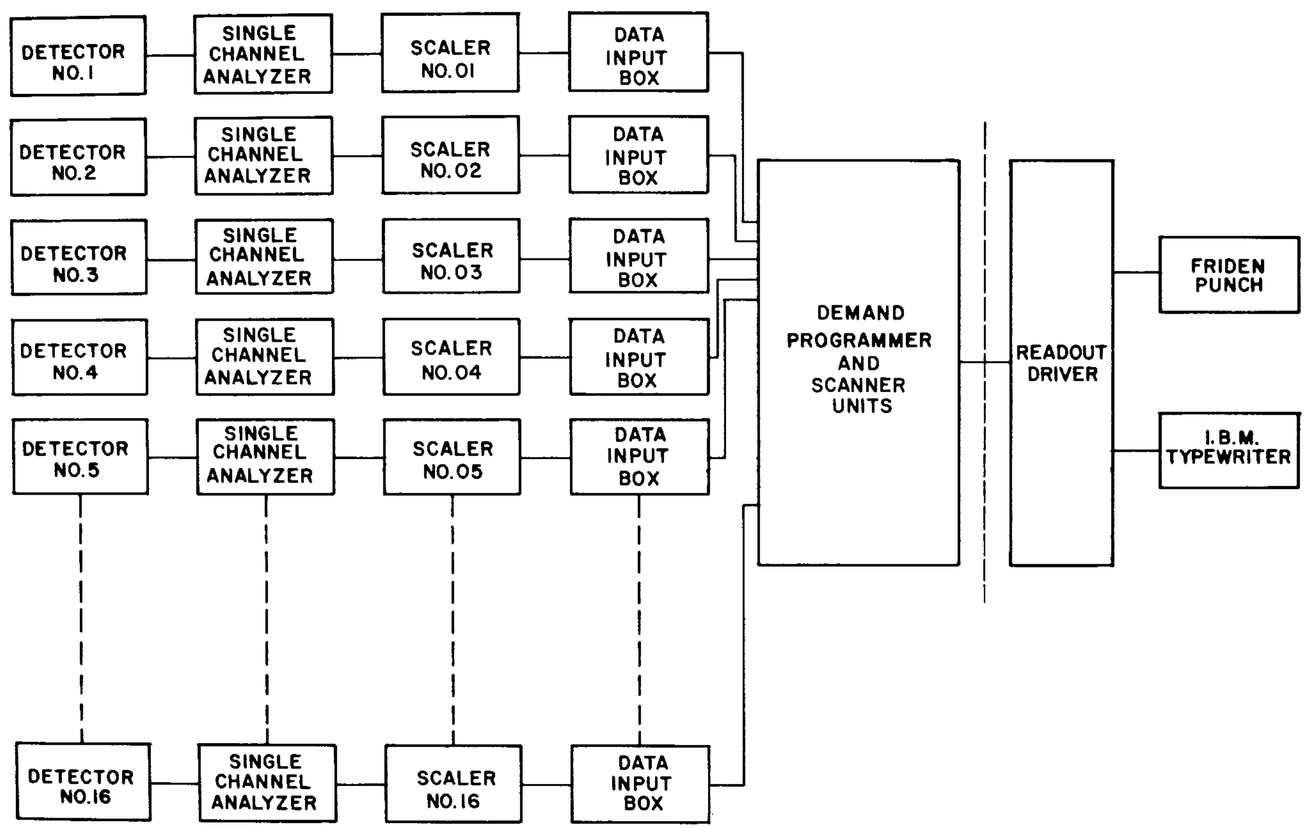
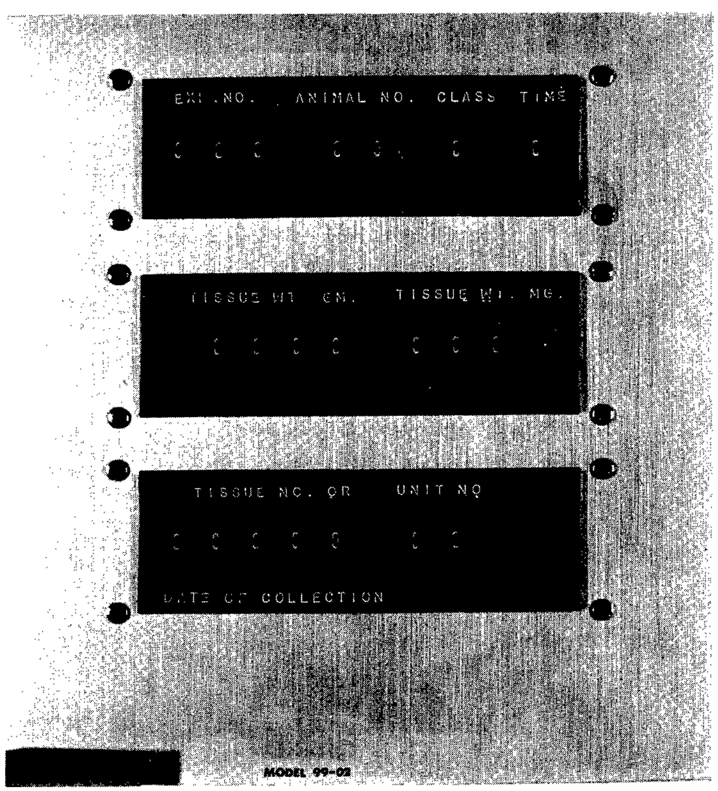


Fig. 1 Simplified Block Diagram of the Automatic Read Out Counting System

count no less than one minute intervals in order to make data input easier, an eight decade unit is being used. The preset time is placed into the data box in minutes, the time of counting depending upon the samples' approximated counting rate. The scalers are of R. I. D. L.'s "Designer Series" and are Model No. 99-10 and they operate off a separate power supply, the R. I. D. L. Model No. 29-1.

3. Data Input Boxes

Manual input of identification data is accomplished with an R.I.D.L. Model No. 99-02 "Phase of the Moon" data input box. This unit may contain 30 binary coded (BCD), ten position, thumbwheel switches to insert numeric information. Only 21 switches are utilized for our purpose and nine blank positions are used to space the digit groupings. The combination of 21 manually set digits and the eight digit read out of the scalers is readily compatible with the Bendix Model G-15 computer currently in use at the Foundation. Minimum tape format is achieved if an input set of 29 or fewer digits per record is used, requiring only an end of word character at the end of record. A photograph of the 99-02 is below:



4. Demand Programmer and Scanner Units

Read out of the Scaler/Data Box combinations is controlled by the Demand Programmer and Scanner Units. The Demand Programmer serially scans up to 16 stations, interrogating for completion of preset time. Upon determination that a system is ready, the scanner reads out the 21 data input switches and then the 9 decade units of the scaler. Completion of scaler read out initiates the resetting of the system in addition to providing an "end-of-word" code for the punch and a "carriage-return" for the typewriter. The Demand Programmer then resumes scanning until the next system reaches preset time.

5. Read out Units

Data are read from the system on 8-level paper tape and roll typing paper. The punch is a Friden Model SP-2 and the typewriter is an I. B. M. 11-C Computer Typewriter. The punch alone provides the essential read out, but the typewriter enables the supervisor to monitor the counting operation in addition to providing immediate data if needed. Since several animals' tissue and excretion samples are counted simultaneously, searching the tape for a particular count can be a very tedious process. The typewriter is a slower device than the punch, and its use requires that read out be done at a slower rate. Read out speed with the typewriter is four seconds per station. Read out speed with the punch only is two seconds per station. A transistorized driver is employed to drive the punch and typewriter selectively or simultaneously.

Preparation for Computer Processing

The punched tape is carried to the computer where it undergoes a tape-to-card conversion. As the sample counts and time of counting are fed in, the division is made to convert these to counts per minute. This is also accomplished for the background for a given detector, and a subtraction of this is made from every successive sample count on this detector until the next applicable background appears. Cards are punched out in terms of disintegrations per minute after correction for background, counter efficiency, and testing for significance. At the completion of an experiment these cards are used as input for the various computational programs; e.g., "tissue distributions".

At equilibrium, when the Inhalation Program is in operation under optimum conditions, it is expected that the following approximate number of radioactive determinations (counts) will be made each year.

Urine and Feces Samples			
1.	Small animals		130, 000/year
2.	Dogs		240, 000/year
		Total	370, 000/year
Tissue Samples			
1.	Small Animals		40, 000/year
2.	Dogs		25, 000/year
		Total	65, 000/year
Whole Body Counts			
1.	Small Animals		75, 000/year
2.	Dogs		50, 000/year
		Total	125, 000/year

The total number of radioactive counts made each year, and presented to the computer by the Radiobiology Department, will ultimately be 5 - 600, 000.

COMPUTER PROCESSING

Specific Data Input

1. Tissues

The data input boxes described on page 7 are utilized to insert the following identification data with each sample count:

Experiment Number	3 digits
Animal Number	2 "
Class Identification (urine, feces, background, etc.)	1 "
Counting Time (minutes)	1 "

Tissue or Excreta Weight	7	"
Tissue Sample Number or Date of Excreta Collection	5	"
Scaling Unit Identification	2	"
Gross Counts (from Scaler)	8	"
	29 digits	

In addition to the above data which are punched with each radioactive determination, certain information is transmitted to the tape as a series of constants which can pertainto a given unit for a sizeable counting period. These bits of information are listed below with the number of digits required for each. Thus, before counting tissues from an entire animal, a special identifying code, including these terms, is fed to the punch. This eliminates the continual use of a large number of data input switches.

Experiment Number	3	digits
Animal Number	2	"
Sacrifice Date or Date of Death	5	"
Initial Body Burden	12	"
Date of Counting	5	"
Background Count Rate	5	"
Isotope Code	2	"
Counting Efficiencies		
a. for whole body data	5	"
b. for tissue and excreta samples	5	"
Unit Number	2	"

It should be pointed out that the information above is for one animal. There may be as few as 20 organs dissected but several samples of many of the larger ones will be counted, and numbers are assigned only to the organ. In this instance, the computer will summate the analytical data from a given tissue, regardless of the number of samples, and produce one end result.

2. Excreta

The same types of information for excreta as for tissues will be entered into the counter. The only major exception is the requirement for daily (or bi-daily) whole body determinations. The manner in which these are handled is described below.

3. Whole Body

The small animal whole body counter, as described briefly under Excreta Counting above, is designed so that an entire metabolism cage and excreta collection tray assembly can be inserted as a unit. This is desirous so that any excretion taking place during counting will not lead to a loss of that day's sample. An animal (guinea pig) or group of animals (two rats or several mice) have two metabolism units, and the same two allotted to them for the entire length of an experiment. At the end of a collection period (one or two days) they are transferred to the cleaned cage. The first cage is then cleaned and the process is repeated throughout the study.

It is practically impossible to get every metabolism cage devoid of any radioactivity during the daily cleaning process. Because the small animals are counted just after transfer to the cleaned cage and because we desire a true determination on the animal(s) itself, it is obvious that the empty cage should be used for the background count. Thus, each cage is counted subsequent to cleaning and the net count above normal background is determined by the computer as described above for tissues. The data from the cage plus animal(s) are treated in a similar manner. The computer then subtracts the two, giving the net radioactivity contained in the animal(s).

These daily (or bi-daily) data for a given animal or animals are stored on cards throughout an experiment. At completion of the study a "best" curve is plotted by the computer and the non-linear least squares fit yields the parameters of the equation. Thus, an accurate value for the body content on any day may be determined, regardless of whether a count was made on that day. These data are then used in conjunction with the excretion data, as outlined in Calculations Required (Excreta) to follow.

Calculations Required

1. Tissues

The sorts of information asked of the computer, given the above information, and the steps required to achieve the end result, are detailed below:

a) The computer calculates the significant counting level it will accept, based upon the average background for the detection unit involved. It then discards any subsequent net count that is below this level.

b) On the basis of the isotope decay constant, the counter efficiency, and the date of counting, the radioactivity for each sample is converted to disintegrations per minute and corrected back to the initial date of the experiment and the date of sacrifice.

c) Using the whole body count (WBC) on day zero, the tissue data are obtained in terms of per cent initial WBC both for day of sacrifice and for day zero.

d) Using the WBC on the day of sacrifice, the tissue data are obtained as per cent of this for that day.

e) The same calculations as in "c" above may be converted to a per gram basis by dividing by the sample weight.

f) A summation of all tissue data from "c" above is made so that a total recovery (balance) may be computed when the excretion data are analyzed.

2. Excreta

The computations required for obtaining excretion data in a workable form follow somewhat the general format used for tissues. However, the specific pieces of output information are quite different in some instances. The steps involved are listed below:

a) Same as 1. a) above.

b) Same as 1. b) above except date of collection is substituted for date of sacrifice.

c) Using the WBC on day zero, the excretion data are obtained in terms of per cent initial WBC both for day of collection and for day zero.

d) The individual excretions are computed in terms of the per cent in the urine or feces on a given day as a function of the WBC on that day. These latter data are entered into the computer as described under Specific Data Input (Whole Body).

e) The daily excreta as a function of the initial body burden are summated over the entire experiment to allow a complete material balance of excreta plus tissues.

Curve Fitting

There are two major reasons for desiring a "best" fit (non-linear least squares) to tissue and whole body data. Firstly, from the fitted exponential expression, an estimated value for various half-lives of the components is implicit. With a representative curve for either individual tissues or the entire body burden, the area beneath the curve can be obtained and hence the radiation dosage can be calculated. This technique is used routinely for hazards evaluation calculations. Secondly, with enough such data, it allows speculation with regard to "metabolism" of the material in question which, in turn, gives a basis for studying kinetics, compartmentalization schemes, etc.

Although at the present time the application of mathematics to this phase of the biological sciences is not far advanced, it does show considerable promise for the future. If the computations described above do nothing else, they at least give a common basis for comparing these simple parameters between the elements. Ultimately we will fit equations other than exponential to the data, whenever they would appear to better describe the processes involved.

APPENDIX I

This is an operational description of the Automatic Read Out Counting System now in use at The Lovelace Foundation. Specifications for an adequate system were written by Foundation personnel and were the basis of competitive bidding for the manufacture of this system. Radiation Instrument Development Laboratories of 4501 West North Avenue, Melrose Park, Illinois, was the successful bidder and they designed a very versatile automatic system by extending greatly the minimum proposed requirements. It is the understanding of the authors that this system, which could appeal to a wide variety of users, is to become a readily available product of the manufacturer. The system is fully transistorized and packed in R. I. D. L. "Designer Series" modules adaptable to many counting and analyzing operations.

For the purpose of this report, the system is herein described only as employed in counting operations at the Foundation. Some discussion of the logic involved is included as an aid in understanding the operation of the system. Any further inquiries should be directed to R. I. D. L.

Counting System - General

The function of the counting system is to provide automatic read out of the sample description and its radioactive content after manual sample changing and starting of counting period. Scalers are automatically reset after read out to provide an indication to the operator that the station is ready to be recycled.

The system was designed with distributed logic which provides that each module added to the system contains the necessary logic to include it in the operation. This precludes the need for modifying any central control or programming unit as the system is enlarged or adapted to a special operation.

Primary cabling of the system is from station to adjoining station and finally to the read out equipment. Thus the counting stations combine in one long chain for read out. The only deviation from this technique is a requirement for a single mini-coax from each scaler to the read out equipment.

The system can be broken down into two groups. First of these is the Read Out and Control Equipment consisting of the Model 99-05 Demand Programmer, the Model 99-06 Serial Scanner, the Model 52-XX Punch-Typewriter Driver, the Model SP-2 Friden Punch and the Model 11-C I. B. M. Computer Typewriter (see Figure 2). As many as 16 Counting and Identification Stations may be employed. These consist of a Model 99-08 Timer, a Model 99-02 "Phase of the Moon" Data Box, and a Model 99-10 Eight Decade Printing Scaler.

Read Out and Control Equipment

1. Demand Programmer

Referring to Figure 2, it may be seen that the Demand Programmer connects directly to each counting station in the system. The Demand Programmer scans the condition of the up to 16 stations continually until it determines that one has reached its preset time. A pulse is then provided to the ready station to set the print bistables and prepare it to read out. The Demand Programmer is locked to this station until read out is complete, and then resumes its scanning for the next ready station.

2. Serial Scanner

The Serial Scanner is the termination of the data lines common to all stations. This unit is a ten-position-plus-home scanner; each position will read one thumb-wheel switch or decade unit and pass it on to the Punch-Typewriter Driver. The home position transmits a reset pulse down the reset common line. The signal to start scanning is derived from the ready station which has been set by the Demand Programmer. After cycling once, the scanner transmits a reset pulse and waits at home position until another start signal is received. The scanner also contains four inverting BCD code drivers as a buffer stage for the four data common lines to the Punch-Typewriter Driver.

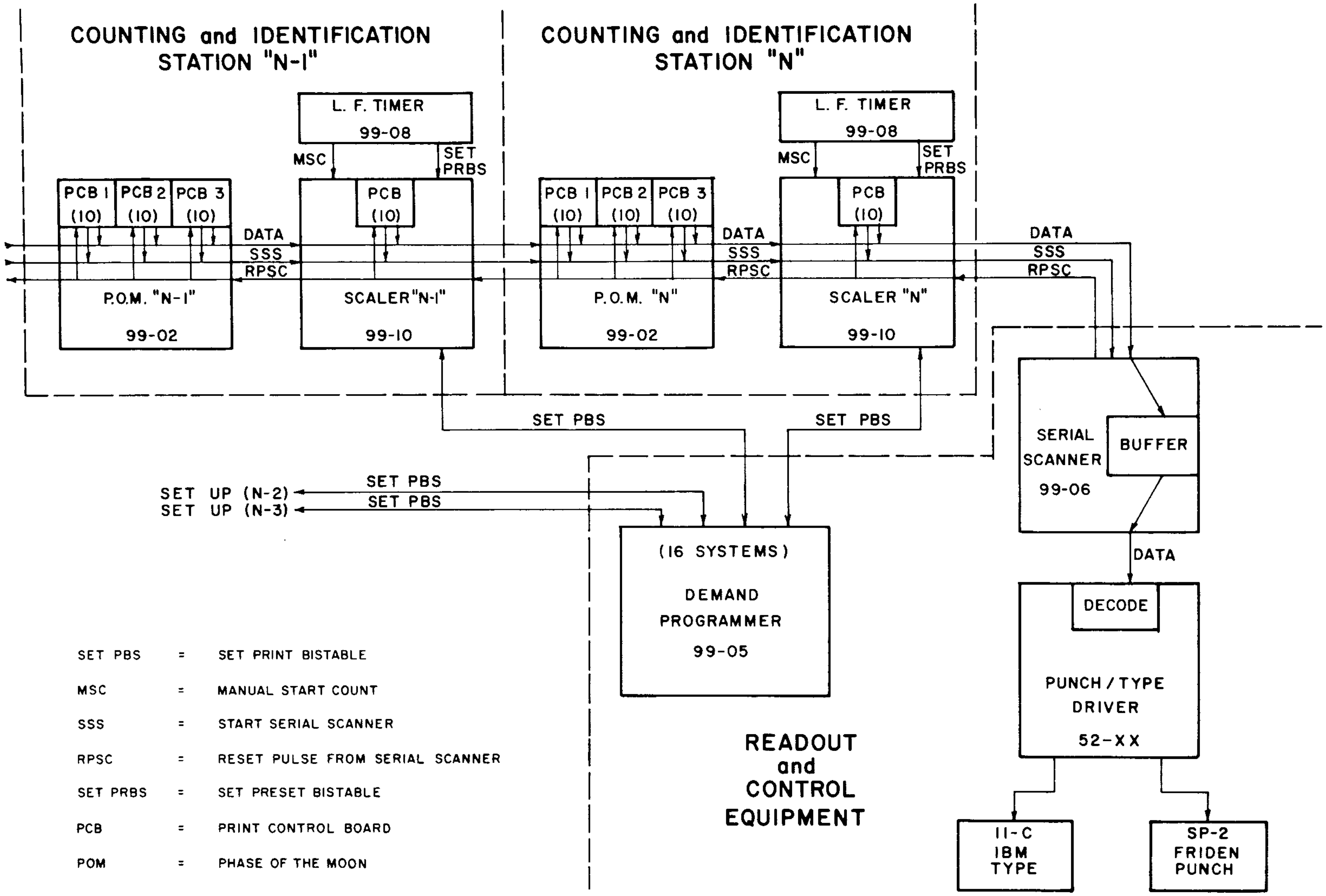


Fig. 2 Detailed Block Diagram of the Automatic Read Out Counting System.

3. Punch-Typewriter Driver

The Punch-Typewriter Driver decodes the 1-2-4-8 BCD as necessary and provides sufficient power to drive the typewriter and punch solenoids. A dial on the driver permits selection of read out to be punch only, typewriter only, or punch and typewriter simultaneously. Read out speed is slower if the typewriter is used than with punch alone, and the driver contains timing circuits to change the speed of the Serial Scanner accordingly.

Counting and Identification Stations

1. Timer

The timer is a mechanical device which contains necessary logic circuitry to start the scaler count gate upon initiation of the timing sequence, stop the scaler count gate after preset time has elapsed, and provide a preset signal to the preset common line to the Demand Programmer. The timer does not recycle automatically, but must be reset and started manually.

2. "Phase of the Moon"

The "Phase of the Moon" data input box contains 21 thumb-wheel switches for manual insertion of sample identification data. The data box switch positions are read out sequentially with each read out of counts from the associated scaler. This data box has provisions for 30 thumb-wheel switches if desired. The extra positions not filled by thumb-wheel switches are available for fixed programming of read out, i.e., space, tab, carriage return, paper-tape codes, etc. If the positions are not used for data or programming read out, they must be set for "skip" code to allow read out to advance.

3. Eight Decade Printing Scaler

The Eight Decade Printing Scaler is the final module to be read out. Ten positions are read in the scalers. Eight of these positions are employed by the decade counters and two are available for programming read out. The scalers contain "Count", "Stop", "Print", and "Reset" pushbutton switches on their front panels. All of these switches are operable, but in the automatic system, the "Count" switch is always depressed and the counting interval and read out time are determined by the timer.

Read Out and Control Logic

Essential logic elements of the system are the count gate, preset bistable, print bistable, data gate and reset gate. Each of these units is discussed with its contribution to the system logic.

1. Count Gate

The count gate controls the counting operation of the scaler. The count gate will pass data input pulses to the scaler if two conditions are present. One of these conditions is that the master count common line is not inhibited. Engaging the "Count" pushbutton on the scaler and depressing the manual start lever on the timer removes the inhibit signal from the master count common line. The other necessary condition is that the preset bistable has not been set, i. e., when the time preset on the timer has elapsed. It follows that the count gate will cease to function upon disengaging the manual start lever or the "Count" pushbutton, or in the alternative, when preset time has elapsed.

2. Print Bistable

Every module in the station has one print control board for each 10 digits to be read out. Each print control board contains a print bistable which controls the module read out sequence. When the Demand Programmer selects a ready station, it provides a pulse to simultaneously set all print bistables. Once set, the print bistable provides a signal to the data gate and an inhibit signal to all print control boards connected to the output connector of the particular print control board. The terms "input connector" and "output connector" refer to modules ahead of and behind the particular module in the common data cabling terminating at the Serial Scanner.

3. Data Gate

Each print control board contains a data gate. The output of the data gate starts the read sequence of the Serial Scanner and enables the 10 digits associated with the print control board to read when interrogated by the Scanner. Necessary conditions for operation of the data gate are that the associated print bistable has been set and that there is no inhibit signal from print control boards connected to the input connector of the particular board. Read out sequence is obtained properly as:

a. All print bistables within a station are initially set, but only the data gate of the first print control board in the station will not be inhibited.

b. After the first print control board is read out, its print bistable is reset and the data gate of the second print control board is no longer inhibited, etc.

4. Reset Gate

Each print control board contains a reset gate whose operation resets the print bistable and the counting decades, if any, associated with the print control board. In addition, a delayed reset pulse from the gate resets the preset bistable associated with the system. Conditions for operation of the gate are that the associated print bistable has been set, that there is not an inhibit signal from a module connected to the input connector, and that a reset signal is received from the Serial Scanner on the data common lines. This pulse from the Serial Scanner originates when it has completed its read scan of ten positions and reaches its eleventh or home position. The logic involved assures that only the reset gate on the print control board which has just been read will be activated, even though the data lines are common to all modules.

Paper Tape Format

The Punch read out is on eight-level paper tape. Our particular format assigns the levels as follows:

1st through 4th levels	numerical information (1-2-4-8 BCD)
5th level	odd-bit parity
6th level	zeroes
7th level	blank (available for future coding requirements)
8th level	end of word code