Question Number 1 Sub Section A

Calculation of Effective Specific power can be conducted in Non Destructive way using two methods, namely the empirical method and the computational method.

The Computational Method uses the standard formula

P_{eff} = Sigma R_i * P_i

A. **Calculation of R_i**

Where R_i is the abundance of the i-th radio-nuclide in the material. This is expressed as a unit of mass-fraction. The Pi is expressed as the specific-power of the i-th radio-nuclide in the material in Watts/Gram.

The determination of R_i can be carried out by using a Gamma-ray-spectroscope which is placed at a distance from the Radio-active material which is stored in a sealed container. Me multi-channel analyzer is also accompanying the spectroscopy.

The measurements are taken with the aid of a germanium-detector which has a 500 Square-millimeter active-area with 10mm thickness and resolution of 560 ev for 122 Kev Gamma-rays. The detector is operated at a gain of 0,075 KEV/Channel. The count rate is kept at 5000 counts/second. By adopting the GUNNINK data Analysis, the calculation was arrived for the determination of R_i. Here, the selected peak-areas are and selected peak-multiples with the description of fundamental-peak shapes. The entire method however is based on a simple formula which says

R_i= I1/I2 * ε2 /ε1 * p2/p1 * ta/tb

here, the elements of the formula are

I1, I2 = Gamma Ray-Intensities which are measured during the experiment.

ε1, ε2 = the efficiency levels at which the Spectroscope detects the peak values.

P1, P2= Gamma-Ray Emission probabilities.

ta/tb are the expected half-life of the isotopic elements.

We are Ignoring the ta/tb values specifically here, to accommodate the Assignment Requirement.

The practical equation however includes certain parameters in addition to the Ideal Equation. The parameters are

1. There are plenty of isotopes in the material being tested apart from Plutonium 238, 242 and 241 Am.
2. If the relative abundance of plutonium is greater than 50%, it can be detected alone. Otherwise, it has to be determined along with the other isotopes with the help of an ALGORITHM based on practical readings which may vary *****
3. The intensity of peaks may overlap each other during the actual recording. because the wavelength sometimes overlap with each other under the region of 94-105 KEV.
4. The Entire equation becomes Non-linear. because the efficiency of the measuring and reading can vary based on
    a. the gamma-ray interactions with the detector
    b. The attenuation factor of the various filters and other masks. These are sued in order to mask the harmful-radioactive elements which may leak out.
    c. Self-Attenuation by Plutonium in the material

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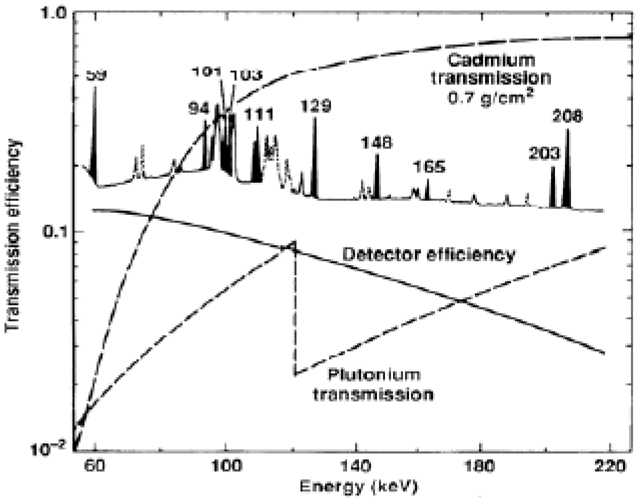

The above sample chart shows the interference of other transmissions along with the Plutonium-transmission. The efficiency factor plays a critical role here. The efficiency is calculated by the formula

$$\varepsilon 2 / \varepsilon 1 = \exp(-\mu j.CD) \,.\, (1 - \exp(-\mu j.PU)) / \mu j.PU \,.\, \varepsilon\, j\, o\, (1 - b.Ej - c.Ej2)$$

Here, the parameters μj is the absorption-coefficient at each peak-energy. They are based on the known figures for Cadmium and Plutonium. The thickness of CD filter and the Plutonium sample thickness are considered to be variable. The Slope b and the curvature c are treated as variables, which depend on the energy and the intensity of radiations.

The sub-routine of calculations depend on

1. initialization of parameters and analysis-flags
2. It depends on whether the SAMPLE being tested is FRESH or AGED.
3. The presence of Uranium

Calculation of Pi

The specific-power table shows the value of **Pi**

Specific Power Values for the Isotopes of Plutonium (ANSI 1987)

Isotope	Half Life (yr)	Specific Power (mW/g isotope)	Standard Deviation (mW/g isotope)
^{238}Pu	87.74	567.57	0.26
^{239}Pu	24119	1.9288	0.0003
^{240}Pu	6564	7.0824	0.002
^{241}Pu	14.348	3.412	0.002
^{242}Pu	376300	0.1159	0.0003
^{241}Am	433.6	114.2	0.42

The Total Effective Specific power is calculated as the summation of

PU -238 = 0.000104052* 567 = 0.0589

PU-239= 0.939694105 * 1.9288 = 1.8124

PU-240= 0.058583702* 7.0824= 0.4149

PU-41= 0.001618142 * 3.412= 0.0055

Pu-242= 0.011808997 * 0.1159 = 0.0014

Am-241= 0.001670955 * 114.2 = 0.1908

The Summation would be 2.4839 W/Gm

Question number 1 Sub section B

The Effective mass-fraction of Plutonium 240 is calculated as the sum of the mass fractions of PU-240 is given by

$$f_{Pu240E} = 2.52 f_{Pu238} + 1.0 f_{Pu240} + 1.68 f_{Pu242}$$

Fraction-mass of Plutonium 240= 2.52 * 0.000104052+ 1.0 * 0.058583702+ 1.68 * 0.011808997

Fraction-mass of Plutonium 240= 0.00026221104+ 0.058583702+ 0.01983911496

Fraction-mass of Plutonium 240= 0.078685028

Question number 1 Sub section C

The Relevance of Specific-Effective-Power and Plutonium mass fraction play a great role in the Non-Destructive Analysis. Because, the NDA is

1. Considering the complete SNM-lot examination, rather than the examination of a sample.
2. Since the method is wholesome, the output is also fairly more accurate

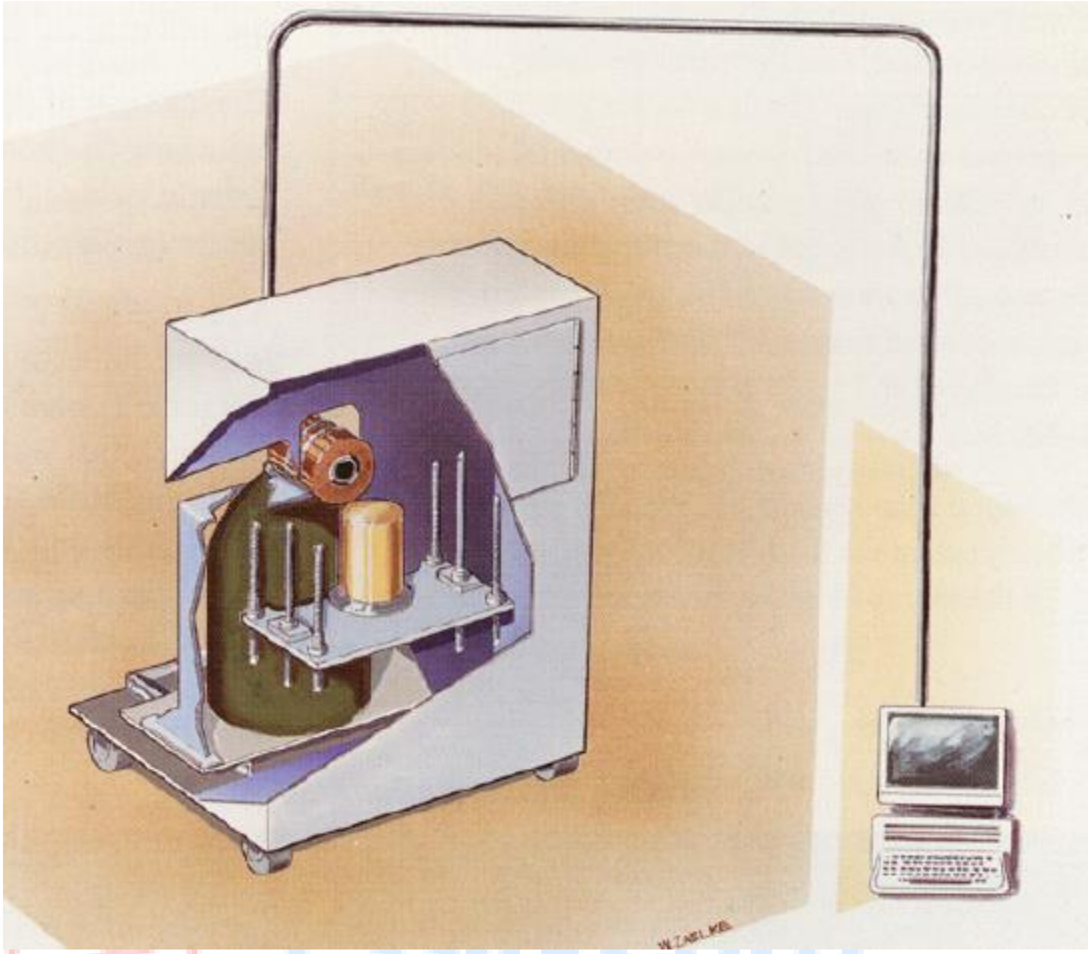

Image Ref:-

As we can observe in the image, The Gamma-ray spectroscopy (An NDA Method) uses the nuclear material placed in a closed-container. The data collected is routed to a remote Analysis and Calculations system.

TABLE II. NDA Plutonium Isotopics of NBS SRM-946 Derived from Gamma-ray Peak Pair Ratios

200-Second Count	Weight Percent ^{238}Pu	^{239}Pu	^{240}Pu	^{241}Pu
1	0.239	84.56	10.68	4.06
2	0.217	87.86	7.39	3.97
3	0.230	88.69	6.44	4.07
4	0.209	83.80	11.24	4.08
5	0.229	89.10	5.83	4.28
6	0.231	85.18	9.90	4.12
7	0.262	81.76	12.56	4.84
8	0.236	83.88	11.26	4.05
9	0.239	84.46	10.68	4.06
Mean	0.232	85.49	9.55	4.17
Std. Dev.	0.015	2.50	2.39	0.26
NBS Value	0.246	83.05	12.11	4.02
Difference	0.014	-2.44	2.56	-0.15
% Difference	5.6	-2.9	21.	-3.7

When the NDA is sued for analyzing the Nuclear-material, we have to depend on both tangible and intangible. The tangible parameter is the specific-power and the mass fraction. The Intangible parameters are the Efficiency, the uncertainty in Peff etc. The uncertainty-factor involved in the isotopic-fractions, the value of Ri and isotopic-specific-powers Pi.

The uncertain-values of the isotopic-fractions are derived from the number of uncertainties which are involved with the different Methodologies like the

- Mass-spectroscopy
- Alpha-counting, and
- Gamma-ray spectroscopy

The huge content of gamma-rays present in the in plutonium-SNM can be sued to study the independently measured isotopic-ratios of the major Isotopes to the material thermal-power: The Individual values of 238Pu, 240Pu, and 241Pu are considered in this analysis and calculations.

The major factors which affect the efficiency of NDA are

1. The count rate with respect to the time frame.
2. The counting time, usually in seconds
3. The Absorbing elements in the instrument and the container which stores the “Mass-Nuclear-material”
4. Dimensions of the Container
5. The isotopic-composition of the Material (Mass Fraction)
6. The efficiency of the measuring instrument under different conditions
7. Total power which can be produced by the given mass of Plutonium

QUESTION 2

The other Major parameters which are implemented in reducing the attractiveness other those listed in the table are Vulnerability Assays. Each waste storage and management facility is expected to develop its own unique vulnerability-assessments for the purpose of identification and evaluation of the facility’s capacity in

- Detecting the life-time of Protective shielding against the regular radiation from within the storage facility. The melting of the cooling-systems and dispersal of radio-active material due to accidents.

- Protecting the reactor and storage facilities with a steel based multiple-reinforcement concrete containment structure.
- The design-infrastructure safe-guarding guidelines include the general-characteristics of risks to which the Nuclear-waste management facilities are exposed to. The possible radiological -sabotage and pilfering of spent-fuel are the other major parameters taken into consideration.
- The storage-of spent-fuel for a long period has to be done with suitable protective systems takes several parameters for reducing the attractiveness of the nuclear-waste. One option is to utilize the spent-fuel by recycling it rather than storing it. This sometimes may take several steps like increasing the production power of the existing production facility, installation of additional reactors which can effectively use the spent-fuel
- The High-metal residual content can be recycled to many isotopes. These isotopes can be sued for medical and other commercial purposes. Thus, the final waste material will be rid of all the radio-active content to the maximum possible extent.
- The major categories of reducing the attractiveness of the waste material consists of regulating the container-properties, assessing the radiological properties of the stored waste, improving the packaging and sealing methods for disposing off

dangerous nuclear-waste materials in the short-term and long-term basis

- Capacity-Control of the Government-run storage facilities and provision for private-sectors in waste-storage management system. The initiatives have been taken which will reduce the burden on individual-facilities
- Reducing the Grades of the attractiveness by processes such as
    - Blending the parent-material with highly radiation absorbing chemicals.

Ref:- E-Books

1. Terminating Safeguards on Excess Special Nuclear Material: Defense TRU Waste Clean-up and Nonproliferation – 12426, WM2012 Conference, February 26 – March 1, 2012, Phoenix, Arizona, USA, taken from www.wmsym.org/archives/2012/papers/**12426**.pdf
2. Principles of Calorimetric Assay, R Likes, taken from www.lanl.gov/orgs/n/n1/panda/00326416.pdf
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