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X and γ reference radiations for calibrating dosemeters and dose ratemeters and for determining their response as a function of photon energy

ADDENDUM 1: High rate series of filtered X-radiations

Addendum 1 to International Standard ISO 4037-1979 was developed by Technical Committee ISO/TC 85, *Nuclear energy*, and was circulated to the member bodies in March 1982.

It has been approved by the member bodies of the following countries:

Australia	Germany, F.R.	Romania
Austria	Hungary	South Africa, Rep. of
Belgium	Italy	Sweden
China	Japan	Switzerland
Czechoslovakia	Korea, Rep. of	Turkey
Egypt, Arab Rep. of	Mexico	United Kingdom
Finland	Netherlands	USA
France	Poland	

No member body expressed disapproval of the document.

1 Scope and field of application

This Addendum specifies a series of lightly filtered X-radiations intended for calibration procedures in which high exposure rates are required. The series is also applicable to, for example, determination of the saturation characteristics of a dosemeter or for checking scale linearity.

Since the spectra obtained are broad and asymmetric, the series is not suitable for accurate energy response measurements and shall only be used when the exposure rates produced by the narrow and wide series prove inadequate.

2 Qualities of specified reference radiations

The quality of the reference radiations is specified in terms of the X-ray tube constant potential, by the first half value layer (HVL_X) and by the homogeneity coefficient. These specifications are listed in table 10.

3 Effective energy

If required, the effective energy[1], E, of the radiations listed in

1) The effective energy of filtered X-radiation with a given half value layer is defined as the energy of the monoenergetic radiation having the same half value layer.

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table 10 may be determined from the half value layer, HLV_x, (in millimetres) using the relationship

$$HLV_x = ln2/\mu(E)$$

where $\mu(E)$ (in reciprocal millimetres) is the characteristic linear attenuation coefficient of the material in which the half value layer has been specified, for photons of energy E.

4 Filtration

4.1 Filters

Filters of aluminium (constant potential < 100 kV) or copper and aluminium (⩾ 100 kV) shall be used.

4.2 Additional filtration

At a given potential, the thickness of the additional filtration shall be adjusted so that the measured first half value layer lies within ± 10 % of that specified for radiation generated up to and including 30 kV and within ± 5 % for the higher energy radiation. The minimum purity of the additional filters and of the absorbers used to determine the half value layer shall be 99,9 % except in the case of aluminium used at and below 20 kV when the minimum shall be 99,99 %.

4.3 Fixed filtration

For tube potentials up to and including 60 kV, the corresponding total filtration (fixed + additional) shall be less than the equivalent of 4 mm of aluminium. An X-ray tube with low inherent filtration is required to generate the lower energy radiations. At potentials of 100 kV and above the fixed filtration should be adjusted to the equivalent of 4 mm of aluminium. The aluminium filter used to supplement the inherent filtration of the tube shall be placed after the additional copper filter in order to reduce any fluorescent radiation arising from the copper. The thickness of aluminium employed shall not be less than 0,5 mm.

4.4 Examples of additional filtration required for specified radiation qualities

Table 11 lists, as an example, the additional filtration required to produce the radiation qualities specified for particular values of the fixed filtration. The air layer thickness included in the additional filtration, is significant in the case of lower energy radiations. Also included in table 11 are values of the first and second half value layer, mean photon energy, effective energy and homogeneity coefficient. The effective energy has been calculated from the first half value layer using the total narrow beam attenuation coefficients, σ (tot) cm^2/g, of Storm and Israel [1], together with densities of aluminium and copper of 2,702 and 8,94 g/cm^3 respectively. The measured photon spectra shown in figures 20-28 apply to the conditions listed in table 11.

1) STORM, E., and ISRAEL, H.I. *Photon cross sections from 1 keV to 100 MeV for elements Z = 1 to z = 100*, Nuclear Data Tables **A7** (1970), pp. 565-681.

Table 10 — Specifications of radiation quality

Series	Constant potential*) kV	First half value layer Aluminium mm	First half value layer Copper mm	Homogeneity coefficient Aluminium	Homogeneity coefficient Copper
High rate	7,5	0,025	—	1,00	—
	10	0,04	—	0,88	—
	20	0,11	—	0,77	—
	30	0,35	—	0,67	—
	60	2,4	0,077	0,75	0,70
	100	—	0,29	—	0,61
	200	—	1,7	—	0,70
	250	—	2,5	—	0,77
	280**)	—	3,4	—	0,84
	300	—	3,4	—	0,80

NOTE — For guidance, it is pointed out that, with a tube current of 10 mA and at 1 m from the tube focus the exposure rate obtainable is :

— about $2,6 \times 10^{-3}$ $C \cdot kg^{-1} \cdot h^{-1}$ ($10\ R \cdot h^{-1}$)***) for a constant potential of 7,5 kV;

— between about $2,6 \times 10^{-2}$ $C \cdot kg^{-1} \cdot h^{-1}$ ($100\ R \cdot h^{-1}$) and $1,3 \times 10^{-1}$ $C \cdot kg^{-1} \cdot h^{-1}$ ($500\ R \cdot h^{-1}$) for constant potential > 7,5 kV.

*) The constant potential is measured under load.

**) This radiation has been introduced as an alternative to that generated at 300 kV for use when this potential cannot be achieved under conditions of maximum load.

***) $1\ R \cdot h^{-1} = 2,58 \times 10^{-4}$ $C \cdot kg^{-1} \cdot h^{-1}$

Table 11 — Conditions of production and characteristics of radiation beams — Low rate series — Example[1)]

Constant potential kV	Filtration mm: Fixed[2)]	Filtration: Additional Al	Filtration: Additional Cu	Filtration: Air	Half-value layer mm: First Al	First Cu	Second Al	Second Cu	Homogeneity coefficient Al	Homogeneity coefficient Cu	Effective energy keV Al	Effective energy keV Cu	Mean photon energy keV $\overline{E}$
7,5	— —	—	—	—	—	—	—	—	—	—	—	—	—
10	*t* + 3,6 Be	—	—	750	0,036	0,010	0,041	0,011	0,88	0,86	7,1	—	7,5
20	*t* + 3,6 Be	0,15	—	750	0,12	0,007	0,16	0,009	0,74	0,76	10,7	—	12,9
30	*t* + 3,6 Be	0,52	—	750	0,38	0,013	0,60	0,018	0,63	0,72	15,6	—	19,7
60	*t* + 3,6 Be	3,2	—	750	2,42	0,079	3,25	0,11	0,74	0,69	30,3	31,1	37,3
100[3)]	*t* + 3,6 Be	3,9	0,15	750	6,56	0,30	8,05	0,47	0,81	0,64	—	50,0	57,4
200	*t* + 4,0 Al		1,15	2250	14,7	1,70	15,5	2,40	0,95	0,71	—	99,6	102
250	*t* + 4,0 Al		1,6	2250	16,6	2,47	17,3	3,29	0,96	0,75	—	121	122
280	*t* + 4,0 Al		3,0	2250	18,6	3,37	19,0	3,99	0,98	0,84	—	146	146
300	*t* + 4,0 Al		2,5	2250	18,7	3,40	19,2	4,15	0,97	0,82	—	147	147

1) The values listed in this example have been taken from *"A Catalogue of Spectra for the calibration of Dosemeters"* GSF Report S 560 (March 1979), tables B4 and B5.

2) The component *t* of the fixed filtration is that due to the monitor chamber (0,075 mm kapton + 0,040 mm graphite) and the detector window (0,2 mm beryllium + 0,000 05 mm palladium).

3) No measured data is available for a fixed filtration adjusted to the equivalent of 4 mm of aluminium. The spectrum quoted does however satisfy the requirements listed in table 10.

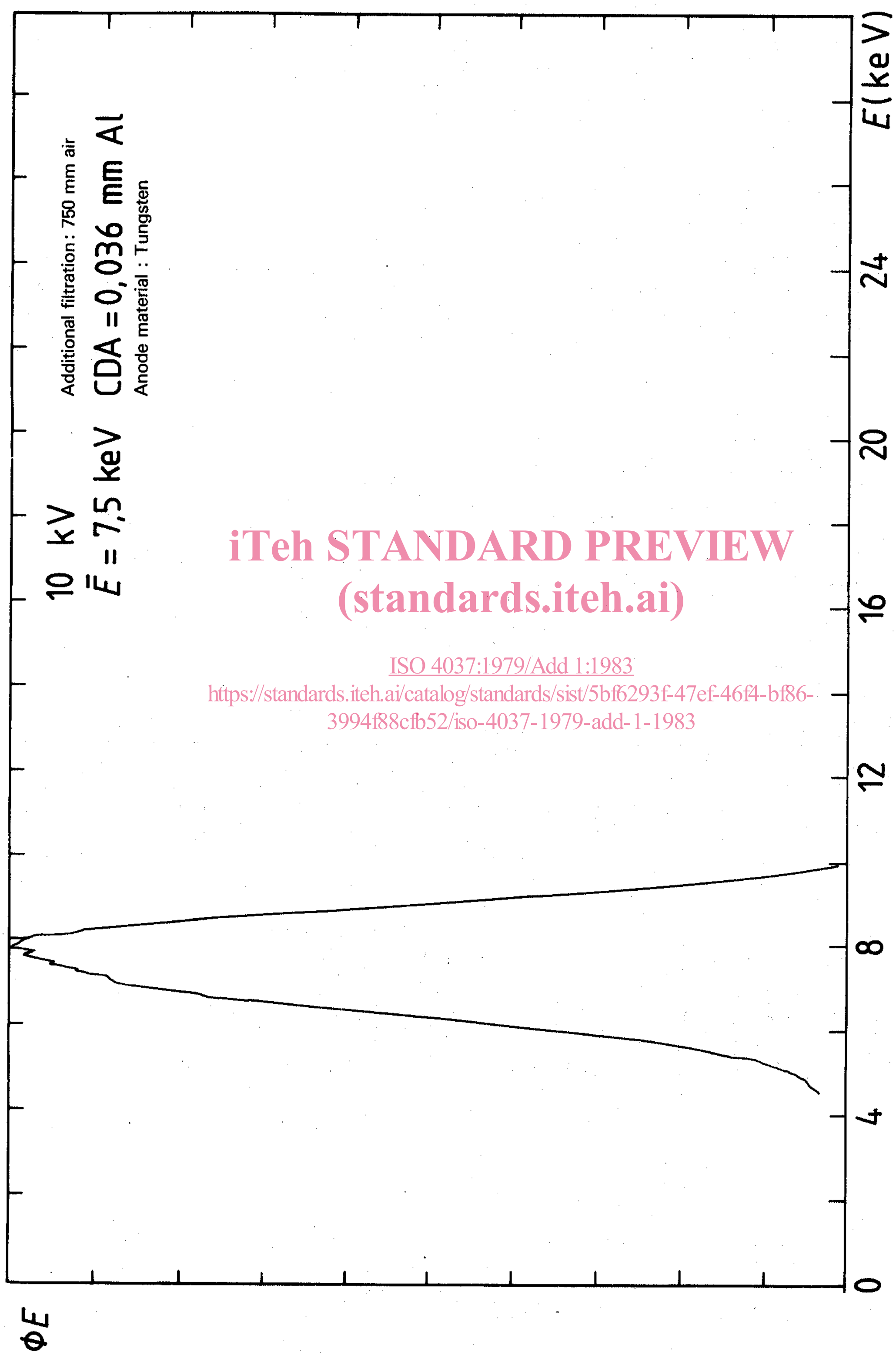

Figure 20 — Measured photon spectra with mean photon energy $\bar{E}$ = 7,5 keV

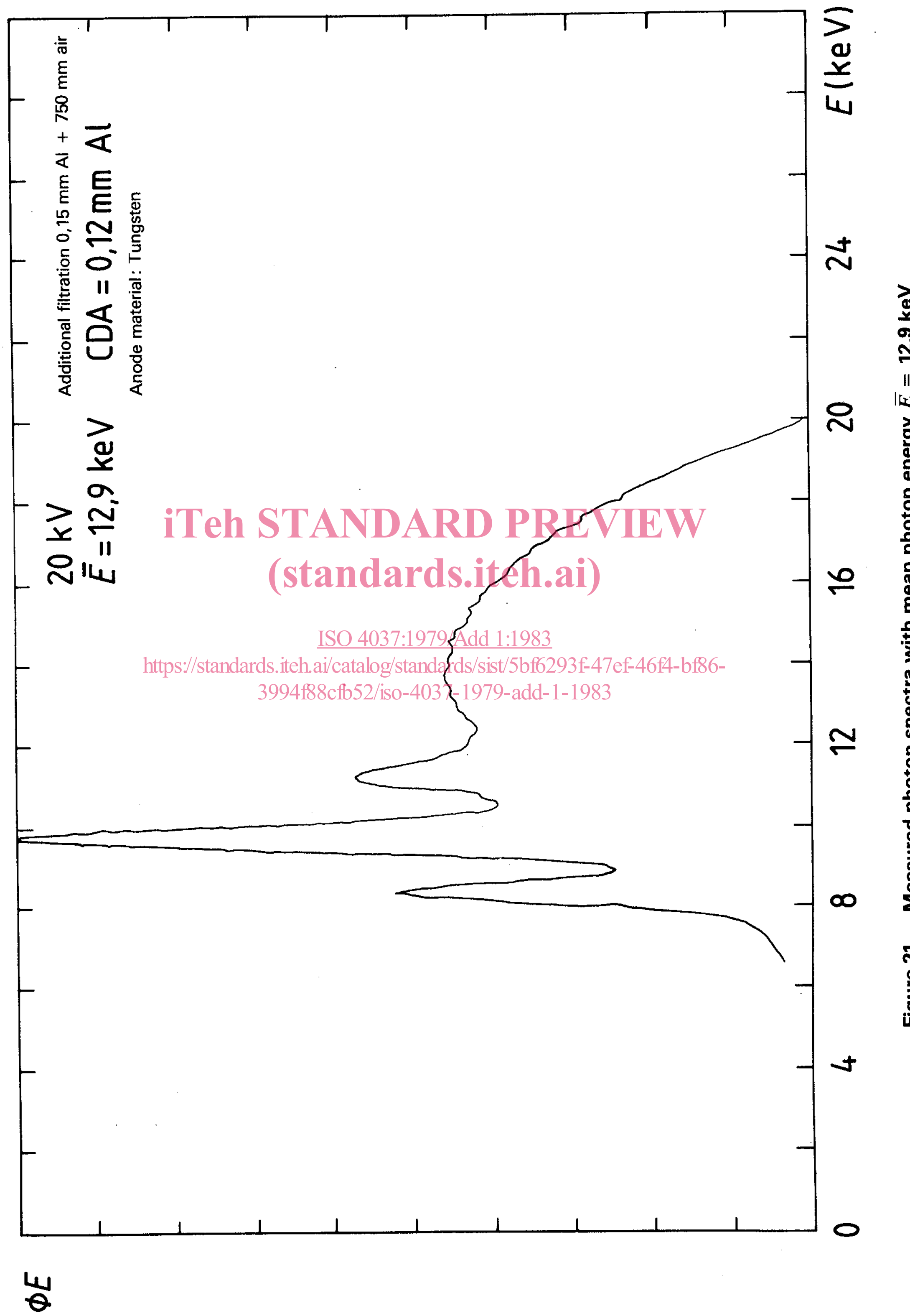

Figure 21 — Measured photon spectra with mean photon energy $\bar{E}$ = 12,9 keV

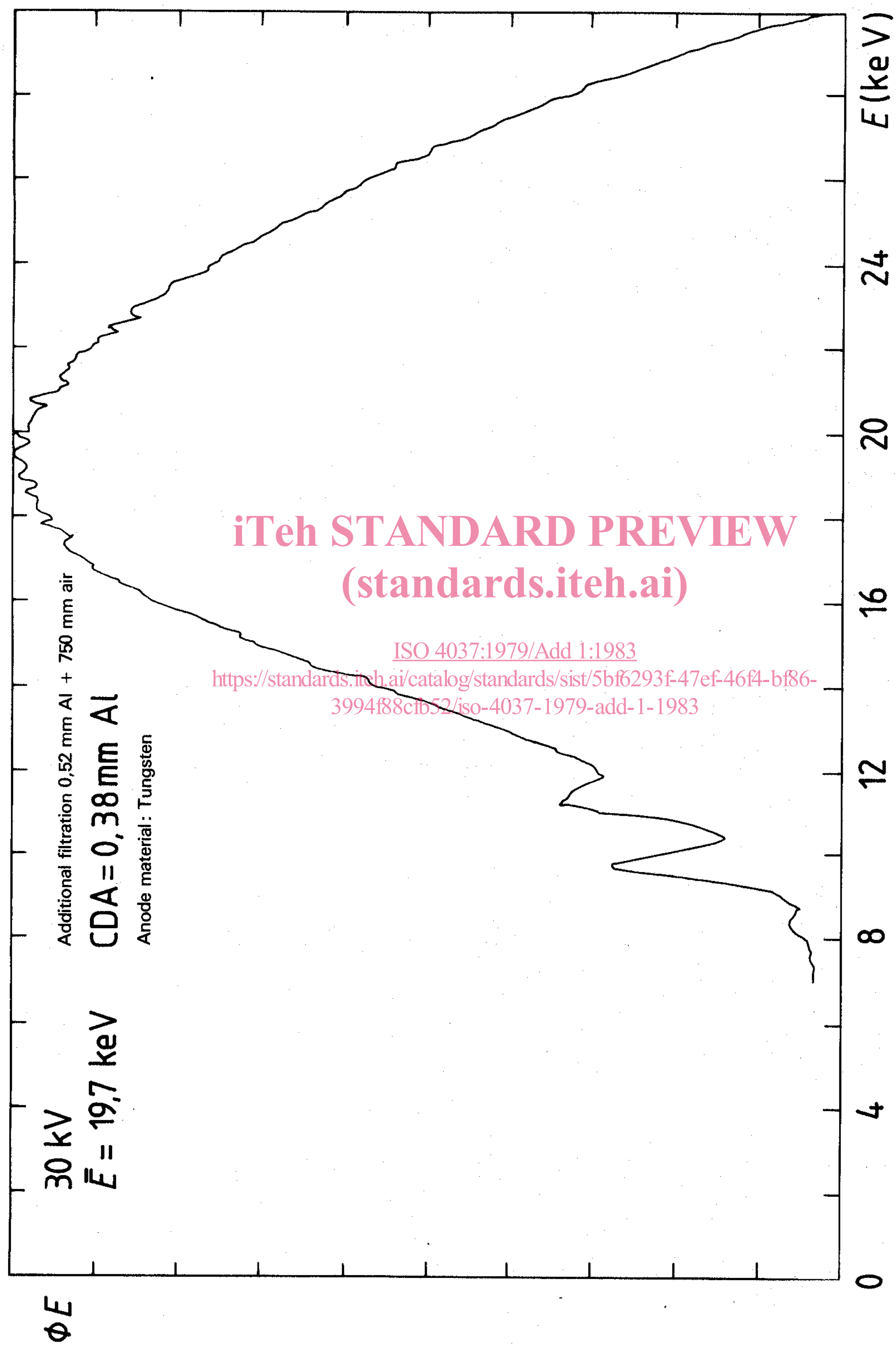

Figure 22 — Measured photon spectra with mean photon energy $\bar{E}$ = 19,7 keV

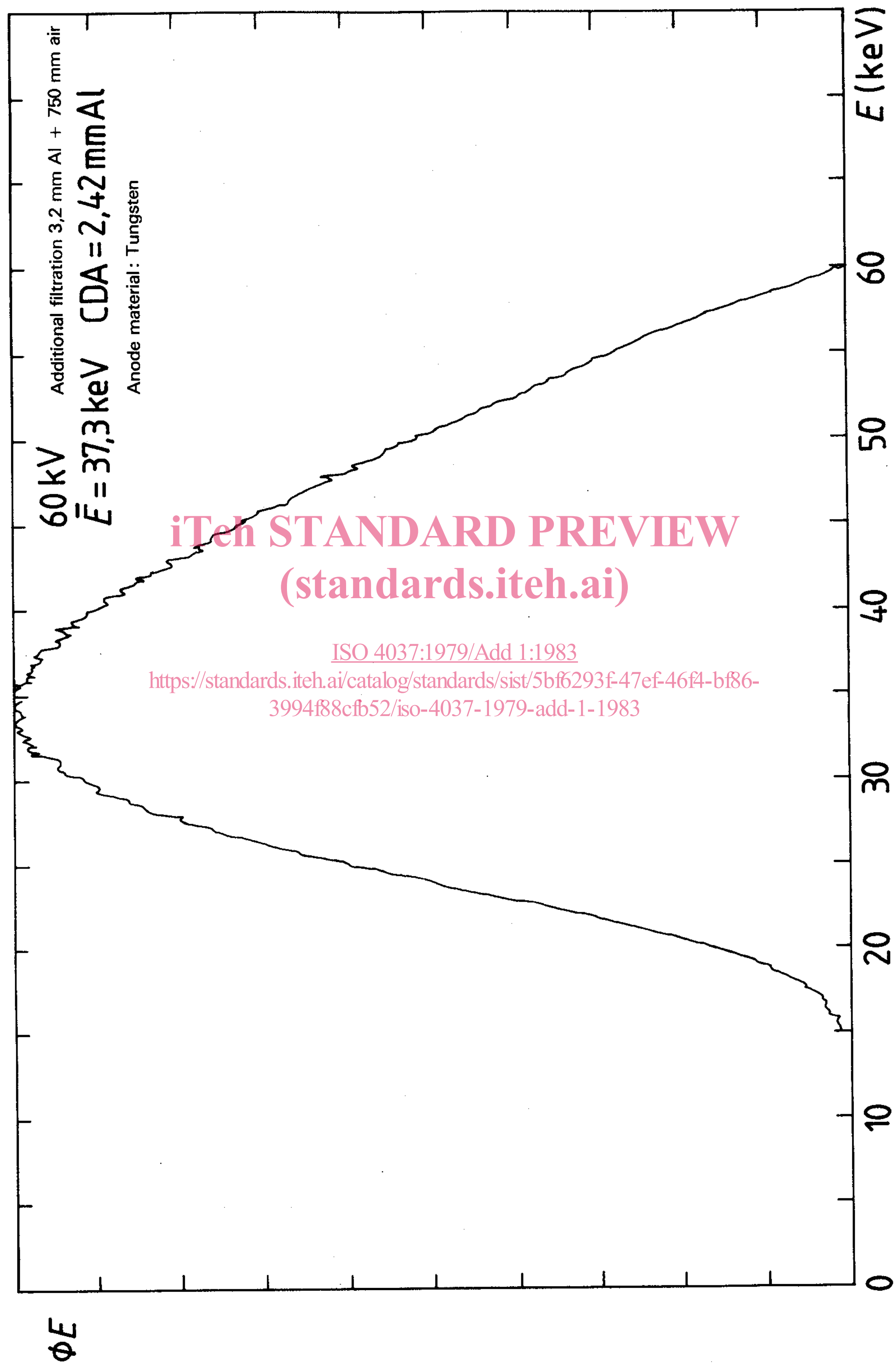

Figure 23 — Measured photon spectra with mean photon energy $\bar{E}$ = 37,3 keV

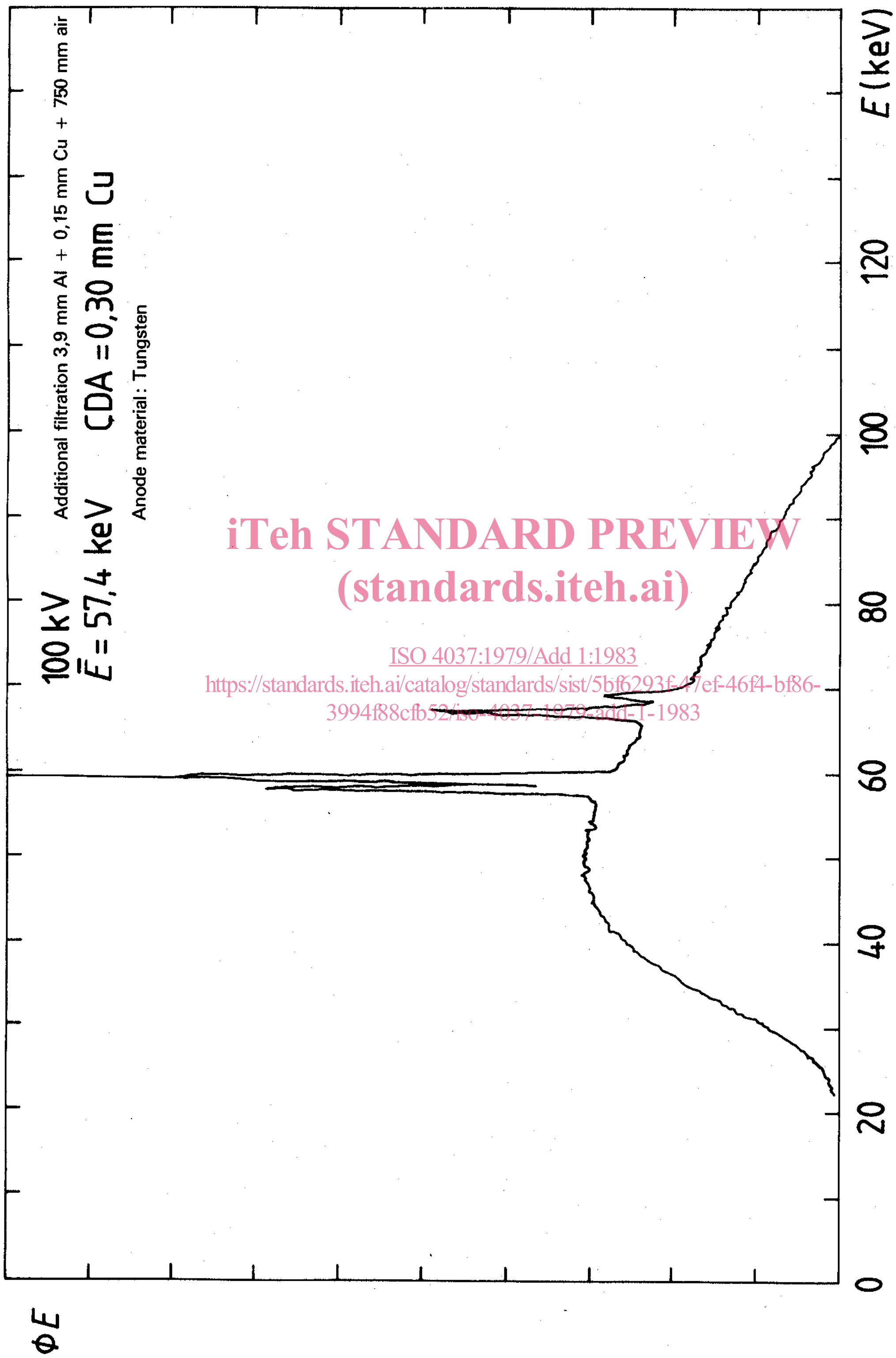

Figure 24 — Measured photon spectra with mean photon energy $\bar{E}$ = 57,4 keV

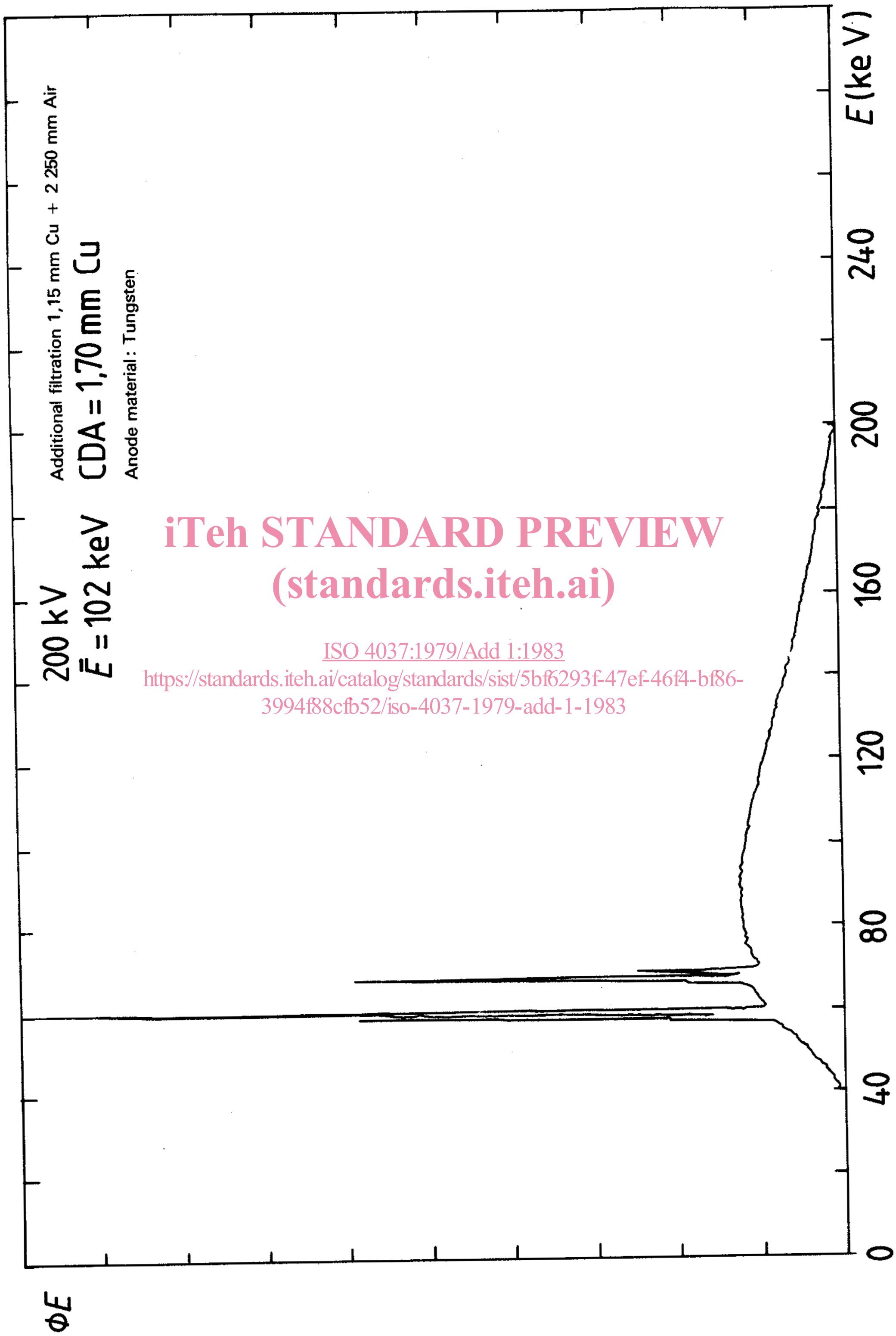

Figure 25 — Measured photon spectra with mean photon energy $\bar{E}$ = 102 keV