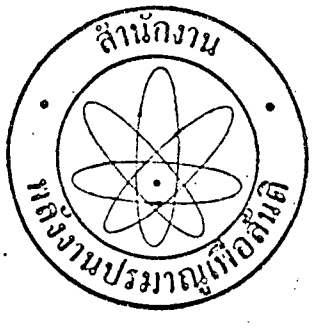

CERTAIN ACCOUNTS ON THE UTILIZATION

OF THE

THAI RESEARCH REACTOR

1967

OFFICE OF THE ATOMIC ENERGY FOR PEACE
BANGKOK, THAILAND.

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Certain accounts on the utilization of the Thai Research Reactor are compiled for the IAEA Study Group Meeting on Research Reactor Utilization which is held in Japan during 19-24 October 1967.

On Reactor Operation.

Reactor operation is aimed to fullfil various requirements arising from current projects and pre-planned operation schedule. At present these requirements can be met more efficiently by operating the reactor on a daily-startup basis rather than by continuous operation. However, continuous 24-hr run for 3 or 4 consecutive days per week may become necessary when research activities and volume of the work increase. A long-term planning is being contemplated toward this direction. From June, 1967 to date the reactor is operated 8-hours per day, 5 days per week.

The interest in using the reactor falls into three main areas viz., reactor characteristics studies and physics experiments, uses of the reactor as a neutron and/or a gamma source for irradiation work and training of personnel in reactor operation and related fields. Training programmes have been arranged for instance the training in reactor operation-supervision. Two classes had already been conducted during the past years and another will be arranged this year.

Safe and efficient reactor operation also involves proper maintenance of the reactor system and related facilities. Minor maintenance work can be performed while the reactor is not operating or, if necessary, on the week-end. For preventive purposes, however, a special shutdown for periodic inspection and maintenance of the reactor and associated system is regularly arranged. Such shutdown, known as the "IRAN" period (Inspection and Repair As Necessary), usually lasts from one to three weeks and is prearranged at an interval of approximately every six months. The maintenance work are under the joint responsibility of the Reactor Operation and Electronic Instrumentation Divisions.

The reactor was brought to first criticality on October 27, 1962. Statistics of reactor operation up to June 30, 1967 can briefly summarized as follows:

	1st year of Operation Oct.62-Sept. 63	2nd year of Operation Oct.63-Sept.64	3rd year of Operation Oct.64-Sept.65	4th year of Operation Oct. 65-Sept.66	5th year of Operation Oct. 66-June 67
Number of Startups	196	225	217	188	94
Operating Hours	436	533	609	544	398
Fuel Exposure (MW-Day)	0.795	8.776	21.193	19.564	14.318
Fuel Burnup (grams U-235)	0.994	10.970	26.491	25.137	18.512

In order to determine the characteristics of the reactor, standard reactor experiments such as critical experiment, rod calibration, detailed flux mapping, etc. were performed, mostly during the first six months after the initial criticality. This type of experiments are repeated whenever the reactor core configuration is changed and also are performed from time to time to familiarize new operation staff members with the techniques.

As the requirements in sample irradiation are growing both in number and in the level of activity involved, it is felt that more irradiation facilities with good accessibility should be installed in the reactor core. Moreover, experience gained under actual working conditions has shown that many irradiation facilities supplied by the reactor manufacturer are not wholly suitable for our purposes. Attempt is being made to bring improvement in this respect by redesigning the facilities and having them fabricated locally, or giving out contract for special fabrication to our own design. It is also planned to change the reactor core configuration to accomodate more irradiation facilities.

On Resonance Integrals.

Measurements of resonance integrals were made by irradiating the target materials bare and cadmium-covered in the pneumatic system. The resonance integrals were then calculated using gold as standard. It was not feasible to simultaneously irradiate the bare and cadmium-covered targets in the same rabbit owing to neutron shielding of cadmium. Therefore, the target was irradiated one at a time. It was observed that sometimes the rabbit didnot seat itself in the proper position resulting in lower neutron flux. In order to avoid some misleading data, many pairs of targets were used and the suspected ones were discarded. Most targets were dissolved and diluted and irradiated in liquid form in order to avoid the self-shielding effect of the resonance neutrons. Handling of diluted materials in liquid was susceptible to adsorption to the pipette and other glass wares. Aliquots were transferred to small polyethelyne capsules and served as targets. The cadmium cover consisted of a cylindrical shell with end caps. If possible, the irradiation time was kept to a few minutes. Few elements were irradiated in the forms of solid foils or wires or as powder. No enriched isotopes were used.

Irradiated targets were counted in a 2 x 2 inch well-type sodium iodide. Energy and half-life were inspected in order to assure that there was no impurity or interference. By checking the energy and half-life, it was found not possible to measure the cadmium ratio of osmium and rhenium.

Variations among samples exceed the variation due to counting statistics. Hence the result of cadmium ratio was tabulated showing the standard deviation which was due to variation among samples alone.

The measurement was limited to isotopes which have high resonance integrals relative to their respective thermal cross sections. In such case, the variation of resonance integrals with cadmium cutoff energy is small unless the resonance peak is very close or overlaps with the cutoff point.

Referring to gold standard, the procedure was as follows:

Cadmium ratio of gold foils of different thicknesses (about 10-100 mg/cm^2) were measured in the same location as previously mentioned. To correct for self-shielding effect, the cadmium ratio for zero thickness was calculated from

$$(CdR_o-1) = \frac{G_r}{G_t} (CdR-1) \qquad \text{--------- (1)}$$

where CdR_o is the cadmium ratio for zero thicknesses.

G_r is the self-shielding for resonance neutrons.

G_t is the self-shielding for thermal neutrons.

From the cadmium ratio for zero thickness, β was calculated from

$$\beta = \sqrt{\frac{\pi}{4}} \frac{\sigma_o}{\sigma_r(CdR_o-1)} \qquad \text{--------- (2)}$$

$$\sigma_o = 98.8$$

$$\sigma_r = 1558$$

$$CdR_o = 6.94 \pm 3\%$$

$$\beta = 0.0095$$

Using 0.0095 as reference, resonance integrals of other materials were calculated from the respective cadmium ratio by using eq.(2).

The values of 2200 m/s cross section used in the calculation were also tabulated. These values were obtained from the Chart of the Nuclides prepared and revised to March 1965 by Knolls Atomic Power Laboratory.

The error of resonance integral depends upon the experimental error, the error in the 2200 m/s cross section and to some extent the error of decay scheme. For example, in the case in which the activated products have isomeric states the cadmium ratio, in principle, should depend on the irradiation time if there occurs total or partial isomeric transitions.

Self-shielding was corrected for in case of platinum only since foils were fairly thick (50 - 70 mg/cm^2). Tantalum result may also be affected by self-shielding although very small pieces of metal were used (15 mg.).

Target Isotopes	Cadmium Ratio	Resonance Integral	2200 m/s cross section
As-75	7.83 ± .09	61.5	4.5
Br-79	9.04 ± .36	98.8	8.5
Br-81	6.89 ± .01	50.6	3.2
Nb-93	17.1 ± .20	5.8	1.0
Mo-98	3.27 ± .04	21.0	0.51
Mo-100	6.68 ± .16	3.29	0.2
Pd-108 → Pd-109 m	12.4 ± .66	1.64	0.2
Pd-108 → Pd-109	14.3 ± .40	84.2	12.0
Sb-121	5.19 ± .04	134	6.0
Sb-123	6.29 ± .10	58.2	3.3
I-127	5.51 ± .25	132	6.4
Cs-133 → Cs-134 m	9.15 ± .12	30	2.6
Cs-133 → Cs-134	7.51 ± .13	400	28.0
Eu-151	77.4 ± 8.1	3420	2800
Sm-152	7.71 ± .20	2920	210
Tb-159	6.51 ± .54	780	46
Ho-165	10.5 ± 1.83	628	64
Er-170	27.1 ± 2.5	32.2	9
Ta-181 → Ta-182 m	7.50 ± .25	1.0	0.07
Ta-181 → Ta-182	7.03 ± .15	800	21
W-186	11.8 ± .17	345	40
Pt-198	7.74	55.3	4

On Neutron Fluxes.

In previous days, fast flux was measured using the following reactions: $P(n,p)Si$, $S(n,p)P$, $Al(n,p)Mg$, $Al(n,\alpha)Na$.

The beta activities of the products were measured by GM counters. There were problems of beta self-absorption which limited the accuracy.

Later a gamma counter was tried. A multichannel spectrometer with 3 x 3 inch NaI is available. The peak efficiency curve was determined using a few calibrated sources. The curve appeared to be a straight line if plotted on the log-log paper. However, at low energy, there was absorption in the casing of NaI. The gamma counting method is more convenient but the accuracy of calibration was considered as fair. The results of fast flux measurements were as follows:

	Dry Tube A-1	Dry Tube A-2
$Al(n,\alpha)Na$	2.5	2.5
$Al(n,p)Mg$	2.5	2.3
$In(n,n')In$	2.4	2.5
$Ni(n,p)Co$	2.2	2.0

Values are in unit of 10^{12} n/cm^2-sec. The reactor power was 1000 KW The positions were the bottoms of the dry tube where the fluxes were not maximum. The maximum fast flux in the tube occured about 1 foot above the bottom, the value was about 6.2×10^{12} n/cm^2-sec. In calculating the flux, the average cross section for fission spectrum was used. Since all four detectors indicated about the same flux notwithstanding different thresholds it meant that the flux has its spectrum close to a fission spectrum. The positions of the two tubes were practically in contact with the reactor core surface.

In the pneumatic system further away the following results were obtained: $Al(n,\alpha)Na$ 9.4×10^{10} , $Al(n,p)Mg$ 8.3×10^{10} , $In(n,n')In$ 5.5×10^{9}.

In this case the average cross section for fission spectrum was also used. The different values of fluxes among the three detectors indicated that the flux has its spectrum much different from the fission spectrum.

Two methods of epithermal flux measurement were tried inside the reactor core. One was the cadmium ratio method (gold), the other was the gold-manganese method in which gold and manganese were irradiated in the core and also in the pneumatic system where the information for resonance neutrons was available. In both methods only the relative activities were required. It was observed that the cadmium ratio method was simpler and subject to less propagation of statistical variations. However, the other method would be very useful in case cadmium is to be avoided. The results showed that in one single fuel element, the epithermal index varied from

0.091 to 0.097. Theoretical calculation assuming homogenized core resulted in the ratio of epithermal flux per unit lethargy to the thermal flux equal to 0.087. For a well moderated core these two parameters are the same.

With regard to thermal neutrons, the main problem has been the measurement of absolute activity of the activated foil. Previously, foils were sent to Australia and Japan for absolute measurements. Now, with the availability of liquid scintillation counter, it is possible to measure the thermal flux using sodium as foil. Sodium may be diluted and counted using liquid scintillation counter. By extrapolation the count versus discriminator setting, the absolute activity may directly be found. It is also possible to measure the absolute activity of sodium using a 4π flow counter. Another possibility is to use the gamma ray spectrometer but in this case the accuracy is inferior to the two other cases. The method for reactor power calibration recently used, was to irradiate copper foils throughout the core volume. Then the same kind of copper foil was irradiated together with sodium. From the absolute activity of sodium, the copper foils could be calibrated in terms of thermal flux. It was necessary to correct for the epithermal activation of copper in the core since copper is not a pure 1/v detector.

On Health Physics.

Radiation in air in the reactor bay area has been routinely monitored using air sampler to collect particulate materials. There exists natural radioactivity in air which must be allowed to decay before identifying the long-lived beta emitters. However, the natural activity was also recorded. In the beginning of the reactor utilization, the natural radioactivity as measured from the filter was of the order of 1000-2000 cpm. In late 1964, the filter showed some days activities of 6000-10000 cpm. In 1965 and later, the activities always exceeded 10000 cpm whereas the maximum recorded was as high as 45000 cpm. Analysis of the filter using gamma ray spectrometer revealed only two elements Cs-138 and Rb-88. They belong to chains of fission products having gaseous ancesters Xe-138 and Kr-88 respectively. Plotting the air activity versus time after startup showed a rise similar to the Geiger counter plateau curve. The plateau was reached within 2 hours. The maximum activities of Cs-138 and Rb-88 were 0.01 microcurie per cubic meter and 2000 picocuries per cubic meter respectively. There have been no MPC for these two elements due to slight hazards. However, by considering the MPC of Cs-137 and Rb-87 which are 0.01 microcurie per cubic meter and 70000 picocuries per cubic meter respectively, it may be concluded that the radiation level in air in the reactor bay area is not dangerous.

With regard to water in the reactor pool, upon allowing one week decay, the activity was found to be in the order of 1000-2000 picocuries per liter. From gamma ray analysis, Ce-141, Cr-51, Zr-95 and Ru-103 were identified.

On Hydrology.

Isotopes produced from the reactor were used as tracers in ground water hydrology. Single-well techniques were used to measure the flow speed and direction.

In the first phase of experiment, the horizontal flow speed was determined by mixing bromine-82 in the form of NH_4Br with water throughout the well depth using a pump and the dilution rate was then observed. The disadvantage was that a large quantity in the order of 50 millicuries of bromine was required. The pump also served as a water sampler. Samples were collected intermittently and brought back to the laboratory for measurement. It was observed that the pump rate should be less than 40 gpm otherwise a strong turbulence would increase the dilution rate and apparently the result would be high.

In the second phase, a horizontal flow-measuring probe was used. The probe consisted of a detector, isotope injector and rubber balloon seals for confining the depth of measurement. In this case a much smaller quantity of isotope was used in each measurement. Another advantage was that the profile of flow speed with depth was also obtained. The main disadvantage was that the probe was susceptible to water leakage. The failure rate was high.

Besides the horizontal flow speed, the vertical flow speed was also measured by a straight forward tracing method using detectors and an isotope injector at different depths. The flow direction was measured by injecting gold colloid into the well. The isotope was allowed to flow out and thus adsorbed by the gravel next to the well. A direction probe consisting of a GM detector and a lead shield was then inserted and the radiation level was scanned in different directions. In principle, the direction of strongest radiation would be the flow direction. So far, the results were not satisfactory partly due to a very low flow rate which resulted in interference by isotope diffusion which was isotropic and partly due to the insufficient sensitivity of the detector.

Recently, a two-well experiment was performed in order to estimate the porosity of the aquifer. 100 mc. of NH_4Br was injected into one well and the water was pumped continuously out from the other well about 15 meters away. The activity of the water siphoned out was monitored. More than one peak of activity were observed. The results are being analyzed by the hydrologists. It is worth mentioned that bromine could be used as tracer along the adsorptive aquifer.

On Radiochemistry.

The work in this field includes not only the interest in research, but also the establishment of services and cooperation with other scientific institutes within the country. Emphasis has been particularly made on the soil-plant relationship study with the Rice Department of the Ministry of Agriculture. Analytical Service by the method of neutron activation had been extended to the soil study of the Department of Land Development.

The current activities in radiochemical work should be mentioned as follows:

1. Lecturing and teaching experiments in Radioisotope Technique Course which has been arranged once a year. This project is to call interests in Reactor Utilization from the scientists outside the Office of the Atomic Energy for Peace.

2. Cooperating with the Department of Toxicology, Siriraj Hospital, in the determination of manganese in body fluids, using samples from non-exposed persons and those suspected of having manganese poisoning. The results appeared in Thai AEC-7 entitled "Manganese Toxication in the Human Body as Determined by Activation Analysis."

3. Now commencing is another cooperative program between physicians from the Department of Toxicology, Siriraj Hospital and chemists from the Office of the Atomic Energy for Peace. This project will concern with the determination of lead in blood.

4. University Relations

The Reactor and Chemistry Divisions offered facilities to the university students as follows:-

With Kasetsart University, the students have made their senior theses on:

- Relation of Rice Blast and Nutrition.
- Study of the Zinc Content of Healthy and Zinc Deficient Citrus Leaves.

With Chulalongkorn University, the students have made some research on:

- The Determination of Manganese and Sodium in Rice from Various Parts of Thailand by Neutron Activation Analysis.
- The Determination of Arsenic in Soil from Durian Orchard by Thermal Neutron Activation Analysis.

With respect to reactor utilization there are quite a number of problems put forward by governmental institutions, for instance the Scientific Crime Detection Laboratory stimulates us in the application of neutron activation analysis to criminalistic problems; the Archeology Division, Department of Fine Arts, believes that this analytical method might possibly reveal identification of archeological ruin pieces from ancient period to the present one. These problems are now under study.

On Isotope Production.

The production of radioisotopes at the Thai Research Reactor are chiefly short-lived isotopes. They have been used in research works in the universities and various research institutes in Thailand. Most of radioisotopes, namely Na-24, K-42, Br-82, I-131 and P-32 from our reactor are used extensively in medical research, diagnoses of thyroid disorder by I-131 as NaI in gelatin capsules as well as NaI solution, radioactive gold grains are implanted in an organ for the treatment of cancer. In addition to these

few of radioisotopes have been used in agricultural researchs, in the study of ground water movement and for demonstration to the students in the universities. However, the needs of radioisotopes especially I-131 is increasing, and we are able to produce only about half of the demand.

The test production of some other important radioisotopes such as colloidal gold-198, Tc-99 and Cr-51 are under study. The production has been gradually improved to meet the required specification for the use in medicine.