CHAPTER III

RADIATION DETECTION AND INSTRUMENTATION

III.1 Method of Detection and Measurement

The radiations which come from radioisotopes interact with all matter (gaseous, liquid or solid), causing chemical changes, ionizations and excitations. These effects are utilized in the various methods of detection and measurement.

For the assay of low-energy beta particles, liquid scintillation counting is often employed, to measure the amount of tritium present in many different types of samples. Liquid scintillation counting is based upon the fact that during the stopping of a radioactive emission (alpha particle, beta particle, gamma ray, etc.) in an organic solution, excited molecules are produced. Upon the spontaneous return of these excited molecules to their ground state, photons are emitted. Each excited molecule has the possibility of emitting only one photon. The fraction of the excited molecules which do emit photons, as opposed to radiationless processes, is known as the quantum yield. Most common scintillator solutes have quantum yields near 90%[1/]. The number of photons emitted

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1/ Horrocks, Donald L.1973. Measuring Tritium with Liquid Scintillation System. ANL, Argonne, Illinois, USA.

is proportional to the number of excited molecules produced during the stopping of the radioactive emission. Many excited molecules are formed even for the stopping of very low energy beta particles, such as those emitted from a tritium decay. The burst of photons is detected with a very sensitive multiplier phototube (MPT) which amplifies the signal and generates a voltage pulse proportional to the number of photons which fell upon the photocathode of the MPT. The output of the MPT can be used to drive a rate meter (to measure count rates) or analyzed by a pulse height analyzer (to sort and record events proportional to the intensity of each event).

The liquid scintillator solution consists of three main parts. The bulk of the solution is the solvent, usually an alkylbenzene (i.e., toluene) or dioxane. To the solvent an organic compound (or compounds) is added which is an efficient photon emitter and which emits photons in the wavelength region which is easily measured by the MPT. And finally the liquid scintillator solution contains the sample; although there are some uses where the excitations are generated by an external sample. The most troublesome problems encountered with liquid scintillation counting involve those associated with the

introduction of the sample into the scintillator solution in a homogeneous (or near homogeneous) form, without causing a drastic reduction in photon emission due to so called quenching processes.

III.2 Instrumentation

There are some main instruments used for this research which can be briefly described. Some of these had to be constructed and some others modified to suit the experimental purposes, so that the experiments could be carried out as best as possible.

III.2-1 Vacuum Freeze Dry Apparatus

This apparatus serves for extraction of tritiated water from the plant and soil samples as shown in Figure III-1[2/]. It has been designed and constructed at Health Physics Division, Office of Atomic Energy for Peace, Bangkok. The apparatus consists of the main tube, of the diameter of about: 39 mm, with a thickness of the wall of 2 mm; the length of the system being about 200 cm. The main trap will be connected to the high vacuum system by means of a thick wall rubber tubing, two pressure gauges (pirani-gauge) are measured at both ends of the system and the third one

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2/ Anan Yuthamanop. 1973. Environmental Behaviour of Tritium. Proc. Symp. The Cycling of Tritium in different Types of Ecosystems, California, Nevada, December 10-14, 1973.

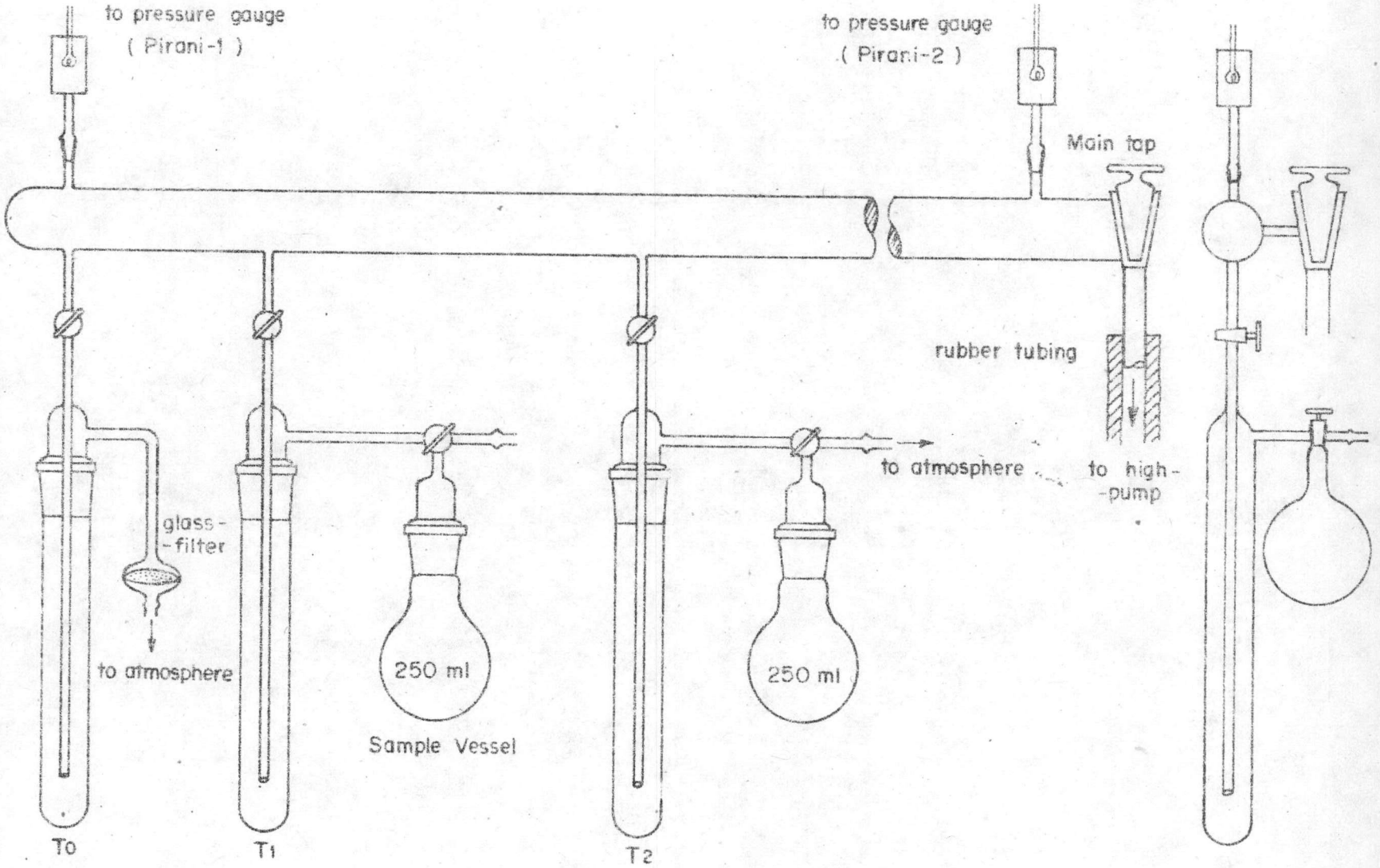


Fig III-1. GLASS-MANIFOLD SYSTEM

(ALL PYREX GLASS)

is installed at the high vacuum pump system itself.

The T_o part is served to pressurise the system. The moisture from the air are trapped into T_o tube by dipping it into Dewar flask which is filled with liquid nitrogen and its main function is at the point when the sample tube is to be disconnected from the system, and to prevent the dust from entering into the system. Use of glass filter was made and the moisture from the air is left in the tube T_o. Only dry air are allowed into the system, so that moist air will not interfere with the sample.

The second part of the system consists of the T_1 to T_6 sections. These T_1 to T_6 sections are used to extract tritiated water (tracer) from the samples. Pyrex glass has been used for designing the whole system. The capacity of the system is about 5 litres. The samples are kept in the flast of the capacity of 250 ml. Under low pressure the water from the samples evaporates and gets trapped into the tube T_1 which, as is shown in ther Figure III-1, is dipped into the Dewar flask filled with liquid nitrogen. After the experiment has been conducted, the sample flask can be removed from the system by means of three-way stop-cock which can be

connected to atmosphere, while the system still remains low pressured.

The tritiated water (tracer) from the sample, which remains in the tube T_1 are sent to measure the activity by using liquid scintillation system. The tritiated water tube (T_1 to T_6) can be removed from the system by means of the first procedure or otherwise, it can be simply disconnected by means of 3-way stop-cock of the sample flask.

III.2-2 Cold Pipe Sampler

This sampler consists of aluminium cone-like shape which is dipped in the Dewar flask filled with liquid nitrogen. It was designed to collect air moisture in the field site to determine tritium content in the air at the time of the application and post-application of the tritiated water. When the Dewar flask is filled with liquid nitrogen, the aluminium cone shape condenses between 5 and 10 ml of water from the air within 1 hour, during which time the liquid nitrogen is dissipated. The condensed water subsequently melts and flows down the pipe into the Dewar flask, from which it is easily collected. Because the water flows into the Dewar flask, the sampler is largely protected

from loss by evaporation or other means until the sampler is picked up for analysis.

III.2-3 Compressed Air Sprayer

This sprayer is used for application of tritiated water to the site of experiment in the form of simulated rain. The capacity of the sprayer is about 15 litres and its nozzle can be adjusted for the fine or coarse spray as desired.

III.2-4 Liquid Scintillation System

This instrument is used to measure the amount of tritium present in the samples. This system is ambient temperature operation and uses an 8-digit Hecon printer for its data printout. It displays the CPM on a ratemeter while counting. Automatic sample changer and 100-standard 20 ml liquid scintillation vials can be worked in each run. This system also has three-channel, serial-counting and Command Tower™ Programming of data channels and samples to be counted. More detailed information of this liquid scintillation system can be seen from Figures III-2, III-3 and III-4.

LS-100 AND LS-100C

Liquid Scintillation System and Direct Data Read

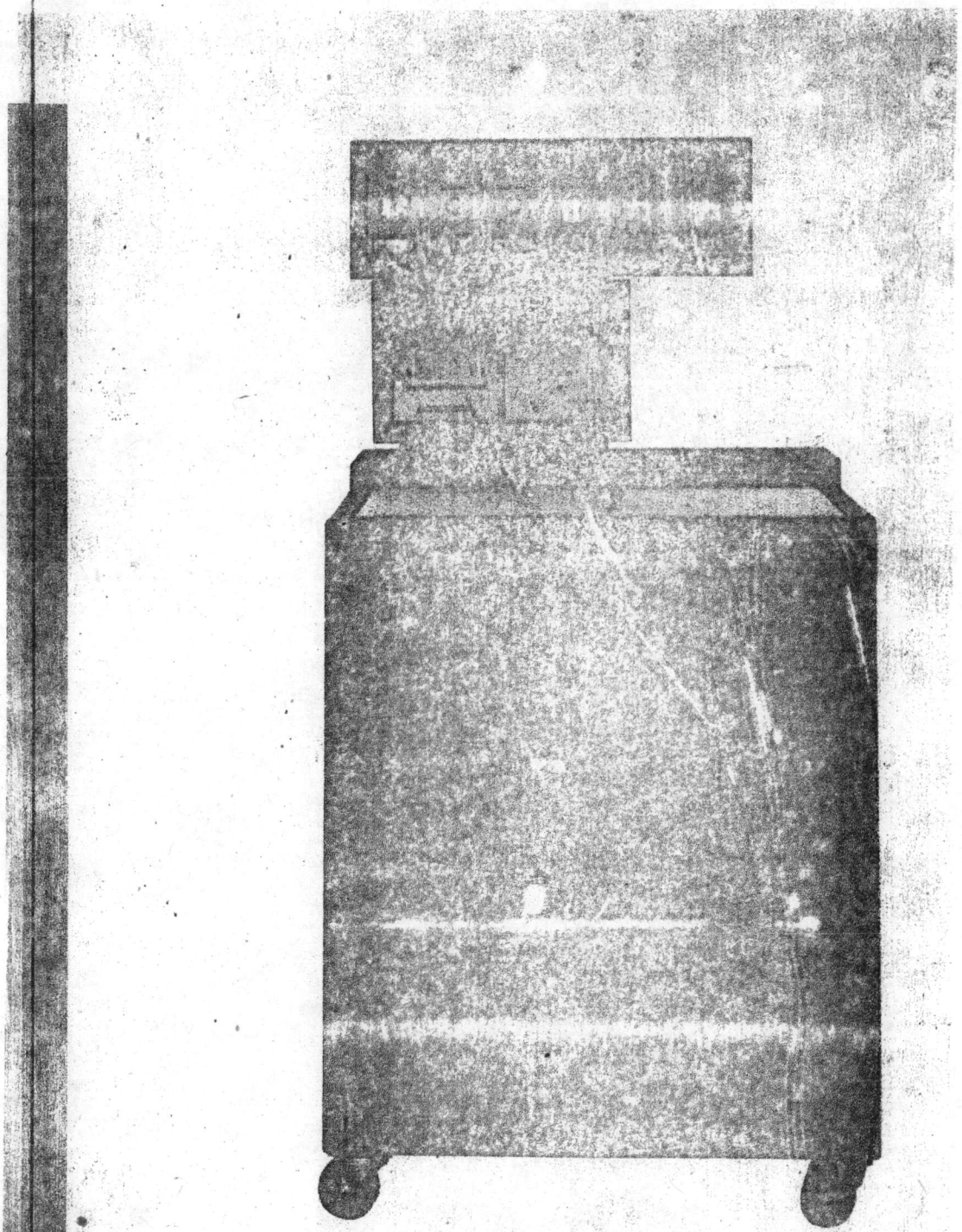
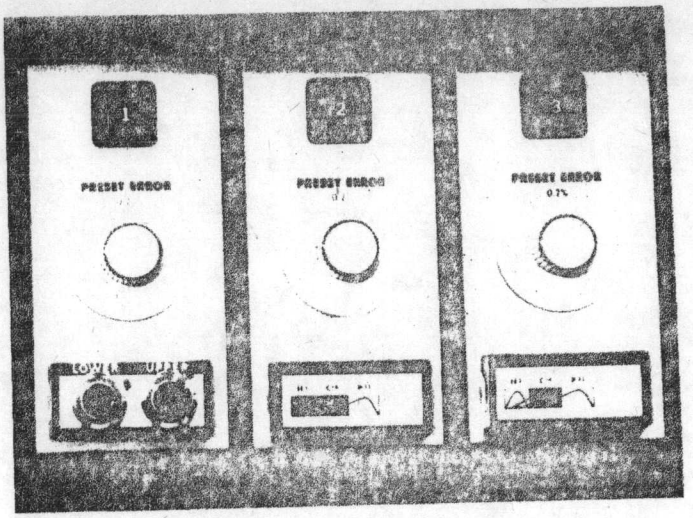
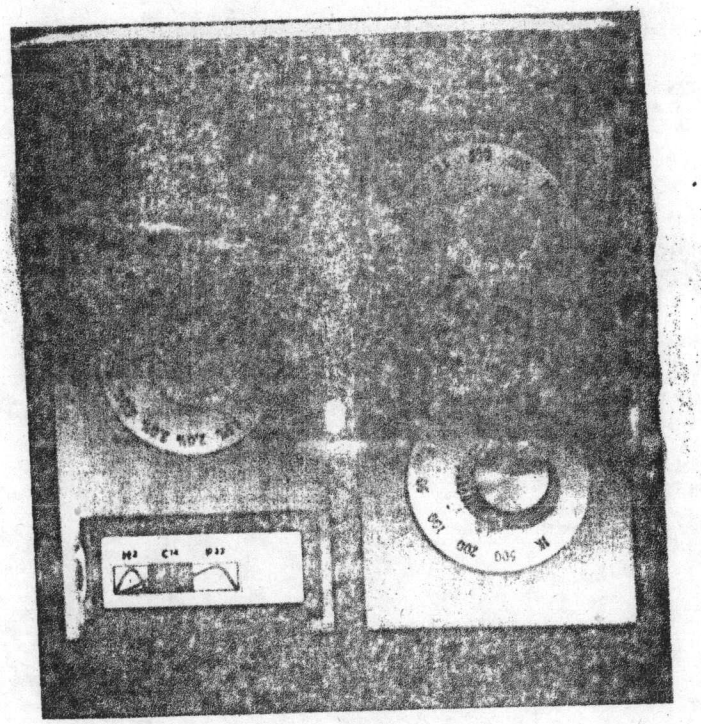


Fig. III-2 Liquid Scintillation System

/ a soft-beta spectr



Channel Control Panels



Override Selectors

Fig. III-3

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0 8 2 7 8 6 .8 3
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        0 1 2 .0 8
3 0 4
0 0 0 9 3 9 .6 0
        0 0 2 .0 0
        0 2 0 .0 0
2 0 4
0 7 9 2 7 9 .3 9  <-- CPM
        0 0 0 .2 0  <-- 2σ ERROR IN %
        0 1 2 .6 2  <-- TIME
1 0 4  <-- CHANNEL AND SAMPLE NO.
0 0 0 0 1 2 .6 9  <-- EXTERNAL STANDARD RATIO

CHANNEL NO. --> 0 0 4
                  <-- SAMPLE NO.
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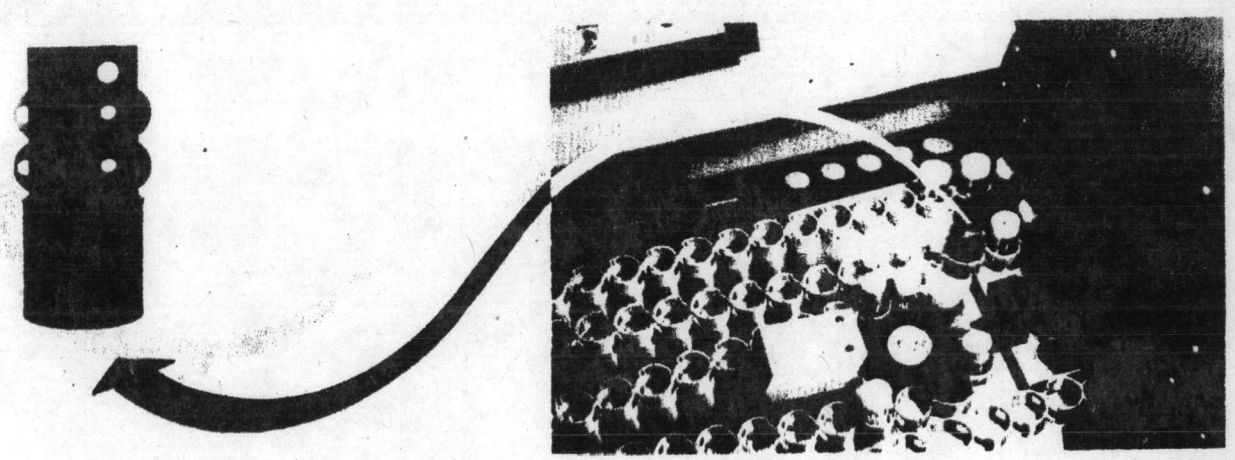
Hecon Printer Format



COMMAND TOWER™

Fig. III-4