LAMPIRAN A

Hasil Pencacahan dan Kalibrasi Efisiensi Fotolistrik Material Jenis Tanah (IAEA-375), Rumput (IAEA-373), dan Susu Bubuk (IAEA-152)

DATA HASIL PENCACAHAN MATERIAL STANDAR JENIS TANAH (IAEA-375), RUMPUT (IAEA-373), DAN SUSU BUBUK (IAEA-152)

A. Pencacahan Material Standar pada Ketebalan 4,5 cm

Tabel A.1. Hasil pencacahan material jenis tanah (IAEA-375)

No.	Isotop	E (keV)	Y(%)	τ (thn)	At(Bq)	cpd	Efisiensi
1.	^{134}Cs	569,33	15,80	2,05E+0	5,08	1,26E-2	1,57E-2
2.	^{134}Cs	604,70	98,00	2,05E+0	5,08	7,21E-2	1,45E-2
3.	^{137}Cs	661,62	84,62	3,00E+1	469,48	5,70E+0	1,43E-2
4.	^{134}Cs	795,79	89,00	2,05E+0	5,08	5,43E-2	1,20E-2
5.	^{134}Cs	801,87	9,50	2,05E+0	5,08	5,32E-3	1,10E-2
6.	^{134}Cs	1365,13	3,00	2,05E+0	5,08	1,51E-3	9,91E-3
7.	^{40}K	1460,75	10,70	1,28E+9	43,94	3,52E-2	7,48E-3

Persamaan regresi: **Y = -0,649 X - 0,072**

dengan : X = ln(Energi)

Y = ln(Efisiensi)

Koefisien korelasi (r) = 0,947

Tabel A.2. Hasil pencacahan material rumput (IAEA-373)

No.	Isotop	E(keV)	Y (%)	τ (thn)	At (Bq)	cpd	Efisiensi
1.	^{134}Cs	563,22	8,82	2,05E+0	3,89	5,04E-3	1,47E-2
2.	^{134}Cs	604,70	98,00	2,05E+0	3,89	5,61E-2	1,47E-2
3.	^{137}Cs	661,62	84,62	3,00E+1	334,80	4,00E+0	1,41E-2
4.	^{134}Cs	795,79	89,00	2,05E+0	3,89	4,30E-2	1,24E-2
5.	^{40}K	1460,75	10,70	1,28E+9	13,65	1,27E-2	8,67E-3

Persamaan regresi: **Y = -0,655 X - 0,004**

dengan : X = ln(Energi)

Y = ln(Efisiensi)

Koefisien korelasi (r) = 1,000

Tabel A.3. Hasil pencacahan material susu bubuk (IAEA-152)

No.	Isotop	E(keV)	Y (%)	τ (thn)	At (Bq)	cpd	Efisiensi
1.	^{134}Cs	604,70	98,00	2,05E+0	1,20	1,34E-2	1,25E-2
2.	^{137}Cs	661,62	84,62	3,00E+1	97,25	1,01E+0	1,23E-2
3.	^{134}Cs	795,79	89,00	2,05E+0	1,20	1,07E-2	1,10E-2
4.	^{40}K	1460,75	10,70	1,28E+9	31,73	2,21E-2	6,52E-3

Persamaan regresi: **Y = -0,764 X + 0,549**

dengan : X = ln(Energi)

Y = ln(Efisiensi)

Koefisien korelasi (r) = 0,994

B. Pencacahan Material Standar pada Ketebalan 1,0 cm

Tabel A.4. Hasil pencacahan material tanah (IAEA-375)

No.	Isotop	E (keV)	Y (%)	τ (thn)	At (Bq)	cpd	Efisiensi
1.	^{134}Cs	569,33	15,80	2,05E+0	1,52	6,95E-3	2,89E-2
2.	^{134}Cs	604,70	98,00	2,05E+0	1,52	4,09E-2	2,74E-2
3.	^{137}Cs	661,62	84,62	3,00E+1	141,35	3,10E+0	2,59E-2
4.	^{134}Cs	795,79	89,00	2,05E+0	1,52	2,76E-2	2,04E-2
5.	^{40}K	1460,75	10,70	1,28E+9	13,23	1,37E-2	9,65E-3

Persamaan regresi: **Y = -1,185 X + 4,006**

dengan : X = ln(Energi)

Y = ln(Efisiensi)

Koefisien korelasi (r) = 0,998

Tabel A.5. Hasil pencacahan material rumput (IAEA-373)

No.	Isotop	E (keV)	Y (%)	τ (thn)	At (Bq)	cpd	Efisiensi
1.	^{137}Cs	661,62	84,62	3,00E+1	82,34	1,76E+0	2,53E-2
2.	^{40}K	1460,75	10,70	1,28E+9	3,38	5,99E-3	1,65E-2

Persamaan regresi: **Y = -0,534 X - 0,210**

dengan : X = ln(Energi)

Y = ln(Efisiensi)

Koefisien korelasi (r) = 1,000

Tabel A.6. Hasil pencacahan material susu bubuk (IAEA-152)

No.	Isotop	E (keV)	Y (%)	τ (thn)	At (Bq)	cpd	Efisiensi
1.	^{137}Cs	661,62	84,62	3,00E+1	21,72	4,35E-1	2,37E-2
2.	^{40}K	1460,75	10,70	1,28E+9	7,09	2,37E-3	3,13E-3

Persamaan regresi: **Y = -2,557 X + 12,860**

dengan : X = ln(Energi)

Y = ln(Efisiensi)

Koefisien korelasi (r) = 1,000

Berikut ini disajikan tabel-tabel nilai efisiensi fotolistrik yang disusun untuk tiap-tiap tingkat energi-γ.

Tabel A.7. Tabel nilai efisiensi fotolistrik pada tingkat energi = 563,22 keV

No.	Sandi Cuplikan	Massa Jenis (gr/cm^3)	Ketebalan = 4,5 cm		Ketebalan = 1,0 cm	
			Data Asli	Data Regresi	Data Asli	Data Regresi
1.	IAEA-375	1,24028	---	1,53E-02	1,47E-02	3,02E-02
2.	IAEA-152	0,59781	---	1,37E-02	---	3,56E-02
3.	IAEA-373	0,33854	1,47E-02	1,57E-02	---	2,75E-02

Tabel A.8. Tabel nilai efisiensi fotolistrik pada tingkat energi = 569,22 keV

No.	Sandi Cuplikan	Massa Jenis (gr/cm^3)	Ketebalan = 4,5 cm		Ketebalan = 1,0 cm	
			Data Asli	Data Regresi	Data Asli	Data Regresi
1.	IAEA-375	1,24028	1,57E-02	1,52E-02	2,89E-02	2,98E-02
2.	IAEA-152	0,59781	---	1,36E-02	---	3,46E-02
3.	IAEA-373	0,33854	---	1,56E-02	---	2,74E-02

Tabel A.9. Tabel nilai efisiensi fotolistrik pada tingkat energi = 604,70 keV

No.	Sandi Cuplikan	Massa Jenis (gr/cm^3)	Ketebalan = 4,5 cm		Ketebalan = 1,0 cm	
			Data Asli	Data Regresi	Data Asli	Data Regresi
1.	IAEA-375	1,24028	1,45E-02	1,46E-02	2,74E-02	2,78E-02
2.	IAEA-152	0,59781	1,25E-02	1,30E-02	---	2,97E-02
3.	IAEA-373	0,33854	1,47E-02	1,50E-02	---	2,65E-02

Tabel A.10. Tabel nilai efisiensi fotolistrik pada tingkat energi = 609,70 keV

No.	Sandi Cuplikan	Massa Jenis (gr/cm^3)	Ketebalan = 4,5 cm		Ketebalan = 1,0 cm	
			Data Asli	Data Regresi	Data Asli	Data Regresi
1.	IAEA-375	1,24028	---	1,45E-02	---	2,75E-02
2.	IAEA-152	0,59781	---	1,29E-02	---	2,91E-02
3.	IAEA-373	0,33854	---	1,49E-02	---	2,64E-02

Tabel A.11. Tabel nilai efisiensi fotolistrik pada tingkat energi = 661,62 keV

No.	Sandi Cuplikan	Massa Jenis (gr/cm^3)	Ketebalan = 4,5 cm		Ketebalan = 1,0 cm	
			Data Asli	Data Regresi	Data Asli	Data Regresi
1.	IAEA-375	1,24028	1,43E-02	1,37E-02	2,59E-02	2,50E-02
2.	IAEA-152	0,59781	1,23E-02	1,21E-02	2,37E-02	2,36E-02
3.	IAEA-373	0,33854	1,41E-02	1,42E-02	2,53E-02	2,53E-02

Tabel A.12. Tabel nilai efisiensi fotolistrik pada tingkat energi = 795,79 keV

No.	Sandi Cuplikan	Massa Jenis (gr/cm^3)	Ketebalan = 4,5 cm		Ketebalan = 1,0 cm	
			Data Asli	Data Regresi	Data Asli	Data Regresi
1.	IAEA-375	1,24028	1,20E-02	1,22E-02	2,04E-02	2,01E-02
2.	IAEA-152	0,59781	1,10E-02	1,05E-02	---	1,47E-02
3.	IAEA-373	0,33854	1,20E-02	1,25E-02	2,33E-03	2,29E-02

Tabel A.13. Tabel nilai efisiensi fotolistrik pada tingkat energi = 801,87 keV

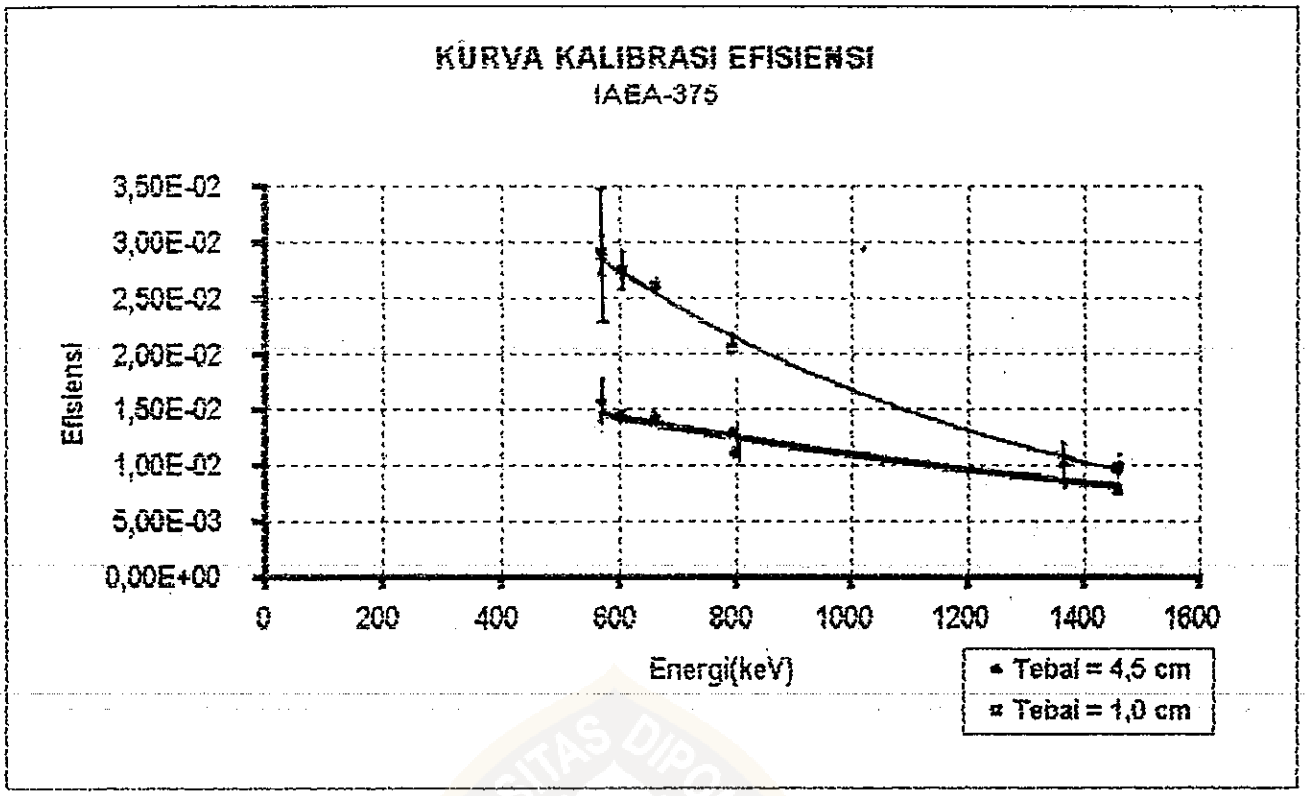
No.	Sandi Cuplikan	Massa Jenis (gr/cm^3)	Ketebalan = 4,5 cm		Ketebalan = 1,0 cm	
			Data Asli	Data Regresi	Data Asli	Data Regresi
1.	IAEA-375	1,24028	1,10E-02	1,21E-02	---	1,99E-02
2.	IAEA-152	0,59781	---	1,05E-02	---	1,44E-02
3.	IAEA-373	0,33854	---	1,25E-02	---	2,28E-02

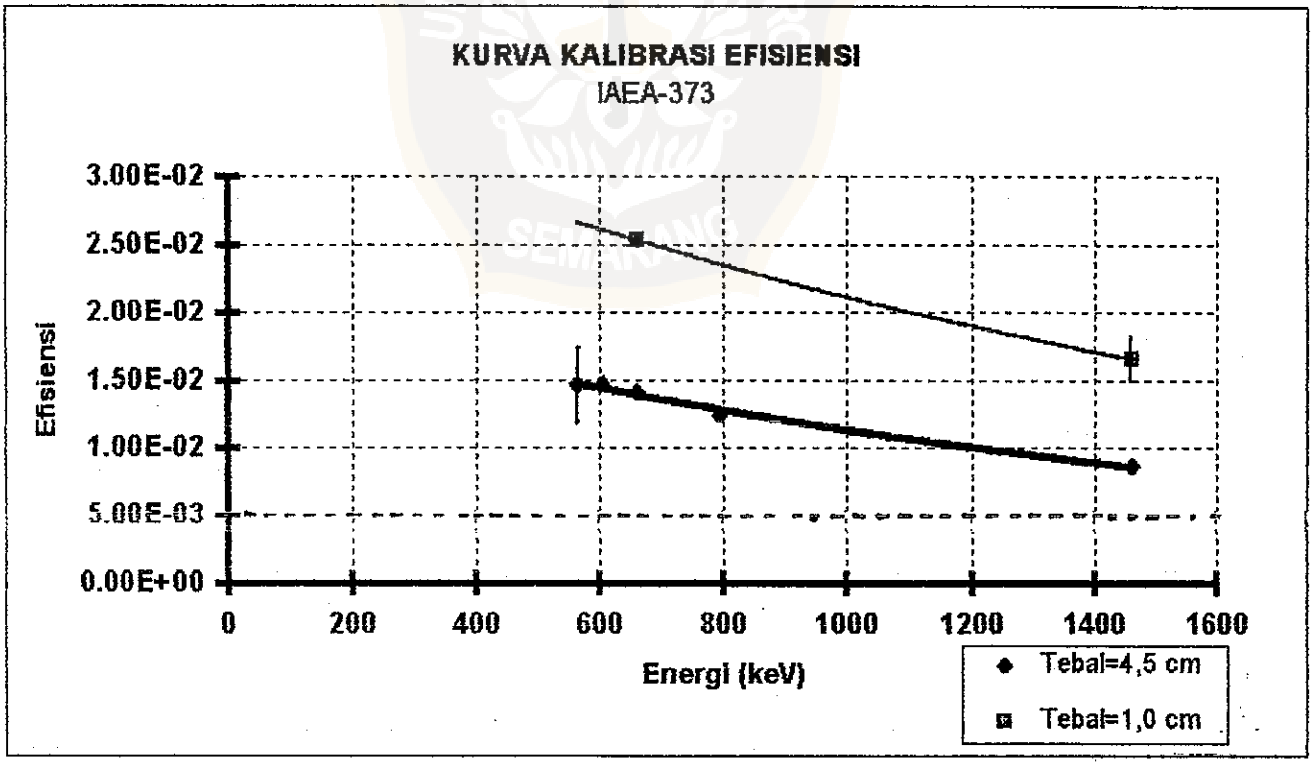
Tabel A.14. Tabel nilai efisiensi fotolistrik pada tingkat energi = 1365,13 keV

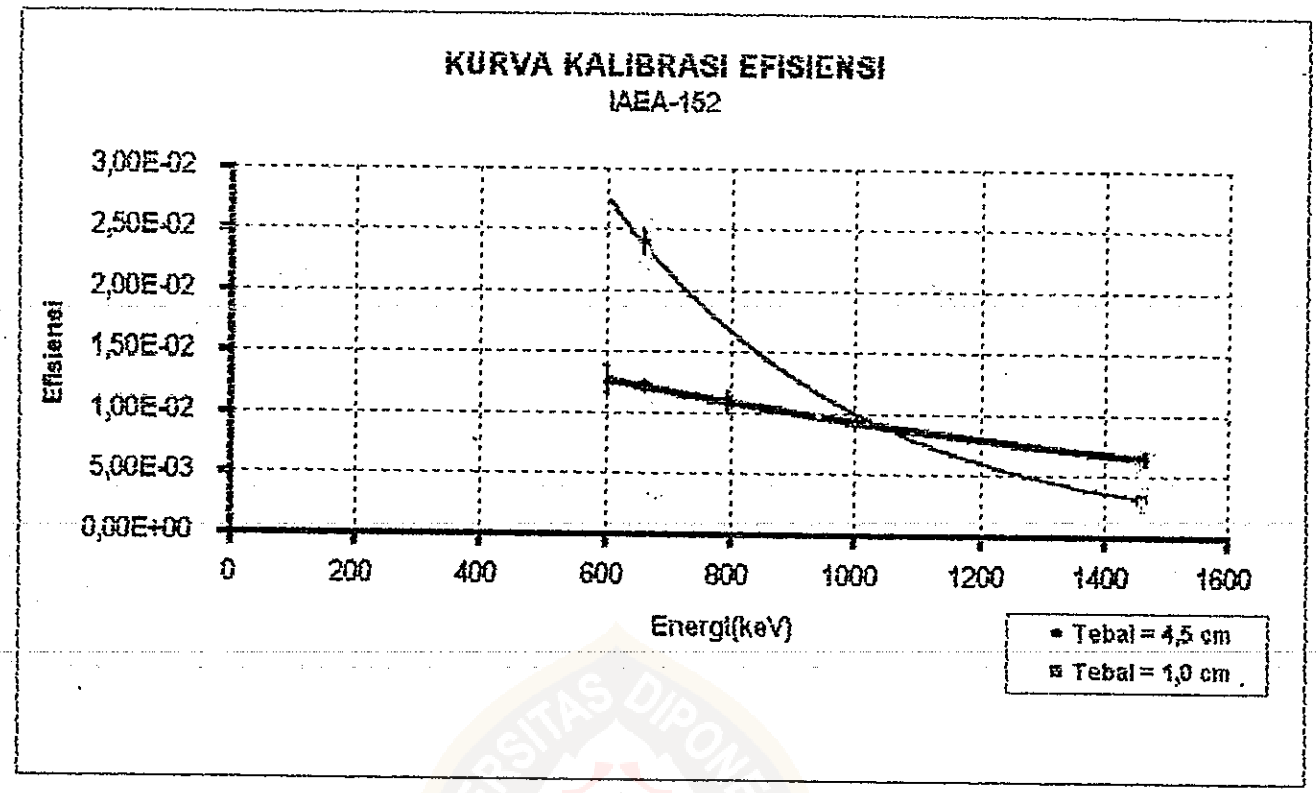
No.	Sandi Cuplikan	Massa Jenis (gr/cm^3)	Ketebalan = 4,5 cm		Ketebalan = 1,0 cm	
			Data Asli	Data Regresi	Data Asli	Data Regresi
1.	IAEA-375	1,24028	9,91E-03	8,95E-03	---	1,06E-02
2.	IAEA-152	0,59781	---	6,97E-03	---	3,70E-03
3.	IAEA-373	0,33854	---	8,81E-03	---	1,72E-02

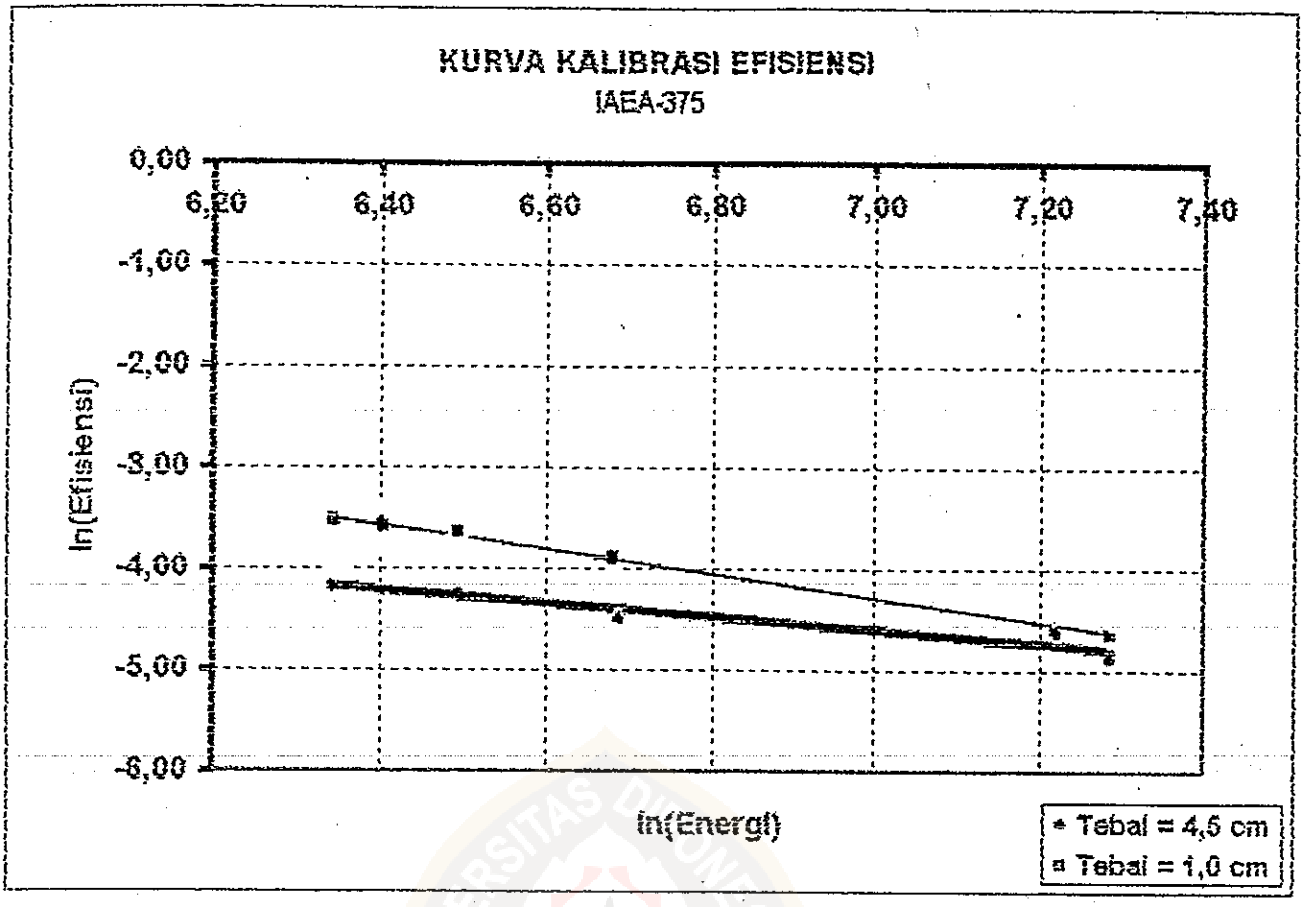
Tabel A.15. Tabel nilai efisiensi fotolistrik pada tingkat energi = 1460,75 keV

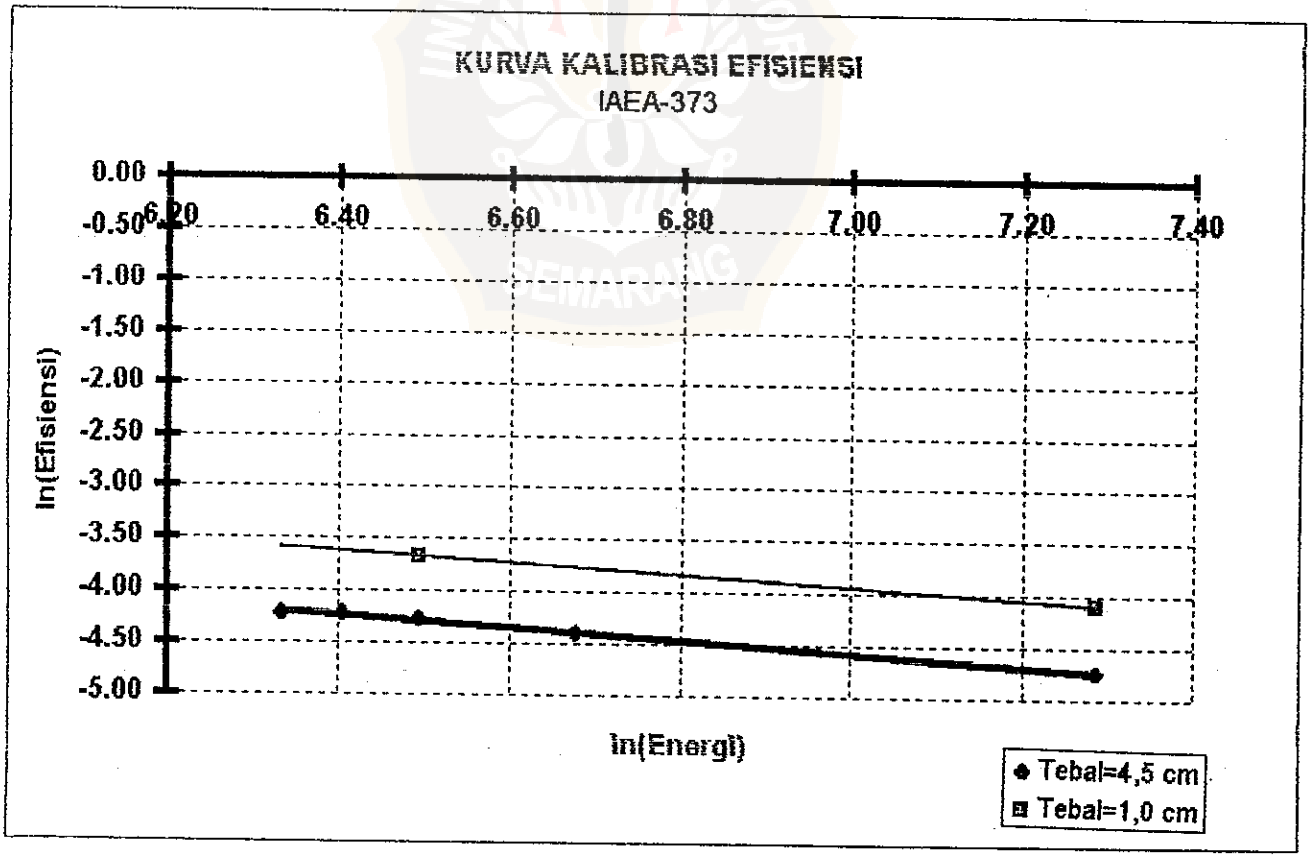
No.	Sandi Cuplikan	Massa Jenis (gr/cm^3)	Ketebalan = 4,5 cm		Ketebalan = 1,0 cm	
			Data Asli	Data Regresi	Data Asli	Data Regresi
1.	IAEA-375	1,24028	7,48E-03	8,22E-03	9,65E-03	9,77E-03
2.	IAEA-152	0,59781	6,52E-03	6,62E-03	3,13E-03	3,11E-03
3.	IAEA-373	0,33854	8,67E-03	8,43E-03	1,65E-02	1,66E-03

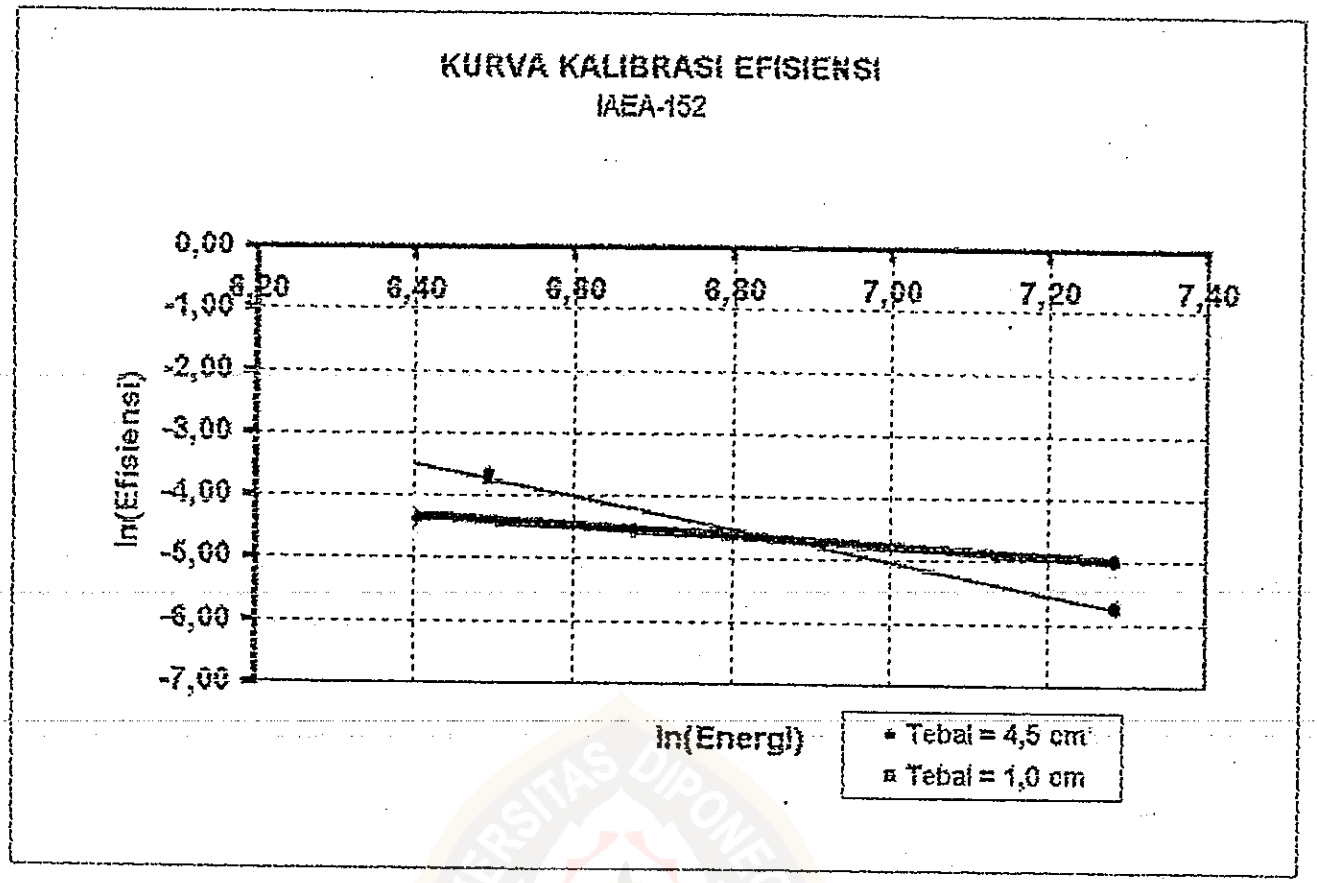












LAMPIRAN B

Ralat Perhitungan Nilai Efisiensi Fotolistrik

B.1. Perhitungan ralat aktivitas mula-mula (S_{A0})

Nilai aktivitas yang tercantum pada sertifikat material standar dianggap sebagai nilai aktivitas mula-mula (A_0). Ralat A_0 dihitung dengan cara sebagai berikut: Misalnya pada cuplikan IAEA-375 akan dihitung ralat S_{A0} pada radioisotop K-40.

A_0 = 424 Bq/kg.

Ralat relatifnya adalah:

S_{A0} = (432 - 417)/2

= 7,5

Jadi: A_0 = (424 ± 7,5) Bq/kg.

B.2. Perhitungan ralat aktivitas tercacah (S_{At})

Nilai aktivitas tercacah dihitung berdasarkan persamaan (3.1) sebagai berikut:

$$A_t = A_0 e^{-0.693.t/\tau} \quad \text{.....(B.1)}$$

dengan:

A_t : aktivitas yang terkoreksi

A_0: aktivitas pada saat direkomendasi oleh IAEA

t : selang waktu antara saat pencacahan dimulai dengan saat sumber direkomendasi oleh IAEA

τ : Waktu paruh radioisotop yang memancarkan sinar-γ.

Tanggal sertifikat material standar adalah IAEA-375 adalah 31 Desember 1991. Material IAEA-375 ini dicacah mulai tanggal 16 Agustus 1998 sampai tanggal 17 Agustus 1998 (24 jam). Maka rentang waktu t dapat dihitung dengan konversi 1 tahun = 365.24 hari. Dengan demikian:

$t_1 = 2421{,}18$ hari

$t_2 = 2422{,}18$ hari

$t = (t_1 + t_2)/2 = 2421{,}68$ hari

Ralat t (S_t) ditetapkan dengan mengambil setengah nilai perhitungan terkecil. Maka: $S_t = 0{,}5$ hari.

Selanjutnya persamaan (B.1) diturunkan terhadap variabel bebasnya. Sehingga:

$$\frac{\partial A_t}{\partial A_0} = e^{-0{,}693.t/\tau} \quad \text{.....(B.2)}$$

$$\frac{\partial A_t}{\partial A_0} = \frac{-0{,}693}{\tau} A_0.e^{-0{,}693.t/\tau} \quad \text{.....(B.3)}$$

$$S_{At} = \sqrt{\left(\frac{\partial A_t}{\partial A_0} S_{A0}\right)^2 + \left(\frac{\partial A_t}{\partial t} S_{At}\right)^2} \quad \text{.....(B.4)}$$

B.3. Perhitungan Ralat Aktivitas Mutlak Pencacahan (S_{mp})

Aktivitas mutlak pencacahan dihitung berdasarkan persamaan:

$$A_{mp} = A_t \frac{m}{1000}$$

dengan:

m : massa material standar yang dicacah (gram)

A_t : aktivitas pencacahan (Bq/kg)

Ralat aktivitas mutalk pencacahan (S_{amp}) dihitung dengan cara sebagai berikut:

$$\frac{\partial A_{mp}}{\partial A_t} = \frac{m}{1000} \quad \text{.....(B.5)}$$

$$\frac{\partial A_{mp}}{\partial A_t} = \frac{A_t}{1000} \quad \text{.....(B.6)}$$

$$S_{Amp} = \sqrt{\left(\frac{\partial_{Amp}}{\partial A_t}.S_{At}\right)^2 + \left(\frac{\partial A_{mp}}{\partial m}.S_m\right)^2} \quad \text{.....(B.7)}$$

B.4. Perhitungan Ralat Efisiensi (S_ε)

Ralat efisiensi dihitung berdasarkan persamaan:

$$\varepsilon = \frac{cpd}{Y.A_{mp}} \quad \text{.....(B.8)}$$

$$\frac{\partial \varepsilon}{\partial_{cpd}} = \frac{1}{Y.A_{mp}} \quad \text{.....(B.9)}$$

$$\frac{\partial \varepsilon}{\partial A_{mp}} = -\frac{cpd}{Y.\left(A_{mp}\right)^2} \quad \text{.....(B.10)}$$

$$S_\varepsilon = \sqrt{\left(\frac{\partial \varepsilon}{\partial cpd}.S_{cpd}\right)^2 + \left(\frac{\partial \varepsilon}{\partial A_{mp}}.S_{Amp}\right)^2} \quad \text{.....(B.11)}$$

S_{cpd} : ralat cacah per detik diperoleh langsung dari pencacahan.

Berdasarkan pada cara perhitungan di atas, dapat dibuat tabel ralat aktivitas mula-mula (S_{A0}), ralat aktivitas tercacah (S_{At}), ralat aktivitas mutlak pencacahan (S_{Amp}), dan ralat efisiensi (S_ε) sebagai berikut:

Tabel B.1. Nilai S_{A0}, S_{At}, S_{Amp}, dan S_{ε} untuk material jenis tanah (IAEA-375) pada ketebalan 4,5 cm

No.	Isotop	E (keV)	S_{A0}	$S_{cps}(\%)$	S_{At}	S_{Amp}	S_{ε}
1.	^{134}Cs	569,33	9,0	1,18E+01	9,52E-01	9,87E-02	1,88E-03
2.	^{134}Cs	604,70	9,0	2,40E+00	9,52E-01	9,87E-02	4,48E-04
3.	^{137}Cs	661,62	80,0	1,00E-01	6,86E+01	7,11E+00	2,18E-04
4.	^{134}Cs	795,79	9,0	1,80E+00	9,52E-01	9,87E-02	3,18E-04
5.	^{134}Cs	801,87	9,0	9,50E+00	9,52E-01	9,87E-02	1,07E-03
6.	^{134}Cs	1365,13	9,0	2,02E+01	9,52E-01	9,87E-02	2,01E-03
7.	^{40}K	1460,75	7,5	4,31E-01	7,50E+00	7,77E-01	1,36E-04

Tabel B.2. Nilai S_{A0}, S_{At}, S_{Amp}, dan S_{ε} untuk material jenis tanah (IAEA-375) pada ketebalan 1,0 cm

No.	Isotop	E(eV)	S_{A0}	S_{At}	S_{Atk}	$S_{cps}(\%)$	S_{ε}
1.	^{134}Cs	569,33	9,00E+00	9,48E-01	2,96E-02	1,99E+01	5,78E-03
2.	^{134}Cs	604,70	9,00E+00	9,48E-01	2,96E-02	5,88E+00	1,70E-03
3.	^{137}Cs	661,62	8,00E+01	6,86E+01	2,14E+00	2,00E-01	3,96E-04
4.	^{134}Cs	795,79	9,00E+00	9,48E-01	2,96E-02	3,00E+00	7,29E-04
5.	^{40}K	1460,75	7,50E+00	7,50E+00	2,34E-01	1,17E+01	1,14E-03

Tabel B.3. Nilai S_{A0}, S_{At}, S_{Amp}, dan S_{ε} untuk material jenis rumput (IAEA-373) pada ketebalan 4,5 cm

No.	Isotop	E(keV)	S_{A0}	S_{At}	S_{Atk}	$S_{cps}(\%)$	S_{ε}
1	^{134}Cs	563.22	2.40E+01	2.53E+00	8.00E-02	1.92E+01	2.84E-03
2	^{134}Cs	604.70	2.40E+01	2.53E+00	8.00E-02	2.80E+00	5.12E-04
3	^{137}Cs	661.62	2.20E+02	1.89E+02	5.96E+00	2.00E-01	2.53E-04
4	^{134}Cs	795.79	2.40E+01	2.53E+00	8.00E-02	2.20E+00	3.74E-04
5	^{40}K	1460.75	1.10E+01	1.10E+01	3.48E-01	2.92E+00	3.36E-04

Tabel B.4. Nilai S_{A0}, S_{At}, S_{Amp}, dan S_{ε} untuk material jenis rumput (IAEA-373) pada ketebalan 1,0 cm

No.	Isotop	E (keV)	S_{A0}	$S_{cps}(\%)$	S_{At}	S_{Atk}	S_{ε}
1.	^{137}Cs	661,62	2,20E+02	3,00E-01	1,87E+02	1,47E+00	4,56E-04
2.	^{40}K	1460,75	1,10E+01	8,81E+00	1,10E+01	8,61E-02	1,52E-03

Tabel B.5. Nilai S_{A0}, S_{At}, S_{Amp}, dan S_{ε} untuk material jenis susu bubuk (IAEA-152) pada ketebalan 4,5 cm

No.	Isotop	E(keV)	S_{A0}	$S_{cps}(\%)$	S_{At}	S_{Atk}	S_{ε}
1.	^{134}Cs	604,70	4,00E+01	6,80E+00	9,76E-01	5,74E-02	1,07E-03
2.	^{137}Cs	661,62	7,80E+01	4,00E-01	6,05E+01	3,56E+00	4,52E-04
3.	^{134}Cs	795,79	4,00E+01	6,86E+00	9,76E-01	5,74E-02	9,45E-04
4.	^{40}K	1460,75	3,20E+01	4,59E+00	3,20E+01	1,88E+00	4,89E-04

Tabel B.6. Nilai S_{A0}, S_{At}, S_{Amp}, dan S_{ε} untuk material jenis susu bubuk (IAEA-152) pada ketebalan 1,0 cm

No.	Isotop	E (keV)	S_{A0}	S_{cps}(%)	S_{At}	S_{Atk}	S_{ε}
1.	^{137}Cs	661,62	7,80E+01	1,28E+00	6,05E+01	7,96E-01	9,19E-04
2.	^{40}K	1460,75	3,20E+01	1,37E+01	3,20E+01	4,21E-01	4,68E-04

LAMPIRAN C

Penjabaran Rumus Efisiensi *(ε)* sebagai Fungsi Faktor Jenis Material *(f_j)*

PENJABARAN RUMUS EFISIENSI *(ε)* SEBAGAI FUNGSI FAKTOR JENIS *(f_j)*

Jumlah cacah yang tidak terserap oleh materi sumber foton-γ *(N)* adalah: (Debertin dan Helmer, 1988)

$$N = \frac{N_0(1-e^{-\mu.t})}{\mu.t} \quad \text{.....(C.1)}$$

dengan:

N : jumlah cacah yang terdeteksi dengan serapan diri

N_0: jumlah cacah yang terdeteksi tanpa serapan diri

t : ketebalan material sumber foton-γ (cm)

μ : koefisien atenuasi linier material (cm^{-1})

Koefisien atenuasi linier *(μ)* pada persamaan (C.1) dapat dinyatakan dengan persamaan:

$$\mu_m = \frac{\mu}{\rho} \quad \text{.....(C.2)}$$

dengan:

μ_m : koefisien atenuasi massa (cm^2/gr)

ρ : massa jenis (gr/cm^3)

sehingga persamaan (C.1) menjadi:

$$N = \frac{N_0(1-e^{-f_j.t})}{f_j.t} \quad \text{.....(C.3)}$$

dengan $f_j = \mu_m \rho$ menyatakan faktor jenis, yaitu besaran yang menyatakan pengaruh jenis material terhadap serapan diri dalam material tersebut.

Dari persamaan (2.20) dapat diketahui bahwa:

$$cpd = \varepsilon A\, Y \quad \text{.....(C.4)}$$

dengan:

cpd : cacah per detik yang diterima oleh detektor

ε : efisiensi pencacahan

A : aktivitas sumber foton-γ yang dicacah

Karena:

$$N = cpd\, T \quad \text{.....(C.5)}$$

dengan T menyatakan lama waktu pencacahan (detik), maka substitusi persamaan (C.4) ke persamaan (C.5) menghasilkan persamaan:

$$N = \varepsilon A\, Y\, T \quad \text{.....(C.6)}$$

Dengan demikian:

$$\varepsilon = \frac{N_0(1-e^{-f_j.t})}{A.Y.T.f_j.t} \quad \text{.....(C.7)}$$

Jika:

$$cpd_0 = \frac{N_0}{T} \quad \text{.....(C.8)}$$

dengan cpd_0 menyatakan cacah yang diterima oleh detektor per detik jika efek serapan diri tidak ada, maka persamaan (C.7) dapat dinyatakan dengan persamaan berikut:

$$\varepsilon = \frac{cpd_0(1-e^{-f_j.t})}{A.Y.f_j.t} \quad \text{.....(C.9)}$$

Jika:

$$\varepsilon_0 = \frac{cpd_0}{A.Y} \quad \text{.....(C.10)}$$

dengan ε_0 menyatakan efisiensi pencacahan jika tidak ada efek serapan diri material, maka:

$$\varepsilon = \frac{\varepsilon_0(1-e^{-f_j.t})}{f_j.t} \quad \text{.....(C.11)}$$

LAMPIRAN D

Data Beberapa Radioisotop

Sumber: Erdtmann, G. dan Soyka, W. (1979)

19 K 40

HALF LIFE: 1.28E+09A
GEN: NTH K 39
NFA CA 40
NAT 0.012
DAU:
PAR:
REF: 70 MA 3

1.46075	10.70000	A	

51 SB 125

HALF LIFE: 2.77A
GEN: NTH SN124
NFA TE125
NFI 0.036
DAU: TE125M
PAR:
REF: 70 MA 3,72 AU 2

0.02720	0.40000	A	X
0.02747	0.75000	A	X
0.03100	0.20000	A	X
0.03170	0.04500	A	X
0.03546	5.80000	A	
0.08180	1.00000	A	
0.10927	0.06600	A	
0.11100	0.09800	A	
0.11697	0.26000	A	
0.12243	0.03600	A	
0.17260	0.20000	A	
0.17629	6.30000	A	
0.17878	0.04300	A	
0.20407	0.25000	A	
0.20812	0.19000	A	
0.22790	0.10000	A	
0.32113	0.44000	A	
0.38051	1.40000	A	
0.40810	0.24000	A	
0.42795	29.60000	A	
0.44362	0.28000	A	
0.46351	10.00000	A	
0.48980	0.25000	A	
0.60077	18.40000	A	
0.60682	5.20000	A	
0.63615	11.20000	A	
0.67166	1.80000	A	

53 J 129

HALF LIFE: 1.7E+07A
GEN: NTH TE128
NFA XE129
NFI 1.000
DAU:
PAR:
REF: 72 HO 2

0.02946	19.00000	A	X
0.02978	36.00000	A	X
0.03360	10.00000	A	X
0.03440	2.20000	A	X
0.03958	7.50000	A	

27 CO 57

HALF LIFE: 270.0D
GEN: CHA MN 55
PHO NI 58
PHO CO 59
DAU:
PAR:
REF: 70 MA 3

0.01441	9.50000	A
0.12207	85.60000	A
0.13643	10.60000	A
0.23060	0.00020	A
0.33970	0.00380	A
0.35240	0.00280	A
0.36670	0.00050	A
0.57030	0.01100	A
0.69210	0.15000	A
0.70680	0.00500	A

27 CO 60

HALF LIFE: 5.263A
GEN: NTH CO 59
NFA NI 60
NFA CU 63
DAU:
PAR: FE 60 100000.0A
REF: 68 RA 3

0.82600	0.00700	A
1.17323	99.88000	A
1.33252	100.00000	A
2.15800	0.00120	A
2.50500	0.00004	A

63 EU 154

HALF LIFE: 16.0A
GEN: NTH EU153
NFA GD154
DAU:
PAR:
REF: 68 LE 1,69 GU 1
69 VA 3,70 RI 3

0.04231	5.50000	A	X
0.04300	10.20000	A	X
0.04870	3.10000	A	X
0.05000	0.70000	A	X
0.08650			
0.10530			
0.12310	40.46000	A	
0.13160			
0.14630	0.02700	A	
0.18070	0.00200	A	
0.18840	0.21000	A	
0.23210	0.02500	A	
0.24804	6.60000	A	
0.30510	0.02000	A	
0.31230	0.02000	A	
0.31540	0.01300	A	
0.32200	0.07000	A	
0.34360			
0.38200			
0.39710	0.02300	A	
0.40130	0.20000	A	
0.40400	0.02500	A	
0.44440	0.48000	A	
0.46790	0.06000	A	
0.47690			
0.47830	0.21000	A	
0.51200	0.03200	A	
0.51800	0.05000	A	
0.54560	0.01200	A	
0.55800	0.60000	A	
0.58230	0.77000	A	
0.59170	4.60000	A	
0.60280			
0.61330	0.10000	A	
0.62520	0.30000	A	
0.62600			
0.64940	0.08000	A	
0.66470			
0.67800	0.02000	A	
0.68200	0.02000	A	
0.69250	1.65000	A	
0.71580	0.14000	A	
0.72330	19.10000	A	
0.75670	4.10000	A	
0.81560	0.53000	A	
0.84560	0.94000	A	
0.85060	0.23000	A	
0.87320	11.30000	A	
0.88060	0.05000	A	
0.89280	0.44000	A	
0.90400	0.78000	A	
0.92450	0.06000	A	
0.99630	10.70000	A	
1.00480	17.60000	A	
1.01280			
1.04740			
1.04940			
1.11850	0.14000	A	
1.12840	0.31000	A	
1.14090	0.22000	A	
1.18860	0.09400	A	
1.21680	0.00400	A<	
1.23210			
1.24160	0.15000	A	
1.24660	0.64000	A	
1.27480	33.60000	A	
1.29000			
1.29200			
1.29550			
1.31640	0.02500	A	
1.38700	0.01000	A<	
1.39780	1.60000	A	
1.40840	0.02000	A	
1.41850	0.00800	A	
1.41920			
1.42590			
1.48960			
1.49460	0.67000	A	
1.50910	0.00400	A<	
1.53170			
1.53780	0.10000	A	
1.59730	1.70000	A	
1.66730			
1.67400			

82 PB 210

HALF LIFE: 20.4A
GEN: NAT U 238
DAU: BI210
PO210
PAR: RA 226 1600.0A
U 238 4.51E+09A
REF: 68 LE 1

0.04652	4.00000	A	

84 PO 210

HALF LIFE: 138.40D
GEN: NTH BI209
NAT U 238
DAU:
PAR: PB 210 22.0A
RA 226 1600.0A
REF: 68 LE 1

0.80300	0.00110	A	

88 RA 226

HALF LIFE: 1600.0A
GEN: NAT U 238
DAU: RN222
PO218
PB214
PAR:
REF: 66 WA 2

0.08187	0.20000	A	X
0.08378	0.40000	A	X
0.09470	0.13000	A	X
0.09760	0.04000	A	X
0.18600	4.00000	A	
0.26000	0.01000	A	
0.42000	0.01000	A	
0.45000	0.00040	A	
0.61000	0.00130	A	

88 RA 228

HALF LIFE: 5.75A
GEN: NAT TH232
DAU: AC228
TH228
RA224
PAR: TH 232 1.39E+10A
REF: 66 WA 2

0.02630			

90 TH 228

HALF LIFE: 1.913A
GEN: NAT TH232
DAU: RA224
RN220
PO216
PAR: U 232 71.7A
REF: 66 WA 2

0.08450	1.60000	A	
0.13200	0.19000	A	
0.16700	0.12000	A	
0.20500	0.03000	A	
0.21600	0.29000	A	
0.23400	0.00007	A	

90 TH 230

HALF LIFE: 77000.0A
GEN: NAT U 236
DAU: RA226
RN222
PAR:
REF: 70 EL 3

0.01540			
0.01850	7.60000	A	X
0.01920			
0.06780	0.40000	A	
0.08544	0.00640	A	X
0.08848	0.01160	A	X
0.10000	0.00430	A	X
0.10300	0.00140	A	X
0.11000	0.00010	A	
0.14200	0.05000	A	
0.18500	0.00900	A	
0.20600	0.00050	A	
0.23500	0.00050	A	
0.25300	0.08000	A	
0.25500	0.01000	A	

90 TH 232

HALF LIFE: 1.41E+10A
GEN: NAT TH232
DAU: RA228
AC228
TH228
PAR:
REF: 68 LE 1,66 WA 2

0.05900	0.50000	A	

92 U 234

HALF LIFE: 248000.0A
GEN: NTH U 233
NPA U 235
NAT U 238
DAU: TH230
PAR:
REF: 70 EL 4,70 CL 1

0.01630			
0.01970			
0.02050			
0.05310	0.68100	A	
0.08996	0.00200	A	X
0.09335	0.00400	A	X
0.10500	0.00150	A	X
0.10860	0.00050	A	X
0.12100	0.23300	A	
0.45600	0.00002	A	
0.50800	0.00002	A	
0.58400	0.00001	A	
0.74000			

92 U 235

HALF LIFE: 7.1E+08A
GEN: NAT U 235
DAU: TH231
PAR:
REF: 70 CL 1,68 LE 1
71 AR 2

0.04600			
0.07492	0.00100	A	
0.08996	1.50000	A	X
0.09335	2.50000	A	X
0.10500	1.00000	A	X
0.10860	0.30000	A	X
0.10912	1.51000	A	
0.11520	0.13000	A	
0.14075	0.17300	A	
0.14378	9.72000	A	
0.15096	0.10800	A	
0.16336	4.59000	A	
0.18072	0.40500	A	
0.18572	54.00000	A	
0.19494	0.65000	A	
0.19891	0.03000	A	
0.20213	1.00000	A	
0.20531	5.00000	A	
0.22138	0.12000	A	
0.23353	0.04000	A	
0.24093	0.07000	A	
0.24683	0.06000	A	
0.26644	0.00750	A	

92 U 238

HALF LIFE: 4.51E+09A
GEN: NAT U 238
DAU: TH234
PA234
U 234
PAR:
REF: 68 LE 1,70 EL 4

0.04800	0.07500	A	

PU 238

F LIFE: 86.0A
: NTH NP237
: U 234
:
: 70 EL 1,70 CL 1

01720			
02090	13.00000	A	X
02180			
04345	0.03800	A	
09466	0.00006	A	X
09844	0.00010	A	X
09970	0.00920	A	
11100	0.00004	A	X
11450	0.00001	A	X
12515	0.00001	A	
15270	0.00130	A	
15880	0.00001	A	
19730	0.00001	A	
19935	0.00001	A	
20090	0.00001	A	
20103	0.00001	A	
23590			
25100	0.00001	A	
25830			
29920			
33860	0.00001	A	
35069	0.00001	A	
41677	0.00001	A	
43986	0.00001	A	
70610			
70842			
74277	0.00001	A	
76635	0.00003	A	
78603	0.00001	A	
80580			
80870	0.00001	A	
81050	0.00001	A	
85220	0.00001	A	
88050			
88323	0.00001	A	
90437			
92672			
94190			
94600			
00103			
04180			
08540			

PU 239

LIFE: 24390.0A
NTH U 238
U 235

70 CL 1,71 AR 3

00300			?
01160	0.13000	A	X
01300			
01360	0.24000	A	X
01720	0.33000	A	X
02020	0.09000	A	X
03010	0.00050	A	?
03870	0.00830	A	
04199	0.00003	A	
04619	0.00024	A	
05161	0.02300	A	
05401	0.00011	A	
05682	0.00073	A	
06100			?
06573	0.00003	A	
06770	0.00014	A	
06872	0.00060	A	
07700			?
07760	0.00004	A	
07848	0.00017	A	
08994	0.00001	A	
09466	0.00800	A	X
09844	0.00700	A	X
09880			
10000			?
10293	0.00026	A	
11038		X	
11139	0.00500	A	X
11455	0.00100	A	X
11532	0.00074	A	
11618	0.00071	A	
11989	0.00003	A	
12235	0.00001	A	
12373	0.00002	A	
12441	0.00005	A	
12500	0.00005	A	

95 AM 241

HALF LIFE: 458.0A
GEN: NTH PU240
DAU: NP237
PAR:
REF: 68 LE 1,70 CL 1
71 EL 4

02636	2.50000	A	
03321	0.20000	A	
04344	0.07000	A	
05556			
05954	35.30000	A	
06750			
07000			
07580			
09500			
09708	0.00023	A	X
09893	0.02900	A	
10107	0.00040	A	X
10293	0.03200	A	
10630	0.00100	A<	
10976	0.00003	A	
11400	0.00016	A	X
11750	0.00006	A	X
12299	0.00220	A	
12526	0.00590	A	
13942	0.00001	A	
14654	0.00080	A	
15010	0.00013	A	
15440	0.00001	A<	
15640	0.00001	A	
15850	0.00001	A	
16170	0.00001	A	
16460	0.00012	A	
16593	0.00004	A	
16954	0.00032	A	
17508	0.00004	A	
19189	0.00005	A	
19700	0.00001	A	
20170	0.00001	A	
20800	0.00160	A	
22145	0.00010	A	
23285	0.00001	A	
23440			
24240	0.00003	A	
24660	0.00001	A	
24910	0.00001	A	
26040	0.00001	A<	
26488	0.00002	A	
26754	0.00006	A	
27564	0.00002	A	
29278	0.00003	A	
29490	0.00005	A	
30019	0.00002	A	
30450			
31030			
31194	0.00013	A	
31700			
32254	0.00033	A	
33020	0.00002	A<	
33239	0.00033	A	
33543	0.00110	A	
34043	0.00002	A	
34850	0.00001	A<	
35103	0.00001	A	
35800	0.00001	A<	
36868	0.00048	A	
37100	0.00011	A	
37668	0.00031	A	
38383	0.00006	A	
39065	0.00002	A	
41679	0.00002	A	
41932	0.00002	A	
42650	0.00005	A	
43170	0.00001	A<	
43530	0.00001	A<	
44011	0.00003	A	
44510	0.00001	A<	
45180	0.00001	A<	
45487	0.00003	A	
45949	0.00001	A	
51400	0.00001	A<	
52570	0.00008	A	
53110	0.00001	A<	
54900	0.00001	A<	
56420	0.00001	A<	
57020	0.00001	A<	
59057	0.00001	A	
59740	0.00002	A	
61901	0.00013	A	
64143	0.00002	A	
65294	0.00008	A	
66242	0.00078	A	
67600	0.00001	A<	
67987	0.00012	A	
68880	0.00007	A	
69660	0.00001	A	
70933	0.00002	A	
72196	0.00042	A	
73070	0.00001	A<	

0.73729	0.00002	A	
0.75596	0.00002	A	
0.76710	0.00001	A	
0.77062	0.00002	A	
0.78300	0.00001	A<	
0.78658	0.00001	A	
0.80300	0.00001	A<	
0.86360	0.00001	A<	
0.87270	0.00001	A<	

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55 CS 134

HALF LIFE: 2.046A
GEN: NTH CS133
NFA BA134
DAU:
PAR:
REF: 69 GU 1,70 AD 1

0.03182	0.20000	A	X
0.03219	0.40000	A	X
0.03640	0.10000	A	X
0.03730	0.02500	A	X
0.47534	1.54000	A	
0.56322	8.82000	A	
0.56933	15.80000	A	
0.60470	98.00000	A	
0.79579	89.00000	A	
0.80187	9.50000	A	
1.03861	1.06000	A	
1.16791	1.85000	A	
1.36513	3.00000	A	
1.40050	0.08000	A	
1.46070			

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55 CS 137

HALF LIFE: 30.0A
GEN: NTH XE136
NFA BA137
NFI 6.170
DAU: BA137M
PAR:
REF: 70 MA 3

0.03182	1.92000	A	X
0.03219	3.70000	A	X
0.03640	1.04000	A	X
0.03730	0.22000	A	X
0.66162	84.62000	A	

LAMPIRAN E

Sertifikat Material Standar Jenis Tanah (IAEA-375), Rumput (IAEA-373), dan Susu Bubuk (IAEA-152)

Sumber: *International Atomic Energy Agency (IAEA)*

INTERNATIONAL ATOMIC ENERGY AGENCY
AGENCE INTERNATIONALE DE L'ENERGIE ATOMIQUE
МЕЖДУНАРОДНОЕ АГЕНТСТВО ПО АТОМНОЙ ЭНЕРГИИ
ORGANISMO INTERNACIONAL DE ENERGIA ATOMICA

WAGRAMERSTRASSE 5, P.O. BOX 100, A-1400 VIENNA, AUSTRIA
TELEX: 1-12645, CABLE: INATOM VIENNA, FACSIMILE: (+43 1) 234564, TELEPHONE: (+43 1) 2360

IN REPLY PLEASE REFER TO:
PRIERE DE RAPPELER LA REFERENCE:

G4.12

DIAL DIRECTLY TO EXTENSION:
COMPOSER DIRECTEMENT LE NUMERO DE POSTE:

1994-08-12

REFERENCE SHEET
REFERENCE MATERIAL
IAEA - 375 SOIL

Reference Date: 31 December 1991

Recommended Values
(based on dry weight)

Radionuclides	Recommended Values Bq kg^{-1}	Confidence Interval Bq kg^{-1}	N*
Cs-134	463	454 - 472	87
Cs-137	5280	5200 - 5360	91
I-129	$1.7 \cdot 10^{-3}$	$1.3 \cdot 10^{-3}$ - $2.1 \cdot 10^{-3}$	10
K-40	424	417 - 432	84
Ra-226	20.0	18.0 - 22.0	35
Ru-106	56	53 - 58	26
Sb-125	77	74 - 79	38
Sr-90	108	101 - 114	43
Th-232	20.7	20.1 - 21.3	37
U-238	22.6	20.6 - 24.6	38
Trace Elements	**mg kg^{-1}**	**mg kg^{-1}**	
Th	5.10	4.95 - 5.25	37
U	1.88	1.72 - 2.05	28

Information Values
(based on dry weight)

Radionuclides	Mean of Accepted Laboratory Results Bq kg^{-1}	Confidence Interval Bq kg^{-1}	N*
Am-241	0.13	0.11 - 0.15	6
Pu-238	0.071	0.056 - 0.085	10
Pu-239+240	0.30	0.26 - 0.34	20
Th-228	21	17 - 25	6
U-234	25	17 - 32	5

* Number of accepted laboratory means which were used for calculation of recommended and information values and confidence intervals.

There is evidence for the presence of small hot particles which can seriously influence the measured activity concentration of transuranics.

1. Activities (concentrations) are expressed on dry weight basis (constant weight at 105°C)
2. The confidence intervals are given for the significance level of $\alpha = 0.05$

INTERNATIONAL ATOMIC ENERGY AGENCY
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IN REPLY PLEASE REFER TO:
PRIERE DE RAPPELER LA REFERENCE:

DIAL DIRECTLY TO EXTENSION:
COMPOSER DIRECTEMENT LE NUMERO DE POSTE:

G4.12

1994-08-24

REFERENCE SHEET
REFERENCE MATERIAL
IAEA - 373 GRASS
Reference Date: 31 December 1991

Recommended Values
(based on dry weight)

Radionuclides	Recommended Values Bq kg^{-1}	Confidence Interval Bq kg^{-1}	N*
Cs-134	1167	1143 - 1191	80
Cs-137	12350	12130 - 12570	84
K-40	432	421 - 443	76
Sr-90	1312	1266 - 1358	37

Information Values
(based on dry weight)

Trace Elements	Mean of Accepted Laboratory Results mg kg^{-1}	Confidence Interval mg kg^{-1}	N*
Th	0.047	0.040 - 0.055	10

* Number of accepted laboratory means which were used for calculation of recommended and information values and confidence intervals.

Some bottles of this material may contain one or more hot particles from Chernobyl fallout origin, which may influence the measurement of activity concentrations of transuranics.

1. Activities (concentrations) are expressed on dry weight basis (constant weight at 80°C).
2. The confidence intervals are given for the significance level of α=0.05

INTERNATIONAL ATOMIC ENERGY AGENCY
AGENCE INTERNATIONALE DE L'ENERGIE ATOMIQUE
МЕЖДУНАРОДНОЕ АГЕНТСТВО ПО АТОМНОЙ ЭНЕРГИИ
ORGANISMO INTERNACIONAL DE ENERGIA ATOMICA

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IN REPLY PLEASE REFER TO:
PRIERE DE RAPPELER LA REFERENCE:
352-G4.12

DIAL DIRECTLY TO EXTENSION:
COMPOSER DIRECTEMENT LE NUMERO DE POSTE:
November 1988

REFERENCE SHEET

IAEA-152 Milk Powder for Radionuclides

A. Description and preparation of the material

A bulk samples of approximately 500 kg (20 sacks of about 25 kg each) of milk powder with elevated radioactivity was collected from a processing plant. These twenty sacks were all from the same batch process. Thus, they were assumed to be as homogeneous as possible. Nevertheless, a preliminary homogeneity testing of every two sacks for ^{134}Cs and ^{137}Cs was performed before bottling in approximate portions of 250 grams. In order to assure long-term stability of the material, all bottles were sterilized by gamma-ray irradiation of about 2.5×10^4 Gy using a ^{60}Co source.

The final homogeneity testing (after bottling) was performed on 12 bottles from different sacks as follows:

bottles A and B - six measurements each of 250 grams
bottles C and D - three measurements each of 250 grams
bottles E to L - one measurement each of 250 grams

Considering the results of ^{134}Cs and ^{137}Cs from the above and employing the Student's t-test it was found that they did not differ by more than 3% of the mean value and thus this material can be considered homogeneous for these components for a sample size of greater or equal to 250 grams.

B. Criteria for recommended values and confidence intervals*

The overall mean values (excluding data that was detected and rejected as outliers) were considered as the recommended values when

1) more than ten laboratory means were available
2) the percentage of outliers was less than 20% and
3) the results of the A and B intercomparisons are mutually consistent (i.e. the mean value for A falls within the confidence interval for B and vice versa).

C. Recommended values and confidence intervals for radionuclides in IAEA-152 (Milk Powder)

Radionuclide	Recommended Value (Bq/kg)	Confidence Interval** (Bq/kg)
^{134}Cs	764	722 - 802
^{137}Cs	2129	2053 - 2209
^{40}K	539	510 - 574
^{90}Sr	7.7	7.0 - 8.3

** Based on the outermost confidence intervals of the A and B intercomparison for a significance level 0.05

Reference date: 31 August 1987.

D. Important Note

The analysts using the Reference Material IAEA-152 are kindly requested to communicate their meaningful analytical results on this material to:

International Atomic Energy Agency
Laboratory Seibersdorf
Analytical Quality Control Services
P.O.Box 100, A-1400 Vienna, Austria

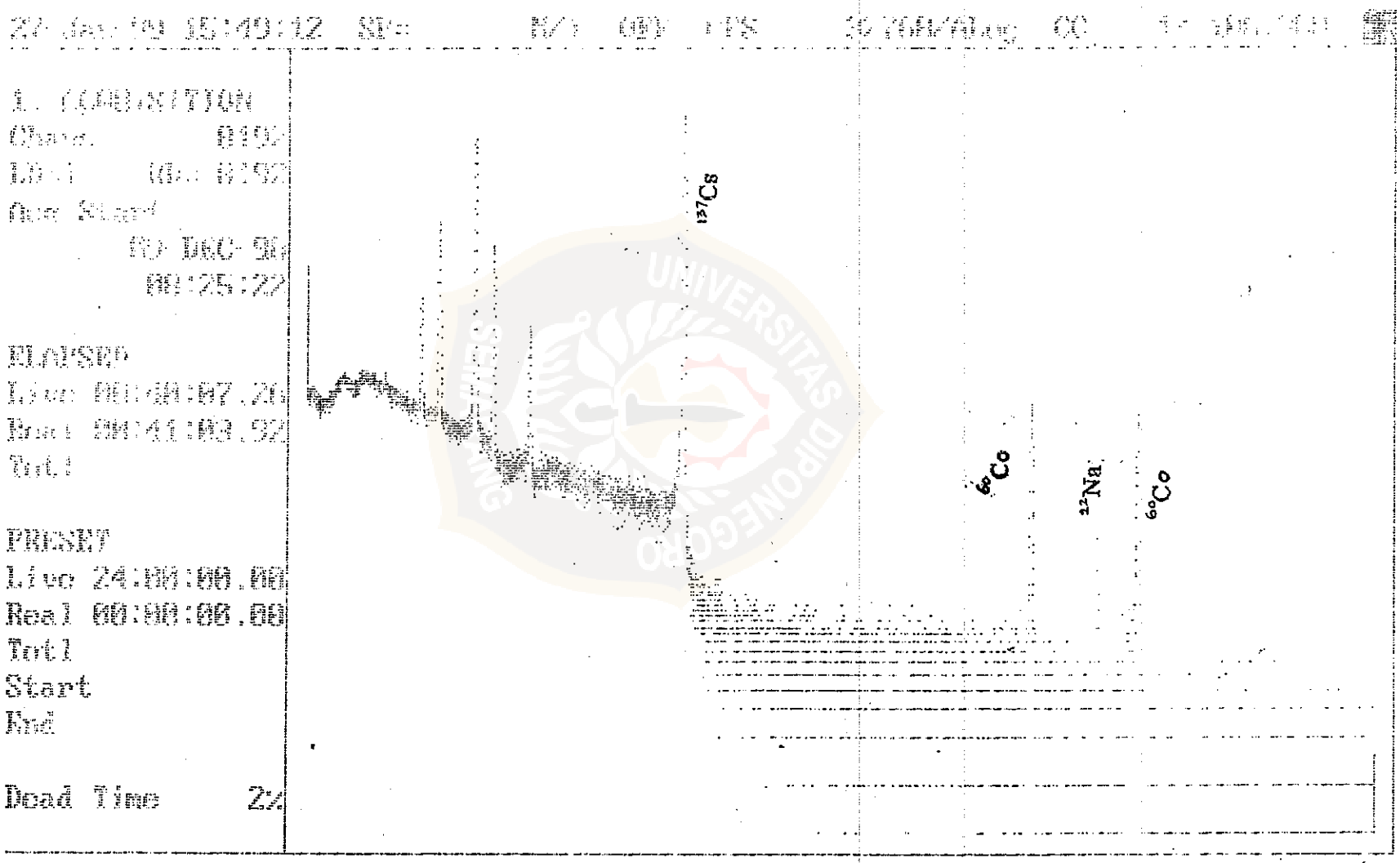
These results may be used in the future for an updating of the recommended values which are the best estimates as of September 1988.

Finally, a detailed description of results of the intercomparison and of the criteria used for their qualification has been published in IAEA/AL/009. This report is free of charge upon request.

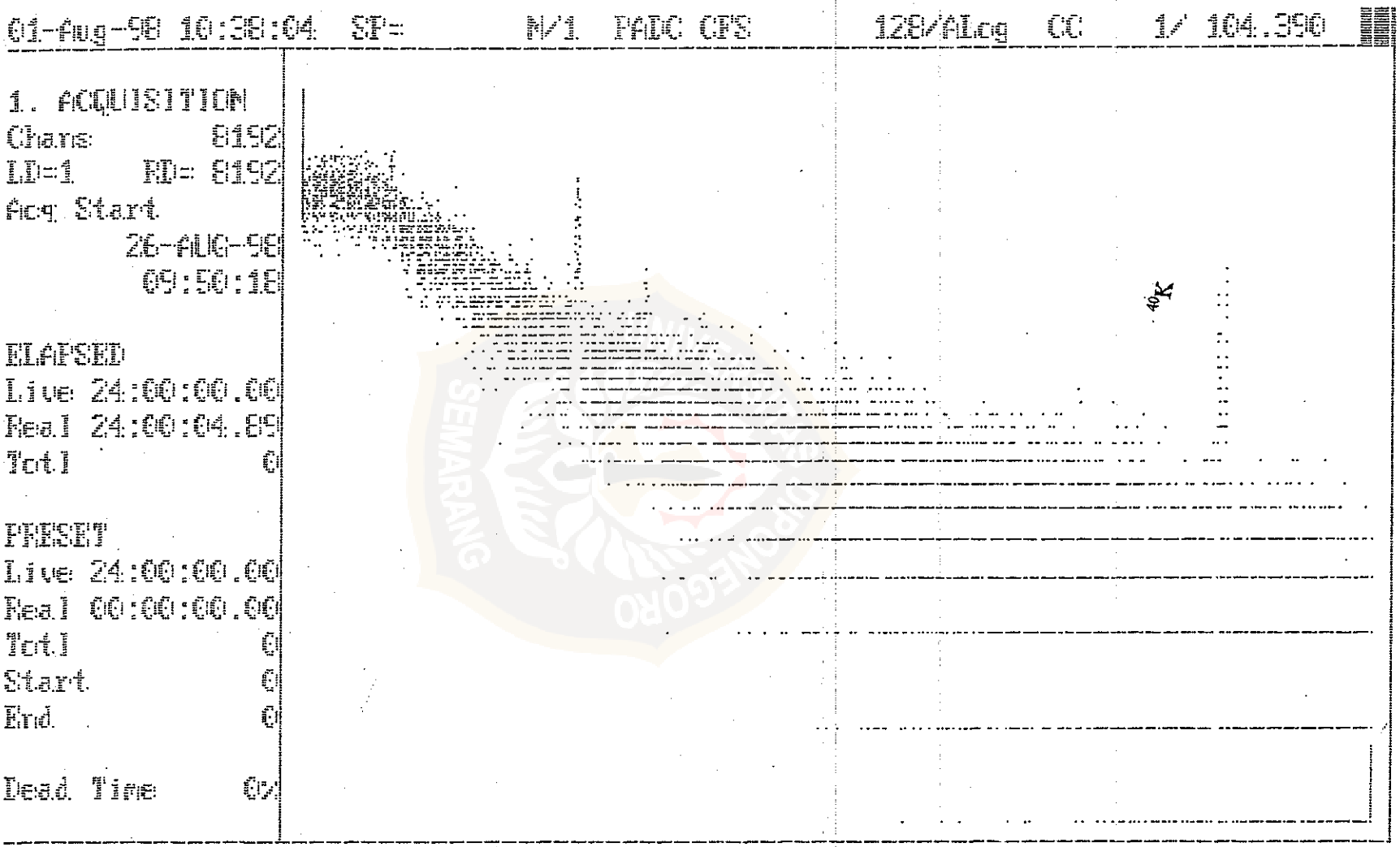
* Please note that these criteria are designed especially for this report and do not apply in general.

LAMPIRAN F

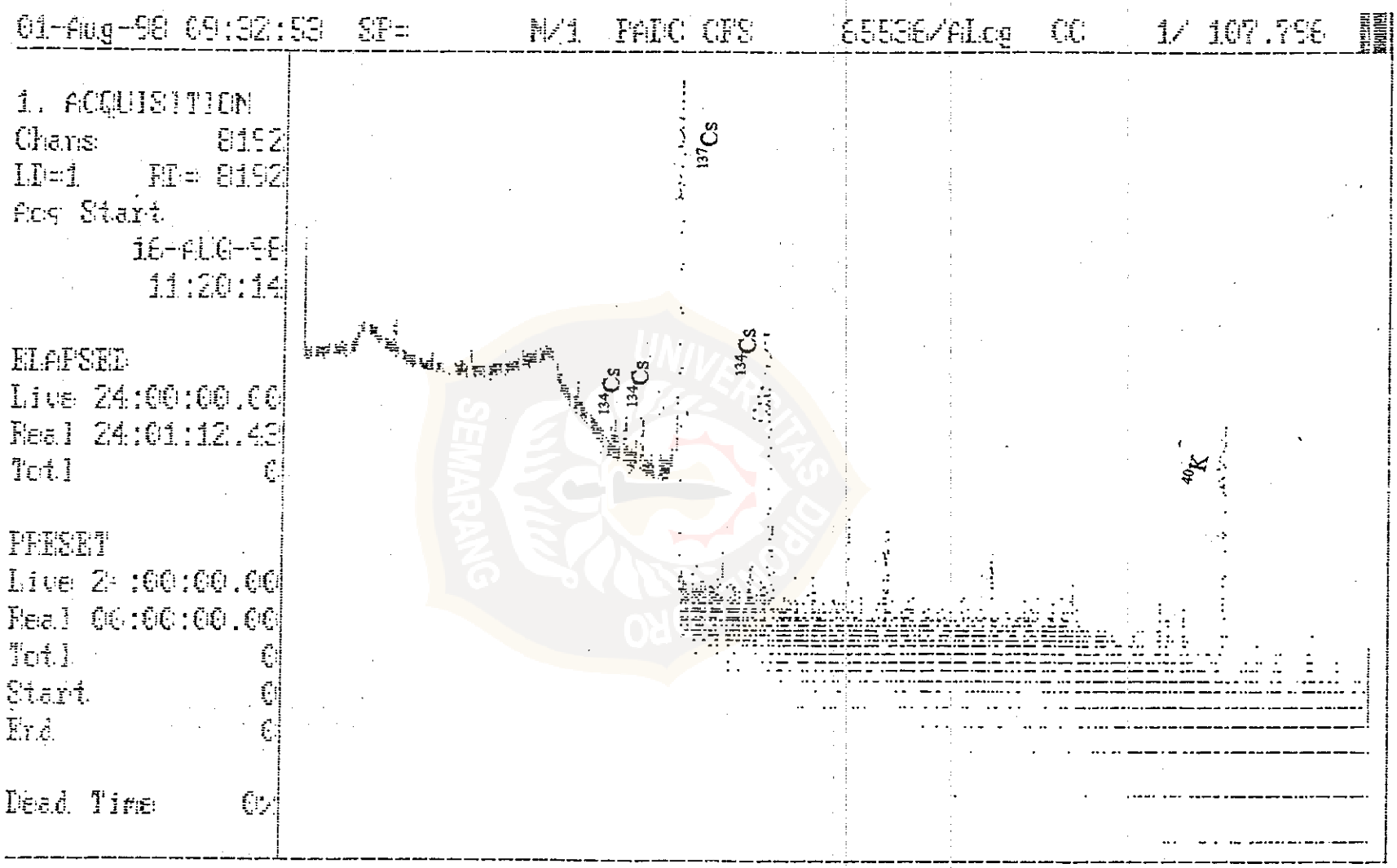
Spektrum-γ Hasil Pencacahan



Gambar F.1. Spektrum-γ hasil pencacahan material standar untuk kalibrasi energi

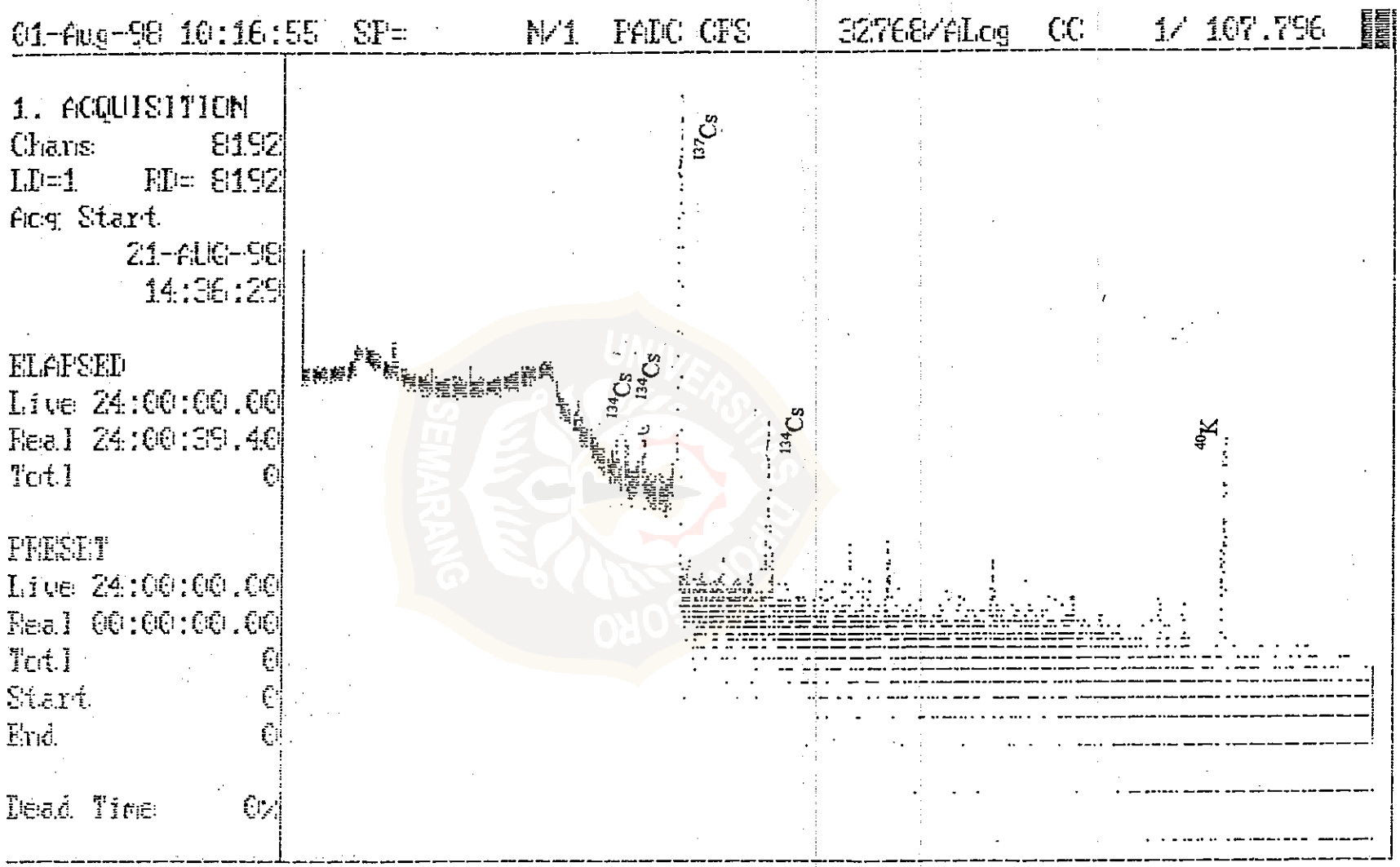


Gambar F.2. Spektrum-γ hasil pencacahan radiasi latar *(background)*



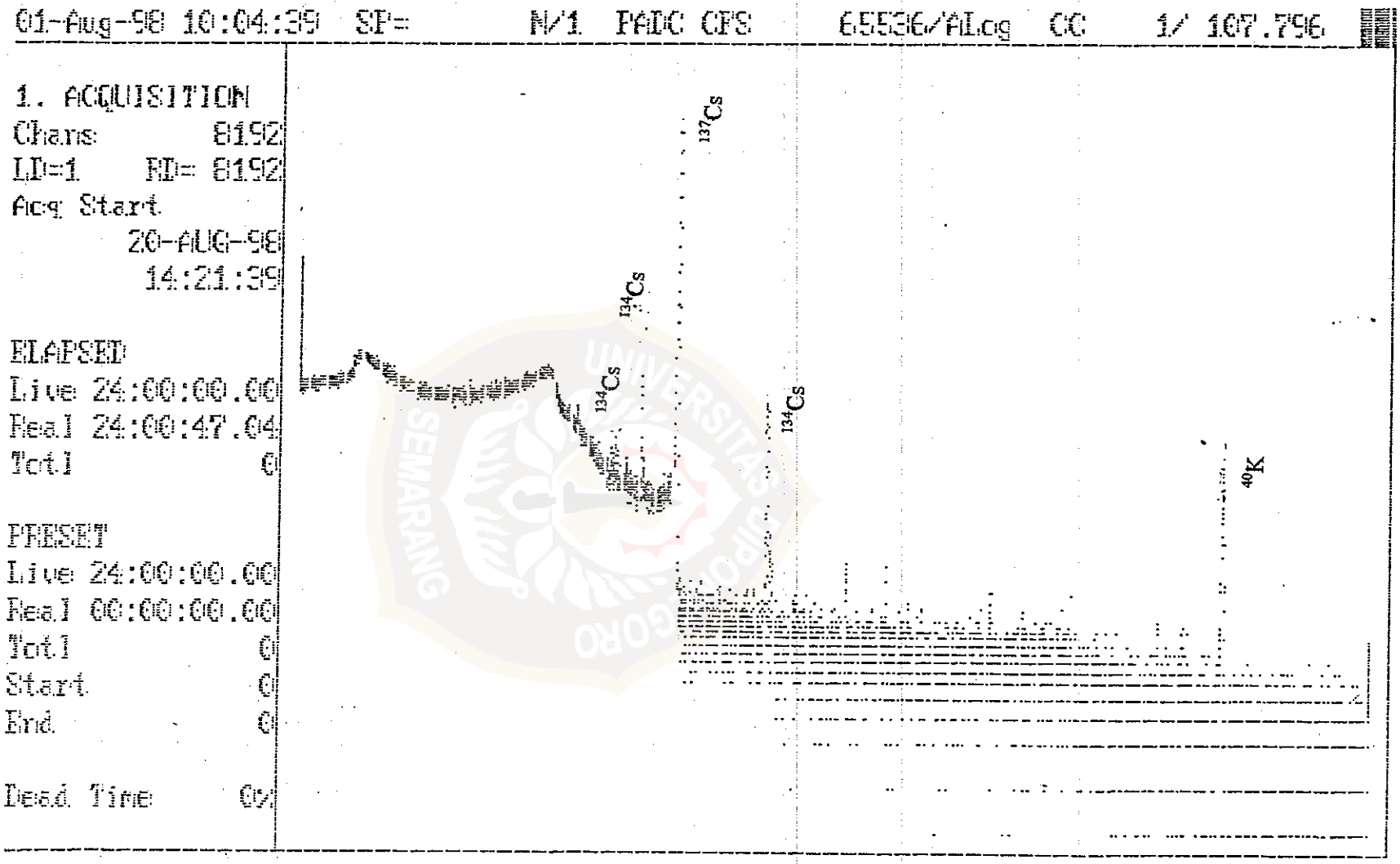
Gambar F.3. Spektrum-γ hasil pencacahan material jenis tanah (IAEA-375)

pada ketebalan 4,5 cm



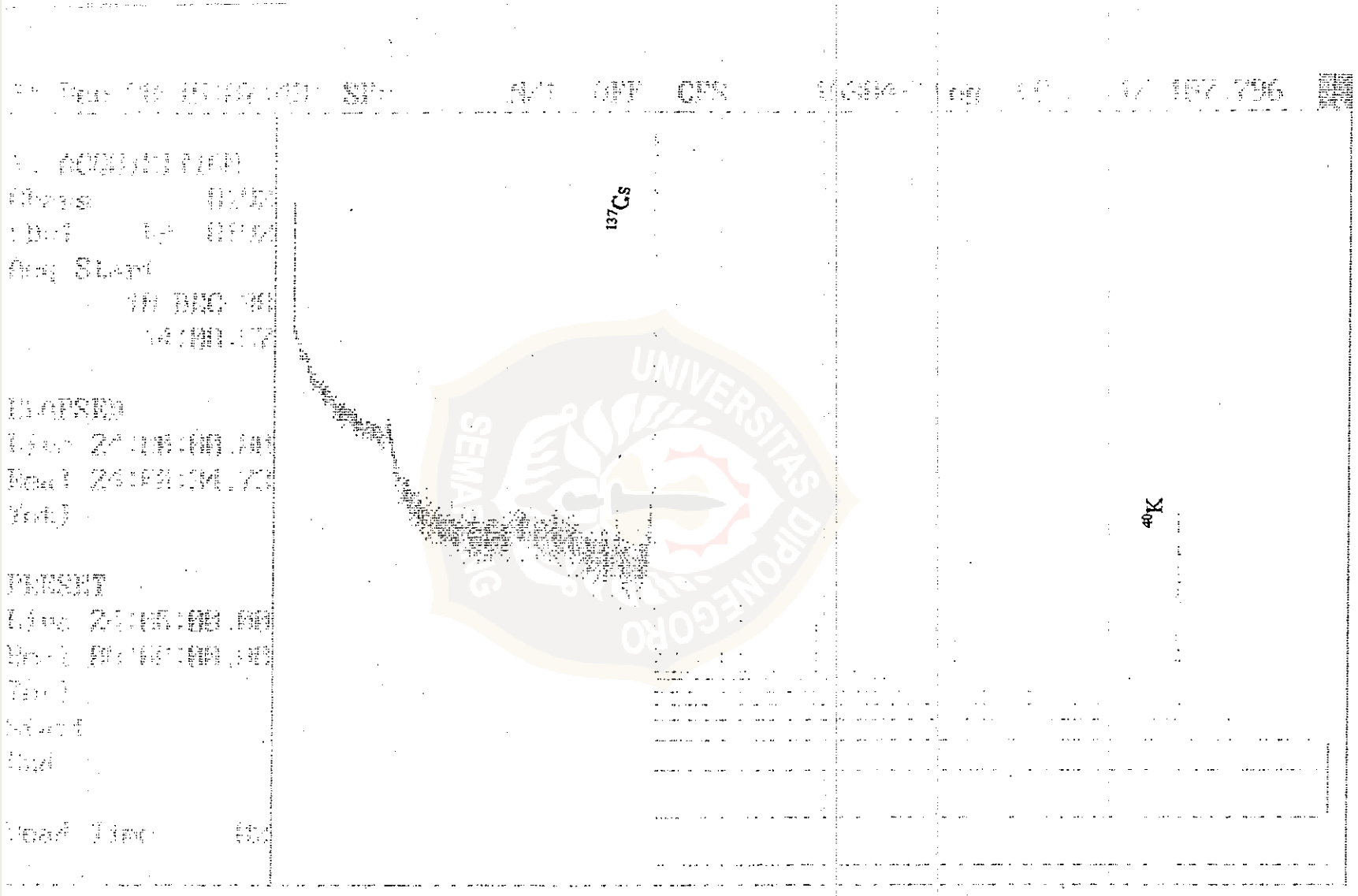
Gambar F.4. Spektrum-γ hasil pencacahan material jenis tanah (IAEA-375)

pada ketebalan 1,0 cm

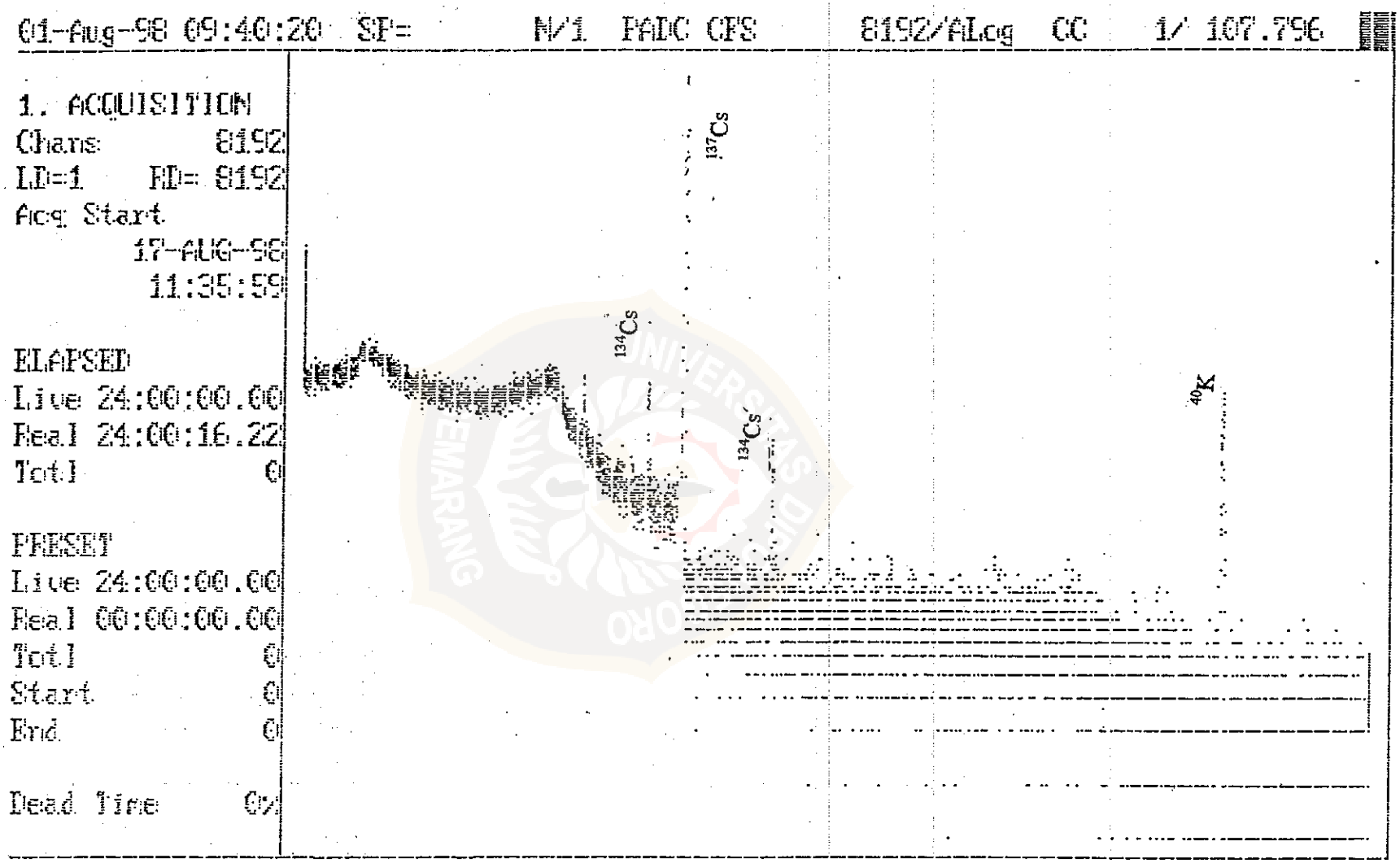


Gambar F.5. Spektrum-γ hasil pencacahan material jenis rumput (IAEA-373)

pada ketebalan 4,5 cm

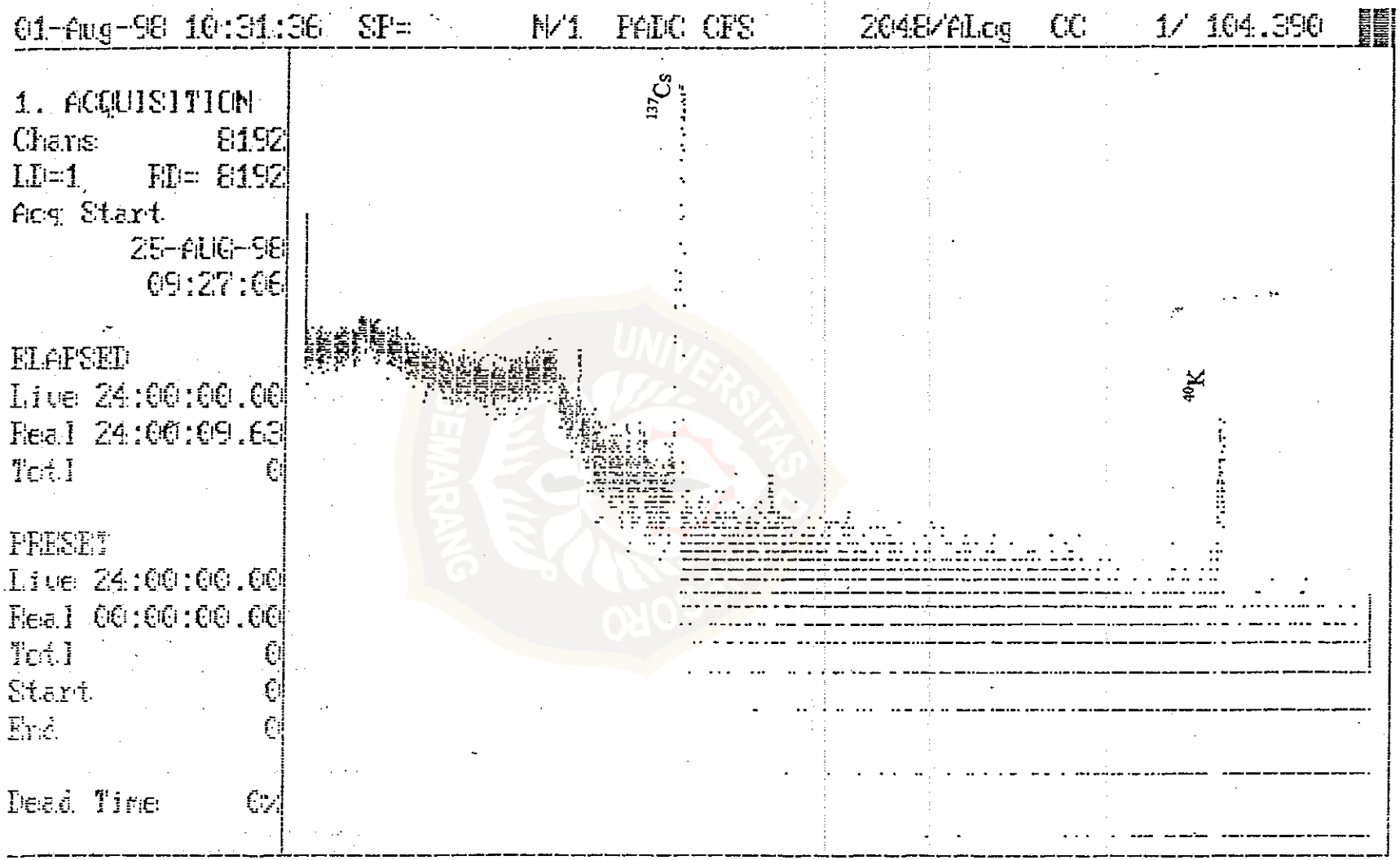


Gambar F.6. Spektrum-γ hasil pencacahan material jenis rumput (IAEA-373)
pada ketebalan 1,0 cm



Gambar F.7. Spektrum-γ hasil pencacahan material jenis susu bubuk (IAEA-152)

pada ketebalan 4,5 cm



Gambar F.8. Spektrum-γ hasil pencacahan material jenis susu bubuk (IAEA-152)

pada ketebalan 1,0 cm

LAMPIRAN G

Data Spesifikasi Alat

DATA SPESIFIKASI ALAT

1. Perisai pasif

a. Buatan : Oxford Instrument Inc., Nuclear Measurements Group, USA
b. Merk : Oxford
c. Bahan : timbal (Pb)

2. Sumber Tegangan Tinggi

a. Buatan : CANBERRA
b. Model : 3106D

3. Detektor Utama

a. Buatan : EG & G ORTEC
b. Jenis : HPGe *(High Purity Germanium)*
c. Tipe : Koaksial
d. Model : GEM - 30185
e. No. Seri : 34 - P11063A
f. Voltase Bias : 2400 Volt

4. Penguat Awal

4.1. Masukan *(Input)*:

a. Buatan : ORTEC, USA
b. Model : 138
c. No. Seri : 7973

4.2. Keluaran *(Output)*:

a. Buatan : ORTEC, USA
b. Model : 237P
c. No. Seri : 913

5. Penganalisis Salur Ganda *(Multi Channel Analyser)*

a. Buatan : Nuclear Data (ND), USA

b. Jumlah salur : 8192

6. Timbangan Massa

a. Merk : SARTORIUS AG GÖTTINGEN, GERMANY

b.Model : BP 210 D

c. No. Seri : 50405462

d. Pengukuran Max. : 210 gram

e. Ketelitian : 1.10^{-5} gram