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AUSTRALIAN NUCLEAR SCIENCE AND

TECHNOLOGY ORGANISATION

LUCAS HEIGHTS RESEARCH LABORATORIES

AUTOMATION OF THE ANSTO WORKING STANDARD OF MEASUREMENT FOR THE ACTIVITY OF RADIONUCLIDES

ABSTRACT

The ANSTO working standard ion chamber is used routinely for the standardisation of a range of gamma emitting radio-isotopes. The ion chamber has recently been automated by replacing the AAEC Type 292 Recycling Discriminator, timer module and model 43 teletype printer with the HP86B computer, HP-59501B voltage programmer and HP-6181C current source. The program "MEASION", which is run on the HP86B computer, controls the ion chamber measurements. The program "IONMAN", run on the Deltacom IBM AT clone, calculates the radioactivity, with full error statements, from the ion chamber measurements. Each of these programs is listed and discussed in this report.

The following descriptors have been selected from the INIS Thesaurus to describe the subject matter of this report for information retrieval purposes. For further details please refer to IAEA-INIS-12 (INIS: Manual for Indexing) and IAEA-INIS-13 (INIS: Thesaurus) published in Vienna by the International Atomic Agency.

ACTIVITY LEVELS; ANSTO; AUTOMATION; CALIBRATION STANDARDS; COMPUTER PROGRAM DOCUMENTATION; DATA PROCESSING; FLOWSHEETS; I CODES; IONIZATION CHAMBERS; M CODES; RADIATION DETECTORS; RADIOISOTOPES

CONTENTS

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1. INTRODUCTION

The ANSTO Radiation Standards Laboratory is responsible for the maintenance of Australia's national standard of measurement for the activity of radionuclides.

It is often possible to measure absolutely the activity of a particular radionuclide using the method of coincidence counting. This measure then represents a primary standardisation of that particular isotope. However, primary standardisations are both time consuming and complex. Therefore the normal procedure for routine standardisations is to calibrate a "working standard" ion chamber directly from the primary standards.

Because of its long term stability and simplicity the TPA ion chamber is ideal as a working standard. The ion chamber discussed in this report is ANSTO's working standard and represents a Secondary Standard of activity measurement. It has been calibrated for 23 different isotopes from absolute activity measurements made in this laboratory. Other gamma emitting isotopes can also be measured using decay scheme information (see Urquhart [1986]).

As routine measurements of activity are regularly made using this ion chamber it is required to produce accurate activity measurements as quickly and as simply as possible. This report discusses the recent modifications and improvements to the ion chamber system. The full capabilities of the ion chamber can now be simply and efficiently utilised with only a introductory knowledge of the ion chamber's operation.

The major changes have been in the development of 2 computer programs. One program automates the measurement procedure, whilst the other calculates the sample's activity, with full error statements, from the results.

2. THEORY

2.1 Ion Chamber Equation

The method of determining a particular sample's activity using an ion chamber is to make ion current measurements for both the sample of unknown activity and a long half-life reference source, such as radium. These results, when combined with measurements made when calibrating the ion chamber, yield a value for the sample's activity. One benefit of this method is that it compensates for any possible drift in the sensitivity of the ion chamber that may have occurred since calibration.

The charge measuring equipment, a Cary electrometer, allows for the selection of any one of a series of voltage range settings ranging from 1mV to 30V and a choice of three different capacitors. There is also a series of six radium reference sources with activities ranging from $\approx$ 60 kBq to $\approx$ 20 MBq. By selecting a suitable combination of radium reference source, capacitor and voltage range a wide interval of activities can be accurately measured.

Usually the same voltage range and capacitor are used for both the sample and radium reference measurements of a particular sample. Under some circumstances, however, it may be convenient to have differing voltage range settings. Under normal circumstances there should be no need to change the capacitor between making the sample and radium reference measurements.

The sample activity is determined from measurements of three different sources:

(i) the sample, measured at time t_m
(ii) the standard source, which will be the same isotope as the sample but of known activity, measured at time t_c
(iii) the radium reference source, measured both at time t_c and at time t_m in order to relate the sensitivity of the chamber at time t_m to the sensitivity when the calibration was performed at t_c, perhaps several years earlier.

In his report on the ANSTO TPA ion chamber, Wyllie [1986], derived the ion chamber equation for the particular case where the capacitor and voltage range settings remain unchanged throughout the measurements. The more general equation, which allows for the change of voltage range and capacitor settings, can be obtained by slightly modifying the derivation given by Wyllie.

Taking into consideration the effect of drifting ion chamber sensitivity, Wyllie derives the following equation (AAEC/E630, Eqn 2.4) for the activity, A_{sm}, of a sample nuclide measured at time t_m:

$$A_{sm} = \frac{(I_{sm} - I_{bm})\,(I_{rc} - I_{bc})\,A_{\sigma c} \,.\, \exp\left[\left(-\frac{\ln 2}{T_r}\right) . (t_m - t_c)\right]}{(I_{rm} - I_{bm})\,(I_{\sigma c} - I_{bc})} \qquad [1]$$

where t_m = time when the sample was measured,
t_c = time when the ion chamber was calibrated,
I_{sm} = ionisation current produced by the sample (including background radiation) at time t_m,
I_{bm} = background ionisation current as measured at time t_m,
I_{bc} = background ionisation current current as measured at time t_c,
I_{rc} = ionisation current produced by the radium reference source (including background) as measured at time t_c,
I_{rm} = ionisation current produced by the radium reference source (including background) as measured at time t_m,
$I_{\sigma c}$ = ionisation current produced by the standard source and background radiation as measured at time t_c,
$A_{\sigma c}$ = activity of the standard source at the time of calibration, t_c,
and T_r = half-life of the radium reference source = 584400 days.

The specific ionisation current, i_{nc}, of the standard source of nuclide n at time t_c is by definition

$$i_{nc} = \frac{I_{\sigma c} - I_{bc}}{A_{\sigma c}} . \qquad [2]$$

The ionisation current, I'_{rc}, produced by the radium reference source (with background subtracted) is by definition

$$I'_{rc} = I_{rc} - I_{bc} . \qquad [3]$$

Substituting [2] and [3] into [1] yields

$$A_{sm} = \frac{(I_{sm} - I_{bm})}{(I_{rm} - I_{bm})} \cdot \frac{I'_{rc}}{i_{nc}} \cdot k_r \qquad [4]$$

$$\text{where } k_r = \exp\left[\frac{\ln 2}{T_r} \cdot (t_m - t_c)\right]$$

$$\text{Now } I_{sm} = \frac{C_m \, \Delta V_m}{\Delta t_{sm}}, \; I_{bm} = \frac{C_b \, \Delta V_b}{\Delta t_{bm}} \text{ and } I_{rm} = \frac{C_r \, \Delta V_r}{\Delta t_{rm}} \qquad [5]$$

where ΔV_m is the increase in potential difference across the capacitor C_m during the time interval Δt_{sm} caused by the sample and background at time of measurement, t_m.

ΔV_b is the increase in potential difference across the capacitor C_b during the time interval Δt_{bm} caused by the background radiation at time of measurement, t_m.

ΔV_r is the increase in potential difference across the capacitor C_r during the time interval Δt_{rm} caused by the radium reference source and background at time of measurement, t_m.

Substituting and making the assumption that the capacitor value is the same both for the radium reference source and the sample measurements (i.e. $C_m = C_r$) yields:

$$A_{sm} = \frac{\left(\frac{C_m \, \Delta V_m}{\Delta t_{sm}} - \frac{C_b \, \Delta V_b}{\Delta t_{bm}}\right)}{\left(\frac{C_m \, \Delta V_r}{\Delta t_{rm}} - \frac{C_b \, \Delta V_b}{\Delta t_{bm}}\right)} \cdot \frac{I'_{rc}}{i_{nc} \cdot k_r} \qquad [6]$$

Dividing numerator and denominator by $C_b \Delta V_b$ yields

$$A_{sm} = \left(\frac{k_b \ \Delta t_{bm} - \Delta t_{sm}}{k_b \ \Delta t_{bm} - k_s \ \Delta t_{rm}} \right) \cdot \frac{\Delta t_{rm}}{\Delta t_{sm}} \cdot \frac{I'_{rc}}{i_{nc} \ . \ k_r} \ . \ k_s \qquad [7]$$

where $k_s = \dfrac{\Delta V_m}{\Delta V_r}$ and $k_b = \dfrac{\Delta V_m \ C_m}{\Delta V_b \ C_b}$.

For a series of measurements this equation becomes:

$$\boxed{A_m = \left(\frac{k_b \ \Delta \bar{t}_b - \Delta \bar{t}_m}{k_b \ \Delta \bar{t}_b - k_s \ \Delta \bar{t}_r} \right) \cdot \frac{\Delta \bar{t}_r \ . \ I_r \ . \ k_s}{\Delta \bar{t}_m \ . \ k_r \ . \ i_c}} \qquad [8]$$

where the subscripts have been simplified and where $\Delta \bar{t}_b$, $\Delta \bar{t}_m$ and $\Delta \bar{t}_r$ are the mean charge time intervals for the background radiation, sample (including background) and radium reference source (including background) respectively. This equation is now in the form used within the program.

The term in the brackets is normally ≈ 1. The term k_r corrects for the change in activity of the radium reference source between the times t_c and t_m. For a period of twenty years this factor is a 1% correction. Tables of I_r and i_c values are given in appendicies A.3 and A.4 respectively.

Furthermore, the activity concentration, C_m, is given by

$$C_m = \frac{A_m}{M} \qquad [9]$$

where M is the mass of the radioactive sample. The activity and activity concentration, respectively, at the reference time, t_0, are given by

$$A_o = A_m \ . \ D \qquad [10]$$

$$C_o = C_m \ . \ D$$

where the decay factor, $D = \exp \left(\dfrac{- \ln 2 * (t_o - t_m)}{T_{1/2}} \right)$

and $T_{1/2}$ is the half-life of the sample being measured.

2.2 Statistics

2.2.1 Standard Formulae

For a set of n observations, $\{x_1, x_2, \ldots, x_n\}$

SAMPLE VARIANCE

$$s^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1} \qquad [11]$$

STANDARD DEVIATION

$$s = \sqrt{s^2} \equiv \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n - 1}} = \sqrt{\frac{\sum_{i=1}^{n}x_i^2 - n\bar{x}^2}{n - 1}} \qquad [12]$$

MEAN

$$\bar{x} = \frac{1}{n} \cdot \sum_{i=1}^{n} x_i \qquad [13]$$

PROPAGATION OF ERRORS

for $x = f(u,v)$ and $\sigma_{uv} = 0$

$$\sigma_x^2 = \sigma_u^2 \left(\frac{\partial x}{\partial u}\right)^2 + \sigma_v^2 \left(\frac{\partial x}{\partial v}\right)^2 \qquad [14]$$

(i) if $x = au \pm bv$ then $\sigma_x^2 = a^2 \sigma_u^2 + b^2 \sigma_v^2$ [15]

(ii) if $x = \pm\, auv$ then $\dfrac{\sigma_x^2}{x^2} = \dfrac{\sigma_u^2}{u^2} + \dfrac{\sigma_v^2}{v^2}$ [16]

(iii) if $x = \pm\, a.\dfrac{u}{v}$ then $\dfrac{\sigma_x^2}{x^2} = \dfrac{\sigma_u^2}{u^2} + \dfrac{\sigma_v^2}{v^2}$ [17]

2.2.2 Standard Deviation in A_m and C_m

Referring to equations [8] and [9], if the term in brackets is assumed to be constant then

$$C_m = f(\Delta\bar{t}_r, \Delta\bar{t}_m, I_r, i_c, M).$$

Using the propagation law, equation [14], yields

$$\left(\frac{\sigma(C_m)}{C_m}\right)^2 = \left(\frac{\sigma(\Delta\bar{t}_r)}{\Delta\bar{t}_r}\right)^2 + \left(\frac{\sigma(\Delta\bar{t}_m)}{\Delta\bar{t}_m}\right)^2 + \left(\frac{\sigma(I_r)}{I_r}\right)^2 + \left(\frac{\sigma(i_c)}{i_c}\right)^2 + \left(\frac{\sigma(M)}{M}\right)^2 \quad [18]$$

where $\sigma(C_m)$ is the standard deviation in C_m and so on in the obvious notation.

$$\text{Also} \quad \sigma(\Delta\bar{t}_m) = \frac{\sigma(\Delta t_m)}{n^{1/2}} \quad [19]$$

Therefore the standard deviation in the sample charge time measurements, as defined by equation [12], is

$$\sigma(\Delta t_m) = \left\{\frac{1}{(n-1)}\left[\Sigma(\Delta t_m)^2 - n(\Delta\bar{t}_m)^2\right]\right\}^{1/2} \quad [20]$$

$$\therefore \left(\frac{\sigma(\Delta\bar{t}_m)}{\Delta\bar{t}_m}\right)^2 = \frac{1}{n(n-1)} \cdot \frac{\left[\Sigma(\Delta t_m)^2 - n(\Delta\bar{t}_m)^2\right]}{(\Delta\bar{t}_m)^2} \quad [21]$$

Similarly,

$$\left(\frac{\sigma(\Delta\bar{t}_r)}{\Delta\bar{t}_r}\right)^2 = \frac{1}{n(n-1)} \cdot \frac{\left[\Sigma(\Delta t_r)^2 - n(\Delta\bar{t}_r)^2\right]}{(\Delta\bar{t}_r)^2} \quad [22]$$

Hence,

$$\sigma(C_m) = C_m \left\{\frac{1}{n(n-1)} \cdot \left(\frac{\left[\Sigma(\Delta t_r)^2 - n(\Delta\bar{t}_r)^2\right]}{(\Delta\bar{t}_r)^2} + \frac{\left[\Sigma(\Delta t_m)^2 - n(\Delta\bar{t}_m)^2\right]}{(\Delta\bar{t}_m)^2}\right) + \left(\frac{\sigma(I_r)}{I_r}\right)^2 + \left(\frac{\sigma(i_c)}{i_c}\right)^2 + \left(\frac{\sigma(M)}{M}\right)^2\right\}^{1/2} \quad [23]$$

Similarly, the standard deviation in A_m is given by

$$\sigma(A_m) = A_m \left\{ \frac{1}{n\,(n-1)} \cdot \left[\frac{[\,\Sigma(\Delta t_r)^2 - n\,(\Delta\bar{t}_r)^2\,]}{(\Delta\bar{t}_r)^2} + \frac{[\,\Sigma(\Delta t_m)^2 - n\,(\Delta\bar{t}_m)^2\,]}{(\Delta\bar{t}_m)^2} \right] + \left(\frac{\sigma(I_r)}{I_r} \right)^2 + \left(\frac{\sigma(i_c)}{i_c} \right)^2 \right\}^{1/2} \qquad [24]$$

2.3 Decay Corrections

It is often necessary to apply a decay correction to activity measurements in order to determine the activity of the sample at some reference time. In this case the activity of a sample, N_r, at the reference time, t_r, is given by:

$$N_r = N_m \exp\,[\,\lambda\,(t_m - t_r)\,] \qquad [25]$$

where N_m is the activity as measured at time, t_m.

The mean activity over the entire measurement period is given by

$$N_{mean} = \frac{\text{Total Number of Disintegrations}}{\text{Measurement Period}} \qquad [26]$$

If the measurement period is sufficiently small compared to the sample's half-life then the decay curve can be assumed to be linear over the duration of the measurement period. The mean activity calculated over the entire measurement period is then equal to the activity half-way through the measurement period.

For longer measurement periods this assumption may no longer be valid, in which case the correction formula derived below may be used:

Consider a measurement period from time $t = -T/2$ to $t = +T/2$ (Figure 2.1). The ionisation current at time t is given by

$$I = C\,\frac{dV}{dt} \qquad [27]$$

where $\frac{dV}{dt}$ is the rate of change in the potential difference across the capacitor which has a capacitance C. The specific ionisation current is defined as the amount of current produced per unit of activity,

$$i_c = \frac{I}{N_t} \qquad [28]$$

where N_t is the activity of the nuclide at time t.

Combining equations [27] and [28] yields

$$\frac{dV}{dt} = \frac{N_t \, . \, i_c}{C} = \frac{N_0 \, . \, i_c \, . \, e^{-\lambda t}}{C} \qquad [29]$$

The change in potential difference over the period T is equal to

$$V = \int_{-T/2}^{+T/2} \frac{N_o \, . \, i_c \, . \, e^{-\lambda t}}{C} \, dt = \frac{N_0 \, . \, i_c}{C \, . \, \lambda} \left[\exp(+\lambda T/2) - \exp(-\lambda T/2) \right] \qquad [30]$$

The mean disintegration rate, N_{mean}, over the period T is given by

$$N_{mean} = \frac{C \, . \, V}{T \, . \, i_c} \qquad [31]$$

Equating equations [30] and [31] yields

$$N_0 = \frac{\lambda . T . N_{mean}}{\exp(+\lambda T/2) - \exp(-\lambda T/2)} \qquad [32]$$

This correction is usually very small; for example the correction when $T = ½ \, T_{1/2}$ is only 0.5%.

3. EXPERIMENTAL ARRANGEMENT AND PROCEDURE

3.1 Superseded Method

Prior to the automation of the ion chamber in June 1990, Ion Chamber measurements required the use of the AAEC type 292 discriminator unit, a teletype printer and a Canberra timer module type 2071.

During charge integration, the electrometer needle sweeps from 0 to full scale whilst the voltage from the electrometer output ramps from 0 to 1 volt.

The AAEC Type 292 Recycling Discriminator was specifically designed to allow the charging capacitor to charge and discharge in a cyclic manner whilst the charge time for each of these cycles is measured. The discriminator is designed to detect upper and lower voltage levels. When the input voltage to the discriminator, from the electrometer, reaches the lower level (set at .1 Volt) the discriminator sends a pulse to the timer which then commences timing. On reaching the upper voltage level (set at .9 Volt) the discriminator sends another pulse which this time stops the timer.

Meanwhile, the discriminator sends another signal which closes the relay connected to the pre-amp thus discharging the capacitor. When this relay is subsequently released the capacitor again begins to charge and a new measurement cycle commences.

3.2 Automated and Semi-Automated Methods

In the process of automating the ion chamber a semi-automated method was also developed. The semi-automated and fully automated methods are also referred to as "Method #1" and "Method #2" respectively. Method #2 is, under normal circumstances, the easiest method to use.

Both methods use the HP86B computer's internal clock to make the necessary time measurements. Method #2, in addition, eliminates entirely the need to use the discriminator unit by using a voltage programmer and current source to open and close the relay which discharges the capacitor.

Test measurements comparing Method #1, Method #2 and the superseded method produced almost identical results.* A block diagram is shown in Figure 3.1.

In designing and building a computerised ion chamber there is no need to include a unit such as the 292 recycling discriminator. Furthermore the method could be simplified by using a gating voltage from within the computer to operate the relay instead of using the method discussed here. The method outlined here has evolved directly from the previous method and was determined by the equipment available at the time of writing.

There are two separate computers used in this system; one for collecting the charge time measurements and the other for analysing these measurements. This again was a result of equipment availablility and convenience. The ideal situation would be to use one computer to perform both the data collection and the data analysis.

The data analysis program has written for the AT computer as it was assumed that this computer would in the future be used for the data collection also. At the moment the data is entered manually into the analysis program. The ideal situation would be to have the measurement program record the results on disc and the analysis program read the results from the same disc.

The superseded and semi-automated methods are discussed here for the sake of completeness only.

* For method #2 it is important that the discriminator be disconnected from the rest of the circuit. If it is left connected and turned off it will draw current from the electrometer output which will subsequently cause an increase in the charge time. If the discriminator is turned on no noticeable change occurs to the charge time.

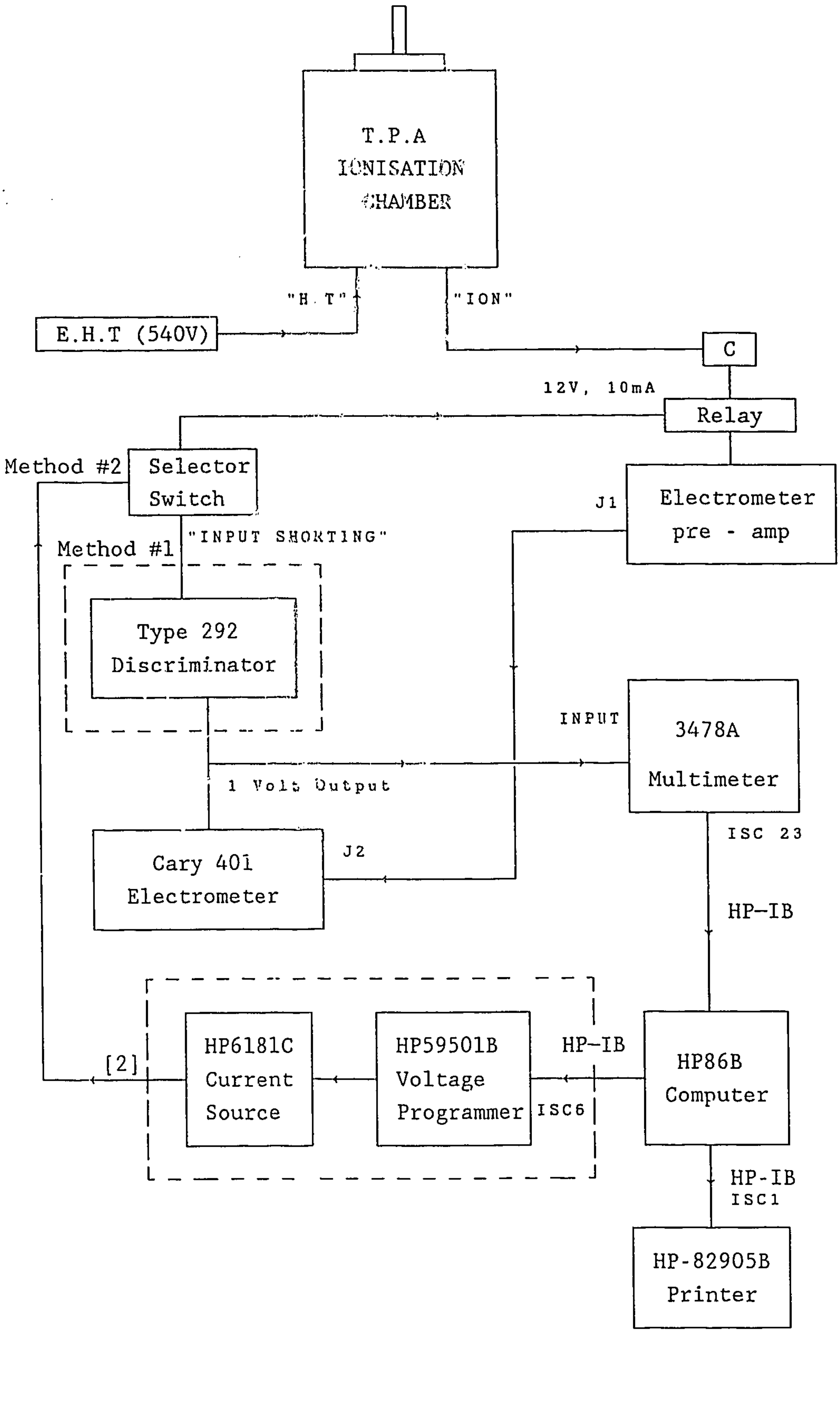


Figure 3.1 – Block diagram of Methods #1 and #2

4. EQUIPMENT

4.1 Cary 401 Electrometer and Pre-Amp

The Cary 401 Vibrating Reed Electrometer is capable of measuring either charge, current, voltage or resistance. It can measure charges as small as 5×10^{-16} coulomb, currents as low as 10^{-17} ampere, voltages down to 2×10^{-5} Volt and resistances of over 10^{12} ohms.

The Cary 401 is an integrating device which measures charge as it collects on the capacitor, C_c (Figure 4.2). A portion of the input signal is converted to alternating current by the vibrating reed capacitor, C_v. The a.c. signal produced, which is proportional to the collected charge, is amplified by an a.c. amplifier, synchronously rectified, filtered and used to drive the indicating needle or recorder. A portion of the d.c. output is applied as negative feedback to provide very high forward gain stability.

In this application, the Cary 401 is being used to measure the ion current produced within the ion chamber. To achieve this the "rate-of-charge" method of operation is used. In this method virtually all of the electrons from the ion chamber are collected on the charge collecting capacitor, C_c (mounted above the pre-amp unit). The change in charge on C_c and thus the rate at which the output voltage, V, increases (as the electrons are collected at the input) is directly proportional to the unknown ion current.

By measuring the time taken for the capacitor to charge over a specified potential difference, the rate of increase $\Delta V/\Delta T$ can be determined and related to the ion current, I, as follows:

$$I = \frac{dQ}{dt} = C_c \frac{dV}{dt} = C_c \frac{\Delta V}{\Delta T} = \frac{C_c \cdot VR \cdot SF}{\Delta T} \qquad [33]$$

where Q = charge in coulombs,

C_c = charge collecting capacitance in farads,

ΔV = potential difference over which the measurement was made,

SF = scaling factor (The fraction of full scale used for the measurement) = 0.8,

VR = voltage range setting on the electrometer

and Δt = time interval in seconds.

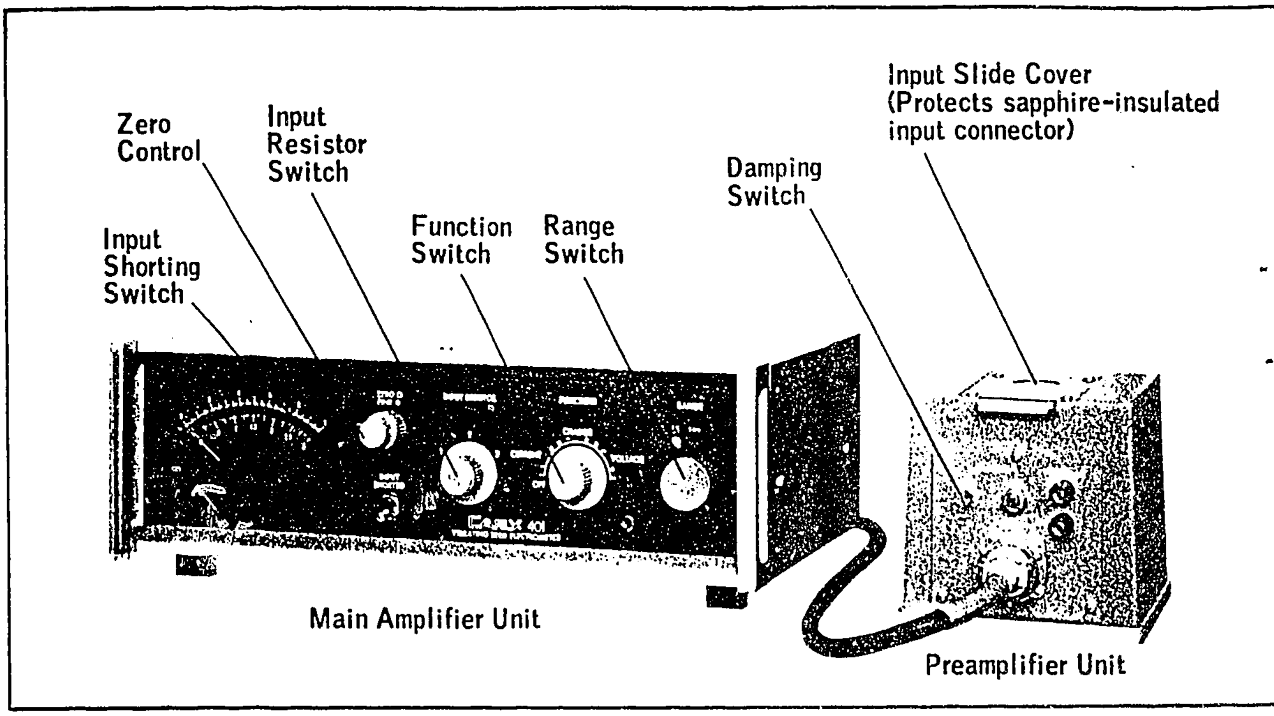


Figure 4.1 - Cary 401 Vibrating Reed Electrometer.

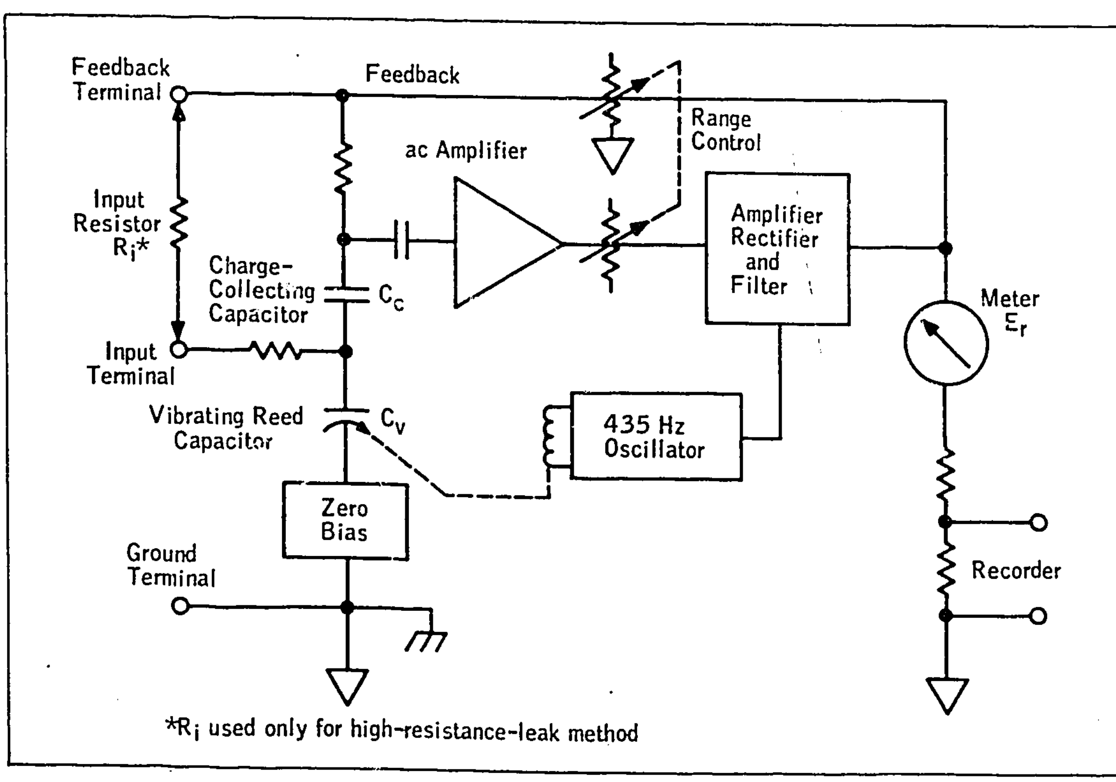


Figure 4.2 - Cary 401 Block Diagram.

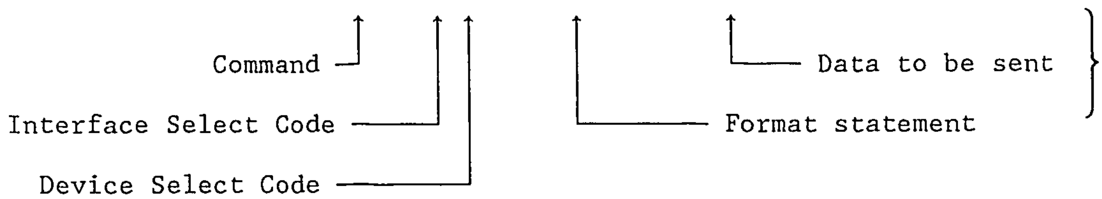
4.2 HP-86B Computer

The measurement procedure is controlled by the Hewlett Packard 86B computer according to the Basic software written for this purpose. The charge time measurements are made using the computer's internal clock. The SETTIME function sets the time and the TIME function recalls the time, in seconds, to one thousandth of a second.

Communications to and/or from the HP-82905B Printer, HP-59501B Voltage Programmer and 3478A Digital Multimeter are achieved via the Hewlett Packard Interface Bus (HP-IB). All the I/O operations made were achieved by using the ENTER and OUTPUT statements.

For example, to send the number 2000 to the Voltage programmer the following format was used:

```
OUTPUT 706 USING "#,4D"; 2000
```



For more information on the Hewlett Packard I/O ROM, formatting I/O ROM operations and I/O error handling see ref (4).

4.3 HP-3478A Digital Multimeter

The HP-3478A Multimeter is fully programmable via the HP-IB on the HP86B computer. In this application the 3478A is used to measure the voltage output from the rear panel of the Cary 401 Electrometer. These measurements are then read, from the multimeter, by the HP86B via the HP-IB. The output from the Cary 401 is connected to the 2 pin input of the 3478A. A HP-IB interface cable connects from the rear of the multimeter to the rear of the computer. The multimeter HP-IB address should be set to 23. At "turn on" the 3478A displays the HP-IB address, after first performing a self-test of its circuitry.

See the ref (5) for the complete list of the 3478A HP-IB programming commands. For the application here it is first necessary to program the 3478A settings. This is achieved using the statement found on line 1340 of the MEASION program.

```
OUTPUT 723;"Function 1, Range 0, Number 5, Zero 1, Trigger 4"
```

The multimeter ignores all lower case letters, spaces, commas and semicolons; hence these may be used freely to format commands for easy readability, as has been done here. An equivalent statement would therefore be:

```
OUTPUT 723; "F1R0N5Z1T4"
```

These statements set the following:

Function 1 – DC Volts

Range 0 – 3 Volt Range

Number 5 – 5½ digit display

Zero 1 – Auto zero off

Trigger 4 – Trigger hold

To now make a voltage measurement, the 3478A is first remotely triggered and then the measurement received by the HP86B computer, from the 3478A, via the HP-IB. To trigger the multimeter the following command is used :

OUTPUT 723; "T3"

The voltage measurement is read using the command :

ENTER 723; V

The triggering of the 3478A is controlled in this way to eliminate the possibility of timing problems which may have occurred if the 3478A triggered internally.

4.4 <u>HP-59501B Power Supply Programmer</u>

The HP Isolated D/A Power Supply Programmer Model 59501B was designed to allow HP power supplies to be digitally controlled via the HP-IB from a computer, calculator or some other suitable controller. The 59501B can also be used on the HP-IB as a digitally programmable low level d.c. signal source. For example, the 59501B has been used previously in the Australian Radiation Standards Laboratory to digitally control Ortec 556 High Voltage Power Supplies (Buckman, AP/TN229 [1991]) and Ortec 551 Single Channel Analysers (Sherlock, AP/TN224 [1989]). In this particular application, the 59501B is being used to control the HP-6181C Current Source.

The digital format is bit parallel, byte serial, ASCII coded format. The 59501B is basically a digital-to-analogue (D/A) converter that provides an output voltage in response to digital data received on the HP-IB. Two programmable output ranges are available. A switch on the rear panel allows the selection of either the unipolar or bipolar output modes. The unipolar mode provides a 0 to .999 V or a 0 to 9.99 V output range whilst the bipolar mode provides a -1 V to +.998 V or -10 to +9.98 V output range.

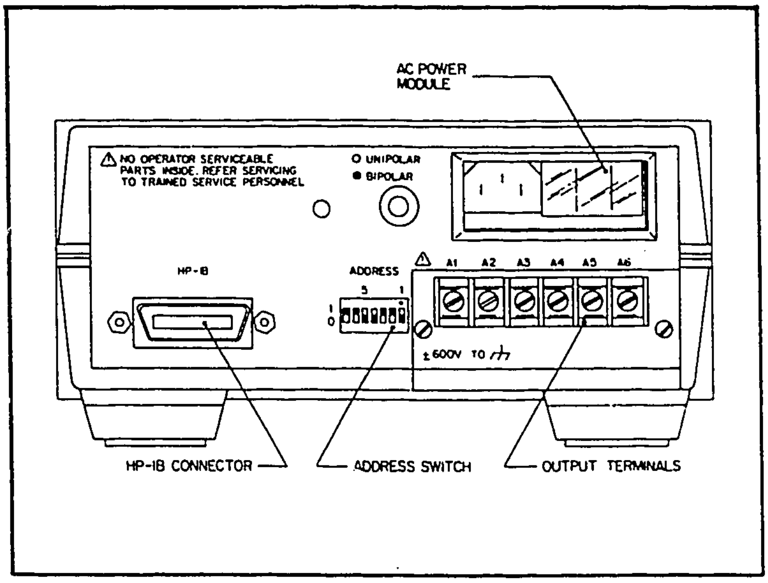


Figure 4.3 - 59501B Rear Panel.

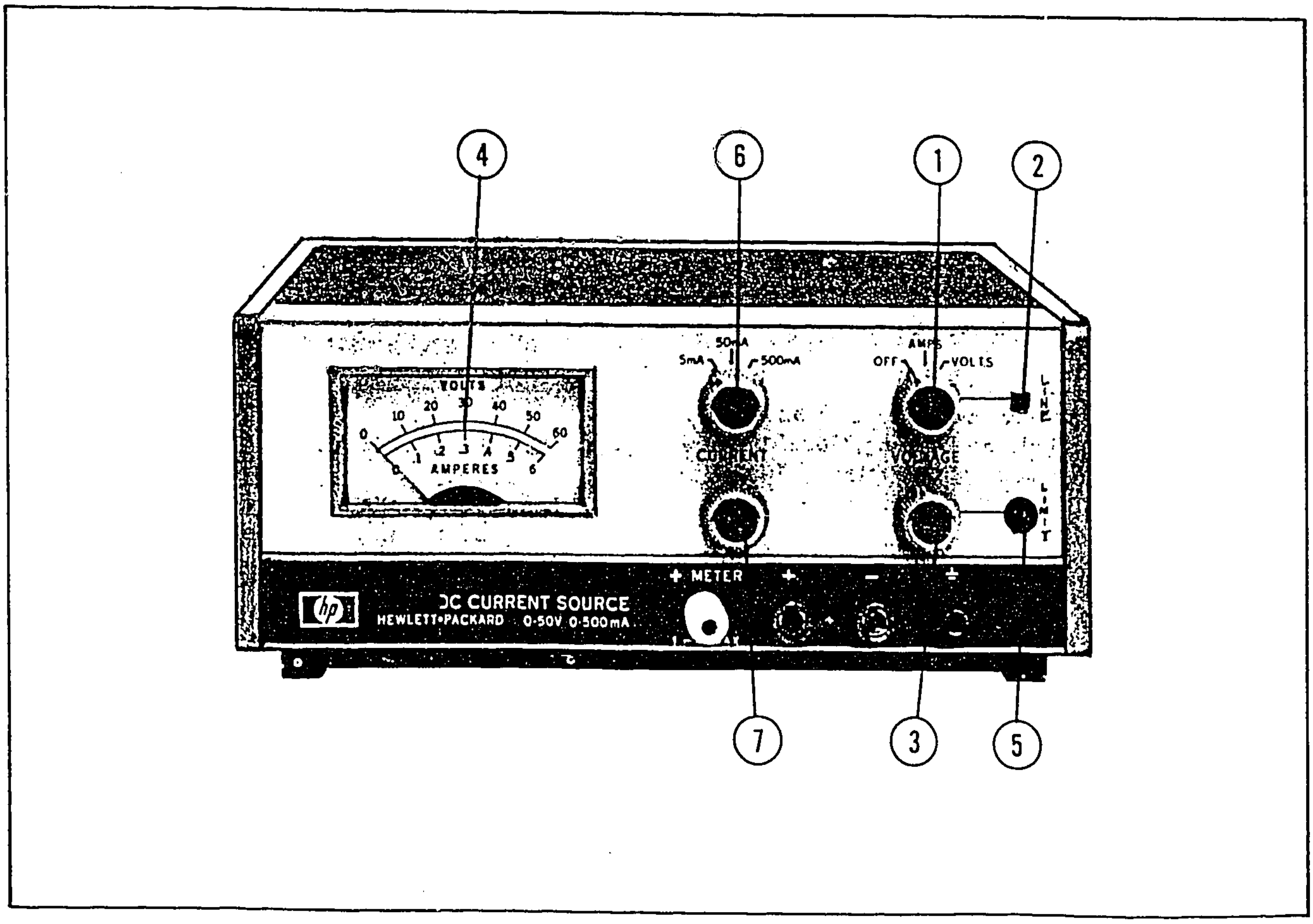


Figure 4.4 - 6181C DC Current Source.

The 59501B's front panel adjustments provide calibration of power supply outputs. The ZERO ADJUST enables the user to correct for small offsets in power supply response to programmed inputs.

The POWER SUPPLY FULL SCALE ADJUSTMENT (COARSE / FINE) allows the user to set the maximum output desired from the power supply when the 59501B is programmed to its maximum output.

The 59501B is a "listen-only" device; the LISTENING indicator on the front panel allows the operating status of the 59501B to be monitored. The listen address for the 59501B is selected by address switches on the rear of the unit. The last two switches, 6 and 7, are ignored and have no effect. For this application, the listen address switch should be set to the preset address "&". This particular listen address corresponds to an address of "06".*

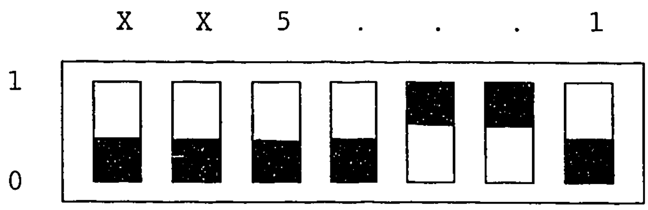


Figure 4.5 – 59501B Listen Address Switch Setting

Programming the 59501B is achieved through the transmission of four consecutive digits. The first digit specifies the output range whilst the next three digits specify the magnitude within the selected range. The high/low range capability provides a ten to one improvement in resolution. Setting the range digit to 1 selects the low range whilst 2 selects the high range. The magnitude digits can be any number from 000 to 999. The 59501B automatically provides an output voltage as soon as the four digits are received and maintains this output until the next four digits are received.

In unipolar mode 000 equals 00.0% of the full range, 500 equals 50.0% of full range and 999 equals 99.9% of full range. In the bipolar mode, 000 equals the maximum negative voltage output, 500 equals 0V output and 999 equals the maximum positive voltage output.

---

* As defined in the HP-98251 General I/O ROM Manual (09825-90024), chapter 4.

Calculating Data Word Values

The 4 digit "data word value", which ets the voltage and range settings on the 59501B, is specified by the equation,

$$N = R + M \qquad [34]$$

where N is the 4 digit "data word value" , R is the "range portion" and M is the "magnitude portion".

The magnitude portion, M, is given by

$$M = INT (V/D + .05) \qquad [35]$$

where V = the desired output voltage (Volts)
and D = the resolution (Volts).

MODE	RANGE	VOLTAGE RANGE	D	R
Unipolar	High	0 to 9.99 V	.01	2000
	Low	0 to .999 V	.001	1000
Bipolar	High	-10 to 9.98 V	.02	2000
	Low	-1 to .998 V	.002	1000

Figure 4.6 – Table of 59501B Range Settings

The rear panel connections are shown in Figure 4.7 on the following page.

4.5 HP-6181C Current Source

The 6181C is a solid-state, precision constant current source. It has several different operating modes; a particular mode is selected by making strapping connections between the specified terminals strips at the rear of the power supply.

The 6181C will furnish full rated output current at the maximum rated output voltage or can be continuously adjusted throughout the output range. The front panel VOLTAGE control is used to establish the output voltage limit (ceiling) when the supply is used as a constant current source. This control is continuously variable throughout the entire voltage range. The front panel CURRENT control can be used to establish the output current limit (overload or short-circuit) if the supply is used as a voltage limited source.

The single meter is used to measure either output voltage or current. The dual selection is accomplished by a METER switch on the front panel. Output current can be measured in one of the three ranges in accordance with the RANGE switch settings on the front panel. Output voltage is measured in only one range.

For this particular application, the 6181C is "remotely programmed" by the voltage from the 59501B Voltage Programmer. The current from the 6181C operates the relay located above the pre-amp unit. The voltage limit is set to 13 V. The rear panel connections between the 59501B and 6181C are shown in Figure 4.7. It was found, for this particular case, that to produce a constant current of 10 mA to the relay, a control voltage of ~2.4 Volts was required.

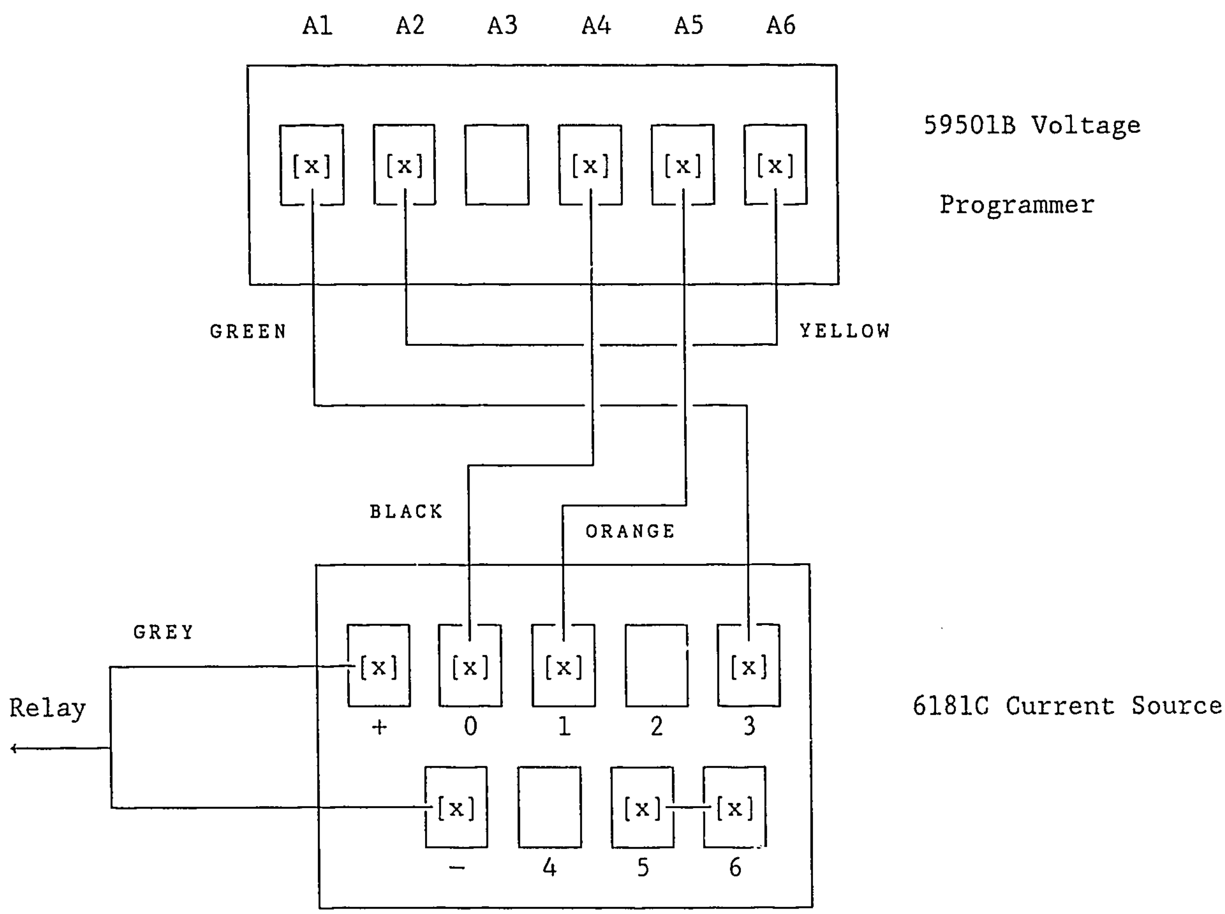


Figure 4.7 – 59501B and 6181C Connections

5. PROGRAMMING OVERVIEW

Two programs are required to determine activity using the ionisation chamber. The program entitled MEASION, run on the HP86B computer, measures the charge times. The program entitled IONMAN, which is run on the Deltacom AT computer, calculates the activity from these measurements. The programs MEASION and IONMAN are listed in Chapter 8.

5.1 HP86B Measurement Program

The program MEASION is for measuring the ion chamber charge times using method #2. The program 1MEASION is for measuring the charge times using method #1. As 1MEASION is almost identical to MEASION and will normally not be used, it has not been listed or discussed here.

The program MEASION is included on the "APPLICATION DISC" and can be run directly from the menu program on the disc. To run the menu program insert the disc into the left disc drive, ":D700", and turn the computer on. As the computer "boots-up" it will automatically load and run the menu program. Selecting option #2 will run the MEASION program.

The program displays the relevant user instructions for setting up the equipment before then proceeding to the measurement section. The user enters the number of samples to be measured and the number of repeat measurements to be made for each of the samples. The user then enters the capacitor and range settings for the first sample.

If desired, the computer will make a test measurement to determine whether the charge time is within 90 sec and 300 sec. If the charge time is not within this interval a message is displayed suggesting the necessary changes to either the voltage range or capacitor settings; if the charge time is within the interval the computer automatically proceeds with the measurements. Appendix A.5 is a guide to determining the correct voltage range and capacitor settings for a given ionisation current.

Results of each measurement are displayed on the computer screen. On completing all of the measurements, for a particular sample, the computer prints a table of results to the HP-82905B printer and waits for the next sample to be inserted. The program automatically calculates the radium reference source suitable for each of the samples. This is found on the printout for each sample. On completing the measurements of each sample the computer instructs the user as to which radium reference source to insert next. The results for each radium reference source are also printed at the completion of the required number of measurements for that source. On completion of all measurements the computer displays further instructions before returning to the menu program.

The voltage from the electrometer cannot be continuously monitored from the computer; this means that the voltage sweep per cycle differs slightly from one measurement to the next. The effect of this is eliminated by correcting each of the charge times to a set voltage sweep of 0.8V.

Hence the corrected charge time = $T/V \times 0.8$ where T is the measured charge time over the measured voltage sweep, V. Values for T, V and the corrected charge time are included in the printout. The time in the middle of each measurement, as well as the mean time over the entire measurement period, is included so that decay corrections may be made if necessary.

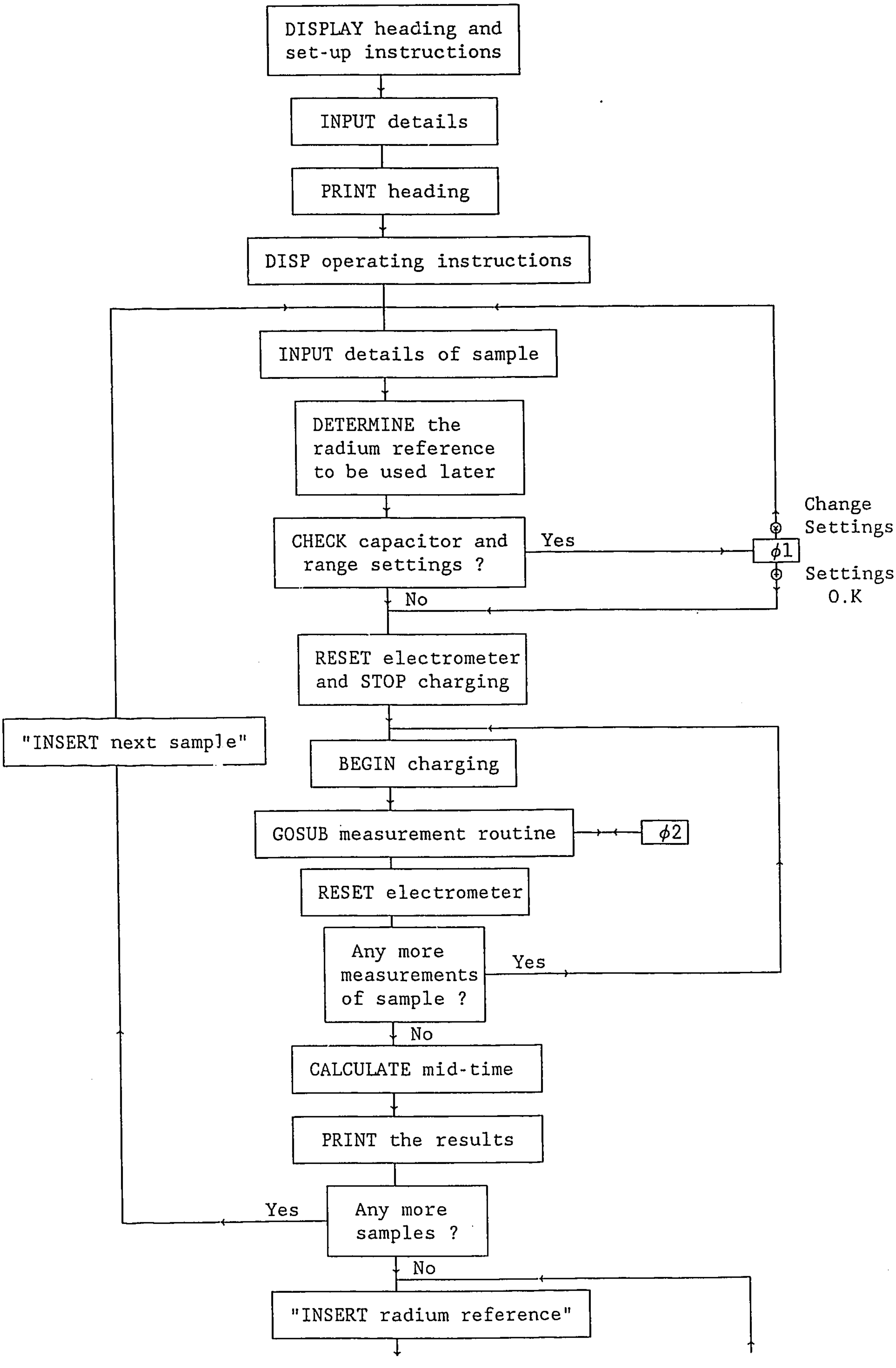
The program MEASION is listed in section 8.1 and the flow diagram in shown in Figure 5.1.

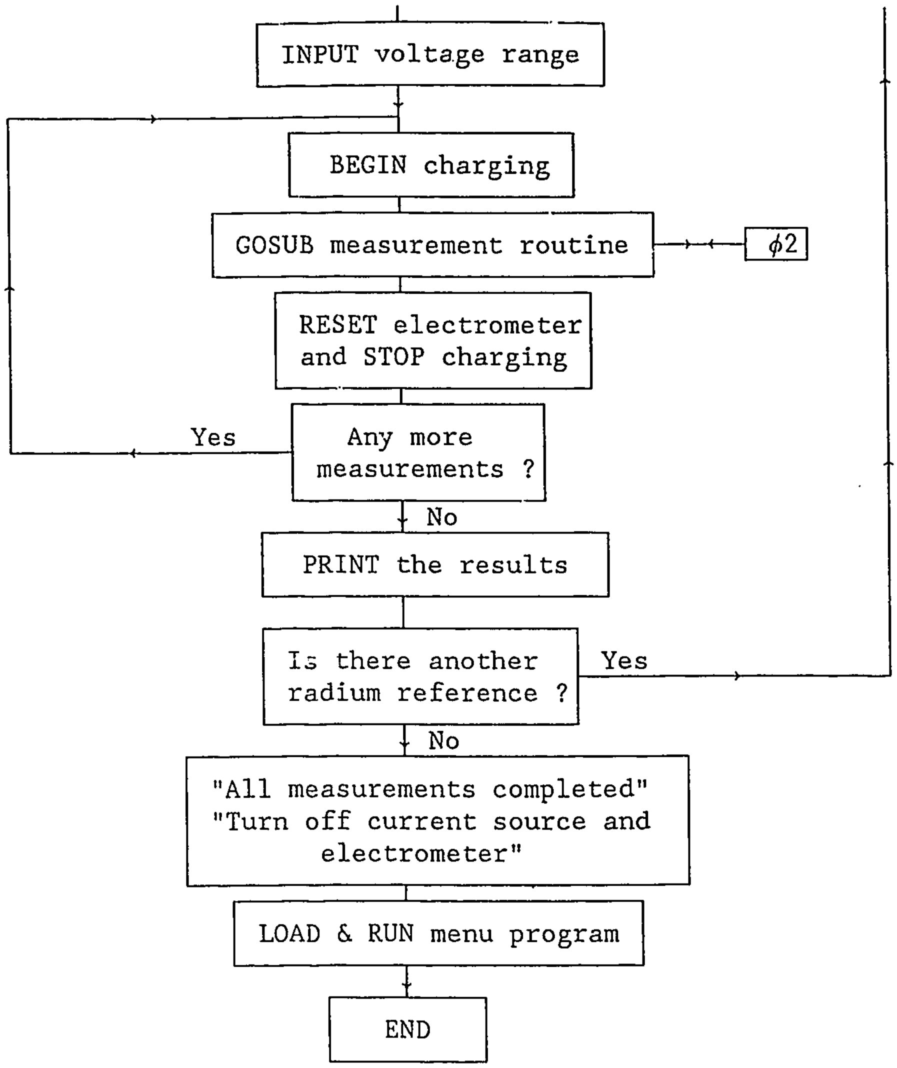
5.2 Deltacom Analysis Program

The program entitled "IONMAN" has been written using QUICKBASIC Version 4.5. It has been designed specifically for a Deltacom 286 IBM clone with a VGA card and KX-P1180 printer however the program could be easily modified to suit other equipment. A flow diagram of the program is shown in Figure 5.2 and the complete listing is found in section 8.2. The program can be accessed via the Quickbasic software. Within Quickbasic the program can be run, modified or compiled.

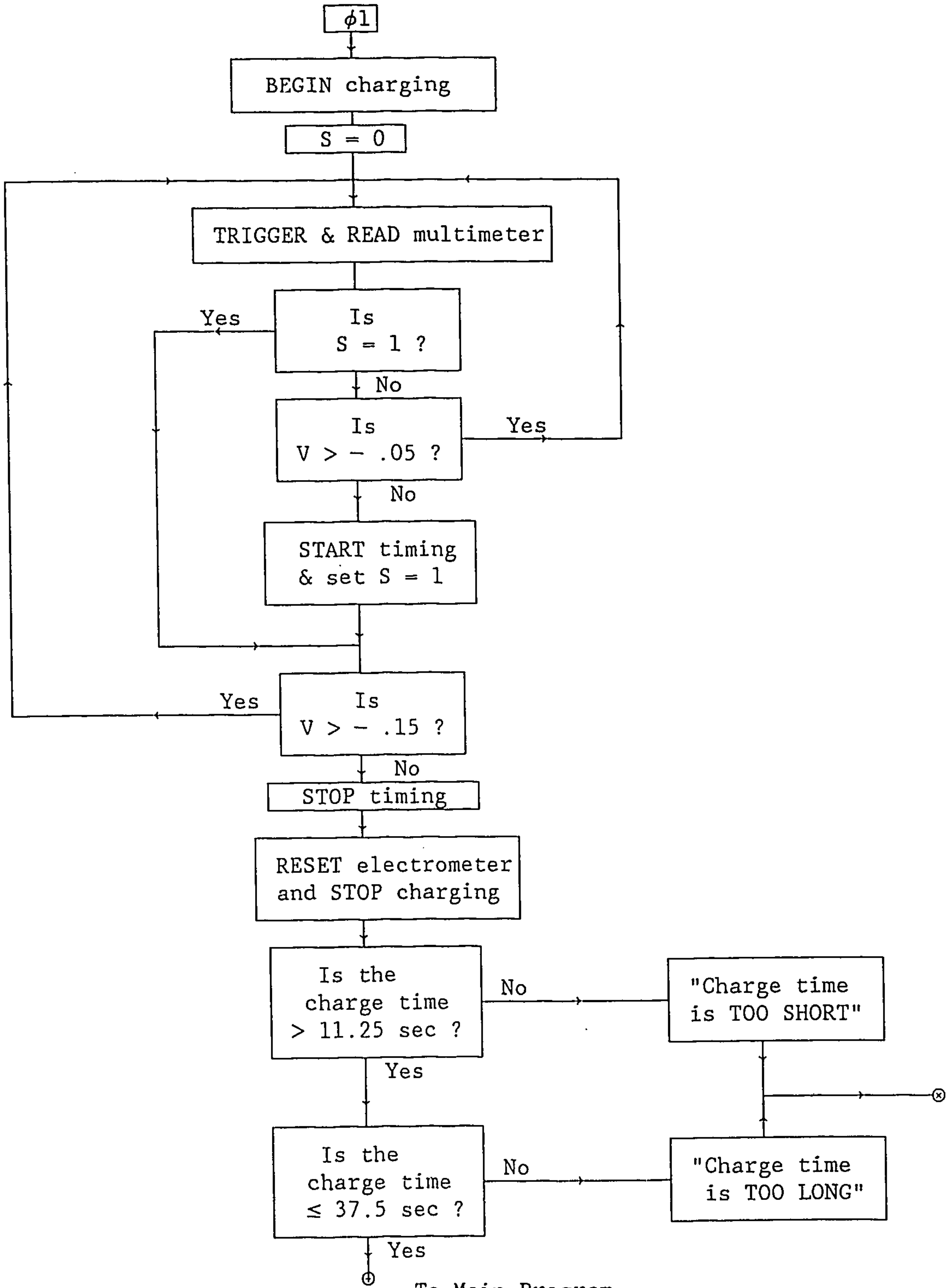
Figure 5.3 is a list of all the variables used within the program with the line number in which they are first used. They are listed sequentially; with the variables contained in the main module listed first followed by those contained in the subroutines. Appendix A.1 provides a summary and brief explanation of all the Quickbasic statements and functions used within the "IONMAN" program. A table of ASCII characters is provided in Appendix A.2.

FIGURE 5.1 - FLOW DIAGRAM : MEASION




INPUT voltage range
BEGIN charging
GOSUB measurement routine
ϕ2
RESET electrometer and STOP charging
Any more measurements ?
Yes
No
PRINT the results
Is there another radium reference ?
Yes
No
"All measurements completed"
"Turn off current source and electrometer"
LOAD & RUN menu program
END

ϕ1 : CAPACITOR & RANGE SETTING CHECK



ϕ2 : MEASUREMENT SUBROUTINE

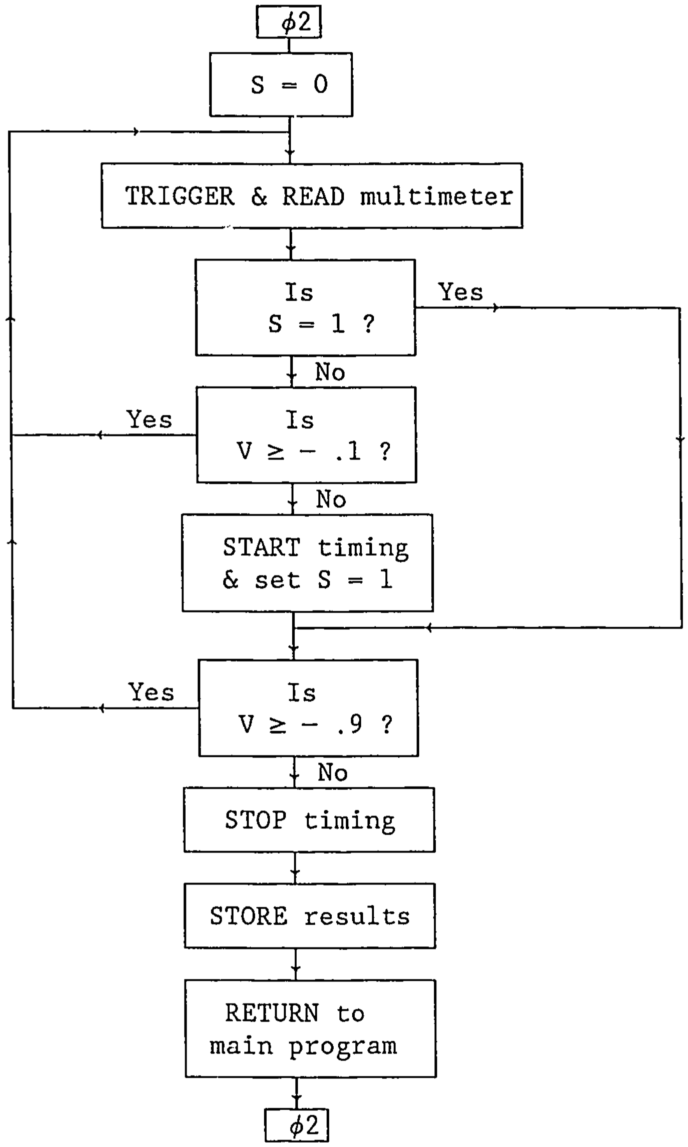
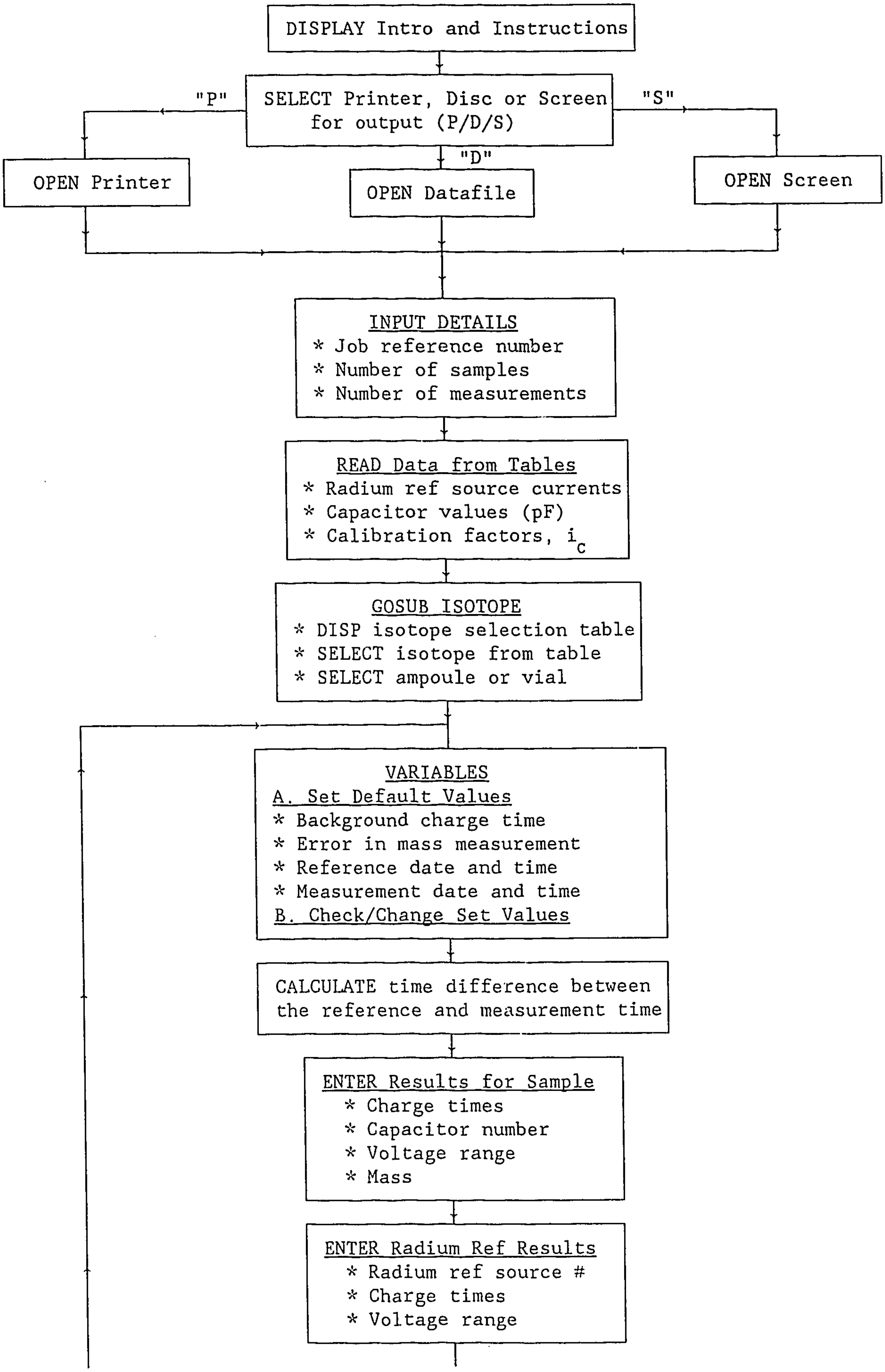


FIGURE 5.2 - FLOW DIAGRAM : IONMAN



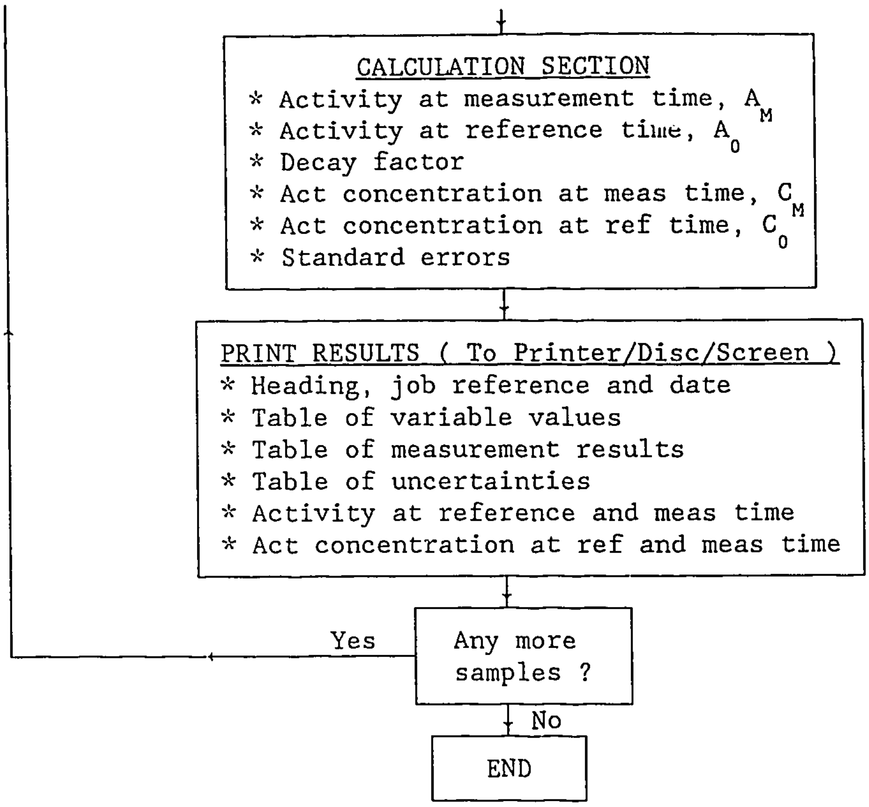

CALCULATION SECTION
* Activity at measurement time, A_M
* Activity at reference time, A_0
* Decay factor
* Act concentration at meas time, C_M
* Act concentration at ref time, C_0
* Standard errors
PRINT RESULTS (To Printer/Disc/Screen)
* Heading, job reference and date
* Table of variable values
* Table of measurement results
* Table of uncertainties
* Activity at reference and meas time
* Act concentration at ref and meas time
Yes
Any more samples ?
No
END

FIGURE 5.3 - Table of Variables used in the IONMAN Program

LINE	VARIABLE NAME	DESCRIPTION
	S	* Current sample number
25	PRT$	* Selects whether the output goes to the screen, to disc or to the KX-P1180 printer. i.e. if PRT$ = "P" then printer if PRT$ = "D" then disc if PRT$ = "S" then screen
50	REF$	* Job reference number
60	NUM	* Number of samples to be measured
70	N	* Number of measurements of each sample ($\geq$ 3)
110	TB	* Background charge time in seconds (100mV, C2)
	MSD	* Standard deviation in mass measurement (grams)
	DAY,MONTH,YEAR	* Present date
	HOURS,MINS	* Present time
	D1,M1,Y1	* Reference date
	HOURS1,MINS1	* Reference time
	D2,M2,Y2	* Measurement date
	HOURS2,MINS2	* Measurement time
130	REFTIME	* Number of days from the beginning of the year to the reference time.
	MEASTIME	* Number of days from the beginning of the year to the measurement time.
	YRDIFF	* YRDIFF = (Y1 - Y2) * 365.25
	TIMEDIFF	* Total time difference between the reference time and the measurement time TIMEDIFF = REFTIME - MEASTIME + YRDIFF
150	X	* Current measurement number i.e. X = 1 to N for each sample
160	TM(X)	* Sample charge time measurement #X (in secs)
170	C	* Capacitor number (1,2 or 3)
180	VM	* Electrometer voltage range setting for sample (Volts) Allowed values : 30, 10, 3, 1, .3, .1, .03, .01 & .003
190	M	* Sample mass (grams) If M = -1 then all mass calculations are skipped
230	RA	* Radium reference source number Allowed values : 1, 3, 4, 5, 6 & 7
235	ROW	* Records cursor line location for use in locate statements

LINE	VARIABLE NAME	DESCRIPTION
	VR	* Electrometer voltage range settings for radium reference source (Volts) Allowed values : 30, 10, 3, 1, .3, .1, .03, .01 & .003 If VR = -1 then VR = VM
240	TR(X)	* Radium reference charge time measurement #X (secs)
260	KB	* $KB = \frac{VM * CM(C)}{302.2} \equiv \frac{V_m * C_m}{V_b * C_b}$
	KS	* $KS = \frac{VM}{VR}$
	TIME	* Time in years since the calibration of August 1978. $TIME \equiv (t_m - t_c) = Y2 + M2/12 + D2/365.25 - 1978.6666$
	KR	* $KR = \exp\left(\frac{\ln 2}{T_r} * TIME \right)$ $= \exp\left(\frac{.693147}{(584400 \div 365.25)} * TIME \right)$
	SUMTR2#[1]	* $SUMTR2\# = \sum_{I=1}^{N} \{TR(I)\}^2$
	SUMTM2#	* $SUMTM2\# = \sum_{I=1}^{N} \{TM(I)\}^2$
	TR	* $TR = \sum_{I=1}^{N} TR(I)$
	TM	* $TM = \sum_{I=1}^{N} TM(I)$
	MNTR#	* Mean radium reference charge time (sec) $MNTR\# \equiv \Delta\bar{t}_r = \frac{TR}{N}$
	MNTM#	* Mean sample charge time (sec) $MNTM\# \equiv \Delta\bar{t}_m = \frac{TM}{N}$
	TERM#	* $TERM\# = \frac{KB * TB - MNTM\#}{KB * TB - KS * MNTR\#}$ $\equiv \frac{k_b \Delta\bar{t}_b - \Delta\bar{t}_m}{k_b \Delta\bar{t}_b - k_s \Delta\bar{t}_r}$

[1] The symbol "#", at the end of a variable name, specifies double precision.

LINE	VARIABLE NAME	DESCRIPTION
	AM#	* Activity at time of measurement, t_m $$AM\# = \frac{TERM\# * MNTR\# * I(RA) * KS}{MNTM\# * KR * IC}$$ $$\equiv \left(\frac{k_b\ \Delta\bar{t}_b - \Delta\bar{t}_m}{k_b\ \Delta\bar{t}_b - k_s\ \Delta\bar{t}_r} \right) . \frac{\Delta\bar{t}_r . I_r . k_s}{\Delta\bar{t}_m . k_r . i_c}$$
	DECAYFACTOR	* Decay factor from measurement time to reference time $$DECAYFACTOR = EXP \left(\frac{- LOG\ 2 * TIMEDIFF}{HL(KI)} \right)$$ $$\equiv \exp \left(\frac{- \ln 2 * (t_o - t_m)}{T_{1/2}} \right)$$
	A0#	* Activity at the reference time, t_0 (in MBq) A0# = AM# * DECAYFACTOR
	BRACKETS#	* $$BRACKETS\# = \frac{SUMTR2\# - N * MNTR\#^2}{MNTR\#^2} + \frac{SUMTM2\# - N * MNTM\#^2}{MNTM\#^2}$$ $$\equiv \frac{[\ \Sigma(\Delta t_m)^2 - n\ (\Delta\bar{t}_m)^2\ ]}{(\Delta\bar{t}_m)^2} + \frac{[\ \Sigma(\Delta t_r)^2 - n\ (\Delta\bar{t}_r)^2]}{(\Delta\bar{t}_r)^2}$$
	AMSD#	* Standard deviation in A_m $$AMSD\# = AM\# * ABS \left(\frac{BRACKETS\#}{N(N-1)} + \frac{ISD(RA)^2}{I(RA)^2} + \frac{ICSD^2}{IC^2} \right)^{1/2}$$ $$\equiv A_0 . \left\{ \frac{1}{n\ (n-1)} . \left(\frac{[\ \Sigma(\Delta t_m)^2 - n\ (\Delta\bar{t}_m)^2\ ]}{(\Delta\bar{t}_m)^2} + \frac{[\ \Sigma(\Delta t_r)^2 - n\ (\Delta\bar{t}_r)^2]}{(\Delta\bar{t}_r)^2} \right) + \frac{\sigma(I_r)^2}{I_r^{\ 2}} + \frac{\sigma(i_c)^2}{i_c^{\ 2}} \right\}^{1/2}$$
	TR.Err	* Percentage error in $\Delta\bar{t}_r$ $$TR.Err = ABS \left\{ \frac{1}{N(N-1)} \left(\frac{SUMTR2\# - N * MNTR\#^2}{MNTR\#^2} \right)^{1/2} \right\} * 100$$

LINE	VARIABLE NAME	DESCRIPTION
	TM.Err	* Percentage error in $\Delta\bar{t}_m$ $TM.Err = ABS \left\{ \frac{1}{N(N-1)} \left[\frac{SUMTM2\# - N * MNTM\#^2}{MNTM\#^2} \right]^{1/2} \right\} * 100$
	IR.Err	* Percentage error in I_r $IR.Err = \frac{ISD(RA)}{I(RA)} * 100$
	M.Err	* Percentage error in M $M.Err = \frac{MSD}{M} * 100$
	IC.Err	* Percentage error in I_c $IC.Err = \frac{ICSD}{IC} * 100$
	CM#	* Activity concentration at the measurement time (MBq/g) $CM\# = \frac{AM\#}{M}$
	CO#	* Activity concentration at the reference time (MBq/g) CO# = CM# * DECAYFACTOR
265	A	* data variable used to define "Δ" symbol for printout to KX-P1180 printer
266	HEADING$	* e.g "Standardisation of Tc-99m in Vial"
	V$	* If V$ = "A" the sample is in a ampoule If V$ = "V" the sample is in a vial
	UNDERLINE$	* UNDERLINE$ = "================================"
269	LOOPCOUNTER	* Records the number of changes made (if any) to the variable list given in the VARIABLES subroutine
	IC	* Calibration factor for sample. Value given in TABLES and determined by the selection made in ISOTOPES
	A$, B & I	* e.g. A$ = STR$(M) B = 10 - LEN(A$) FOR I = 1 TO B : PRINT #1," ";: NEXT These variables are used in setting out the various tables. Following a variable's value, I spaces are printed to make up the correct spacing for the next column
	KI	* Isotope number (1 to 24) selected in ISOTOPES
	HL(KI)	* Half-life (in days) of the isotope selected

LINE	VARIABLE NAME	DESCRIPTION
2000	QUADSUM1	* Quadratic sum of the type A errors QUADSUM1 = $(TR.Err^2 + TM.Err^2)^{1/2}$
	QUADSUM2	* Quadratic sum of the type B errors QUADSUM2 = $(IR.Err^2 + IC.Err^2 + M.Err^2)^{1/2}$
	A0$	* A0# rounded to two decimal places If A0# > 10 MBq then A0$ is in MBq else A0$ is in KBq
	A0SD$	* A0SD# rounded to two decimal places
	C0$	* C0# rounded to two decimal places If C0# > 10 MBq/g then C0$ is in MBq/g else C0$ is in KBq/g

SUBROUTINES

	I(1-7)	* Radium reference source current (pA)
	ISD(1-7)	* Standard deviation in I_r
	CM(1-3)	* Capacitor values (pF)
	NUC$(1-24)	* Title.of isotope
	HL(1-24)	* Half-life of isotope
	IcA(1-24)	* Calibration factor for ampoule
	IcV(1-24)	* Calibration factor for vial
	C$	* Variable letter selected for alteration in VARIABLES Allowed values : " " - no changes "0" - return to previous section "A" - Background, TB "B" - std deviation in mass, MSD "C" - std deviation in calibration factor, ICSD "D" - reference time "E" - reference date "F" - measurement time "G" - measurement date
	LINE.COUNTER	* Keeps a tally of the lines to be printed. For example, if a particular table will not fit all on the current page, a new form is started.

5.3 KX-P1180 Printer Control Codes

Various printer functions can be set through the use of control codes. These control codes can be sent to the printer from the computer either directly from the keyboard or from within a program. In the IONMAN program various control codes have been used and these are listed below (for more details see the KX-P1180 instruction manual). The program requires that the printer dip switch #1 be turned ON; this selects the IBM mode. This is necessary for the tables to be printed correctly and for the control codes to be correctly executed.

Emphasized printing : CHR$(27) + "G"
Formfeed : CHR$(12)
Set top of form : CHR$(27) + "4"
Subscript printing : CHR$(27) + "S" + "1"
Superscript printing : CHR$(27) + "S" + "0"
Release sub\superscript : CHR$(27) + "T"

5.3.1 Downloadable Character Definition

It is possible to custom design characters that the printer may not contain in its character set. In the IONMAN program the character "Δ" was designed.

To define a draft and text character, in IBM mode, into a specified address location the following command is used:

$$ESC + = + n_1 + n_2 + 20 + Cs + At_1 + At_2 + Data$$

where n_1 and n_2 indicate the number of bytes of character data to be loaded,
Cs determines where in RAM the character is to be stored,
At_1 and At_2 are the attribute bytes #1 and #2 respectively
and Data defines the form of the character.

For a series of q characters

$$T = q * 13 + 2 ,$$
$$n_2 = \text{integer portion of } T/256$$
$$\text{and } n_1 = T - n_2$$

where T is the total number of character data bytes.

For this particular case $n_1 = 15$
$n_2 = 0$
Cs = "@"; stores character in the ASCII location where @ is normally stored
$At_1 = 0$; prints normal character using upper 8 bits
$At_2 = 11$; prints 11 dot columns

To determine the data information the character is drawn within a 8 x 11 matrix. The value of each dot column, P_1 - P_{11}, is determined by summing the powers of two represented by each dot. eg. $P_4 = 2^1 + 2^4 = 18$ Thus the data statement appears as

DATA 2, 6, 10, 18, 34, 66, 34, 18, 10, 6, 2

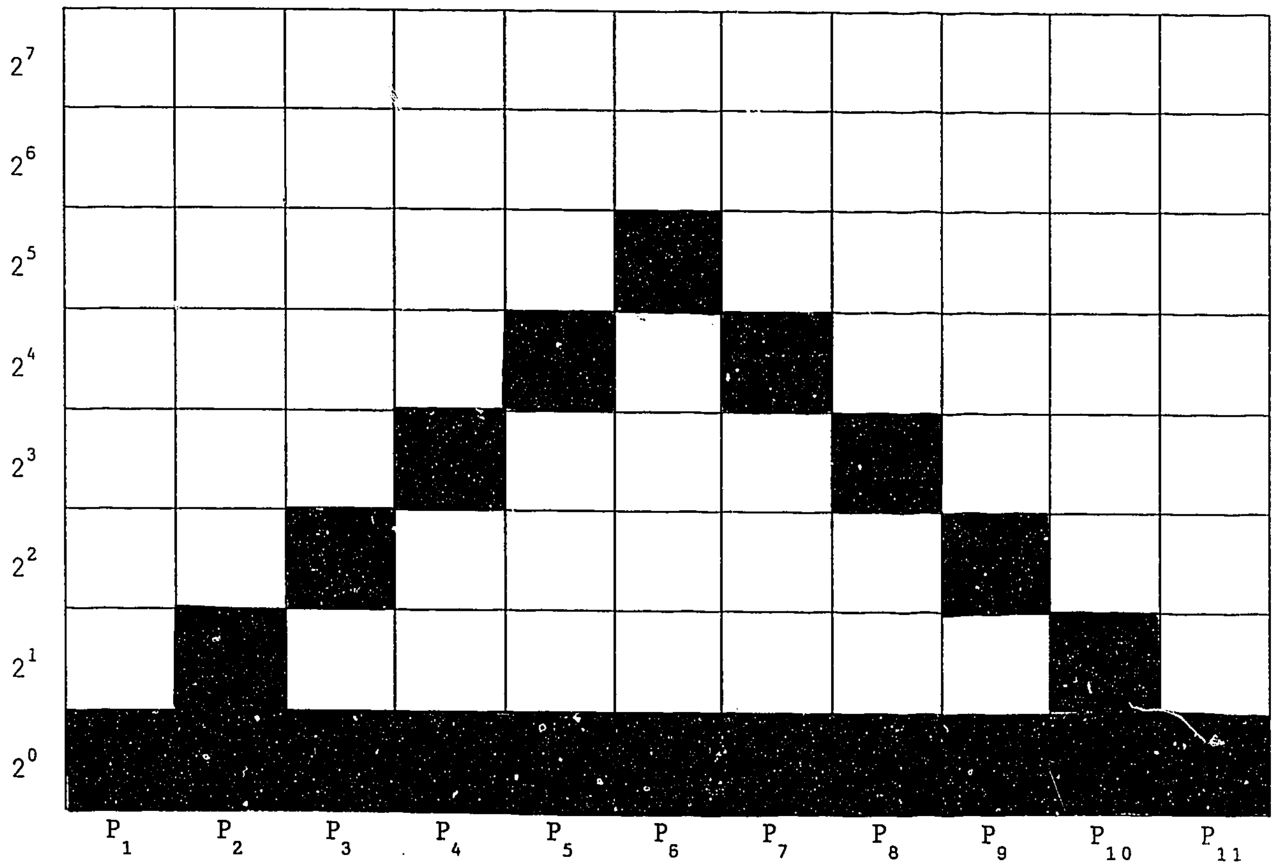


Figure 5.4 – Defining "Δ" as a downloadable character

6. TYPICAL RESULTS

6.1 "MEASION"

ION CHAMBER MEASUREMENTS : METHOD #2

DATE : 31 / 10 / 1990
SOURCE : TC-99M (for A.R.I calibration check)
JOB REFERENCE #1443

SAMPLE # 1
****

CAPACITOR # 2
VOLTAGE RANGE = 3 Volts
RADIUM REF: # 4

No.	T	V	MID-TIME	CHARGE TIME (secs)
1	138.519	.7980	14:12:55	138.87
2	139.790	.8013	14:15:36	139.57
3	140.640	.8026	14:18:16	140.19
4	141.214	.8011	14:20:57	141.02
5	141.768	.7999	14:23:40	141.79
6	142.413	.7997	14:26:23	142.47
7	142.985	.7985	14:29:06	143.26
8	144.161	.8011	14:31:51	143.97
9	144.668	.7996	14:34:36	144.74
10	145.870	.8022	14:37:23	145.48

MEAN TIME OF MEASUREMENT 14:25 HOURS

SAMPLE # 2
****

CAPACITOR # 2
VOLTAGE RANGE = 3 Volts
RADIUM REF: # 4

No.	T	V	MID-TIME	CHARGE TIME (secs)
1	146.844	.7984	14:41:33	147.15
2	147.832	.7989	14:44:22	148.04
3	148.724	.7995	14:47:11	148.83
4	149.847	.8016	14:50:02	149.54
5	150.429	.8000	14:52:54	150.42
6	151.019	.7992	14:55:47	151.17
7	152.159	.8003	14:58:40	152.10
8	152.721	.7990	15:01:35	152.91
9	153.937	.8003	15:04:31	153.88
10	154.434	.7987	15:07:28	154.68

MEAN TIME OF MEASUREMENT 14:54 HOURS

RADIUM REFERENCE # 4
****

VOLTAGE RANGE = 3 Volts

No.	T	V	CHARGE TIME (secs)
1	219.494	.7994	219.67
2	220.034	.8010	219.75
3	219.671	.7994	219.85
4	219.545	.7990	219.81
5	219.686	.7994	219.84
6	219.625	.7993	219.83
7	219.770	.8007	219.59
8	219.662	.8001	219.65
9	219.705	.8004	219.60
10	219.643	.8002	219.59

6.2 "IONMAN"

RADIATION STANDARDS LABORATORY

ACTIVITY DETERMINATION USING IONISATION CHAMBER

STANDARDISATION OF Tc-99m IN VIAL

JOB REF #1443

DATE: 2 / 11 / 1990

SAMPLE # 1

VARIABLES:

SYMBOL	DESCRIPTION	VALUE	ERROR
C	Capacitor	# 2	–
i_c	Calibration Factor (pA.MBq^{-1})	5.743	.1
I_r	RA Reference Source Current (pA)	2.269	.016
$T_{½}$	Sample Half Life (days)	.2508	–
$\overline{\Delta T_b}$	Background Charge Time (secs)	4103	–
t_0	Reference Time	9:28 hours	–
	Reference Date	30/10/1990	–
t_m	Time at Measurement of Sample	12:11 hours	–
	Date at Measurement of Sample	1/11/1990	–
V_m	Sample Voltage Range (Volts)	.3	–
V_r	Radium Ref Voltage Range (Volts)	.1	–

MEASUREMENTS:

CHARGE TIME RESULTS (seconds)		
No.	SAMPLE	RADIUM # 1
1	173.24	105.81
2	173.49	105.30
3	173.34	105.15
4	173.12	105.00
5	172.93	104.92
6	172.85	105.16
7	173.05	105.09
8	173.25	104.54
9	173.23	104.83
10	173.48	104.40
MEAN	173.20	105.02

ERRORS:

SOURCE OF THE UNCERTAINTY		UNCERTAINTY IN %	
SYMBOL	MEASURED QUANTITY	TYPE A ;(n)[1]	TYPE B
$\Delta\overline{T}_m$	Mean Sample Charge Time	0.04 ;(9)	
$\Delta\overline{T}_r$	Mean Rad Ref Charge Time	0.12 ;(9)	
I_r	Radium Source Current		0.71
i_c	Specific Ionisation Current		1.74
QUAD SUM (Root of sum of squares)		0.13	1.88
COMBINED UNCERTAINTY (Quadratic sum)		1.88	

[1] n ≡ degrees of freedom

RESULTS:

AT MEASUREMENT TIME : Total Radioactivity = 723.35 +/- 13.62 KBq
Percentage Error = 1.88 %

AT REFERENCE TIME : Total Radioactivity = 248.75 MBq

JOB REF #1443 DATE: 2 / 11 / 1990

SAMPLE # 2

VARIABLES:

SYMBOL	DESCRIPTION	VALUE	ERROR
C	Capacitor	# 2	–
i_c	Calibration Factor ($pA.MBq^{-1}$)	5.743	.1
I_r	RA Reference Source Current (pA)	2.269	.016
$T½$	Sample Half Life (days)	.2508	–
$\Delta\overline{T}_b$	Background Charge Time (secs)	4103	–
t_0	Reference Time	9:28 hours	–
	Reference Date	30/10/1990	–
t_m	Time at Measurement of Sample	12:46 hours	–
	Date at Measurement of Sample	1/11/1990	–
V_m	Sample Voltage Range (Volts)	.3	–
V_r	Radium Ref Voltage Range (Volts)	.1	–

MEASUREMENTS:

CHARGE TIME RESULTS (seconds)		
No.	SAMPLE	RADIUM # 1
1	185.84	105.81
2	185.67	105.30
3	185.60	105.15
4	185.73	105.00
5	185.48	104.92
6	185.48	105.16
7	185.18	105.09
8	185.65	104.54
9	185.50	104.83
10	185.71	104.40
MEAN	185.58	105.02

ERRORS:

SOURCE OF THE UNCERTAINTY		UNCERTAINTY IN %	
SYMBOL	MEASURED QUANTITY	TYPE A ;(n)[1]	TYPE B
$\Delta\overline{T}_m$	Mean Sample Charge Time	0.03 ;(9)	
$\Delta\overline{T}_r$	Mean Rad Ref Charge Time	0.12 ;(9)	
I_r	Radium Source Current		0.71
i_c	Specific Ionisation Current		1.74
QUAD SUM (Root of sum of squares)		0.12	1.88
COMBINED UNCERTAINTY (Quadratic sum)		1.88	

[1] n ≡ degrees of freedom

RESULTS:

AT MEASUREMENT TIME : Total Radioactivity = 674.38 +/- 12.70 KBq
Percentage Error = 1.88 %

AT REFERENCE TIME :Total Radioactivity = 248.03 MBq

---

7 PROGRAM LISTINGS

7.1 "MEASION"

```
10 !                             STORE "MEASION:D700"
20 ! ************************************************************************
30 !
40 !      ACTIVITY MEASUREMENT USING IONISATION CHAMBER: METHOD #2
50 !
60 ! ************************************************************************
70 !
80 !                       Written by S.BUCKMAN  21/6/1990
90 !
100 !                            Version 1.2
110 !
120 ! ***********************************************************************
130 !
140 ! PURPOSE : This program automates the measurement of charge times for the
150 !           measurement of activity using the TPA Ionisation Chamber. The
160 !           program is designed to be used in conjunction with the Deltacom
170 !           program IONMAN.BAS.
180 !
190 !           This program collects the data by using the Ion Chamber, Cary
200 !           Electrometer, 3478A Multimeter, 59501B Voltage Programmer and
210 !           6181C Current Source. The other program processes these
220 !           measurements.
230 !
240 !           A full discussion of this and the other programs associated
250 !           with the Ion Chamber can be found in the report ANSTO/M118.
260 !
270 ! BACKGROUND : When the sample is inserted into the ionisation chamber
280 !              an ionisation current is produced. This ionisation current
290 !              is then used to charge a capacitor [C(1) - C(3)]. The voltage
300 !              V across the capacitor is measured by the Cary Electrometer.
310 !
320 !              The Cary Electrometer has a series of Voltage Range
330 !              settings ranging from 1 mV to 30 V. By connecting to points
340 !              on the rear of the Electrometer the time taken for each
350 !              cycle can be measured. For a full cycle, on any range
360 !              setting, the voltage (from the rear of the Electrometer)
370 !              varies from 0 to 1 Volt.
380 !
390 !              This voltage is measured using the 3478A Digital Multimeter.
400 !              The multimeter is connected to the HP86B via the HP-IB. The
410 !              time taken for the Electrometer to sweep from .1V to .9V
420 !              is measured by the HP86B. This measurement is repeated
430 !              several times for each sample.
440 !
450 !              The measurements are then repeated for a radium reference
460 !              source of comparable activity.
470 !
480 !              The resulting measurements can then be substituted into the
490 !              equations given by Urquhart [1986] to determine the
500 !              activity of the sample.
510 !
```

```
520 ! METHOD : The method used in this program differs from that used
530 !          previously in that the 292 Discriminator is no longer required
540 !          nor is it necessary to connect it to the scaler "daisy-chain",
550 !          as was done previously.
560 !
570 !          The requirement to connect the 292 Discriminator to the
580 !          scaler "daisy-chain" has been eliminated by using the
590 !          HP86B internal timer. The relay which resets and commences the
600 !          Electrometer after each cycle has been placed under computer
610 !          control by using the voltage programmer and current source
620 !          to open and shut the relay. This task was also previously
630 !          performed by the 292 discriminator.
640 !
650 !          In addition to being more efficient than previous methods this
660 !          method also eliminates a non-linearity which was inherent in the
670 !          design of the discriminator unit.
680 !
690 !
700 ! *************************************************************************
710 !
720      OPTION BASE 0@ PAGESIZE 24 @ PRINTER IS 701 @ DEFAULT ON
730 !
740 ! DIMENSION ARRAYS AND INITIALISE VARIABLES
750 ! ****************************************
760 !
770      DIM T(30,30),RADIUM(30),C(30),RANGE(30) !      DIMENSION ARRAYS
780      DIM MT(30,30),VR(30,30),MIDDLE$(30,30)
790 !
800      X=0 @ REF(0)=9999 !                       RADIUM REFERENCE COUNTER
810      OPEN=2000 @ SHUT=2240 !              COMMAND TO OPEN AND SHUT RELAY
820 !
830  GOSUB INVERSE  !                             DEFINE ENDLINE$ & YORN$
840 !
850 !
860 ! PRINT INTRODUCTION
870 ! ******************
880 !
890         CLEAR
900    DISP TAB (13);"ACTIVITY MEASUREMENT USING IONISATION CHAMBER : METHOD #2"
910    DISP TAB (13);"---------------------------------------------------------"
920         GOSUB PRT
930     DISP TAB (20);"AUSTRALIAN RADIATION STANDARDS LABORATORY"
940     DISP TAB (20);"-----------------------------------------"
950         GOSUB PRT
960     DISP TAB (28);"*-------------------------*"
970     DISP TAB (28);"| PROGRAM    : MEASION    |"
980     DISP TAB (28);"| PROGRAMMER: S.BUCKMAN   |"
990     DISP TAB (28);"| VERSION    : 1.2        |"
1000    DISP TAB (28);"| DATE       : 20/6/1990  |"
1010    DISP TAB (28);"*-------------------------*"
1020        GOSUB PRT
1030        WAIT 2000
1040 !
```

```
1050 ! DISPLAY SETUP INSTRUCTIONS
1060 ! ****************************
1070 !
1080       CLEAR
1090    DISP TAB (28);"SETUP INSTRUCTIONS"
1100    DISP TAB (28);"------------------"
1110    DISP TAB (5);"*------------------------------------------------------------------
------*"
1120    DISP TAB (5);"| 1. Check that SELECTOR SWITCH is set to 2
        |"
1130    DISP TAB (5);"|
        |"
1140    DISP TAB (5);"| 2. Connect 3478A MULTIMETER to ELECTROMETER
        |"
1160    DISP TAB (5);"|
        |"
1170    DISP TAB (5);"| 3. Check that 3478A MULTIMETER is turned ON
        |"
1180    DISP TAB (5);"|
        |"
1190    DISP TAB (5);"| 4. Check that 59501B VOLTAGE PROGRAMMER is in UNIPOLAR m
ode     |"
1200    DISP TAB (5);"|
        |"
1210    DISP TAB (5);"| 5. Check HP-IB connection from HP86B computer to MULTIME
TER and VOLTAGE PROGRAMMER |"
1220    DISP TAB (5);"|
        |"
1230    DISP TAB (5);"| 6. Check that 59501B is connected to 6181C CURRENT SOURC
E       |"
1240    DISP TAB (5);"|
        |"
1250    DISP TAB (5);"| 7. Check that 6181C CURRENT SOURCE is turned to AMPS
        |"
1260    DISP TAB (5);"|
        |"
1270    DISP TAB (5);"| 8. Check that 82905B PRINTER is turned ON
        |"
1280    DISP TAB (5);"|
        |"
1290    DISP TAB (5);"| 9. Check that 82905B PRINTER is ON LINE
         |"
1300    DISP TAB (5);"*------------------------------------------------------------------
------*"
1310    DISP TAB (5);"PRESS ";ENDLINE$;" TO CONTINUE";@ INPUT Q$
1320 !
1330 ! SEND INSTRUCTIONS TO MULTIMETER:
1340   OUTPUT 723 ;"Function 1, Range 0, Number 5, Zero 1, Trigger 4"
1350 !
1360 ! SHUT RELAY TO HOLD ELECTROMETER AT 0 VOLTS
1370   OUTPUT 706 USING "#,4D" ; SHUT
1380 !
```

```
1390 ! INPUT DETAILS
1400 ! *************
1410 !
1420      CLEAR
1430    ON ERROR GOSUB ERROUTINE
1440    DISP TAB (25);"INPUT DETAILS"
1450    DISP TAB (25);"-------------"
1460    DISP
1470    DISP "1. SOURCE IDENTIFICATION ";
1472    INPUT SOURCE$ @ GOTO 1480
1475    GOTO 1460
1480    DISP
1490    DISP "2. REFERENCE NUMBER ";
1492    INPUT REF$ @ GOTO 1500
1495    GOTO 1480
1500    DISP
1510    DISP "3. TYPE IN PRESENT TIME (HOURS, MINUTES,SECS) ";
1520    INPUT HOURS,MINS,SECS@ GOTO 1540
1530    GOTO 1510 !                AFTER ERROUTINE : INPUT AGAIN !!!
1535 !
1540    TISEC=(HOURS*60+MINS)*60+SECS !                      TIME IN SECONDS
1542    SETTIME TISEC,9999 !                                 SET INTERNAL TIMER
1544    DISP
1545 !
1550    DISP "4. TYPE IN DATE (DAY, MONTH, YEAR) ";
1560    INPUT DAT,MONTH,YEAR@ GOTO 1580
1570    GOTO 1550 !                RETURN TO PREVIOUS LINE IF ERROR OCCURRED
1575 !
1578 ! CHECK FOR ERROR IN DAY OR MONTH INPUT
1590 !
1600    IF DAT>31 THEN GOSUB ERROUTINE  ELSE GOTO 1620
1610    GOTO 1550
1620    IF MONTH>12 THEN GOSUB ERROUTINE  ELSE GOTO 1640
1630    GOTO 1550
1640    DISP
1650 !
1660 ! CONVERT 2 DIGIT YEAR TO 4 DIGIT FORMAT IF NECESSARY.
1670    IF INT (YEAR/100)=0 THEN YEAR=YEAR+1900
1710 !
1720    DISP "5. NUMBER OF SAMPLES TO BE MEASURED ";
1730    INPUT SAMPLE@ GOTO 1750
1740    GOTO 1720
1750      IF SAMPLE<= 0 THEN GOSUB ERROUTINE  ELSE 1770
1760    GOTO 1720
1770    DISP
1775 !
1780    DISP "6. NUMBER OF MEASUREMENTS FOR EACH SAMPLE ";
1790    INPUT NUMEA@ GOTO 1810
1800    GOTO 1780 !             IF ERROR HAS OCCURED THEN GOTO PREVIOUS LINE
1810      IF NUMEA<= 0 THEN GOSUB ERROUTINE  ELSE 1830
1820    GOTO 1780
1830    DISP
1835 !
1840    DISP "ARE THESE ALL CORRECT ";YORN$;@ INPUT Q$
1850      IF Q$="N" THEN 1390 !          RETURN TO BEGINNING OF SECTION
1860    OFF ERROR
1870 !
```

```
1880 ! PRINT HEADING
1890 ! *************
1900 !
1910   PRINT TAB (15);"ION CHAMBER MEASUREMENTS : METHOD #2"
1920   PRINT TAB (15);"===================================="
1930   PRINT
1940   PRINT "DATE : ";DAT;"/";MONTH;"/";YEAR
1950   PRINT "SOURCE : ";SOURCE$
1960   PRINT "JOB REFERENCE #";REF$
1970   PRINT @ PRINT
1980 !
1990 ! OPERATING INSTRUCTIONS FOR MODE #2
2000 ! **********************************
2010 !
2020      CLEAR
2030   DISP TAB (30);"OPERATING INSTRUCTIONS"
2040   DISP TAB (30);"----------------------"
2050   DISP @ DISP
2060   DISP TAB (5);"*------------------------------------------------------------
-----------*"
2070   DISP TAB (5);"|
           |"
2080   DISP TAB (5);"| 1. Insert first sample into IONISATION CHAMBER
           |"
2090   DISP TAB (5);"|
           |"
2100   DISP TAB (5);"| 2. Connect CAPACITOR (1 - 3)
           |"
2110   DISP TAB (5);"|
           |"
2120   DISP TAB (5);"| 3. Set the CARY ELECTROMETER as follows : A. INPUT RESIST
OR to 1    |"
2130   DISP TAB (5);"|                                          : B. FUNCTION to
-VE CHARGE |"
2140   DISP TAB (5);"|                                          : C. Suitable RAN
GE         |"
2150   DISP TAB (5);"|
           |"
2160   DISP TAB (5);"*------------------------------------------------------------
-----------*"
2170           GOSUB PRT
2180   DISP TAB (5);"PRESS ";ENDLINE$;" TO CONTINUE ";@ INPUT Q$
2190   DISP
2200 !
2210 !
2220   FOR N=1 TO SAMPLE !                              SAMPLE No. LOOP
2230 !
2240 ! INPUT DETAILS FOR SAMPLE #N
2250 ! ***************************
2260 !
2270      CLEAR
2280   DISP
2290   DISP TAB (20);"SAMPLE #";N
2300   DISP TAB (20);"---------"
2310   DISP @ DISP
2315 !
```

```
2320   DISP "VOLTAGE RANGE (Volts) = ";@ INPUT RANGE(N)
2330   Q=RANGE(N) @ IF Q=.01 OR Q=.03 OR Q=.1 OR Q=.3 OR Q=1 OR Q=3 OR Q=10 OR Q
=30 THEN 2350 ELSE GOSUB ERROUTINE
2340   GOTO 2320
2350   DISP
2355 !
2360   DISP "CAPACITOR # ";@ INPUT C(N)
2370   IF C(N)=1 OR C(N)=2 OR C(N)=3 THEN 2390 ELSE GOSUB ERROUTINE
2380   COTO 2360
2390 !
2400 ! CALCULATE & RECORD THE CORRECT RADIUM REF SOURCE TO USE
2410 ! ********************************************************
2415 !
2420      GOSUB REFERENCE
2430      IF REF(X)<> RADIUM(N) THEN X=X+1 @ REF(X)=RADIUM(N)
2440 !
2450        CLEAR @ GOSUB PRT  @ GOSUB PRT
2460     DISP TAB (20);"*--------------------------------------------*"
2470     DISP TAB (20);"| DO YOU WANT THE COMPUTER TO CHECK THAT    |"
2480     DISP TAB (20);"|    90 sec < CHARGE TIME < 300 sec           |"
2490     DISP TAB (20);"*--------------------------------------------*"
2500     DISP @ DISP TAB (35);YORN$;@ INPUT Q$
2510     IF Q$ <> "Y" THEN 3080
2520        CLEAR
2530 !
2540 ! CHECK THAT CHARGE TIME IS BETWEEN 90 AND 300 SECONDS.
2550 ! ******************************************************
2560 !
2570 !
2580        OUTPUT 706 USING "#,4D" ; OPEN !      OPEN RELAY TO COMMENCE CHARGING
2590 !
2600          CLEAR @ GOSUB PRT  @ GOSUB PRT
2610     DISP TAB (10);"*------------------------------------------------------*"
2620     DISP TAB (10);"| TESTING THAT 90 secs < CHARGE TIME < 300 secs !!!! |"
2630     DISP TAB (10);"*------------------------------------------------------*"
2640          GOSUB PRT
2650 !
2660 ! START CYCLE
2670 ! -----------
2680 !
2690          S=0 !                              S = 1 AFTER TIMING STARTS
2700 !
2710     OUTPUT 723 ;"Trigger 3" !               TRIGGER MULTIMETER
2720     ENTER 723 ; V !                         READ MULTIMETER
2730 !
2740     IF S=1 THEN 2800 !                      i.e. IF TIMING HAS STARTED
2750 !
2760     IF V>-.05 THEN 2710
2770          S=1
2780          START=TIME
2790 !
2800     IF V>-.15 THEN 2710 !                   STOP TIMER WHEN V=-.15
2810          STP=TIME  !                          STP = STOP TIME
2820          CHT=STP-START !                      CHT = CHARGE TIME
2830 !
```

```
2840 ! IF 90 < CHT < 300 THEN CONTINUE ELSE CHANGE SETTINGS AND RETEST
2850 ! ----------------------------------------------------------------
2860 !
2870   IF CHT>11.25 THEN GOTO 2980 !              CHARGE TIME > 90 SECS
2880 !
2890       BEEP 30,300
2900       OUTPUT 706 USING "#,4D" ; SHUT !  RESET & HOLD ELECTROMETER AT OV
2920       DISP "Charge time is too short EITHER: A. INCREASE RANGE or
                                            B. DECREASE CAP No."

2930       DISP @ DISP
2940       DISP "PRESS ";ENDLINE$;" TO CONTINUE:";@ INPUT Q$
2950 !
2960   GOTO 2240
2970 !
2980   IF CHT<= 37.5 THEN GOTO 3080 !             CHARGE TIME < 300 SECS
2990 !
3000       BEEP 30,300
3010       OUTPUT 706 USING "#,4D" ; SHUT !  RESET & HOLD ELECTROMETER AT OV
3020       DISP "Charge time is too long EITHER : A. DECREASE RANGE or
                                                B. DECREASE CAP No."

3030       DISP @ DISP
3040       DISP "PRESS ";ENDLINE$;" TO CONTINUE:";@ INPUT Q$
3050 !
3060   GOTO 2240
3070 !
3080 ! MEASUREMENT SECTION
3090 ! ********************
3100 !
3120   CLEAR @ GOSUB PRT  @ GOSUB PRT
3130       OUTPUT 706 USING "#,4D" ; SHUT !   RESET & HOLD ELECTROMETER AT OV
3140       WAIT 1000 !                         WAIT WHILE RELAY IS TRIGGERED
3150   DISP TAB (20);"*-----------------------------------------*"
3160   DISP TAB (20);"| WAITING FOR NEW CYCLE TO BEGIN !!!!!!! |"
3170   DISP TAB (20);"*-----------------------------------------*"
3180 !
3190   S=99 !                                  TELLS PROGRAM TO CLEAR MESSAGE
3200 !
3210   BEGIN=TIME
3220 !
3230 !
3240       FOR R=1 TO NUMEA !                  MEASUREMENT No. LOOP
3250       OUTPUT 706 USING "#,4D" ; OPEN !     START CHARGING
3260         GOSUB MEASUREMENT
3270       OUTPUT 706 USING "#,4D" ; SHUT !     RESET ELECTROMETER
3280         WAIT 1000
3290       NEXT R
3300 !
3310   FINISH=TIME
3320 !
3330 ! CALCULATE TIME IN MIDDLE OF MEASUREMENT
3340 ! ---------------------------------------
3350 !
3360       MIDT=(BEGIN+FINISH)/2 !              MIDDLE TIME IN SECS
3370       MINS=INT (MIDT/60) !                 MIDDLE TIME IN MINS
3380       HOURS=INT (MINS/60) !                WHOLE NUMBER OF HOURS
3390       MINS=MINS-HOURS*60 !                 REMAINING MINS
3400 !
```

```
3410 ! PRINT RESULTS
3420 ! ─────────────
3430          CLEAR
3440     PRINT TAB (20);"SAMPLE #";N
3450     PRINT TAB (20);"**********"
3460     PRINT "CAPACITOR #";C(N)
3470     PRINT "VOLTAGE RANGE = ";RANGE(N);" Volts"
3480     PRINT "RADIUM REF: #";RADIUM(N)
3490     PRINT
3500     PRINT "No.      T         V       MID-TIME         CHARGE TIME (secs) "
3510     PRINT "=============================================================== "
3520 !
3530   FOR Z=1 TO NUMEA
3540      PRINT USING 3550 ; Z;MT(N,Z);VR(N,Z);MIDDLE$(N,Z);T(N,Z)
3550      IMAGE 2D,3X,4D.3D,3X,.4D,4X,8A,11X,4D.2D
3560      PRINT
3570    NEXT Z
3580      PRINT "=============================================================== "
3590      PRINT
3600 !
3610      PRINT USING 3620 ; "MEAN TIME OF MEASUREMENT ";HOURS;":";MINS;" HOURS"
3620      IMAGE 25A,2D,A,2Z,6A
3630      PRINT @ PRINT
3640      FOR I=1 TO 5 @ BEEP 50,100 @ NEXT I
3650 !
3660 ! COMMENCE NEW SAMPLE OR RADIUM REFERENCE
3670 ! ************************************
3680 !
3690          CLEAR
3700  IF N=SAMPLE THEN 3760
3710
3720      DISP "1. INSERT SAMPLE #";N+1
3740      DISP "2. PRESS ";ENDLINE$;" WHEN READY ";@ INPUT Q$
3750
3760  NEXT N
3770 !
3780 ! MEASURE RADIUM REFERENCE SOURCE(S)
3790 ! *********************************
3800 !
3810  FOR N=SAMPLE+1 TO SAMPLE+X
3820 !
3830        DISP "1. INSERT RADIUM REFERENCE SOURCE #";REF(N-SAMPLE)
3840        DISP
3850        DISP "2. INPUT VOLTAGE RANGE (Volts) ";@ INPUT RANGE(N)
3860        DISP
3870        DISP "3. PRESS ";ENDLINE$;" WHEN READY ";@ INPUT Q$
3880 !
3890            CLEAR @ GOSUB PRT  @ GOSUB PRT
3900        DISP TAB (20);"*──────────────────────────────────────*"
3910        DISP TAB (20);"| WAITING FOR NEW CYCLE TO BEGIN !!!!!!! |"
3920        DISP TAB (20);"*──────────────────────────────────────*"
3930        S=99 !                             TELLS PROGRAM TO CLEAR MESSAGE
3940 !
3950      FOR R=1 TO NUMEA                              START CHARGING
3960        OUTPUT 706 USING "#,4D" ; OPEN !
3970          GOSUB MEASUREMENT                     RESET & STOP CHARGING
3980        OUTPUT 706 USING "#,4D" ; SHUT !
3990              WAIT 1000
4000      NEXT R
```

```
4010          CLEAR
4020      PRINT TAB (20);"RADIUM REFERENCE #";REF(N-SAMPLE)
4030      PRINT TAB (20);"******************"
4040      PRINT
4050      PRINT "VOLTAGE RANGE = ";RANGE(N);" Volts"
4060      PRINT                                              CHARGE TIME (secs) "
4070      PRINT "No.              T               V            ================= "
4080      PRINT "=============================================================
4090 !
4100   FOR Z=1 TO NUMEA
4110     PRINT USING 4120 ; Z,MT(N,Z);VR(N,Z);T(N,Z)
4120     IMAGE 2D,10X,4D.3D,10X,.4D,10X,4D.2D
4130     PRINT
4140   NEXT Z
4150 !                                                   ======================= "
4160     PRINT "=============================================================
4170     PRINT @ PRINT
4180        FOR I=1 TO 5 @ BEEP 50,100 @ NEXT I
4190 !
4200 ! DISPLAY "COMPLETED" MESSAGE
4210 ! ****************************
4220 !
4230        CLEAR @ GOSUB PRT                                        -----------*"
4240     DISP TAB (15);"*----------------------------------------------------|"
4250     DISP TAB (15);"|                                                     |"
4260     DISP TAB (15);"|   YOUR MEASUREMENTS ARE NOW COMPLETED.......        |"
4270     DISP TAB (15);"|                                                     |"
4280     DISP TAB (15);"| Please turn FUNCTION to OFF on the ELECTROMETER     |"
4290     DISP TAB (15);"|                                          -----------*"
4300     DISP TAB (15);"*-----------------------------------------"
4310         GOSUB PRT
4320     DISP TAB (20);"PRESS ";ENDLINE$;" TO CONTINUE";@ INPUT Q$
4330 !
4340       OUTPUT 706 USING "#,4D" ; 2000 ! TURNS OFF CURRENT FROM CURRENT SOURCE
4350 !
4360 ! DISPLAY FINAL INSTRUCTIONS
4370 ! ****************************
4380 !
4390          CLEAR
4400     DISP TAB (25);"PROCESSING YOUR MEASUREMENTS"
4410     DISP TAB (25);"----------------------------"        -------------*"
4420     DISP TAB (15);"*--------------------------------------------------|"
4430     DISP TAB (15);"|                                                   |"
4440     DISP TAB (15);"| Your measurements may now be processed using     |"
4450     DISP TAB (15);"|                                                   |"
4460     DISP TAB (15);"| the ION CHAMBER PROGRAM available on the         |"
4470     DISP TAB (15);"|                                                   |"
4480     DISP TAB (15);"| DELTACOM Computer                                 |"
4490     DISP TAB (15);"|                                      ------------*"
4500     DISP TAB (15);"*----------------------------------------------*"
4510     DISP TAB (17);"*----------------------------------------------|"
4520     DISP TAB (17);"|                                               |"
4530     DISP TAB (17);"|  TO COMMENCE THE DELTACOM PROGRAM :          |"
4540     DISP TAB (17);"|                                               |"
4550     DISP TAB (17);"| 1. Turn ON DELTACOM COMPUTER and MONITOR     |"
4560     DISP TAB (17);"|                                               |"
4570     DISP TAB (17);"| 2. Select ION CHAMBER PROGRAM from MENU      |"
4580     DISP TAB (17);"|                                  ------------*"
4590     DISP TAB (17);"*----------------------------------"
```

```
4600        DISP
4610    DISP TAB (22);"PRESS ";ENDLINE$;" TO RETURN TO MENU";@ INPUT Q$
4620 !
4630 ! EXIT PROGRAM & RETURN TO MENU
4640 ! ******************************
4645 !
4650         CLEAR @ GOSUB PRT  @ GOSUB PRT
4660     DISP TAB (20);"*------------------------------------------------*"
4670     DISP TAB (20);"| *-------------------------------------------* |"
4680     DISP TAB (20);"| | NOW RETURNING YOU TO THE MENU......... | |"
4690     DISP TAB (20);"| *-------------------------------------------* |"
4700     DISP TAB (20);"*------------------------------------------------*"
4710     FOR I=1 TO 6 @ GOSUB PRT  @ NEXT I
4720     CHAIN "Autost:D700" !                LOAD & RUN MENU PROGRAM
4730 !
4740  STOP
4750 ! ************************************************************************
4760 PRT:
4770  DISP @ DISP @ DISP @ DISP @ RETURN
4780 ! ************************************************************************
4790  REFERENCE:
4800 !
4810 ! This subroutine selects the correct radium reference source for the
4820 ! voltage range and capacitor used.
4830 !
4840  IF C(N)=1 THEN 4850 ELSE 4890
4850     IF RANGE(N)=.03 OR .1 OR .3 OR 1 THEN RADIUM(N)=1
4860     IF RANGE(N)=3 THEN RADIUM(N)=3
4870     IF RANGE(N)=10 THEN RADIUM(N)=4
4880     IF RANGE(N)=30 THEN RADIUM(N)=5
4890  IF C(N)=2 THEN 4900 ELSE 4950
4900     IF RANGE(N)=.03 OR .1 OR .3 THEN RADIUM(N)=1
4910     IF RANGE(N)=1 THEN RADIUM(N)=3
4920     IF RANGE(N)=3 THEN RADIUM(N)=4
4930     IF RANGE(N)=10 THEN RADIUM(N)=5
4940     IF RANGE(N)=30 THEN RADIUM(N)=6
4950  IF C(N)=3 THEN 4960 ELSE 5020
4960     IF RANGE(N)=.03 OR .1 THEN RADIUM(N)=1
4970     IF RANGE(N)=.3 THEN RADIUM(N)=3
4980     IF RANGE(N)=1 THEN RADIUM(N)=4
4990     IF RANGE(N)=3 THEN RADIUM(N)=5
5000     IF RANGE(N)=10 THEN RADIUM(N)=6
5010     IF RANGE(N)=30 THEN RADIUM(N)=7
5020  RETURN
5030  !
5040 ! ************************************************************************
5050 MEASUREMENT:
5060 !
5070 ! This subroutine reads in the Time and Voltage for a series of cycles of
5080 ! the Electrometer.
5090 !
5100 !
5110     IF S<> 99 THEN 5160 !                  CLEAR "WAITING" MESSAGE
5120       CLEAR
5130       DISP TAB (30);"SAMPLE #";N
5140       DISP TAB (30);"          "
5150      DISP
5160        S=0
5170 !
```

```
5180     OUTPUT 723 ;"Trigger 3" !                      TRIGGER MULTIMETER
5190     ENTER 723 ; V !                                READ MULTIMETER
5200     T=TIME  !                                    RECORD TIME AT TRIGGER
5210 !
5220     IF S=1 THEN 5410 !                           S=1 WHEN TIMER STARTS
5230 !
5240 !
5250 ! LOOP UNTIL V=-.1
5260 ! ----------------
5270 !
5280      IF V>= -.1 THEN 5180 !                        LOOP UNTIL V = -.1
5290 !
5300          V1=V @ START=T !                      READ V1 @ START TIMER
5310 DISP "RUN #";R
5320 DISP "          "
5330 DISP "START Voltage = ";V1;" Volts";
5340 DISP TAB (40);"START Time = ";START;" secs"
5350          S=1
5360 !
5370 !
5380 ! LOOP UNTIL V=-.9
5390 ! ----------------
5400 !
5410      IF V>= -.9 THEN 5180 !                         LOOP UNTIL V = -.9
5420         STP=T @ V2=V !                              READ V2 @ STOP TIMER
5430 DISP "STOP Voltage  = ";V2;" Volts";
5440 DISP TAB (40);"STOP Time  = ";STP;" secs"
5450         VR(N,R)=ABS (V2-V1)
5460 !
5470 ! STORE CYCLE TIME IN ARRAY
5480 ! -------------------------
5490 !
5500         MT(N,R)=STP-START !              MEASURED CHARGE TIME FOR CYCLE
5510         MIDDLE=(START+STP)/2 !        TIME (IN SECS) AT MIDDLE OF CYCLE
5520         H=INT (MIDDLE/3600) !                           NUMBER OF HOURS
5530         H$=VAL$ (H)
5540         IF H<10 THEN H$="0"&H$ !                   e.g. CHANGE "5" TO "05"
5550         M=INT (MIDDLE/60-VAL (H$)*60) !               NUMBER OF MINUTES
5560         M$=VAL$ (M)
5570         IF M<10 THEN M$="0"&M$
5580         S=INT (MIDDLE-M*60-H*3600) !                  NUMBER OF SECONDS
5590         S$=VAL$ (S)
5600         IF S<10 THEN S$="0"&S$
5610         MIDDLE$(N,R)=H$&":"&M$&":"&S$
5620         T(N,R)=(STP-START)/VR(N,R)*.8 !                      DATA ARRAY
5630 !
5640 ! DISPLAY RESULTS ON SCREEN
5650 ! -------------------------
5660 !
5670 DISP
5680 DISP "  Voltage = ";VR(N,R);" Volts";
5690 DISP TAB (40);"  Time = ";INT ((STP-START)*100)/100;" secs"
5700 DISP
5710 DISP "Corrected CHARGE TIME = ";INT (T(N,R)*100)/100;" secs";
5720 DISP " ( i.e  V = .8 Volts )"
5730 DISP "MID-TIME of run = ";MIDDLE$(N,R)
5740 DISP
5750 !
5770  RETURN
```

```
5780 ! ****************************************************************************
5790 INVERSE:
5800 !
5810 ! This subroutine defines string variables which when printed are words
5820 ! in inverse video.
5830 !
5840 ! <END LINE>
5850   ENDLINE$=""
5860   FOR I=1 TO 10
5870     READ A
5880     ENDLINE$=ENDLINE$&CHR$ (128+A)
5890   NEXT I
5900     DATA 60,69,78,68,32,76,73,78,69,62
5910 !
5920 ! (Y/N)
5930   YORN$=""
5940  FOR I=1 TO 6
5950   READ A
5960   YORN$=YORN$&CHR$ (128+A)
5970  NEXT I
5980 !
5990     DATA 40,89,92,78,41,-96
6000 !
6010   RETURN
6020 ! ****************************************************************************
6030 !
6040 ERROUTINE: !       ERROR HANDLING SUBROUTINE
6050 !
6060  OFF ERROR
6070  BEEP 30,300 @ WAIT 1 @ BEEP 30,300
6080  DISP
6090  DISP "BAD INPUT : TRY AGAIN !!"
6100  DISP
6110  ON ERROR GOSUB ERROUTINE
6120  RETURN
6130 END
```

7.2 "IONMAN"

7.2.1 Program Summary

7.2.2 Program Listing

```
DECLARE SUB PROMPT (X)
DECLARE SUB BOX (X1!, X2!, Y1!, Y2!, C1!, C2!)
DECLARE SUB OPENFILE ()
DECLARE SUB KBQ (PRT$)
DECLARE SUB KBQ (PRT$)
DECLARE SUB MBQ (PRT$)
DECLARE SUB ERRORS (TR.Err, TM.Err, IR.Err, IC.Err, M.Err, N, OPTION$, NUM, S)
DECLARE SUB CLEARLINE (X!)
DECLARE SUB TIMECHECK (MINS!, HOURS!, STATUS$)
DECLARE SUB DATECHECK (DAY!, MONTH!, YEAR!, STATUS$)
DECLARE SUB CONVERT (DAY!, MONTH!, YEAR, MINS!, HOURS!, TOTAL#)
DECLARE SUB TRIM (X#, X$)

' ******************************************************************************

'   IONMAN.BAS - ACTIVITY DETERMINATION FROM T.P.A ION CHAMBER MEASUREMENTS

'                  Written by S.Buckman 28/3/1990.

'                       Updated to 16/11/1990

'                            Version 2.0

' ******************************************************************************

' This program calculates the radioactivity from the Ion Chamber measurements.
' The program has been written to be used in conjunction with the measurement
' software developed for the HP86B Computer ( see the report ANSTO/M-118 ).
'
' ******************************************************************************

   CLS : SCREEN 9 '                                SELECT HIGH RES COLOR SCREEN
   DIM NUC$(24), HL(24), IcA(24), IcV(24) '      DIMENSION ARRAYS
   DIM TM(20), TR(20)
   S = 1'                                           S ≡ SOURCE NUMBER
   LINE.COUNTER = 1 '                               LINE COUNTER FOR PRINTER

'*******************************************************************************
'                           1. PRELIMINARIES
'*******************************************************************************

   '
10 '                       1A. DISPLAY PROGRAM INFO
   '
        COLOR 4, 0: LOCATE 8, 1 '                         COLOR 4 ≡ RED

    ' DRAW LARGE BOXES
    LINE (100, 80)-(520, 270), , B : LINE (90, 70)-(530, 280), , B
    LINE (95, 75)-(525, 275), , B

    ' DRAW SMALL BOXES
    LINE (254, 95)-(324, 115), , B : LINE (252, 93)-(326, 117), , B
    LOCATE 8, 34: COLOR 10 '                          COLOR 10 ≡ LIGHT GREEN
```

```
PRINT "IONMAN": LOCATE 11, 16
PRINT "ACTIVITY DETERMINATION USING IONISATION CHAMBER": LOCATE 12, 16
PRINT "————————————————————————————————————————————————": LOCATE 14, 28
COLOR 11
PRINT "Written by S.Buckman": LOCATE 16, 22
PRINT "For the Radiation Standards Group": LOCATE 18, 26
PRINT "Version 2.0    16/11/1990"

   SLEEP 2'                                         WAIT A SECOND
    CLS

  '
20 '                1B. DISPLAY OPERATING INSTRUCTIONS
  '

' DRAW BOX TO ENCLOSE HEADING
COLOR 4
LINE (228, 23)-(332, 47), , B
LINE (230, 25)-(330, 45), , B
COLOR 11: LOCATE 3, 30 '                      COLOR 11 = LIGHT CYAN
PRINT "INSTRUCTIONS"
LOCATE 5, 1: COLOR 7, 1

' DRAW BOX TO ENCLOSE INSTRUCTIONS
LINE (60, 60)-(530, 160), , B: LOCATE 7, 11: COLOR 11
PRINT "1."; : COLOR 7: PRINT " Check that <CAPS LOCK> and <NUM LOCK> are
ON"
PRINT : COLOR 11: LOCATE 9, 11
PRINT "2."; : COLOR 7
PRINT " To return to the previous input type either <ENTER> "
LOCATE 10, 13: PRINT " OR 0 < ENTER > "
PRINT

LOCATE 20, 1: COLOR 11
PROMPT (23) '                            "Press any key to continue"

'
'      1C. SELECT EITHER PRINTER, DISC OR SCREEN FOR OUTPUT
'

25      CLS : CLOSE : DISC$ = "N" '           CLEAR SCRN & CLOSE ALL FILES
 CALL BOX(100, 510, 130, 160, 4, 7): LOCATE 11, 15
 PRINT "SEND OUTPUT TO PRINTER, SCREEN OR DISC (P/S/D) ? ";
 PRT$ = INPUT$(1)
 PRT$ = UCASE$(PRT$) '                  CONVERT LOWER CASE TO UPPER CASE

      CLS
IF PRT$ = "P" THEN
    CALL BOX(80, 500, 100, 220, 4, 6)
    LOCATE 10, 14: COLOR 7
    PRINT "1. Ensure that printer is ON LINE": LOCATE 12, 14
    PRINT "2. ADVANCE PAPER to the beginning of new page": LOCATE 14, 14
    PRINT "3. Check that printer DIP SWITCH #1 is turned ON"
    PROMPT (23)
    OPEN "LPT1:" FOR RANDOM AS #1 '                   OPEN PRINTER PORT
```

```
    ELSEIF PRT$ = "S" THEN
        OPEN "SCRN:" FOR RANDOM AS #1 '                        OPEN SCREEN
    ELSEIF PRT$ = "D" THEN
        CALL OPENFILE
    ELSEIF PRT$ = "O" THEN CLS @ GOTO 10
    ELSE
        CLS : SOUND 600, 3: GOTO 25 '                          TRY AGAIN
    END IF

    IF PRT$ = "D" THEN PRT$ = "S": DISC$ = "Y"
    IF PRT$ = "S" THEN 30

    PRINT #1, CHR$(27) + "C" + CHR$(66); '          SET PAGE LENGTH TO 66 LINES
    '
30  '                   1D. INPUT MEASUREMENT DETAILS
    '

        COLOR 11: CLS
    PRINT
    PRINT TAB(30); "INPUT DETAILS"
    PRINT TAB(30); "——————————————"
        COLOR 7
40  PRINT

50  INPUT " Job Reference Number "; Ref$
      IF Ref$ = "" THEN 25 '                                  PREVIOUS INPUT

        PRINT : PRINT

60 INPUT " How many samples do you wish to measure"; NUM
      IF NUM = 0 THEN LOCATE 5, 1: GOTO 50 '         RETURN TO PREVIOUS INPUT
      IF NUM < 1 THEN LOCATE 8, 1: SOUND 600, 3: GOTO 60 ' TRY AGAIN
        PRINT

70 INPUT " How many measurements of each "; N
      IF N = 0 THEN LOCATE 8, 1: GOTO 60 '           RETURN TO PREVIOUS INPUT
      IF N <= 2 THEN LOCATE 10, 1: SOUND 600, 3: GOTO 70 '  TRY AGAIN

80 GOSUB TABLES '                          READ IN TABLES FROM AAEC/E627

90 GOSUB ISOTOPES: '                       PRINT ISOTOPE SELECTION TABLE
        '                            AND MAKE SELECTION
   '
110 '                  1E. CHECK/CHANGE OTHER VARIABLES
   '

     TB = 4103 '                       BACKGROUND CHARGE TIME (100mV, C2)
     MSD = .000005 '                   STD DEV IN MASS MEASUREMENT

     DAY = VAL(MID$(DATE$, 4, 2)) '    PRESENT DAY
     MONTH = VAL(LEFT$(DATE$, 2)) '    PRESENT MONTH
     YEAR = VAL(RIGHT$(DATE$, 4))'     PRESENT YEAR (4 digit format)
     HOURS = VAL(LEFT$(TIME$, 2)) '    PRESENT NUMBER OF HOURS
     MINS = VAL(MID$(TIME$, 4, 2)) '   PRESENT NUMBER OF MINUTES

     D1 = DAY: M1 = MONTH: Y1 = YEAR ' SET REFERENCE DATE TO PRESENT DATE
     HOURS1 = HOURS: MINS1 = MINS'     SET REFERENCE TIME TO PRESENT TIME
```

```
    D2 = DAY: M2 = MONTH: Y2 = YEAR'   SET DATE OF MEASUREMENT TO PRESENT
    HOURS2 = HOURS: MINS2 = MINS'      SET TIME OF MEASUREMENT TO PRESENT

120 WIDTH 80, 25'                      SET DEFAULT SCREEN MODE
    GOTO VARIABLES '            SUBROUTINE TO CHECK/CHANGE VARIABLE VALUES

   '
130 ' 1F. CALCULATE TIME DIFFERENCE BETWEEN REFERENCE AND MEASUREMENT TIME
   '
   CALL CONVERT(D1, M1, Y1, MINS1, HOURS1, REFTIME#)'  CALC REF TIME IN DAYS
   CALL CONVERT(D2, M2, Y2, MINS2, HOURS2, MEASTIME#)' CALC MEAS TIME IN DAYS
   YRDIFF = (Y1 - Y2) * 365 '                   CONVERT DIFF IN YEARS TO DAYS
   TIMEDIFF# = (REFTIME# - MEASTIME# + YRDIFF) '     TOTAL TIME DIFF IN DAYS

140        CLS

' ****************************************************************************
145 '                      2. MEASUREMENT SECTION
' ****************************************************************************

   '
   '                        2A. SAMPLE MEASUREMENTS
   '

150        COLOR 11
     PRINT
     PRINT TAB(25); "MEASUREMENTS OF SAMPLE #"; S
     PRINT TAB(25); "---------------------------"
           COLOR 7: PRINT

    FOR X = 1 TO N

160 ' (i) INPUT SAMPLE CHARGE TIME, TM(X)
    ' ____________________________________

      PRINT " CHARGE TIME ("; X; ")= "; : INPUT TM(X)

      IF TM(X) = 0 THEN '                    "RETURN TO PREVIOUS INPUT"
          SELECT CASE X
               CASE 1 '                       RETURN TO PREVIOUS SECTION
                    GOTO 120 '
               CASE ELSE '                    RETURN TO PREVIOUS ENTRY
                    LOCATE CSRLIN - 2, 1
                    X = X - 1
          END SELECT
          GOTO 160

      ELSEIF TM(X) < 1 THEN '                 BAD INPUT : TRY AGAIN
          SOUND 600, 3
          LOCATE CSRLIN - 1, 1
          GOTO 160
      END IF

    NEXT X
          PRINT
```

```
170 ' (ii) INPUT CAPACITOR NUMBER
    ' ______________________________

    INPUT " CAPACITOR NUMBER (1-4) "; C

       ROW = CSRLIN '                 CURSOR LOCATION ROW NUMBER
       SELECT CASE C '                CHECK THAT C = 1,2 or 3.
           CASE 1 TO 3 '              ALLOWABLE VALUES
           CASE 0 '                   IF C=0 : RETURN TO BEGINNING OF SECTION
                CLS : GOTO 145
           CASE ELSE '                BAD INPUT : TRY AGAIN
                LOCATE ROW - 1, 1'
                SOUND 600, 3
                GOTO 170
        END SELECT

180 ' (iii) INPUT VOLTAGE RANGE
    ' ___________________________

    INPUT " VOLTAGE RANGE, Vm (Volts) "; VM

       ROW = CSRLIN '                CURRENT CURSOR ROW POSITION

     SELECT CASE VM '               CHECK THAT VM IS AN ACTUAL RANGE SETTING
         CASE 30, 10, 3, 1, .3, .1, .03, .01, .003 '          ALLOWED VALUES
         CASE 0 '                                 RETURN TO CAPACITOR INPUT
            LOCATE ROW - 2, 1: GOTO 170
         CASE ELSE '                                   BAD INPUT : TRY AGAIN
            LOCATE ROW - 1, 1'
            SOUND 600, 3
            GOTO 180
     END SELECT
            PRINT

190 ' (iv) INPUT MASS
    ' _______________

      PRINT TAB(28); "(Type in -1 to skip all mass calculations)"
      LOCATE CSRLIN - 1, 1 '                           GO UP ONE LINE

    INPUT " MASS (grams)="; M
       ROW = CSRLIN

       SELECT CASE M '                        CHECK THAT MASS IS ACCEPTABLE
           CASE 0 '                           RETURN TO VOLTAGE INPUT
               LOCATE ROW - 3, 1: GOTO 180
           CASE IS > 15 '                     LARGE MASS:DOUBLE CHECK VALUE
               LOCATE ROW + 1, 1'
               SOUND 850, 2
               PRINT " ARE YOU SURE (Y/N) "; : Q$ = INPUT$(1)
               IF Q$ <> "Y" THEN LOCATE ROW - 1, 1: GOTO 190

           CASE -1 '                        -1 ≡ NO MASS MEASUREMENT
           CASE IS > 0'                     0 < MASS < 15 grams, O.K
           CASE ELSE
               SOUND 600, 3
               LOCATE ROW - 1, 1: GOTO 190'   BAD REPLY : TRY AGAIN
       END SELECT
```

```
     LOCATE ROW + 1, 1:  CLEARLINE (1)'        CLEAR POSSIBLE QUESTION

   ' (v) CHECK THAT DETAILS ARE CORRECT
   ' ________________________________

          LOCATE 22, 1: COLOR 11
200 CLEARLINE (1)
    PRINT "  ARE THESE ALL CORRECT (Y/N) ?"; : Q$ = INPUT$(1): Q$ = UCASE$(Q$)

      SELECT CASE Q$
          CASE "Y" '                         DETAILS CORRECT : CONTINUE
          CASE "N" '                         DETAILS INCORRECT : TRY AGAIN
               COLOR 7: GOTO 140
          CASE ""'                           RETURN TO MASS INPUT
               LOCATE ROW - 1, 1: COLOR 6: GOTO 190

          CASE ELSE '                        INCORRECT RESPONSE: TRY AGAIN
               LOCATE 22, 1: SOUND 600, 3
               GOTO 200
      END SELECT
               CLS : COLOR 7

     IF S = 1 THEN 220 '                     FOR FIRST SAMPLE GO STRAIGHT
 '                                           TO INPUTING RAD REF RESULTS

   '
210 '              2B. RADIUM REFERENCE MEASUREMENTS
   '

     CALL BOX(130, 520, 150, 200, 4, 7): LOCATE 13, 18
     PRINT " USE THE SAME RADIUM REFERENCE RESULTS (Y/N) ? "; : Q$ = INPUT$(1)
     Q$ = UCASE$(Q$)

        SELECT CASE Q$
           CASE "Y" '                        USE THE SAME RADIUM REF RESULTS
                GOTO 260
           CASE "N" '                        ENTER NEW RADIUM REF RESULTS
           CASE "0" '                        RETURN TO CAPACITOR INPUT
                CLS : GOTO 170
           CASE ELSE '                       BAD INPUT : TRY AGAIN
                SOUND 600, 3
                LOCATE 1, 1
                GOTO 210
        END SELECT

220 ' (i) INPUT RADIUM REFERENCE SOURCE NUMBER
    ' ________________________________________

               CLS : COLOR 11
     PRINT
     PRINT TAB(25); "RADIUM REFERENCE SOURCE"
     PRINT TAB(25); "_______________________"
     PRINT
               COLOR 7
230  PRINT " RADIUM REFERENCE SOURCE NUMBER (1-7)"; : RA$ = INPUT$(1)
```

```
SELECT CASE RA$
    CASE "0" '                              RETURN TO PREVIOUS QUESTION
        CLS : GOTO 210
    CASE "1", "3", "4", "5", "6", "7" '     POSSIBLE CORRECT VALUES
    CASE "2" '                              NO #2:PRT MESSAGE & TRY AGAIN
        LOCATE 7, 1: SOUND 600, 3
        PRINT "SORRY, RAD REF #2 IS NOT AVAILABLE !!"
        LOCATE 5, 1: GOTO 230
    CASE ELSE '                             BAD INPUT : TRY AGAIN
        LOCATE 5, 1: SOUND 600, 3
        GOTO 230
END SELECT

PRINT TAB(38); "= "; RA$
RA = VAL(RA$)
LOCATE 8, 1: CLEARLINE (1): LOCATE 6, 1' CLEAR POSSIBLE ERROR MESSAGE
             PRINT

235 ' (ii) INPUT VOLTAGE SETTING FOR RADIUM REFERENCE
    ' ______________________________________________

ROW = CSRLIN '                              CURRENT CURSOR ROW POSITION

PRINT TAB(35); "TYPE"; : COLOR 11: PRINT " - 1"; : COLOR 7
PRINT " IF  SAME AS FOR SAMPLE"
LOCATE ROW, 1 '                             "TYPE -1 IF SAME AS SAMPLE"

INPUT " VOLTAGE RANGE (Volts) "; VR

 SELECT CASE VR '                           CHECK VR SELECTION

   CASE 30, 10, 3, 1, .3, .1, .03, .01, .003 '   ALLOWED VALUES

   CASE 0 '                                 RETURN TO PREVIOUS INPUT
      GOTO 220

   CASE -1 '                                SAME AS FOR SAMPLE
      VR = VM

   CASE ELSE '                              BAD INPUT : TRY AGAIN
      LOCATE ROW, 1 '
      SOUND 600, 3
      GOTO 235
 END SELECT

      PRINT
```

```
240 ' (iii) INPUT CHARGE TIME MEASUREMENTS FOR RADIUM REFERENCE
    '

    FOR X = 1 TO N

245    PRINT " CHARGE TIME ("; X; ")= "; : INPUT TR(X)'    INPUT CHARGE TIME

       IF TR(X) = 0 THEN '                         "RETURN TO PREVIOUS INPUT"

             SELECT CASE X
                 CASE 1 '                          RETURN TO BEGINNING OF SECTION
                     LOCATE 4, 1: CLS
                     GOTO 220
                 CASE ELSE '                       RETURN TO PREVIOUS ENTRY
                     LOCATE CSRLIN - 2, 23: PRINT "         " '  CLEAR VALUE
                     LOCATE CSRLIN - 1, 1
                     X = X - 1
                     GOTO 245
             END SELECT


       ELSEIF TR(X) < 1 THEN '                     BAD RESPONSE : TRY AGAIN
                     SOUND 600, 3
                     LOCATE CSRLIN - 2, 1
                     GOTO 245
       END IF

    NEXT X

    ' (iv) DOUBLE CHECK THAT DETAILS ARE CORRECT
    '

             LOCATE 22, 1: COLOR 11: PRINT
250 PRINT "  ARE THESE ALL CORRECT (Y/N) "; : Q$ = INPUT$(1)
    Q$ = UCASE$(Q$)

       SELECT CASE Q$
           CASE "Y"'                               DETAILS CORRECT : CONTINUE
           CASE "" '                               RETURN TO SECTION BEGINNING
               GOTO 220
           CASE "N"'                               MISTAKE : START SECTION AGAIN
               GOTO 220
           CASE ELSE '                             BAD RESPONSE : TRY AGAIN
               LOCATE 23, 1: SOUND 600, 3
               GOTO 250
       END SELECT
```

```
' ****************************************************************************
'                         3. CALCULATION SECTION
' ****************************************************************************

           '
260 '                  ┌──────────────────────────────────────────┐
                       │ 3A. CALCULATE ACTIVITY AND STANDARD DEVIATION │
           '           └──────────────────────────────────────────┘

      KB = VM * CM(C) / 302.2'              Kb=(VmCm)/(VbCb)
      KS = VM / VR'                         Ks=Vm/Vr

      ' TIME BETWEEN MEASUREMENT & AUG 1978
      TIME = Y2 + M2 / 12 + D2/365.25- 1978.6666#
      KR# = EXP(4.33217 / 10000 * TIME)'    Kr = EXP( LOG(2) / T½ * TIME )

    ' (i) CALCULATE MNTR ,MNTM, SUMTM2 @ SUMTR2
    ' ______________________________________

          SUMTR2# = 0: SUMTM2# = 0: TR = 0: TM = 0

      FOR I = 1 TO N
          TR = TR + TR(I)
          TM = TM + TM(I)
          SUMTR2# = SUMTR2# + TR(I) ^ 2
          SUMTM2# = SUMTM2# + TM(I) ^ 2
      NEXT I

          MNTR# = TR / N'                        MNTR = MEAN VALUE OF TR
          MNTM# = TM / N'                        MNTM = MEAN VALUE OF TM

    ' (ii) SUBSTITUTE INTO EQUATIONS
    ' ____________________________

    TERM# = (KB * TB - MNTM#) / (KB * TB - KS * MNTR#)' TERM IN SQUARE BRACKETS
    AM# = TERM# * MNTR# * I(RA) * KS / (MNTM# * KR# * IC)'ACTIVITY AT MEAS TIME
    DECAYFACTOR# = EXP(-LOG(2) * TIMEDIFF# / HL(KI))'  DECAY CORRECTION
    A0# = AM# * DECAYFACTOR# '                    TOT ACTIVITY AT REF TIME
    BRACKETS# = (SUMTR2# - N * MNTR# ^ 2) / MNTR# ^ 2 + (SUMTM2# - N * MNTM# ^ 2)
              / MNTM# ^ 2
    AMSD# = AM# * ABS(1 / (N * (N - 1)) * BRACKETS# + ISD(RA) ^ 2 / I(RA) ^ 2 +
          ICSD ^ 2 / IC ^ 2) ^ .5

    ' (iii) VARIABLES REQUIRED FOR "ERRORS" TABLE
    ' _________________________________________

    TR.Err = (ABS(1 / (N * (N - 1)) * (SUMTR2# - N * MNTR# ^ 2) / MNTR# ^ 2))
           ^ .5 * 100
    TM.Err = (ABS(1 / (N * (N - 1)) * (SUMTM2# - N * MNTM# ^ 2) / MNTM# ^ 2))
           ^ .5 * 100
    IR.Err = ISD(RA) / I(RA) * 100
    IF M = -1 THEN M.Err = 0 ELSE M.Err = MSD / M * 100
    IC.Err = ICSD / IC * 100

   IF M = -1 THEN 265'           SKIP ACTIVITY CONCENTRATION IF NO MASS MEAS
```

```
' (iv) CALCULATE ACTIVITY CONCENTRATION
' ________________________________________

CM# = AM# / M '                         ACTIVITY CONCENTRATION AT MEAS TIME
CO# = CM# * DECAYFACTOR# '              ACTIVITY CONC AT REF TIME
CMSD# = CM# * ABS(1 / (N * (N - 1)) * BRACKETS# + ISD(RA) ^ 2 / I(RA) ^ 2 +
        MSD ^ 2 / M ^ 2 + ICSD ^ 2 / IC ^ 2) ^ .5

                CLS

' ************************************************************************
265 '           4. PRINTOUT RESULTS TO KX-P1180 PRINTER
' ************************************************************************

    COLOR 7: CLS  '                         GREY ON BLACK SCREEN

  IF PRT$ = "P" THEN
      CALL BOX(200, 400, 150, 200, 4, 6)
      LOCATE 13, 27: PRINT "PRINTING IN PROGRESS !!"
  END IF

  IF PRT$ = "S" THEN WIDTH 80, 43 '        INCREASE THE NUMBER OF ROWS

  IF S <> 1 THEN 269 '                SKIP "@" AND HEADING FOR SAMPLE# <> 1

  IF PRT$ = "S" GOTO 266

   '
   '            +----------------------------+
   '            | 4A. DEFINE @ = DELTA SYMBOL |
   '            +----------------------------+

' ( PRINTER SET TO IBM MODE )

  PRINT #1, CHR$(27) + "=" + CHR$(15) + CHR$(0) + CHR$(20) + "@"; '"DOWNLOAD"
  PRINT #1, CHR$(0) + CHR$(11); '                                ATTRIBUTES

  RESTORE 999'                          READ DATA DEFINING DELTA

     FOR I = 1 TO 11
       READ A
       PRINT #1, CHR$(A);
     NEXT I

999 DATA 2,6,10,18,34,66,34,18,10,6,2 '       DATA FOR DEFINING CHARACTER

' DOWNLOAD TEXT FONT ( IBM DOWNLOAD NLQ )
  PRINT #1, CHR$(27) + "I" + CHR$(6);

   '
266 '           +-------------------------------+
   '            | 4B. PRINT HEADING ON PRINTER  |
                +-------------------------------+

   IF PRT$ = "S" THEN LOCATE 10, 1
      PRINT #1,
      PRINT #1, TAB(23); "+-------------------------------+"
      PRINT #1, TAB(23); "| RADIATION STANDARDS LABORATORY |"
      PRINT #1, TAB(23); "+-------------------------------+"
```

```
IF PRT$ = "S" THEN PRINT #1, : SLEEP 1

  PRINT #1,
  PRINT #1, TAB(15); "ACTIVITY DETERMINATION USING IONISATION CHAMBER "
  PRINT #1, TAB(15); "───────────────────────────────────────────────"
  PRINT #1,

    HEADING$ = "STANDARDISATION OF " + NUC$(KI) + " IN "
      IF V$ = "A" THEN HEADING$ = HEADING$ + "AMPOULE"
      IF V$ = "V" THEN HEADING$ = HEADING$ + "VIAL"
    UNDERLINE$ = STRING$(LEN(HEADING$), "M")

  PRINT #1, TAB(22); HEADING$
  PRINT #1, TAB(22); UNDERLINE$
  PRINT #1,

LINE.COUNTER = LINE.COUNTER + 11 '              + No. LINES IN HEADING

269 IF LOOPCOUNTER = 0 AND S <> 1 THEN '              "SAME AS PREVIOUSLY"
      IF 55 - LINE.COUNTER < 6 THEN GOSUB NEWFORM
   ELSE '                                             PRINT COMPLETE TABLE
      IF 55 - LINE.COUNTER < 31 THEN GOSUB NEWFORM
   END IF

   PRINT #1, "JOB REF #"; Ref$;
   PRINT #1, TAB(56); "DATE: "; DAY; "/"; MONTH; "/"; YEAR
   PRINT #1, TAB(32); "SAMPLE #"; S
   PRINT #1, TAB(32); "──────────"
   PRINT #1,

  '
  '                    4C. PRINT TABLE OF VARIABLES
  '

   PRINT #1, "VARIABLES:"
   PRINT #1, "──────────"
   PRINT #1,

   IF LOOPCOUNTER = 0 AND S <> 1 THEN '   If the variable values have not
       PRINT #1, "Same as previously" '   changed from previous sample then
       PRINT #1, '                        skip printing them again.
       LINE.COUNTER = LINE.COUNTER + 5
       GOTO 280
   END IF

   ' (i) PRINT HEADINGS
   ' ──────────────────

   PRINT #1, TAB(5); "┌────────┬──────────────────────────────────┬─────────
   ─────┬──────────┐"
   PRINT #1, TAB(5); "│ SYMBOL │            DESCRIPTION           │";
   PRINT #1, "    VALUE    │ ERROR  │"
   PRINT #1, TAB(5); "├────────┼──────────────────────────────────┼─────────
   ─────┼──────────┤"
```

```
' (ii) PRINT CHARGING CAPACITOR
'

PRINT #1, TAB(5); "|          |                                    |
     |          |"
PRINT #1, TAB(5); "|   C";
PRINT #1, "     | Capacitor                       |     #"; C;
PRINT #1, "      |    -    |";

' (iii) PRINT CALIBRATION FACTOR
'

PRINT #1, TAB(5); "|          |                                    |
     |          |"
PRINT #1, TAB(5); "|   i";

 IF PRT$ = "S" THEN
     PRINT #1, "c";
     PRINT #1, "    | Calibration Factor (pA/MBq)      |    ";
 ELSE
     PRINT #1, CHR$(27) + "S" + "1"; '       SELECT SUPERSCRIPT PRINTING
     PRINT #1, "c";
     PRINT #1, CHR$(27) + "T"; '             RELEASES SUPERSCRIPT PRINTING
     PRINT #1, "    | Calibration Factor (pA.MBq";
     PRINT #1, CHR$(27) + "S" + "0"; '       SELECT SUPERSCRIPT PRINTING
     PRINT #1, "-1";
     PRINT #1, CHR$(27) + "T"; '             RELEASES SUPERSCRIPT PRINTING
     PRINT #1, ")     |    ";
 END IF

PRINT #1, IC;

  A$ = STR$(IC) '                    CONVERT NUMBER TO STRING EXPRESSION
  B = 10 - LEN(A$)'                  CALCULATE SPACES REQUIRED
  FOR I = 1 TO B: PRINT #1, " "; : NEXT

PRINT #1, "|  ";
PRINT #1, ICSD;

  A$ = STR$(ICSD) '                  CONVERT NUMBER TO STRING EXPRESSION
  B = 6 - LEN(A$)'                   CALCULATE SPACES REQUIRED
  FOR I = 1 TO B: PRINT #1, " "; : NEXT I

PRINT #1, "|";

' (iv) PRINT RADIUM SOURCE CURRENT
'
PRINT #1, TAB(5); "|          |                                    |
     |          |"
PRINT #1, TAB(5); "|   I";

 IF PRT$ = "S" THEN
     PRINT #1, "r";
 ELSE
     PRINT #1, CHR$(27) + "S" + "1"; '       SELECT SUBSCRIPT PRINTING
     PRINT #1, "r";
     PRINT #1, CHR$(27) + "T"; '             RELEASES SUBSCRIPT PRINTING
 END IF
```

```
PRINT #1, "    | RA Reference Source Current (pA) |    ";
PRINT #1, I(RA);

  A$ = STR$(I(RA)) '                CONVERT NUMBER TO STRING EXPRESSION
  B = 10 - LEN(A$)'                 CALCULATE SPACES REQUIRED
  FOR I = 1 TO B: PRINT #1, " "; : NEXT

PRINT #1, "|  ";
PRINT #1, ISD(RA);

  A$ = STR$(ISD(RA)) '              CONVERT NUMBER TO STRING EXPRESSION
  B = 6 - LEN(A$)'                  CALCULATE SPACES REQUIRED
  FOR I = 1 TO B: PRINT #1, " "; : NEXT

PRINT #1, "|"
PRINT #1, TAB(5); "|        |                                   |
     |         |"

' (v) PRINT SOURCE MASS
'
 IF M <> -1 THEN
    PRINT #1, TAB(5); "|   M";
    PRINT #1, "    | Source Mass (grams)              |    ";
    PRINT #1, M;

       A$ = STR$(M) '               CONVERT NUMBER TO STRING EXPRESSION
       B = 10 - LEN(A$)'            CALCULATE SPACES REQUIRED
       FOR I = 1 TO B: PRINT #1, " "; : NEXT

    PRINT #1, "| ";
    PRINT #1, USING ".##^^^^"; MSD;
    PRINT #1, " |";
    PRINT #1, TAB(5); "|        |                                   |
          |         |"
 END IF

' (vi) PRINT HALF LIFE
'
 PRINT #1, TAB(5); "|   T";

  IF PRT$ = "S" THEN
      PRINT #1, "+";
  ELSE
      PRINT #1, CHR$(27) + "S" + "1"; '      SELECT SUBSCRIPT PRINTING
      PRINT #1, "+";
      PRINT #1, CHR$(27) + "T"; '            RELEASES SUBSCRIPT PRINTING
  END IF

 PRINT #1, "    | Sample Half Life (days)          |    ";
 PRINT #1, HL(KI);

   A$ = STR$(HL(KI)) '              CONVERT NUMBER TO STRING EXPRESSION
   B = 10 - LEN(A$) '               CALCULATE SPACES REQUIRED
   FOR I = 1 TO B: PRINT #1, " "; : NEXT

 PRINT #1, "|     -     |";
```

```
' (vii) PRINT BACKGROUND CHARGE TIME
' ________________________________________

PRINT #1, TAB(5); "|     _    |                              |
     |          |"
PRINT #1, TAB(5); "|    ";

IF PRT$ = "S" THEN
      PRINT #1, CHR$(127);
ELSE
      PRINT #1, "@";
END IF

PRINT #1, "T";

  IF PRT$ = "S" THEN
      PRINT #1, "b";
  ELSE
      PRINT #1, CHR$(27) + "S" + "1"; '          SELECT SUBSCRIPT PRINTING
      PRINT #1, "b";
      PRINT #1, CHR$(27) + "T"; '                RELEASES SUBSCRIPT PRINTING
  END IF

PRINT #1, "  | Background Charge Time (secs)    |   ";
PRINT #1, TB;

  A$ = STR$(TB) '                       CONVERT NUMBER TO STRING EXPRESSION
  B = 10 - LEN(A$)'                     CALCULATE SPACES REQUIRED
  FOR I = 1 TO B: PRINT #1, " "; : NEXT

PRINT #1, "|     -    |"
PRINT #1, TAB(5); "|        |                              |
     |          |"

' (viii) PRINT REFERENCE TIME
' ________________________________________

  PRINT #1, TAB(5); "|    t";

    IF PRT$ = "S" THEN
        PRINT #1, "0";
    ELSE
        PRINT #1, CHR$(27) + "S" + "1"; '         SELECT SUBSCRIPT PRINTING
        PRINT #1, "0";
        PRINT #1, CHR$(27) + "T"; '               RELEASES SUBSCRIPT PRINTING
    END IF
```

```
PRINT #1, "    | Reference Time                         |  ";
PRINT #1, USING "##"; HOURS1; : PRINT #1, ":";
PRINT #1, USING "##"; MINS1; : PRINT #1, " hours";
PRINT #1, " |";
PRINT #1, "    -     |"
PRINT #1, TAB(5); "|         | Reference Date                          |  ";
PRINT #1, USING "##"; D1; : PRINT #1, "/";
PRINT #1, USING "##"; M1; : PRINT #1, "/";
PRINT #1, USING "####"; Y1;
PRINT #1, "  |";
PRINT #1, "    -     |";
PRINT #1, TAB(5); "|         |                                      |
     |         |"

' (ix) PRINT TIME OF MEASUREMENT
'

PRINT #1, TAB(5); "|   t";

  IF PRT$ = "S" THEN
      PRINT #1, "m";
  ELSE
      PRINT #1, CHR$(27) + "S" + "1"; '       SELECT SUBSCRIPT PRINTING
      PRINT #1, "m";
      PRINT #1, CHR$(27) + "T"; '             RELEASES SUBSCRIPT PRINTING
  END IF

PRINT #1, "    | Time at Measurement of Sample    |  ";
PRINT #1, USING "##"; HOURS2; : PRINT #1, ":";
PRINT #1, USING "##"; MINS2; : PRINT #1, " hours";
PRINT #1, " |";
PRINT #1, "    -     |"
PRINT #1, TAB(5); "|         | Date at Measurement of Sample    |  ";
PRINT #1, USING "##"; D2; : PRINT #1, "/";
PRINT #1, USING "##"; M2; : PRINT #1, "/";
PRINT #1, USING "####"; Y2;
PRINT #1, "  |";
PRINT #1, "    -     |";
PRINT #1, TAB(5); "|         |                                      |
     |         |"

' (x) PRINT VOLTAGE RANGE FOR SOURCE
'

PRINT #1, TAB(5); "|   V";

  IF PRT$ = "S" THEN
      PRINT #1, "m";
  ELSE
      PRINT #1, CHR$(27) + "S" + "1"; '       SELECT SUBSCRIPT PRINTING
      PRINT #1, "m";
      PRINT #1, CHR$(27) + "T"; '             RELEASES SUBSCRIPT PRINTING
  END IF

PRINT #1, "    | Sample Voltage Range (Volts)     |   ";
PRINT #1, VM;
```

```
    A$ = STR$(VR) '                         CONVERT NUMBER TO STRING EXPRESSION
    B = 10 - LEN(A$)'                       CALCULATE SPACES REQUIRED
    FOR I = 1 TO B: PRINT #1, " "; : NEXT

  PRINT #1, "|";
  PRINT #1, "    -     |";
  PRINT #1, TAB(5); "|         |                                    |
      |         |"

' (xi) PRINT VOLTAGE RANGE FOR RADIUM REFERENCE
'

  PRINT #1, TAB(5); "|   V";

    IF PRT$ = "S" THEN
        PRINT #1, "r";
    ELSE
        PRINT #1, CHR$(27) + "S" + "1"; '       SELECT SUBSCRIPT PRINTING
        PRINT #1, "r";
        PRINT #1, CHR$(27) + "T"; '             RELEASES SUBSCRIPT PRINTING
    END IF

  PRINT #1, "    | Radium Ref Voltage Range (Volts) |    ";
  PRINT #1, VR;

    A$ = STR$(VM) '                         CONVERT NUMBER TO STRING EXPRESSION
    B = 10 - LEN(A$)'                       CALCULATE SPACES REQUIRED
    FOR I = 1 TO B: PRINT #1, " "; : NEXT

  PRINT #1, "|";
  PRINT #1, "    -     |";
  PRINT #1, TAB(5); "|         |                                    |
      |         |"
  PRINT #1, TAB(5); "└─────────┴────────────────────────────────────┴────────
  ──────┴─────────┘"
  PRINT #1,

 IF M = -1 THEN
    LINE.COUNTER = LINE.COUNTER + 29 '              NO MASS MEASUREMENT
 ELSE
    LINE.COUNTER = LINE.COUNTER + 31 '              WITH MASS MEASUREMENT
 END IF

IF DISC$ <> "Y" THEN
 IF PRT$ = "S" THEN PROMPT (41): COLOR 7, 0
END IF

280  IF 55 - LINE.COUNTER < 12 + N THEN GOSUB NEWFORM
```

```
'
'                    4D. PRINT TABLE OF MEASUREMENTS
'

  PRINT #1, "MEASUREMENTS:"
  PRINT #1, "————————————"
  PRINT #1,
  PRINT #1, TAB(16); "┌──────────────────────────────────┐"
  PRINT #1, TAB(16); "│      CHARGE TIME RESULTS (seconds) │"
  PRINT #1, TAB(16); "├─────────┬───────────────┬─────────┤"
  PRINT #1, TAB(16); "│";
  PRINT #1, " No.  ";
  PRINT #1, "│    SAMPLE    │ RADIUM #"; RA; " │";
  PRINT #1,
  PRINT #1, TAB(16); "├─────────┼───────────────┼─────────┤"

FOR I = 1 TO N
    PRINT #1, TAB(16); "│  "; I;
    IF I < 10 THEN PRINT #1, "   │   "; ELSE PRINT #1, "  │   ";
    PRINT #1, USING "####.##"; TM(I);
    PRINT #1, "   │   ";
    PRINT #1, USING "####.##"; TR(I);
    PRINT #1, "   │"
NEXT I

  PRINT #1, TAB(16); "├─────────┼───────────────┼─────────┤"
  PRINT #1, TAB(16); "│  MEAN   │    ";
  PRINT #1, USING "####.##"; MNTM#;
  PRINT #1, "   │   ";
  PRINT #1, USING "####.##"; MNTR#;
  PRINT #1, "   │"
  PRINT #1, TAB(16); "└─────────┴───────────────┴─────────┘"

  LINE.COUNTER = LINE.COUNTER + 12 + N

285 IF DISC$ <> "Y" THEN
       IF PRT$ = "S" THEN PROMPT (41): COLOR 7, 0  '    DISPLAY PROMPT MESSAGE
    END IF

  '
290 '                    4E. PRINT TABLE OF UNCERTAINTIES
  '

  IF 55 - LINE.COUNTER < 25 THEN GOSUB NEWFORM

  ' (i) PRINT HEADING
  ' ─────────────────

  PRINT #1, "ERRORS:"
  PRINT #1, "———————"
  PRINT #1, TAB(5); "┌──────────────────────────────────────┬───────────────────
  ─────────────┐"
  PRINT #1, TAB(5); "│     SOURCE OF THE UNCERTAINTY        │      UNCERTAINTY
   IN %";
  PRINT #1, "      │"
  PRINT #1, TAB(5); "├────────┬─────────────────────────────┼───────────────────┬─
  ─────────────┤"
  PRINT #1, TAB(5); "│ SYMBOL │      MEASURED  QUANTITY     │  TYPE A ;(n)";
```

```
IF PRT$ <> "S" THEN
    PRINT #1, CHR$(27) + "S" + "0"; '      SELECTS SUPERSCRIPT PRINTING
    PRINT #1, "1";
    PRINT #1, CHR$(27) + "T"; '            RELEASES SUPERSCRIPT PRINTING
ELSE
    PRINT #1, " ";
END IF

PRINT #1, "|    TYPE B    |"
PRINT #1, TAB(5); "├────────┼──────────────────────────────┼──────────────┼
───────────────┤"
PRINT #1, TAB(5); "|    _    |                              |              |
|"
PRINT #1, TAB(5); "|";

' (ii) MEAN SAMPLE CHARGE TIME
' ─────────────────────────────

  IF PRT$ = "S" THEN
     PRINT #1, "  "; CHR$(127); "Tm"; "   ";
  ELSE
     PRINT #1, "  "; "@T";
     PRINT #1, CHR$(27) + "S" + "1"; '         SELECT SUBSCRIPT PRINTING
     PRINT #1, "m";
     PRINT #1, CHR$(27) + "T"; '               RELEASES SUBSCRIPT PRINTING
     PRINT #1, "   ";
  END IF

 PRINT #1, "| Mean Sample Charge Time    |";
 PRINT #1, USING " ##.## ;("; TM.Err;
 PRINT #1, N;
 IF N < 10 THEN PRINT #1, ") |";  ELSE PRINT #1, ")|";
 PRINT #1, "                |"
 PRINT #1, TAB(5); "|    _    |                              |              |
 |"
 PRINT #1, TAB(5); "|";

IF PRT$ = "S" THEN
   PRINT #1, "  "; CHR$(127); "Tr"; "   ";
ELSE
   PRINT #1, "  "; "@T";
   PRINT #1, CHR$(27) + "S" + "1"; '          SELECT SUBSCRIPT PRINTING
   PRINT #1, "r";
   PRINT #1, CHR$(27) + "T"; '                RELEASES SUBSCRIPT PRINTING
   PRINT #1, "   ";
END IF
```

```
' (iii) MEAN RADIUM REFERENCE CHARGE TIME
'

 PRINT #1, "|  Mean Rad Ref Charge Time    |";
 PRINT #1, USING " ##.## ;("; TR.Err;

 PRINT #1, N;
 IF N < 10 THEN PRINT #1, ") |";  ELSE PRINT #1, ")|";
 PRINT #1, "                |"
 PRINT #1, TAB(5); "|         |                              |              |
  |"
 PRINT #1, TAB(5); "|   I";

IF PRT$ = "S" THEN
    PRINT #1, "r";
ELSE
    PRINT #1, CHR$(27) + "S" + "1"; '          SELECT SUBSCRIPT PRINTING
    PRINT #1, "r";
    PRINT #1, CHR$(27) + "T"; '                RELEASES SUBSCRIPT PRINTING
END IF

' (iv) RADIUM SOURCE CURRENT
'

 PRINT #1, "    |  Radium Source Current      |              |";
 PRINT #1, USING "     ##.##     "; IR.Err;
 PRINT #1, "|";
 PRINT #1,
 PRINT #1, TAB(5); "|         |                              |              |
  |"
 PRINT #1, TAB(5); "|   i";

IF PRT$ = "S" THEN
    PRINT #1, "c";
ELSE
    PRINT #1, CHR$(27) + "S" + "1"; '          SELECT SUBSCRIPT PRINTING
    PRINT #1, "c";
    PRINT #1, CHR$(27) + "T"; '                RELEASES SUBSCRIPT PRINTING
END IF

' (v) SPECIFIC IONISATION CURRENT
'

 PRINT #1, "    |  Specific Ionisation Current|              |";
 PRINT #1, USING "     ##.##     "; IC.Err;
 PRINT #1, "|"
 PRINT #1, TAB(5); "|         |                              |              |
  |"

IF M.Err = 0 THEN 2000
```

```
' (vi) MASS
'

PRINT #1, TAB(5); "|   M    |  MASS (grams)                          |         |";
PRINT #1, USING "    .#^^^^    "; M.Err;
PRINT #1, "|"
PRINT #1, TAB(5); "|        |                                        |         |
|"
2000

' (vi) ROOT SUM OF SQUARES & COMBINED UNCERT
'

PRINT #1, TAB(5); "├────────┴────────────────────────────────────────┼─────────┼
──────────────┤"
PRINT #1, TAB(5); "|   QUAD SUM (Root of sum of squares)   |";
QUADSUM1 = (TR.Err ^ 2 + TM.Err ^ 2) ^ .5
PRINT #1, USING "   ###.##     "; QUADSUM1;
PRINT #1, "|";
QUADSUM2 = (IR.Err ^ 2 + IC.Err ^ 2 + M.Err ^ 2) ^ .5
PRINT #1, USING "   ###.##     "; QUADSUM2;
PRINT #1, "|"
PRINT #1, TAB(5); "├─────────────────────────────────────────────────┴─────────┴
──────────────┤"
PRINT #1, TAB(5); "|   COMBINED UNCERTAINTY (Quadratic sum)       ";
PRINT #1, USING "     ##.##           "; (QUADSUM1 ^ 2 + QUADSUM2 ^ 2) ^
.5;
PRINT #1, "|"
PRINT #1, TAB(5); "└────────────────────────────────────────────────────────────
──────────────┘"

IF PRT$ <> "S" THEN
    PRINT #1, CHR$(27) + "S" + "0"; '      SELECTS SUPERSCRIPT PRINTING
    PRINT #1, "  1";
    PRINT #1, CHR$(27) + "T"; '            RELEASES SUPERSCRIPT PRINTING
END IF

 PRINT #1, " n ≡ degrees of freedom "
 PRINT #1,

 IF M = -1 THEN
    LINE.COUNTER = LINE.COUNTER + 23 '                 NO MASS MEASUREMENT
 ELSE
    LINE.COUNTER = LINE.COUNTER + 25 '                 WITH MASS MEASUREMENT
 END IF
```

```
'
'                         4F. PRINT RESULTS
'
IF M = -1 THEN
   IF TIMEDIFF# <> 0 THEN '                       WITHOUT MEASUREMENT TIME
       IF 55 - LINE.COUNTER < 7 THEN GOSUB NEWFORM
   ELSE '                                         WITH MEASUREMENT TIME
       IF 55 - LINECOUNTER < 9 THEN GOSUB NEWFORM
   END IF
ELSE
   IF TIMEDIFF# <> 0 THEN '                       WITHOUT MEASUREMENT TIME
       IF 55 - LINE.COUNTER < 9 THEN GOSUB NEWFORM
   ELSE '                                         WITH MEASUREMENT TIME
       IF 55 - LINECOUNTER < 11 THEN GOSUB NEWFORM
   END IF
END IF

PRINT #1, "RESULTS:"
PRINT #1, "--------"
PRINT #1,
PRINT #1, "AT MEASUREMENT TIME : ";

' (i) PRINT ACTIVITY AT MEASUREMENT TIME
' ----------------------------------------

' Print activity (in either KBq or MBq)
' --------------------------------------

IF AM#  > 10 THEN
  CALL TRIM(AM#, AM$) '                      ROUND TO TWO DECIMAL PLACES
  CALL TRIM(AMSD#, AMSD$)
  PRINT #1, "Total Radioactivity ="; AM$; " +/- "; AMSD$; " MBq"
  PRINT #1, "                        ";
ELSE
  CALL TRIM(AM# * 1000, AM$)
  CALL TRIM(AMSD# * 1000, AMSD$)
  PRINT #1, "Total Radioactivity ="; AM$; " +/- "; AMSD$; " KBq"
  PRINT #1, "                        ";
END IF

PRINT #1, USING "Percentage Error = ##.##"; AMSD# / AM# * 100;
PRINT #1, " %"
```

```
' Print activity concentration (in either KBq/gram or MBq/gram)
'
                                                PRINTER POSITION
IF M <> -1 THEN
  LINE.COUNTER = LINE.COUNTER + 2 '
  IF CM# > 10 THEN
    CALL TRIM(CM#, CM$)
    CALL TRIM(CMSD#, CMSD$)
    PRINT #1, TAB(23); "Radioactivity Concentration = ";
    PRINT #1, CM$; " +/- "; CMSD$;      PRINT "MBq/gram" or "MBq.gram^-1"
    CALL MBQ(PRT$) '
  ELSE
    CALL TRIM(CM# * 1000, CM$)
    CALL TRIM(CMSD# * 1000, CMSD$)
    PRINT #1, TAB(23); "Radioactivity Concentration = ";
    PRINT #1, CM$; " +/- "; CMSD$;      PRINT "KBq/gram" or "KBq.gram^-1"
    CALL KBQ(PRT$) '
  END IF
END IF
    PRINT #1, : PRINT #1,

' (ii) PRINT ACTIVITY AT REFERENCE TIME  ( IF TIMEDIFF# <> 0 )
'
        IF TIMEDIFF# <> 0 THEN '
          LINE.COUNTER = LINE.COUNTER + 2
          PRINT #1, "AT REFERENCE TIME :";
            IF A0# > 10 THEN
              CALL TRIM(A0#, A0$)
              PRINT #1, "Total Radioactivity = ";
              PRINT #1, A0$; " MBq"
                IF M <> -1 THEN                            ";
                  PRINT #1, "
                  CALL TRIM(C0#, C0$)
                  PRINT #1, "Radioactivity Concentration = ";
                  PRINT #1, C0$;
                  CALL MBQ(PRT$) '
                  PRINT #1,
                END IF

            ELSE
              CALL TRIM(A0# * 1000, A0$)
              PRINT #1, "Total Radioactivity = ";
              PRINT #1, A0$; " KBq"

                IF M <> -1 THEN                            ";
                    PRINT #1, "
                    CALL TRIM(C0# * 1000, C0$)
                    PRINT #1, "Radioactivity Concentration = ";
                    PRINT #1, C0$;
                    CALL KBQ(PRT$)
                    PRINT #1,
                END IF

            END IF

        END IF
```

```
PRINT #1,
FOR I = 1 TO 80: PRINT #1, TAB(I); "-"; : NEXT I'     DRAW LINE ACROSS PAGE
PRINT #1,

LINE.COUNTER = LINE.COUNTER + 7
IF 55 - LINE.COUNTER < 12 THEN GOSUB NEWFORM '        START NEW PAGE

IF DISC$ <> "Y" THEN
   IF PRT$ = "S" THEN PROMPT (41): COLOR 7, 0
END IF

2400 IF DISC$ <> "Y" THEN
       FOR I = 1 TO 4: SOUND 1000, 1: FOR X = 1 TO 300: NEXT X: NEXT I
     END IF
                                               LOOP BACK TO INPUT SECTION
S = S + 1 '                                    UNTIL ALL SAMPLES ARE DONE
IF S <= NUM THEN 120 '

IF PRT$ <> "S" THEN PRINT #1, CHR$(27) + "H"'      RELEASES DOUBLE PRINTING

     GOSUB NEWFORM
2500 CLOSE  '                                  CLOSE FILES

     WIDTH 80, 25 '                            RETURN TO NORMAL SCREEN MODE

     ' EXIT PROGRAM
     CALL BOX(150, 450, 150, 200, 4, 2)
     COLOR 4: LOCATE 13, 25
     PRINT "NOW LEAVING IONMAN !!": FOR I = 1 TO 3000: NEXT I
     CLS
' ******************************************************************************
                                  END
' ******************************************************************************
```

```
' ******************************************************************
'                         5. SUBROUTINES
' ******************************************************************

TABLES:  ' This series of arrays are taken from the report AAEC/E627 pp 7-10

'
'                       TABLES OF VALUES
'

' RADIUM REFERENCE SOURCE CURRENTS  (see AAEC/E627 p8.)
'

    I(1) = 2.269: ISD(1) = .016
    I(2) = 0
    I(3) = 15.322: ISD(3) = .07
    I(4) = 33.182: ISD(4) = .07
    I(5) = 162.88: ISD(5) = .07
    I(6) = 428.55: ISD(6) = .12
    I(7) = 784.77: ISD(7) = .18

' CAPACITOR VALUES (in pF)
'

    CM(1) = 1029
    CM(2) = 3022
    CM(3) = 100100

' CALIBRATION FACTORS (Table 5, p10)
'

NUC$(1) = "Na-22": HL(1) = 950.4: IcA(1) = 59.24: IcV(1) = 58.76
NUC$(2) = "P-32": HL(2) = 14.29: IcA(2) = .1323: IcV(2) = 0
NUC$(3) = "K-42": HL(3) = .515: IcA(3) = 0: IcV(3) = 7.315
NUC$(4) = "Sc-46": HL(4) = 83.83: IcA(4) = 53.8  IcV(4) = 53.45
NUC$(5) = "Cr-51": HL(5) = 27.704: IcA(5) = 1.008: IcV(5) = 1.0021
NUC$(6) = "Mn-54": HL(6) = 312.5: IcA(6) = 23.27: IcV(6) = 23.1
NUC$(7) = "Co-57": HL(7) = 290.9: IcA(7) = 6.27: IcV(7) = 6.159
NUC$(8) = "Fe-59": HL(8) = 44.529: IcA(8) = 31.01: IcV(8) = 30.77
NUC$(9) = "Co-60": HL(9) = 1925: IcA(9) = 63.77: IcV(9) = 63.34
NUC$(10) = "Zn-65": HL(10) = 243.9: IcA(10) = 15.14: IcV(10) = 15.06
NUC$(11) = "Se-75": HL(11) = 119.8: IcA(11) = 15.61: IcV(11) = 0
NUC$(12) = "Y-88": HL(12) = 106.64: IcA(12) = 65.39: IcV(12) = 65.04
NUC$(13) = "Tc-99m": HL(13) = .2508: IcA(13) = 5.846: IcV(13) = 5.743
NUC$(14) = "Ag-110m": HL(14) = 249.9: IcA(14) = 0: IcV(14) = 74.63
NUC$(15) = "I-131": HL(15) = 8.04: IcA(15) = 11.85: IcV(15) = 11.78
NUC$(16) = "Ba-133": HL(16) = 3846: IcA(16) = 12.57: IcV(16) = 12.35
NUC$(17) = "Cs-134": HL(17) = 754.4: IcA(17) = 44.37: IcV(17) = 44!
NUC$(18) = "Cs-137": HL(18) = 11100: IcA(18) = 16.37: IcV(18) = 16.16
NUC$(19) = "Ce-139": HL(19) = 137.66: IcA(19) = 5.48: IcV(19) = 5.458
NUC$(20) = "Au-198": HL(20) = 2.696: IcA(20) = 0: IcV(20) = 12.4
NUC$(21) = "Au-198 WIRE": HL(21) = 2.696: IcV(21) = 12.63 ' WIRE IN VIAL
NUC$(22) = "Ra-226": HL(22) = 584400: IcA(22) = 45.68: IcV(22) = 0
NUC$(23) = "Am-241": HL(23) = 158153: IcA(23) = 1.032: IcV(23) = .9018
NUC$(24) = "  Your Own Choice"

RETURN
' ******************************************************************
```

```
ICSD: ' This subroutine sets the "Standard Deviation in the Calibration
      ' Factor", ICSD, for the particular isotope chosen.

' STANDARD DEVIATION IN CALIBRATION FACTORS (see p10)
' ________________________________________

  SELECT CASE V$ '                                  V$ : AMPOULE or VIAL

    CASE "A" '                                        AMPOULE

         SELECT CASE KI
            CASE 9 '                                  60-Co
               ICSD = .1
            CASE 16 '                                 133-Ba
               ICSD = .05
            CASE 17 '                                 134-Cs
               ICSD = .2
            CASE 18 '                                 137-Cs
               ICSD = .21
            CASE 22 '                                 226-Ra
               ICSD = .32
            CASE ELSE '                               ALL OTHERS
               ICSD = .1
         END SELECT

    CASE "V" '                                        VIAL

         SELECT CASE KI
            CASE 9 '                                  60-Co
               ICSD = .1
            CASE 16 '                                 133-Ba
               ICSD = .05
            CASE 17 '                                 134-Cs
               ICSD = .2
            CASE 18 '                                 137-Cs
               ICSD = .21
            CASE 22 '                                 226-Ra
               ICSD = .32
            CASE ELSE '                               ALL OTHERS
               ICSD = .1
         END SELECT

    END SELECT

  RETURN
' ***************************************************************************
```

```
ISOTOPES: ' This subroutine prints out a table of various isotopes from which
          ' a selection may be made. This includes the possibility of
          ' selecting an isotope not in the table and entering manually the
          ' values for that isotope. A choice is given between ampoules and
          ' vials. If the choice is not available an error message is printed.
          ' The selection is then confirmed before continuing.

'
500 '                    | PRINT ISOTOPE SELECTION TABLE |
'

   ' PRINT HEADING
   ' _____________

          CLS : COLOR 11, 1
   PRINT
   PRINT TAB(24); "RADIOISOTOPE SELECTION TABLE"
   PRINT TAB(24); "____________________________"
          COLOR 15
   PRINT
   PRINT TAB(3); "NUMBER";
   PRINT TAB(14); "NUCLIDE";
   PRINT TAB(25); "HALF LIFE";
   PRINT TAB(39); "NUMBER";
   PRINT TAB(51); "NUCLIDE";
   PRINT TAB(62); "HALF LIFE"
   PRINT

510 ' PRINT VALUES FROM TABLES
    ' ________________________

     FOR I = 1 TO 12
            COLOR 11
        PRINT TAB(4); I;
            COLOR 7
        PRINT TAB(14); NUC$(I);
        PRINT TAB(25); HL(I); : PRINT TAB(36); CHR$(179);

            COLOR 11
        PRINT TAB(40); I + 12;
            COLOR 7

        PRINT TAB(52); NUC$(I + 12);
     IF I = 12 THEN 520
        PRINT TAB(63); HL(I + 12)

520  NEXT I

        LOCATE 20, 1: COLOR 15
```

```
530 ' INPUT SELECTED ISOTOPE
    ' ______________________

540 INPUT " TYPE IN YOUR CHOICE (1-24)"; KI

              PRINT

  IF KI = 0 THEN CLS : GOTO 30   '                  RETURN TO PREVIOUS INPUT
  IF KI > 24 THEN LOCATE 20, 1: SOUND 600, 3: GOTO 540 ' BAD INPUT: TRY AGAIN
  IF KI < 0 THEN LOCATE 20, 1: SOUND 600, 3: GOTO 540 '  BAD INPUT: TRY AGAIN
  IF KI = 24 THEN '                                  ENTER YOUR OWN DETAILS
     CLS
     INPUT " NAME OF NUCLIDE "; NUC$(24)
     INPUT " HALF-LIFE (days)"; HL(24)
     INPUT " AMPOULE OR VIAL (A/V)"; V$
     INPUT " CALIBRATION FACTOR "; IC
     INPUT " ERROR IN CALIBRATION FACTOR "; ICSD
     GOTO 560
  END IF


550  INPUT " AMPOULE OR VIAL (A/V) "; V$
      IF V$ = "A" THEN '                             IC = IC for Ampoule
         IC = IcA(KI) '
      ELSEIF V$ = "" THEN '                          RETURN TO PREVIOUS SECTION
         LOCATE 20, 1: GOTO 540
      ELSEIF V$ = "V" THEN '                         IC = IC for Vial
         IC = IcV(KI)
      ELSE LOCATE 22, 1: SOUND 600, 3: GOTO 550' BAD RESPONSE: TRY AGAIN
      END IF

    ' PRINT ERROR MESSAGE IF SELECTION IS NOT AVAILABLE
    ' _________________________________________________

      IF IC = 0 THEN
          LOCATE 23, 1: SOUND 600, 3
          PRINT "NOT AVAILABLE. TRY AGAIN !!"
          LOCATE 22, 1
          GOTO 550
      END IF

     GOSUB ICSD '                              SUBROUTINE TO SET STD DEV IN IC
```

```
560 ' CHECK DETAILS OF SELECTION
    ' ______________________________

         CLS : LOCATE 5, 1: COLOR 11
    PRINT TAB(30); "YOUR SELECTION:"
    PRINT TAB(30); "________________"
    COLOR 15: LINE (150, 110)-(470, 200), , B
         LOCATE 10, 23: COLOR 7
    PRINT "NUCLIDE :    "; : COLOR 15
    PRINT NUC$(KI): LOCATE 11, 23: COLOR 7

    PRINT "HALF LIFE :"; : COLOR 15
    PRINT HL(KI); " days": LOCATE 12, 23: COLOR 7

    PRINT "CONTAINER : "; : COLOR 15
    IF V$ = "A" THEN PRINT "AMPOULE" ELSE PRINT "VIAL"
    LOCATE 13, 23: COLOR 7

    PRINT "CALIBRATION FACTOR :"; : COLOR 15
    PRINT IC; " +/- "; ICSD

570 LOCATE 20, 25: COLOR 15
    PRINT "IS THIS CORRECT (Y/N) ?"; : A$ = INPUT$(1)

       IF A$ = "N" OR A$ = "" AND KI = 24 THEN '     RESET NUC$(24)
            NUC$(24) = "  YOUR OWN CHOICE"
            GOTO 500
       ELSEIF A$ = "N" OR A$ = "" THEN '             MAKE NEW SELECTION
            GOTO 500
       ELSEIF A$ = "Y" THEN '                       CONTINUE
       ELSE '                                       BAD REPLY: TRY AGAIN
            LOCATE 23, 1: SOUND 600, 3
            GOTO 570
       END IF
   RETURN


' ****************************************************************************
```

```
VARIABLES: ' This subroutine print out a series of variables with their
           ' default values. Changes to any or all can then be made. The
           ' program checks the values and prints error messages when
           ' necessary.

                LOOPCOUNTER = 0 '        RECORDS IF ANY CHANGES ARE MADE
800             CLS : COLOR 11, 1: LOCATE 5, 1: I = 1: STATUS$(1) = ""
     PRINT TAB(20); "OTHER VARIABLES : SAMPLE #"; S
     PRINT TAB(20); "-----------------------------"

     PRINT : COLOR 11
     PRINT " A.";
             COLOR 7
     PRINT " Background Charge Time = "; TB; " secs (for 100mV and C2 setting)"
     PRINT : COLOR 11
     PRINT " B.";
             COLOR 7
     PRINT " Standard Deviation in Mass Measurement = "; MSD; " grams"
     PRINT : COLOR 11
     PRINT " C.";
             COLOR 7
     PRINT " Standard Deviation in Calibration Factor =  "; ICSD
     PRINT : COLOR 11
     PRINT " D.";
             COLOR 7
     PRINT " Reference Time :"; HOURS1; " hours"; MINS1; " mins"
     PRINT : COLOR 11
     PRINT " E.";
             COLOR 7
     PRINT " Reference Date :"; D1; "/"; M1; "/"; Y1
     PRINT : COLOR 11
     PRINT " F.";
             COLOR 7
     PRINT " Measurement Time : "; HOURS2; " hours"; MINS2; " mins"
     PRINT : COLOR 11
     PRINT " G.";
             COLOR 7
     PRINT " Measurement Date :"; D2; "/"; M2; "/"; Y2
     PRINT
             LOCATE 24, 5: COLOR 11
```

```
810 ' EITHER MAKE CHANGE OR CONTINUE
    ' ______________________________

    PRINT "EITHER :";
            COLOR 7
    PRINT " Choose "; : COLOR 11: PRINT "letter "; : COLOR 7
    PRINT "and make correction"
    PRINT TAB(14); "Enter "; : COLOR 11: PRINT "0 "; : COLOR 7
    PRINT "to return to previous section"
            COLOR 11
    PRINT "                        or"
            COLOR 7
    PRINT "              Press "; : COLOR 11: PRINT "<ENTER> "; : COLOR 7
    PRINT "to Continue";
815   C$ = INPUT$(1)

    ' CHANGE VALUE
    ' ____________

            COLOR 15: LOCATE 24, 5
      IF C$ <> CHR$(13) THEN LOOPCOUNTER = LOOPCOUNTER + 1 'RECORDS CHANGES
820   IF C$ = CHR$(13) THEN
        GOTO 830 '                         NO CHANGES :GO TO NEXT SECTION
      ELSEIF C$ = "A" THEN '               CHANGE BACKGROUND MEASUREMENT
        LOCATE 5, 29: PRINT "        " '     CLEAR OLD VALUE
        LOCATE 5, 29
        INPUT TB: CLEARLINE (1)
        IF CSRLIN <> 6 THEN 800  '           REPRINT THE ENTIRE TABLE
        LOCATE 5, 1: CLEARLINE (1): COLOR 11
        PRINT " A."; : COLOR 7
        PRINT " Background Charge Time = "; TB; " secs (for 100mV and C2 set
              ting)"
      ELSEIF C$ = "B" THEN '                 CHANGE MASS STD DEVIATION
        LOCATE 7, 45: PRINT "          ": LOCATE 7, 45'    CLEAR OLD VALUE
        INPUT MSD
        IF CSRLIN <> 8 THEN 800  '           REPRINT THE ENTIRE TABLE
        LOCATE 7, 1: CLEARLINE (1): COLOR 11
        PRINT " B."; : COLOR 7
        PRINT " Standard Deviation in Mass Measurement = "; MSD; " grams"
      ELSEIF C$ = "C" THEN '          CHANGE STD DEV IN CALIBRATION FACTOR
        LOCATE 9, 48: PRINT "      ": LOCATE 9, 48
        INPUT ICSD
        IF STATUS$(I) <> "" THEN 800 '       REPRINT ENTIRE TABLE
        IF CSRLIN <> 10 THEN 800  '          REPRINT THE ENTIRE TABLE
        LOCATE 9, 1: CLEARLINE (1): COLOR 11
        PRINT " C."; : COLOR 7
        PRINT " Standard Deviation in Calibration Factor =  "; ICSD
      ELSEIF C$ = "D" THEN '                 CHANGE REFERENCE TIME
        LOCATE 11, 5
        CLEARLINE (5)
```

```
   INPUT "REFERENCE TIME (HOURS,MINS) : "; HOURS1, MINS1
   IF STATUS$(I) <> "" THEN 800 '           REPRINT ENTIRE TABLE
   IF CSRLIN <> 12 THEN 800  '              REPRINT THE ENTIRE TABLE
   LOCATE 11, 1: CLEARLINE (1): COLOR 11
   PRINT " D."; : COLOR 7
   PRINT " Reference Time :"; HOURS1; " hours"; MINS1; " mins"
ELSEIF C$ = "E" THEN '                      CHANGE REFERENCE DATE
   LOCATE 13, 5
   CLEARLINE (5)
   PRINT "REFERENCE DATE (DAY,MONTH,YEAR) "; : INPUT D1, M1, Y1
   IF INT(Y1 / 100) = 0 THEN Y1 = Y1 + 1900
   IF STATUS$(I) <> "" THEN 800 '           REPRINT ENTIRE TABLE
   IF CSRLIN <> 14 THEN 800  '              REPRINT THE ENTIRE TABLE
   LOCATE 13, 1: CLEARLINE (1): COLOR 11
   PRINT " E."; : COLOR 7
   PRINT " Reference Date :"; D1; "/"; M1; "/"; Y1
ELSEIF C$ = "F" THEN '                      CHANGE MEASUREMENT TIME
  LOCATE 15, 5
   CLEARLINE (5)
   PRINT "MEASUREMENT TIME (HOURS,MINS) "; : INPUT HOURS2, MINS2
   IF STATUS$(I) <> "" THEN 800 '           REPRINT ENTIRE TABLE
   IF CSRLIN <> 16 THEN 800  '              REPRINT THE ENTIRE TABLE
   LOCATE 15, 1: CLEARLINE (1): COLOR 11
   PRINT " F."; : COLOR 7
   PRINT " Measurement Time : "; HOURS2; " hours"; MINS2; " mins"
ELSEIF C$ = "G" THEN '                      CHANGE MEASUREMENT DATE
   LOCATE 17, 5
   CLEARLINE (5)
   INPUT "MEASUREMENT DATE (DAY,MONTH,YEAR) "; D2, M2, Y2
   IF INT(Y2 / 100) = 0 THEN Y2 = Y2 + 1900
   IF STATUS$(I) <> "" THEN 800 '           REPRINT ENTIRE TABLE
   IF CSRLIN <> 18 THEN 800  '              REPRINT THE ENTIRE TABLE
   LOCATE 17, 1: CLEARLINE (1): COLOR 11
   PRINT " G."; : COLOR 7
   PRINT " Measurement Date :"; D2; "/"; M2; "/"; Y2
ELSEIF C$ = "0" THEN '                      RETURN TO PREVIOUS SECTION
   GOTO 90 '
ELSE
   SOUND 600, 3: GOTO 800 '                 BAD REPLY: TRY AGAIN

END IF

GOTO 815 '                                  CHANGE OR CONTINUE
```

```
830 ' CHECK THAT DATE AND TIMES ARE SENSIBLE
    ' ______________________________________

   ' CHECK REFERENCE DATE
     CALL DATECHECK(D1, M1, Y1, STATUS$(1))

   ' CHECK MEASUREMENT DATE
     CALL DATECHECK(D2, M2, Y2, STATUS$(2))

   ' CHECK REFERENCE TIME
     CALL TIMECHECK(MINS1, HOURS1, STATUS$(3))

   ' CHECK MEASUREMENT TIME
     CALL TIMECHECK(MINS2, HOURS2, STATUS$(4))

840 ' PRINT ERROR STATEMENTS AS REQUIRED
    ' _________________________________

   FOR I = 1 TO 4

       SELECT CASE I
            CASE 1 '                              REFERENCE DATE
                 C$ = "E"
            CASE 2 '                              MEASUREMENT DATE
                 C$ = "G"
            CASE 3 '                              REFERENCE TIME
                 C$ = "D"
            CASE 4 '                              REFERENCE DATE
                 C$ = "F"
       END SELECT

   IF STATUS$(I) = "" THEN 860 '          NO INCONSISTENCIES: CONTINUE


850     ' PRINT ERROR MESSAGE
        ' ___________________

        FOR Z = 20 TO 23: LOCATE Z, 1: CLEARLINE (1): NEXT Z'   CLEAR BLOCK
        LOCATE 24, 1: PRINT "                                       ";
        SOUND 600, 3:  LOCATE 21, 1
        PRINT "                "; STATUS$(I); " incorrect.    ";
        PRINT " TRY AGAIN !!";
        GOTO 820 '                        MADE THE NECESSARY CORRECTIONS

860 NEXT I

    GOTO 130 '                                          RETURN

' ****************************************************************************
```

```
NEWFORM: ' This subroutine advances the paper to the next form, sets the top
        ' of form and resets the variable: LINE.COUNTER.

   IF PRT$ = "P" THEN
      PRINT #1, CHR$(12); '                                    FORM FEED
      PRINT #1, CHR$(27) + "4"; '                        SET TOP OF FORM
      LINE.COUNTER = 1
   END IF

      RETURN
' ****************************************************************************

SUB BOX (X1, X2, Y1, Y2, C1, C2)

' Draw box with border. C1 and C2 specify the foreground and background
' colour. X1, X2, Y1 and Y2 specify the co-ordinates of the box.

CLS : SCREEN 9 : COLOR C1

FOR W = 1 TO 5
LINE (X1 - 1 - W, Y1 - 1 - W)-(X2 + 1 + W, Y2 + 1 + W), , B
NEXT W

COLOR C2 : LINE (X1, Y1)-(X2, Y2), , B
PAINT (X1 + 1, Y1 + 1)

END SUB


SUB CLEARLINE (X)

' This subprogram clears the line that the cursor is on and returns the cursor
' to position X on that line

  PRINT "                                                                    "
  LOCATE CSRLIN - 1, X

END SUB

SUB CONVERT (DAY, MONTH, YEAR, MINS, HOURS, TOTAL#)

' This subprogram converts a date and time into a total number of days

   TOTAL# = 0
```

```
' CONVERT MONTHS TO DAYS
' ______________________

   SELECT CASE MONTH
      CASE 2
         D = 31
      CASE 3
         D = 59
      CASE 4
         D = 90
      CASE 5
         D = 120
      CASE 6
         D = 151
      CASE 7
         D = 181
      CASE 8
         D = 212
      CASE 9
         D = 243
      CASE 10
         D = 273
      CASE 11
         D = 304
      CASE 12
         D = 334
   END SELECT

 IF MONTH > 2 AND YEAR / 4 = INT(YEAR / 4) THEN D = D - 1'   LEAP YEAR

 TOTAL# = D + DAY - 1'                  TOTAL NUMBER OF DAYS FROM START OF YEAR

 ' CONVERT HOURS AND MINS TO DAYS
   SUBTOTAL = (HOURS + MINS / 60) / 24

TOTAL# = TOTAL# + SUBTOTAL
END SUB
```

```
SUB DATECHECK (DAY, MONTH, YEAR, STATUS$)

' This subprogram checks the "DATE" information that has been input.
' The string "STATUS$" indicates the results of the test. If STATUS$=0
' then the values entered are reasonable. If the values are different to what
' would be expected then STATUS$ is set to "Day", "Month" or "Year"
' depending on which one was inconsistent. If several are inconsistent then
' each is recorded. For example if both the DAY and the YEAR are incorrect
' then STATUS$= "Day and Year"

   ' CHECK DAY
   ' ─────────
    SELECT CASE DAY
      CASE IS <= 0, IS > 31
         STATUS$ = "Day" '                         DAY IS INCORRECT
      CASE ELSE
         STATUS$ = "" '                                  DAY IS OK
    END SELECT

   ' CHECK MONTH
   ' ───────────
    SELECT CASE MONTH
      CASE IS <= 0, IS > 12

         SELECT CASE STATUS$
            CASE "" '                                MONTH ONLY INCORRECT
               STATUS$ = "Month"
            CASE "Day" '                             DAY AND MONTH INCORRECT
               STATUS$ = STATUS$ + ", Month"
         END SELECT

      CASE ELSE
         STATUS$ = STATUS$ + "" '                      MONTH IS OK
    END SELECT

   ' CHECK YEAR
   ' ──────────
    SELECT CASE YEAR
       CASE IS < 60

         SELECT CASE STATUS$
            CASE "Day", "Month", "Day, Month"
               STATUS$ = STATUS$ + " and Year"
            CASE ""
               STATUS$ = "Year" '                   YEAR ONLY INCORRECT
         END SELECT
       CASE ELSE '                                  YEAR IS OK
      IF STATUS$ = "Day, Month" THEN STATUS$ = "Day and Month"
    END SELECT
 END SUB
```

```
SUB KBQ (PRT$)

' This subprogram prints out "KBq/gram" to the screen if PRT$ = "S" and
' prints out "KBq.gram^-1" to the printer if PRT$ = "P"

   IF PRT$ = "S" THEN
        PRINT #1, " KBq/gram"
   ELSE
        PRINT #1, " KBq.gram";
        PRINT #1, CHR$(27) + "S" + "0"; '   SELECT SUPERSCRIPT PRINTING
        PRINT #1, "-1";
        PRINT #1, CHR$(27) + "T"; '         RELEASES SUPERSCRIPT PRINTING
   END IF

END SUB


SUB MBQ (PRT$)

' This subprogram prints out "MBq/gram" to the screen if PRT$ = "S" and
' prints out "MBq.gram^-1" to the printer if PRT$ = "P"

   IF PRT$ = "S" THEN
        PRINT #1, " MBq/gram"
   ELSE
        PRINT #1, " MBq.gram";
        PRINT #1, CHR$(27) + "S" + "0"; '   SELECT SUPERSCRIPT PRINTING
        PRINT #1, "-1";
        PRINT #1, CHR$(27) + "T"; '         RELEASES SUPERSCRIPT PRINTING
   END IF

END SUB


SUB OPENFILE

1000 CLS : SCREEN 9: CLOSE

' SET THE BOX CO-ORDINATES
  X1 = 180: X2 = 440
  Y1 = 140: Y2 = 180

' DRAW BOX
' ________
  COLOR 15
  LINE (X1 - 2, Y1 - 2)-(X2 + 2, Y2 + 2), , B
  COLOR 4
  LINE (X1, Y1)-(X2, Y2), , B
  PAINT (X1 + 1, Y1 + 1)
```

```
' ENTER FILENAME
' ______________

  COLOR 15: LOCATE 12, 25
  PRINT "TYPE IN FILENAME "; : INPUT NAME$
  NAME$ = UCASE$(NAME$)

' OPEN/CREATE FILE
' ________________

  OPEN NAME$ FOR RANDOM AS #1: CLOSE

' DOES THE FILE ALREADY EXIST ?
' _____________________________

  OPEN NAME$ FOR INPUT AS #1

  IF EOF(1) THEN
  ELSE
      X1 = 170: X2 = 440
      Y1 = 240: Y2 = 300

  COLOR 15
  LINE (X1 - 2, Y1 - 2)-(X2 + 2, Y2 + 2), , B
  COLOR 3
  LINE (X1, Y1)-(X2, Y2), , B
  PAINT (X1 + 1, Y1 + 1)

     LOCATE 19, 24: COLOR 15
     PRINT "FILE ALL READY EXISTS !!"
     LOCATE 21, 24
     PRINT "OVERWRITE EXISTING FILE ? (Y/N)"; : Q$ = INPUT$(1)
     Q$ = UCASE$(Q$)
     IF Q$ = "N" THEN GOTO 1000
END IF

CLOSE : OPEN NAME$ FOR OUTPUT AS #1 LEN = 30000

END SUB

SUB PROMPT (X)
' The subprogram PROMPT displays "Press any key to continue" and loops until
' a key is pressed. X specifies the row on which the text appears.

  LOCATE 23, 15: C = 15
  DO
  COLOR C: LOCATE X, 23
  PRINT "Press any key to continue ";
  FOR T = 1 TO 1000: NEXT
  IF C = 15 THEN C = 2 ELSE C = 15
  LOOP UNTIL INKEY$ <> ""
  CLS
END SUB
```

```
SUB TIMECHECK (MINS, HOURS, STATUS$)
' TIMECHECK is similiar to DATECHECK. It reads in the time concerned and
' checks whether it is reasonable. The string STATUS$ contains the result of
' the test. For example  STATUS$ = "" if there is no error and STATUS$ =
' "MINUTES AND HOURS" if both the hours and minutes are incorrect.

  ' CHECK MINUTES
  ' -------------
    SELECT CASE MINS
      CASE 0 TO 59
         STATUS$ = ""
      CASE ELSE
         STATUS$ = "Minutes "
    END SELECT

  ' CHECK HOURS
  ' -----------
    SELECT CASE HOURS
      CASE 0 TO 24
         STATUS$ = STATUS$ + ""
      CASE ELSE
         IF STATUS$ = "Minutes " THEN
            STATUS$ = STATUS$ + " and Hours"
         ELSE STATUS$ = "Hours"
         END IF
    END SELECT

END SUB

SUB TRIM (X#, X$)
' This subroutine rounds a number, X#, to two decimal places and returns the
' string, X$.
 MAT$ = LTRIM$(STR$(INT((X# - INT(X#) + .005) * 100)))
 IF VAL(MAT$) < 10 THEN MAT$ = "0" + MAT$
 X$ = STR$(INT(X#)) + "." + MAT$
END SUB
```

8. ACKNOWLEDGEMENTS

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10. APPENDICIES

A1. Quickbasic Statement and Function Summary

CHR$ Function : Returns a one-character string whose ASCII code is the argument.

CLOSE Statement : Conclude I/O to a file or device.

CLS Statement : Clears the screen.

COLOR Statement : Selects screen display colors.

CSRLIN Function : Returns the current line (row) position of the cursor.

DATA Statement : Stores the numeric and string constants used by a program's READ statements.

DATE$ Function : Returns a string containing the current date.

DECLARE Statement : Declares references to BASIC procedures.

DIM Statement : Declares a variable and allocates storage space.

DO...LOOP Statements : Repeats a block of statements while a condition is true or until a condition becomes true.

EOF Function : Tests for end of file condition.

FOR...NEXT Statement : Repeats a group of instructions a specified number of times.

GOSUB...RETURN Statements : Branches to, and returns from, a subroutine.

GOTO Statement : Branches unconditionally to the specified line.

IF...THEN...ELSE Statements : Allows conditional execution, based on the evaluation of a Boolean expression.

INKEY$ Function : Reads a character from the keyboard.

INPUT$ Function : Returns a string of characters read from a sequential file. eg. Q$ = INPUT$(1) accepts one character input from the keyboard.

INT Function : Returns the largest integer less than or equal to a numeric expression.

LEFT$ Function : Returns a string consisting of the leftmost characters of a string.

LEN Function : Returns the number of characters in a string or the number of bytes required by a variable.

LINE Statement : Draws a line or box on the screen.

LTRIM$ Function : Returns a copy of a string with leading spaces removed.

LOCATE Statement : Moves the cursor to the specified position.

MID$ Statement : Returns the substring of a string.

OPEN Statement : Enables I/O to a file or device.
eg. OPEN "LPT1:" opens the printer port for output.

PAINT Statement : Fills the graphics area with the colour or pattern specified.

PRINT # Statement : Writes data to a sequential file.

PRINT USING Statement : Prints strings or numbers using a specified format.

READ Statement : Reads values from a DATA statement and assigns the values to variables.

RIGHT$ Function : Returns the rightmost n characters of a string.

SCREEN Statement : Sets the specifications for the screen display.

SELECT CASE Statement : Executes one of several statement blocks depending on the value of an expression.

SLEEP Function : Suspends execution of the program.

SOUND Statement : Generates sound through the speaker.
Syntax - SOUND frequency, duration

STR$ Function : Returns a string representation of the value of a numeric expression.

SUB Statements : Marks the beginning and end of a subprogram.

TAB Function : Moves the print position.

TIME$ Function : Returns the current time from the operating system.

UCASE$ Function : Returns a string expression with all letters in uppercase.

VAL Function : Returns the numeric value of a string of digits.

WIDTH Statement : Changes the number of columns and lines displayed on the screen.

A2 - ASCII TABLE

Dec	Hex	Char	Code
0	00		NUL
1	01	☺	SOH
2	02	☻	STX
3	03	♥	ETX
4	04	♦	EOT
5	05	♣	ENQ
6	06	♠	ACK
7	07	•	BEL
8	08	◘	BS
9	09	○	HT
10	0A	◙	LF
11	0B	♂	VT
12	0C	♀	FF
13	0D	♪	CR
14	0E	♫	SO
15	0F	☼	SI
16	10	►	DLE
17	11	◄	DC1
18	12	↕	DC2
19	13	‼	DC3
20	14	¶	DC4
21	15	§	NAK
22	16	▬	SYN
23	17	↨	ETB
24	18	↑	CAN
25	19	↓	EM
26	1A	→	SUB
27	1B	←	ESC
28	1C	∟	FS
29	1D	↔	GS
30	1E	▲	RS
31	1F	▼	US

Dec	Hex	Char
32	20	
33	21	!
34	22	"
35	23	#
36	24	$
37	25	%
38	26	&
39	27	'
40	28	(
41	29	)
42	2A	*
43	2B	+
44	2C	,
45	2D	-
46	2E	.
47	2F	/
48	30	0
49	31	1
50	32	2
51	33	3
52	34	4
53	35	5
54	36	6
55	37	7
56	38	8
57	39	9
58	3A	:
59	3B	;
60	3C	<
61	3D	=
62	3E	>
63	3F	?

Dec	Hex	Char
64	40	@
65	41	A
66	42	B
67	43	C
68	44	D
69	45	E
70	46	F
71	47	G
72	48	H
73	49	I
74	4A	J
75	4B	K
76	4C	L
77	4D	M
78	4E	N
79	4F	O
80	50	P
81	51	Q
82	52	R
83	53	S
84	54	T
85	55	U
86	56	V
87	57	W
88	58	X
89	59	Y
90	5A	Z
91	5B	[
92	5C	\
93	5D	]
94	5E	^
95	5F	_

Dec	Hex	Char
96	60	`
97	61	a
98	62	b
99	63	c
100	64	d
101	65	e
102	66	f
103	67	g
104	68	h
105	69	i
106	6A	j
107	6B	k
108	6C	l
109	6D	m
110	6E	n
111	6F	o
112	70	p
113	71	q
114	72	r
115	73	s
116	74	t
117	75	u
118	76	v
119	77	w
120	78	x
121	79	y
122	7A	z
123	7B	{
124	7C	|
125	7D	}
126	7E	~
127	7F	⌂†

Dec	Hex	Char
128	80	Ç
129	81	ü
130	82	é
131	83	â
132	84	ä
133	85	à
134	86	å
135	87	ç
136	88	ê
137	89	ë
138	8A	è
139	8B	ï
140	8C	î
141	8D	ì
142	8E	Ä
143	8F	Å
144	90	É
145	91	æ
146	92	Æ
147	93	ô
148	94	ö
149	95	ò
150	96	û
151	97	ù
152	98	ÿ
153	99	Ö
154	9A	Ü
155	9B	¢
156	9C	£
157	9D	¥
158	9E	₧
159	9F	ƒ

Dec	Hex	Char
160	A0	á
161	A1	í
162	A2	ó
163	A3	ú
164	A4	ñ
165	A5	Ñ
166	A6	ª
167	A7	º
168	A8	¿
169	A9	⌐
170	AA	¬
171	AB	½
172	AC	¼
173	AD	¡
174	AE	«
175	AF	»
176	B0	░
177	B1	▒
178	B2	▓
179	B3	│
180	B4	┤
181	B5	╡
182	B6	╢
183	B7	╖
184	B8	╕
185	B9	╣
186	BA	║
187	BB	╗
188	BC	╝
189	BD	╜
190	BE	╛
191	BF	┐

Dec	Hex	Char
192	C0	└
193	C1	┴
194	C2	┬
195	C3	├
196	C4	─
197	C5	┼
198	C6	╞
199	C7	╟
200	C8	╚
201	C9	╔
202	CA	╩
203	CB	╦
204	CC	╠
205	CD	═
206	CE	╬
207	CF	╧
208	D0	╨
209	D1	╤
210	D2	╥
211	D3	╙
212	D4	╘
213	D5	╒
214	D6	╓
215	D7	╫
216	D8	╪
217	D9	┘
218	DA	┌
219	DB	█
220	DC	▄
221	DD	▌
222	DE	▐
223	DF	▀

Dec	Hex	Char
224	E0	α
225	E1	ß
226	E2	Γ
227	E3	π
228	E4	Σ
229	E5	σ
230	E6	µ
231	E7	τ
232	E8	Φ
233	E9	Θ
234	EA	Ω
235	EB	δ
236	EC	∞
237	ED	φ
238	EE	ε
239	EF	∩
240	F0	≡
241	F1	±
242	F2	≥
243	F3	≤
244	F4	⌠
245	F5	⌡
246	F6	÷
247	F7	≈
248	F8	°
249	F9	∙
250	FA	·
251	FB	√
252	FC	ⁿ
253	FD	²
254	FE	■
255	FF	

† ASCII code 127 has the code DEL. Under DOS, this code has the same effect as ASCII 8 (BS).

A.3 - Radium Reference Charge Times and Source Currents

The following is a comparison of calculated and measured charge times for the radium reference source #3 measured with capacitor #2 and a voltage range of 1 volt.

By performing similiar calculations on all the radium reference sources the table shown on the following page was produced. This table indicates the appropriate reference source for a given capacitor and voltage range setting. Furthermore, it provides a means of checking the operation of the ion chamber by comparing the theoretical values listed with the values actually measured on any particular occasion.

The ionisation current, I, is given by equation [33],

$$I = \frac{C_c \cdot VR \cdot SF}{\Delta T}$$

Now the total current $I = I_r + I_b$, where I_r is the radium reference source current and I_b is the background current. The current produced by a particular radium reference source is given by

$$I_r = I_r' \cdot \exp\left(\frac{-\ln 2 \cdot \Delta T}{T_{1/2}}\right) \qquad [36]$$

where I_r' is the radium reference source current as measured on 1/8/1978 and ΔT is the time which has elapsed since 1/8/1978.

For the 1/11/1990, $\Delta T = 12.25$ years.

For a background charge time of 4103 seconds (100mV, C2),

$$I_b = \frac{C \cdot \Delta V}{\Delta T} = \frac{3022 \times .8 \times .1}{4103} = 0.05892 \text{ pA.} \qquad [37]$$

For the case of radium reference #3 being measured on the 1 Volt range of the electrometer with capacitor #2,

$$I_r = I_r' \times \left(\frac{-\ln 2 \times 12.25}{1600}\right) = 15.322 \times .994707 = 15.241 \text{ pA}$$

and the charge time,

$$\Delta T = \frac{3022 \times 0.8 \times 1}{15.241 + 0.05892} = 158.01 \text{ seconds.}$$

This result was within 0.1% of the measured charge time. For this case 0.4% of the current produced was due to background.

Radium Reference Charge Times (as at 1/11/90)

CAPACITOR #1 (1029 pF)

RADIUM	10 mV	30 mV	100 mV	300 mV	1 V	3 V	10 V	30 V
# 1	4	11	35	107	356	1067	3556	> 5000
# 2	—	—	—	—	—	—	—	—
# 3	< 1	2	5	16	54	161	538	1614
# 4	< 1	< 1	2	7	25	75	249	747
# 5	< 1	< 1	< 1	2	5	15	51	152
# 6	< 1	< 1	< 1	< 1	2	6	19	58
# 7	< 1	< 1	< 1	< 1	1	3	11	32

CAPACITOR #2 (3022 pF)

RADIUM	10 mV	30 mV	100 mV	300 mV	1 V	3 V	10 V	30 V
# 1	10	31	104	313	1044	3133	> 5000	> 5000
# 2	—	—	—	—	—	—	—	—
# 3	2	5	16	47	158	474	1580	4740
# 4	< 1	2	7	22	73	219	731	2193
# 5	< 1	< 1	2	4	15	45	149	447
# 6	< 1	< 1	< 1	2	6	17	57	170
# 7	< 1	< 1	< 1	1	3	9	31	93

CAPACITOR #3 (10100 pF)

RADIUM	10 mV	30 mV	100 mV	300 mV	1 V	3 V	10 V	30 V
# 1	35	105	349	1047	3490	> 5000	> 5000	> 5000
# 2	—	—	—	—	—	—	—	—
# 3	5	16	53	159	528	1590	> 5000	> 5000
# 4	2	7	24	73	244	733	2444	> 5000
# 5	< 1	2	5	15	50	150	499	1496
# 6	< 1	< 1	2	6	19	57	190	569
# 7	< 1	< 1	1	3	10	31	103	310

Radium Reference Source Currents (at 1/8/1978)

This table lists the source current for each of the radium reference sources. These figures are required for calculating the figures shown in the tables on the preceding page.

RADIUM	I_R (pA)*	Ra (μg)*	Activity (KBq)
# 1	2.268 ± .016	1.537 ± .077	57 ± 3
# 2	————	————	————
# 3	15.322 ± .07	10.33 ± .42	382 ± 15
# 4	33.182 ± .07	22.55 ± 1.14	834 ± 42
# 5	162.88 ± .07	108.59 ± 3.3	4018 ± 122
# 6	428.55 ± .12	307.4 ± ?	11373 ± ?
# 7	784.77 ± .18	524.6 ± ?	19410 ± ?

* These figures are quoted directly from Table 2, Urquhart [1986].

A.4 Table of Isotopes

The following table lists all the nuclides to date, including calibration factors and half-lives, which have been directly calibrated in the ANSTO secondary standard ionisation chamber.

KI	NUCLIDE	HALF-LIFE (days)	i_c (pA.MBq^{-1})	
			Ampoule	Vial
1	Na-22	950.4	59.24	58.76
2	P-32	14.29	.1323	———
3	K-42	0.515	———	7.315
4	Sc-46	83.83	53.8	53.45
5	Cr-51	27.704	1.008	1.0021
6	Mn-54	312.5	23.27	23.1
7	Co-57	290.9	6.27	6.159
8	Fe-59	44.529	31.01	30.77
9	Co-60	1925	63.77	63.34
10	Zn-65	243.9	15.14	15.06
11	Se-75	119.8	15.61	———
12	Y-88	106.64	65.39	65.04
13	Tc-99m	0.2508	5.846	5.743
14	Ag-110m	249.9	———	74.63
15	I-131	8.04	11.85	11.78
16	Ba-133	3846	12.57	12.35
17	Cs-134	754.4	44.37	44.0
18	Cs-137	11100	16.37	16.16
19	Ce-139	137.66	5.48	5.458
20	Au-198	2.696	———	12.4
21	Au-Wire	2.696	———	12.63
22	Ra-226	584400	45.68	———
23	Am-241	158153	1.032	0.9018

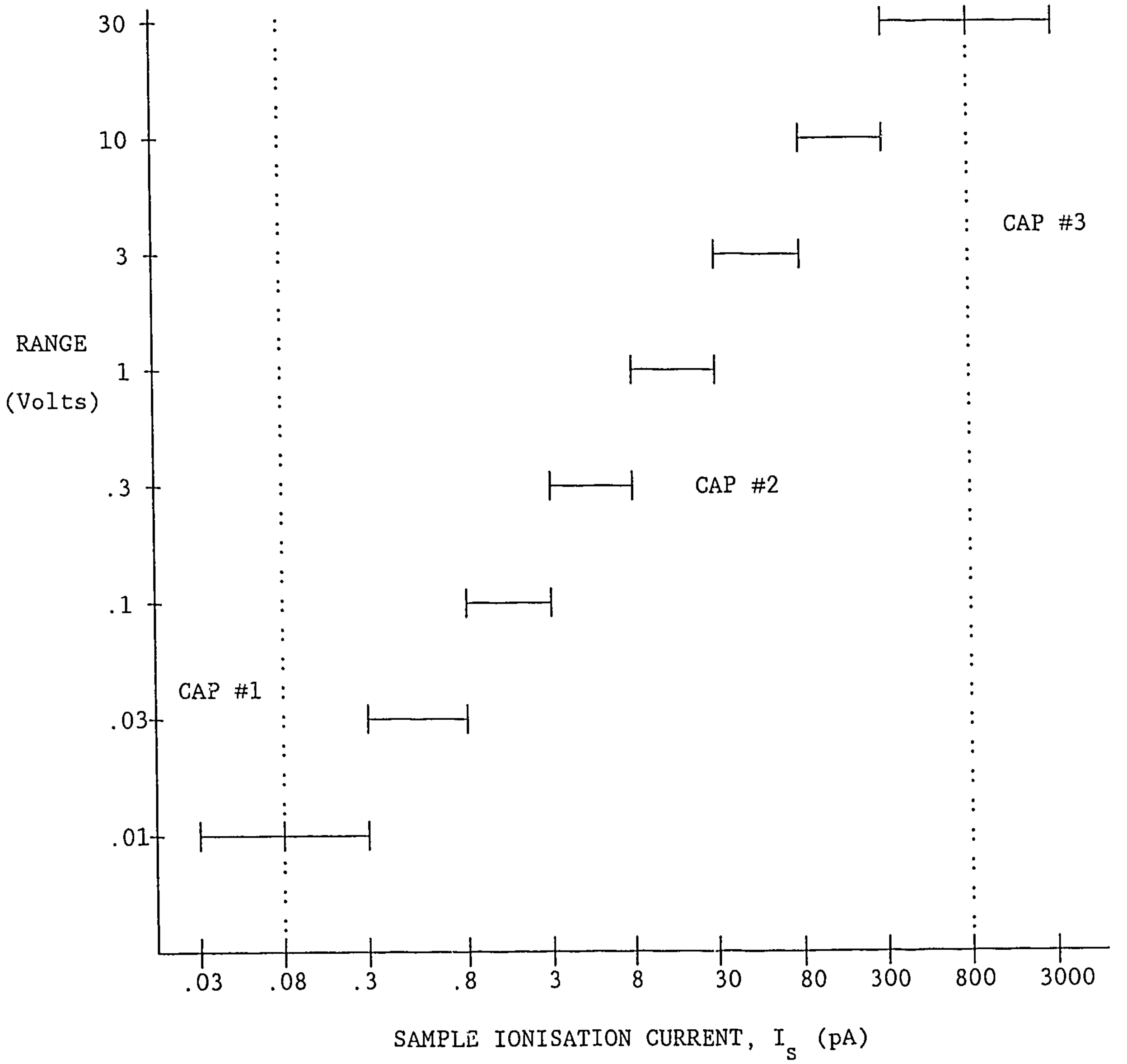
A.5 - Electrometer Voltage Range Settings

The following graph provides a guide to the selection of the appropriate voltage range and capacitor settings, for a given ionisation current, to give a charge time of between 90 and 300 seconds.

For example, consider a vial containing a Co-60 solution having an approximate activity of 1MBq. The approximate ionisation current produced by this solution will be

$$I_s = 1\text{MBq} \times 63.34\ \text{pA/MBq} = 63.34\text{pA}$$

Therefore a charge time of between 90 and 300 seconds can be obtained by selecting capacitor #2 and a voltage range of 3 Volts.



1. Sample Current = Sample Activity * specific current
2. The marker, |——|, indicates where 90 sec < charge time < 300 sec.

A6 - Recombination Correction Factor

An ion chamber is said to be saturated when all the ions produced within the chamber are collected at the electrodes. At saturation the measured ion current is a maximum for a given radiation intensity and is proportional to that intensity. In addition, the ion current will be independent of small fluctuations in the polarizing voltage.

Whilst the chamber remains saturated the current produced will vary linearly with the activity of the source. Ion chambers are normally operated saturated; however, under some circumstances recombination of the ions can occur. When this happens it becomes necessary to apply a correction factor.

The two main ways that ions may recombine within an ion chamber are by "initial recombination" and "general recombination". Initial recombination occurs when +ve and -ve ions formed in the same electron path meet and recombine. It is dependent on the polarizing voltage and is independent of the dose rate. General recombination occurs when the ions produced in different tracks meet and recombine whilst drifting towards their respective electrodes. This is dependent on the dose rate.

Initial recombination is included in the ion chamber calibration and therefore no correction needs to be applied unless the polarizing voltage is changed. General recombination needs to be considered when there is a high density of tracks produced within the ion chamber. The density of ions produced is dependent on both the activity of the source and the energy of the γ-rays emitted. The amount of ionisation produced by the γ-rays from a particular nuclide is reflected in the calibration factor, i_c, for that nuclide.

It is possible to determine the correction factor theoretically using the theory of Boag (see ref.8) but as it depends on the geometry of the chamber, the applied voltage, the rate of charge production and the position of the central electrode it is difficult to determine simply and accurately. The correction factor can also be determined experimentally using the "two-voltage" method. Due to its simplicity this method has been used here.

The principle of the method is to measure the collected charges, Q_1 and Q_2, for the bias voltages, V_1 and V_2, respectively (where V_1 is the normal operating voltage and V_2 is some fraction of V_1). The recombination correction factor, p_1, at the normal operating voltage, V_1, can then be obtained from the graph on the following page.

In this case a series of charge time measurements were made for each of the 6 radium reference sources at polarizing voltages equal to 1/3 and 1/2 of the normal operating voltage. The results are summarised in figure A1.

A recombination correction of 1.0008 was obtained. This figure appears to be independent of source activity over the range of the radium reference source activities. There is hence no need to apply a correction for recombination unless the polarizing voltage is changed (which would change the amount of initial recombination) or a source is measured which produces an ion current significantly greater than 800pA (this could produce significant amounts of general recombination).

Radium Ref	Q_1/Q_2	
	$V_1/V_2 = 2$	$V_1/V_2 = 3$
# 1	1.0021	1.005
# 3	1.003	1.005
# 4	1.0025	1.0042
# 5	1.0030	1.0041
# 6	1.0026	1.0042
# 7	1.0032	1.0040
Mean	1.0027 ± .0004	1.0044 ± .0004
P_1	1.0008	1.0008

Fig A1 - Table of recombination correction measurements

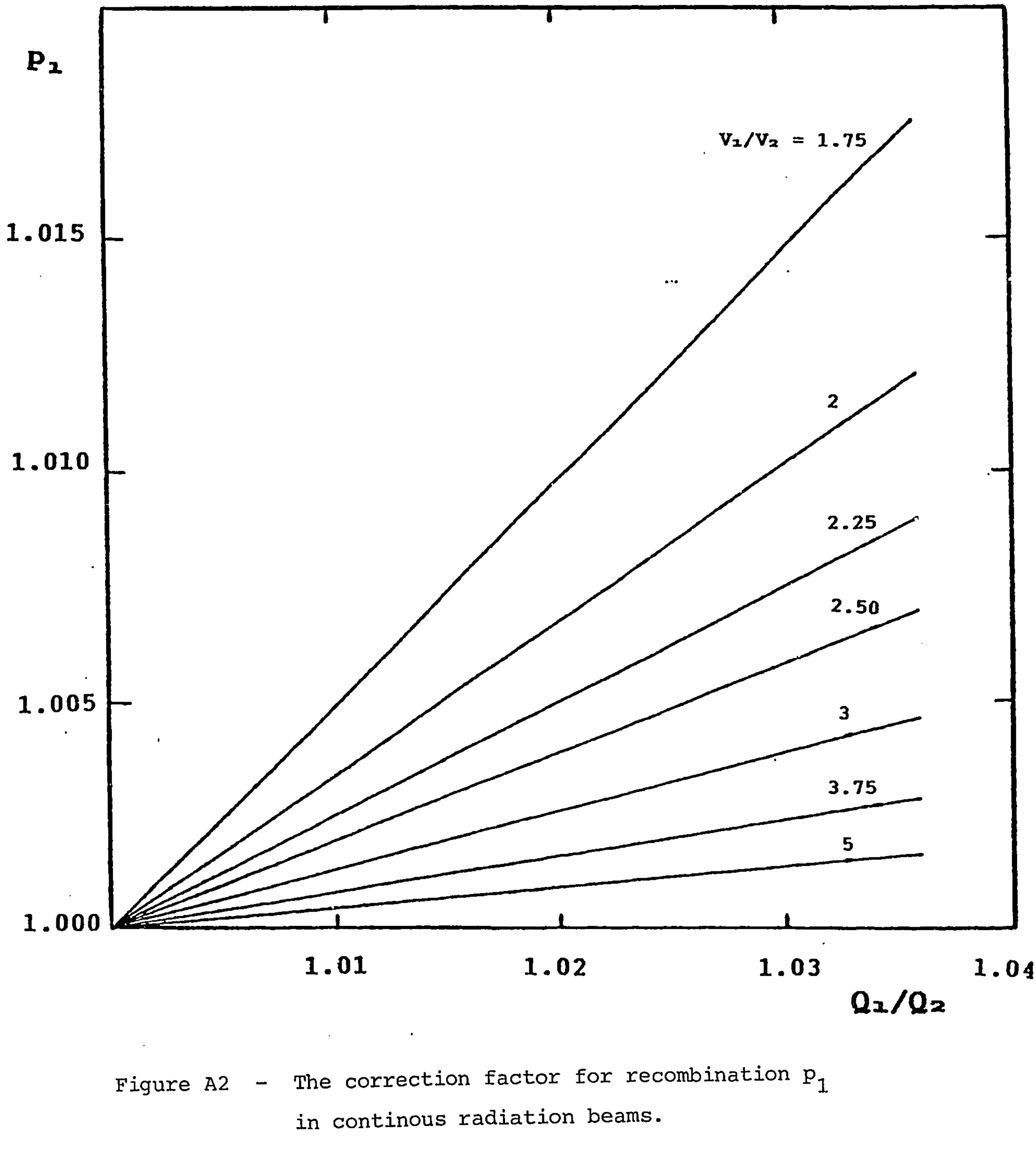


Figure A2 - The correction factor for recombination p_1 in continous radiation beams.

A7. Error due to Uncertainties in Half-life and Dilution

Consider a 10ml radioactive solution having an unknown activity, N_r, at some reference time, t_r. The solution is diluted by a factor D to produce a 10ml solution containing an activity of 1/Dth the original solution. The activity of the diluted solution, as measured in the ionisation chamber at time t_m, is N_m. The activity of the original solution, N_r, at the reference time, t_r, can then be calculated using equation [25],

$$N_r = N_m \,.\, D \,.\, \exp\left[\frac{\ln 2}{T_{1/2}} . (t_m - t_r)\right] \qquad [38]$$

where $T_{1/2}$ is the half-life.

The error associated with the calculated value for N_r is derived as follows:

From the propagation of errors law (equation [14]),

$$\sigma^2(N_r) = \sigma^2(N_m)\left[\frac{\partial N_r}{\partial N_m}\right]^2 + \sigma^2(D)\left[\frac{\partial N_r}{\partial D}\right]^2 + \sigma^2(T_{1/2})\left[\frac{\partial N_r}{\partial T_{1/2}}\right]^2 \qquad [39]$$

$$\text{Now, } \frac{\partial N_r}{\partial N_m} = D \,.\, \exp\left[\frac{\ln 2}{T_{1/2}} . (t_m - t_r)\right] = \frac{N_r}{N_m}, \qquad [40]$$

$$\frac{\partial N_r}{\partial D} = N_m \,.\, \exp\left[\frac{\ln 2}{T_{1/2}} . (t_m - t_r)\right] = \frac{N_r}{D} \quad \text{and} \qquad [41]$$

$$\frac{\partial N_r}{\partial T_{1/2}} = \frac{- N_r \,.\, \ln 2 \,.\, (t_m - t_r)}{(T_{1/2})^2} \qquad [42]$$

Substituting equations [40], [41] and [42] into equation [39] yields

$$\sigma^2(N_r) = \sigma^2(N_m)\left[\frac{N_r}{N_m}\right]^2 + \sigma^2(D)\left[\frac{N_r}{D}\right]^2 + \sigma^2(T_{1/2}) . N_r^2 . \left[\frac{\ln 2.(t_m - t_r)}{(T_{1/2})^2}\right]^2 \qquad [43]$$

Therefore,

$$\frac{\sigma(N_r)}{N_r} = \left\{\left[\frac{\sigma(N_m)}{N_m}\right]^2 + \left[\frac{\sigma(D)}{D}\right]^2 + \left[\frac{\sigma(T_{1/2}).\ln 2.(t_m - t_r)}{(T_{1/2})^2}\right]^2\right\}^{0.5} \qquad [44]$$

As a practical example consider a 10ml solution of Tc^{99m}. A 1ml aliquot of this solution is diluted to 10ml; the 1ml aliquot being measured with an uncertainty of 0.6%.

The diluted solution is measured in the ANSTO secondary standard ionisation chamber; the measured activity being (2.31 ± 0.03) MBq when measured at 13:00 hours on the 31/10/1990. The half-life of Tc^{99m} is (6.019 ± 0.005) hours.

For a reference time of 9:00 hours on the 29/10/1990 the activity of the undiluted solution is

$$N_r = 2.31 \times 10 \times \exp\left(\frac{\ln 2 \times 52}{6.019} \right) = 9211 \text{ MBq}$$

The uncertainty in N_r, as calculated using equation [45], is

$$\frac{\sigma(N_r)}{N_r} = \left\{ \left(\frac{0.03}{2.31} \right)^2 + \left(\frac{0.6}{100} \right)^2 + \left(\frac{0.005 \times \ln 2 \times 52}{(6.019)^2} \right)^2 \right\}^{0.5}$$

$$= (1.69 \times 10^{-4} + 3.6 \times 10^{-5} + 2.47 \times 10^{-5})^{0.5}$$

$$= 1.5 \%$$

Therefore the activity of the original solution at the reference time is

$$N_r = (9.2 \pm 0.1) \text{ GBq}.$$