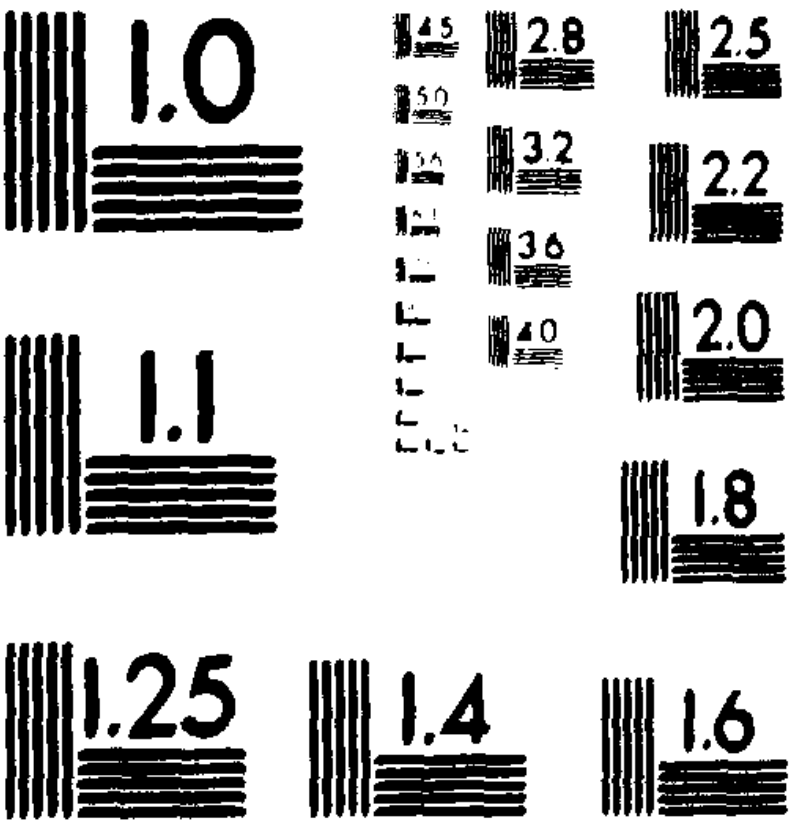

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P. BARTOLOMEI, A. CABRINI, P.G. FUOCHI, P. NEUHOLD

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COMITATO NAZIONALE PER LA RICERCA E PER LO SVILUPPO DELL'ENERGIA NUCLEARE E DELLE ENERGIE ALTERNATIVE

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RELATIVE EFFECTIVENESS OF ELECTRON - PHOTON DAMAGE ON ORGANIC COATINGS

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ABSTRACT

With aim to verify the validity of simulation with photon irradiators, of damage caused on internal containment coatings by beta plus gamma mixed field following to a LOCA in LWR, irradiation tests with Co 60 photons and with nearly 1.5 MeV mean energy electrons have been performed. Changes of some properties of coating film have been verified versus absorbed doses up to 1000 KGy (100 Mrad).

A special technique for measurement of dose absorbed in thin film of coating has been tested, to be related to absorbed dose in organic dosimeters and in water (Fricke solution) dosimeter.

The changes of considered properties (tensile strength, ease to decontamination, color, brightness) do not allow at the moment, to determine undoubtedly the degree of equivalence between radiation damage to coatings by two types of radiation.

A strong backscatter effect mainly evident in electron irradiation, has been pointed out, which contribute to damage to coating film.

SOMMARIO

Per verificare la validità della simulazione con irraggiamento di fotoni del danno causato sulle pitture interne del contenimento primario di un LWR del campo misto di radiazioni beta e gamma a seguito di un LOCA sono state eseguite prove di confronto con irraggiamenti gamma da Co 60 e con elettroni di energia media circa 1,5 MeV.
Sono state verificate le variazioni di alcune proprietà dei film di rivestimento in funzione delle dosi assorbite fino a 1000 kGy (100 Mrad).
Si è sperimentata una tecnica per la misura della dose realmente assorbita nei film sottili di pittura da confrontare con quella assorbita in dosimetri organici ed in soluzioni di Fricke.
La variazione delle proprietà considerate (resistenza a trazione, decontaminabilità, colore, brillantezza) non consentono, per ora, di determinare con certezza un grado di equivalenza tra il danno prodotto sulle pitture dai due tipi di radiazione.
E' stato evidenziato un forte effetto di "backscatter", più evidente per gli irraggiamenti con elettroni, che contribuisce a degradare i film di pittura.

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ACNOWLEDGEMENTS

The gamma irradiations have been carried out at care of ENEA/TIB/SettoreA.Q.. We wishes to thank the Director, Prof.A.SERRA and his collaborators for the important contribute in this work.
Helpful discussion and suggestion have been given by Prof.G.SCARPA on problems of dosimetry, with participation of F.PERSIA, which has performed also the dosimetric measurements.

WORKING PROGRESS REPORT

RELATIVE EFFECTIVENESS OF ELECTRON - PHOTON DAMAGE ON ORGANIC COATING

Work realized in Coordination Research Program - Sponsored by IAEA

1. FOREWORD

During a Loss of Coolant Accident (LOCA) in the Primary Containment of a 4100 MW PWR Reactor, the release is expected of radioactive materials in such a quantity to cause on primary Containment walls and facilities the absorption of 2200 KGy (220 Mrad) from beta radiation and of 150 KGy (15 Mrad) from gamma radiation (1), both integrated during a period of one year.

Similar doses are calculated for the 1000 MWe BWR Alto Lazio Reactor (Italy) and in particular (2) in the Drywell it will be absorbed 2700 KGy (270 Mrad) from beta and 90 KGy (9 Mrad) from gamma during a period of 100 days following accident.

Other reports on radiation signature define not very different rates and doses, as indicated in (3), (4), (5) that is beta and gamma initial exposure-rates, for a typical PWR containment 70 and 3,5 MR/h and 30 days absorbed doses of 3000 and 500 KGy (300 and 50 Mrad) respectively.

In all cases the irradiation is realized by emission both of airborne materials and of aerosol or particulate form; these

three will depositate on surfaces and will contribute to long-term received dose.

It may be noted that the greater part of absorbed dose is due to β radiation (beta/gamma ratio from 6 to 15) and will change both as dose-rate and as energy spectrum during the time quickly decreasing too.1).

In the problem of simulation of this mixed field of radiation with the aim of equipment qualification, it is recognized the opportunity of the utilization of photon irradiation, due to easier application:

- beam of radiation more spreaded and homogeneous;
- possibility to give more accurately the fixed dose, with a minimum of errors due to change of energy spectrum and dose-rate.

NOTE: 1) For a 4100 MW PWR Reactor the initial beta dose-rate is nearly 70 KGy/h in the first hour. During the first 30 d half of the total dose (3000 KGy) will be absorbed, say 1500 KGy/720 h at a mean dose-rate of 2 KGy/h.

Using this irradiation technique it is supposed, of course, that the damage caused by radiation to material is only function of the amount of absorbed energy, at least on a microscopie scale (5), (6) and it is independent from particle type.

But how is really true this simulation?

As it is well-known, the energy deposition profile of electrons is much less pronunced than that of photons and different are the damage mechanisms (different ratio of crosslinking, charge-building, chain breakdown, etc.), and this is more evident as a function of thickness and atomic weight of the absorber. Significant errors in this simulation may arise in the irradiation of organic materials thicker than 1-2 mm (for energies, both of photons and electrons, close to 1 MeV).

Let us consider now the problem of simulation in relation to the case of paints.

For the well known reasons of anticorrosive protection and to ease decontamination of the substrate, almost all the surfaces at the internal part of the reactor, are coated with a layer of coating as thick as 0.2-0.3 mm.

The absorption both of photons and electrons in this layer is dependent, besides by the respective energies, by the amount of mineral filling and inorganic pigments into the coat; for mean energies of nearly 1 MeV, it can be supposed that the layer is completely crossed from both types of radiation, without a great loss of energy.

On the other hand it has to be remembered that the performance of coatings in LOCA conditions is important for its qualification and that only the coatings adequately tested can warrant its perfect adequacy and resistance.

The main reason for the safety-relation of coatings within containment is that the coating must not jeopardize the emergency cooling of the reactor core by flaking, peeling or delamination of the film that could clog the strainers and thus possibly restrict or cut-off recirculation of the emergency core cooling water.

However, with aim of qualification, it is started also at ENEA (Comitato Nazionale per la ricerca e lo sviluppo dell'energia nucleare e delle energie alternative), with the cooperation of ANSALDO, a research program to verify the validity of the cited simulation; this research program is described hereafter.

2. RESEARCH PROGRAM

The material for these tests is the same protective coating, qualified for nuclear environments, in the same condition of application and thickness as used in actual conditions.

This is irradiated as to give it an integrated dose up to 3000 KGy (300 Mrad), including dose absorbed in 40 years of normal operation of reactor plus dose absorbed during a LOCA, both for BWR and PWR power reactors.

This irradiation is performed together on a double set of samples both with a photon irradiator and an electron accelerator.

For this comparison very high doses are given because this material shows high radiation resistance up to doses of that magnitude; moreover is important the comparison of relative effectiveness at these dose levels.

Dose levels of 10-100-1000-3000 KGy (1-10-100-300 Mrad) are released with both types of radiation.1); this allows to verify the change of properties considered as significance of damage.

NOTE: 1) The photon irradiation may be done either with gamma radionuclide irradiator, or in Research Nuclear Reactor, after the "Scram". This last technique shows these characteristics:

- Energy and dose-rate of radiation incident changes with time ;
- The irradiation is perhaps more similar to that of LOCA ;
- Difficulty to take accurate dosimetric measurements and to control the irradiation time ;
- Difficulty to irradiate the samples, limited by size (26 mm diameter) of the irradiation channels. It is considered therefore that the disadvantages of this second technique are higher than the benefits and the Co60 cell is so chosen.

As significative parameters i.e. expected to change in measurable amount the following ones are considered:

- tensile strength and, if possible, elongation at break of free coating film;
- decontaminability index (ratio between residual contamination after standard cleaning and the original contamination deliberately carried out on surface with radionuclides in acqueous solution). This index is related to phisical conditions of surface and to microstructural modifications;
- change in color, brightness and chalking, which can be represented in numerical forms following International Standard.

  physical state of the surface, hardness and defects verified to S.E.M.

The change of these parameters, versus received dose, may be represented in plots for both the radiations.

The trend of two series of plots may allow to determine a conversion ratio between effectiveness of electrons and photons, limited to considered properties, which moreover are taken as significative of the performance of coating subjected to two types of radiation.

3. EQUIPMENT AND PERFORMANCE OF TEST

3.1. The photon irradiation has been performed in CALLIOPE (ex AGRIGAMMA) plant, in C.R.E. Casaccia of ENEA (ROMA).

That is set as follows:

- irradiation cell, 40 m^2 surface, with labyrinth entrance and safety system, equipped with Co60 source, with activity in the period of tests (may-august 1987) of 2.6×10^{15} Bq (nearly 70 KCi)
- swimming pool 2 m x 4.5 m x 8 m (depth) into the cell; it is the biological shield for people working in the cell during preparation of facilities
- radioactive source: it consits of 6x7 double incapsulated bars fixed to plane vertical rack 1.00×1.50 m^2; the source can be extracted from pool by means of a winch driven (out from the cell) from the control room
- facilities to allocate the samples; there are mobile carriages and fixed racks. The samples are fixed to this rack at a distance of 30 cm from source, where isodose contour line enough homogeneous and a dose rate as high as 0.8 Gy/sec (0.3 Mrad/h) exist.

3.2. The electron irradiation has been performed at LINAC piant of Centro di Ricerche Fossatone (C.N.R. FRAE Bologna).

The source is a 12 MeV Radiation Dynamic linear accelerator with maximum current 5A, it is a pulsed electron source which energy is greater than the beta typical one.

It is necessary then to lower the energy changing the parameters of the irradiator. At first it has been analysed the electron beam through deflection with an acromatic Brown type system, realized by two 45° deflector magnets and a quadrupolar lens placed in the simmetry plane of the magnets.

The energetic resolution has been performed through adjustable window placed soon after the quadrupolar lens and the electrons, now monocromatic, are collected finally on a graphite absorber placed in front of the exit window.

The mean energy, lowered to 8 MeV, is decreased down to 1-1,5 MeV (Fig. 1) by means of an absorber realized with two Aluminium thicknesses with an internal water circulation, acting as energy absorber and cooling medium.

The electrons are so focused on the samples to be irradiated, and an adequate ventilation is provided around the samples, both to exclude ozone excess, and to lower the raising of temperature, so to minimize the damage to the samples.

3.3. For substrate of the coatings it has been utilized:

- 70x70x0,5 mm^3 sheets UNI 5866 steel equivalent to ASTM A 36
- polyetilene commercial foils, thickness 0,2 m.

This has been layed out on Aluminium 250x250 mm^2 sheets, so to make easy the painting and transport, without damaging the coating film.

3.4. The painting has been performed following the specification of the manufacturer; the steel samples have been sand-blasted before to a level foreseen to be used in nuclear facilities. It is used epoxipoliamidic TITANIA EM paint, of Italian manufacturer VENEZIANI-ZONCA VERNICI S.p.A. (MAX-FIN Group). The coating work has been done by means of spray with two crossed coat; after 24 hours drying the operation was repeated. The coating is cured during 10 days in a room with control both of temperature and relative humidity. The final mean thickness measured on different samples and zone of the samples is 160 $\mu m \pm 10\%$.
It has been used, for transport to irradiation facilities and after to experimental tests, package of Aluminium sheets and corrugated cardboard to allow the coating film to undergo mechanical stresses (impact, abrasion, folding) at a minimum.

3.5. The photon irradiation has been realized (fig. 2.A) on one of these "packages" of four PE coated foils divided by cardboard and maintained in a plane by two 1 mm thick

Al sheets, from which that one exposed directly to source allows also to create on the samples electronic equilibrium conditions.

The assigned doses are, until now, 10-100-1000 KGy which seem adequate for comparison. When the first of these doses is reached, the irradiation is stopped and the upper sample is removed; the irradiation is continued till the next dose; the operation is repeated till the last sample. It has been calculated that, so doing, the absorption in upper layers do not affect in valuable amount the received dose.

The irradiation of metallic samples has been performed in the same manner (fig. 2.B), on three samples placed side by side, laid upon in four layers and removing each time the upper sample; in this case too the absorption in the layers of iron sheets do not affect, in a significative amount, the beam energy and the doses received by the last samples.

3.6. The electron irradiation has been performed through the sample-holder shown in Fig. 3; it contains three sheets of steel and the fourth position allows dosimetric measurements.

A 250 mm x 250 mm painted PE foil and a paper foil to realize electronic equilibrium conditions have been laid upon the holder.

The irradiation has been stopped at the foreseen dose, and four of these packages have been prepared one for each dose to be received.

Until now the assigned doses are 10-100-1000 KGy which as in the case of gamma irradiation, seem adequate; of course with this method the loss of energy and of intensity in PE-coating foil, is considered irrelevant.

The samples have been set at 40 cm from the exit window of electrons; so homogeneity at $\pm$20% of the beam is allowed, according to data obtained with ITS code used for calculations, on transversal surface delimited by a 20 cm diameter circle.

This homogeneity has been controlled by means of photosensible paper at 40 cm from the window. The measure of the blackening, with reflection densitometer allows to confirm the homogeneity is better than foreeseen by calculation.

3.7. The photon and electron irradiated samples together with those not irradiated, as a reference, undergo experimental tests to determine the change of properties which are considered as a measure of radiation damage.

3.7.1. The tensile strength and elongation tests have been realized by means of INSTRON/Mod. TT-CM apparatus, equipped with

suitable load-cell and paper recorder; the speed of displacement of clamps was 10 mm/min.

From PE supported coating samples with suitable tools, ten or more shaped pieces (see fig. 4) of coating 10 mm width x 50 mm, free length have been obtained and gently divided from substrate and then tested.

On all samples, not irradiated too, the elongation was of the order of 1-2% and then not measurable.

The elongation at break and tensile strength are usually considered for organic materials as significative parameters of the received damage even if, as in this case, have little relation to the performance of coating layer.

The results are shown in Table I and in figure 5.

3.7.2. The decontaminability index is a parameter connected to the conditions of the coating surface and has choosen as indicative of radiation damage because usually shows sensible changes with different treatments.

It has been measured following the procedure of Italian Standard UNI 7158, which uses controlled contamination with Co60 and Cs 134 in aqueous solution as chloride, subsequent counting with pulse counter, decontamination with standard solution, and final count of residual pulses. From ratio of two countings (before and after decontamination) the easiness of surface to decontamination can be expressed.

The results are shown in Table II and in plot (figure 6).

3.7.3. The indentation hardness has been determined, for coating films according to Std ISO 6441 (84), where it has been established that this parameter is measurable, provided the penetration of the piramidal top is less than one tenth of the thickness of the coating film, that is in our case less than 16 μm. The measure has been realized through microdurometer DURIMET Leitz; the Wickers hardness has been measured, with 100 g load (HV100).

The results, unfortunately not significant, are shown in Table III.

3.7.4. The colorimetric measurements have been carried out with HUNTERLAB/D25 ML Colorimeter equipped with a D56 lamp. Changes of colour and brigthness have been measured, following the Y,x,y scale of C.I.E. Paris Convention.

The considered changes of parameters are not strictly connected to a loss of good properties of coating film, but measurements versus received doses shown sensible modifications and so it is considered useful to take them as measurement of radiation damage.

The values obtained are shown in tables IV, V, VI, VII and in plots of figures 7 and 8, where the values are obtained on steel supported and PE supported coatings and give different results still to be verified.

4. DOSIMETRY

A comparison of the type here realized is more valid if the same dose is absorbed and if is exactly known in both cases. The differences in energy deposition profile (at the same energy) between electrons and photons, and the differences in damage mechanisms have been already outlined.

It must also be considered that:

- the arrangement of samples in front of sources is different;
- the different type of substrate (steel and PE) can affect the measures due to thermal and backscattering effects;
- the dose-rate is different and for the electrons is almost twenty times greater;
- the small thickness of the coating films is an essential difference in the dosimetric technique.

The techniques used in both cases and the corrections used to take account of cited factors are now described.

4.1.

The dosimetry or irradiations of photons was realized with solid state dosimeter CLEAR PERSPEX Hx according to the usual procedures used in plant (7). This dosimeter is a polimetilmetacrilate manufactured for dosimetric use in form of little sheets: from the change of the optical density after irradiation, measured at 315 mm with spectrophotometer

is possible, through calibration curve, calculate the value of absorbed dose, in Gray, and hence of dose-rate (Gy/s).
It has been choosen this dosimeter for the high accuracy of results, the simple preparation, the independence from dose-rate also when this is high, as in our case; for each reference sample five dosimeters on back face and five on front face have been placed. A dose-rate of 0,85 Gy/s (306 Krad/h) has been measured.
Since the dosimetry with PERSPEX dosimeter allows a relative measurement of the absorbed dose, a calibration with absolute method is needed. It has been used for this the Fricke dosimeter, according to the usual procedures of the plant (7).

4.2. To verify the dose absorbed during electron irradiations a $70x70mm^2$ Faraday Cup 100 mm deep has been realized, with aim to survey an area equal to that of steel samples. The cup and the samples have been mounted on a support as in figure 3; the measurement of the flowing charge is realized through an ORTEC 439 integrator, and to correlate this charge to absorbed dose a calibration has been performed with Fricke dosimeter, as in the case cited in 4.1. Obviously several measurements have been performed to obtain values less affected from casual fluctuations of the electron beam. The so measured dose-rate is 21 Gy/s (7,6 Mrad/h).

4.3. With the methods cited in 4.1 and 4.2 it is possible to obtain the doses absorbed in Fricke dosimeter, where the geometrical conditions are not exactly the same as in protective coating film; in this case the absorbed dose can be therefore measured with more precision and adequacy with other methods.

4.3.1. A series of dosimetric "differential" measurements is in progress (see figure 9):

- the dose absorbed from a particular Fricke dosimeter, which shape is wide and flat (Hettinger dosimeter) is measured, D1 (Gy)
- likewise the absorbed dose, when a protective coating film is interposed, is measured, D2<D1 (Gy)
- if: m 1 the mass of Fricke solution (Kg)
  m 2 the mass of coating sample (Kg)
  the energy loss is $\Delta E = (D1-D2) \cdot m1$
- From here the dose absorbed in the sample is
  $DS = \Delta E/m\ 2$ (Gy)

This method is used for both types of radiation

- The gamma radiation measurements are in progress at CASACCIA, at care of G. SCARPA, Laboratorio Dosimetria and the first results seem adequate to give measurable energy loss, ΔE.

- The electron radiation measurements are in progress at FOSSATONE (CNR-FRAE, Bologna) at care of P. BARTOLOMEI, and in this case too the results seem promising.

4.3.2. It has been proposed during the fist IAEA Research Coordination Meeting (Roma, 1987 September) the use of dosimetric films, for instance the commercial DYE-films.
These are used for measurements of backscattering on electron-irradiated coating films.
The dose is measured when the dosimetric film is put before the paint film (or in place of it), without support (or with PE support); another dose is similarly measured when the dosimetric film is placed before steel supported coating film (or simply before steel support).
The difference between the two measurements give the contribute of the backscatter caused by support. It is remembered that these measurements can be performed with help of efficient ventilation, so to minimize the thermal effects and the contribute of ozone to damage.
The work is in progress, together with calibration of dosimetric films, always with use of Fricke solution; also the irradiations in this case are performed at FOSSATONE.
These measurements cannot be performed with other types of dosimeter because its thickness can quite completely absorb the direct radiation.

5. ANALYSIS OF RESULTS

Both types of irradiation have been ended at 1000 KGy, because for the great part of considered properties the change in comparison to not irradiated samples is already significative. It is remembered that not only radiation damage, but also thermal effects, backscatteri-ng from substrate and oxidation by ozone and peroxides can contribute to this change.

As said before, the elongation of break for all samples is not determinable

- The tensile strength, on the contrary shows a decrease which seems to become very evident for electron irradiated samples at 100 KGy. As said iN 3.7.1. from a foil of PE supported coating, when not irradiated, ten or more shaped pieces can be obtained. On the contrary, when irradiated, the amount of pieces which can be obtained decreases quickly with received dose until not more then three-four integral pieces can be submitted to the test after irradiation at 1000 KGy, so to decrease the accuracy of this measurements.

  The difference between electron and photon irradiated samples can be attributed, besides to a greater effectiveness of electrons, to some backscatter effect, which with the experimental arrangement used for electron irradiation is possible also on PE supported

films. The sensitivity of this property to a little difference of amount of stress make this change especially evident.

- The change in Colorimetric properties, yellowness and brightness, are almost the same for PE supported coatings exposed to both types of radiation. On the contrary, valuable differences exist between the samples irradiated at 1000 KGy with different types of radiation on steel supported samples; the effect is greater for electron-irradiated samples; nevertheless it appears that some amount of backscatter effect exist also for gamma irradiated samples.
- The decontaminability shows a progressive decrease with received dose, more evident for electron irradiated samples at 1000 KGy.

  The samples were on steel substrate and so the clear change of these can be partly due to backscatter effects. The test can be possibly repeated on PE supported coatings, so to verify if this greater change exists also in absence of backscatter effects.
- The indentation hardness shows no significant change and the reproducibility of results is low.

In conclusion, on PE supported coating films, the different radiations cause almost the same change except for tensile strength; on steel support the changes are different and greater for electron irradiated samples; this can be

explained with backscatter effects to be measured, as said, in the further activity. On the other hand, all coatings placed in Reactor Containment are, or on steel substrate, or on massive concrete, which both cause a great amount of backscatter when beta-irradiated.

It must be observed, finally, that the two different types of irradiation are performed, as said, at different dose-rates, greater for electron irradiation. This cannot be the cause of the different damage (8). The material irradiated is oxygen-rich and the low thickness allows in both cases a quick oxygen diffusion.

6. FURTHER ACTIVITY

The dosimetric measurement cited in 4.3.1. can be completely performed within a brief time; after this the plots of figures 5,6,7 and 8 can be adjusted in abscissa, following the corrective parameters resulting from these measurements (DS instead of D1).

Likewise, after the experimental measurements of 4.3.2., can be determined the importance of backscatter on radiation damage of steel supported coating film exposed to electrons. However, when also the decontaminability measurements will be performed on PE supported coating films, it will be possible to take a conclusion on substantial equivalence of electrons and photons on damage, as it appears from colorimetric results, or on greater influence of electrons, as pointed out from tensile strength results.

Finally it must be repeated if possible the electron irradiation on PE supported coating, with a type of sample-holder (a simple frame which mantains in a plane the coating film (*)) which allows that only direct radiation damage, and not also the substrate backscatter, contribute to change the considered properties; in particular the tensile strength measurement will be repeated notwithstanding the delicacy of operations needed to take accurate results, to confirm the previous results.

(*) Adequately ventilated to minimize thermal and ozone effects.

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(8) H. WILSKI - The Radiation induced degradation of Polymers Radiat. Phys. Chem. 29, 1, 1-14, 1987.

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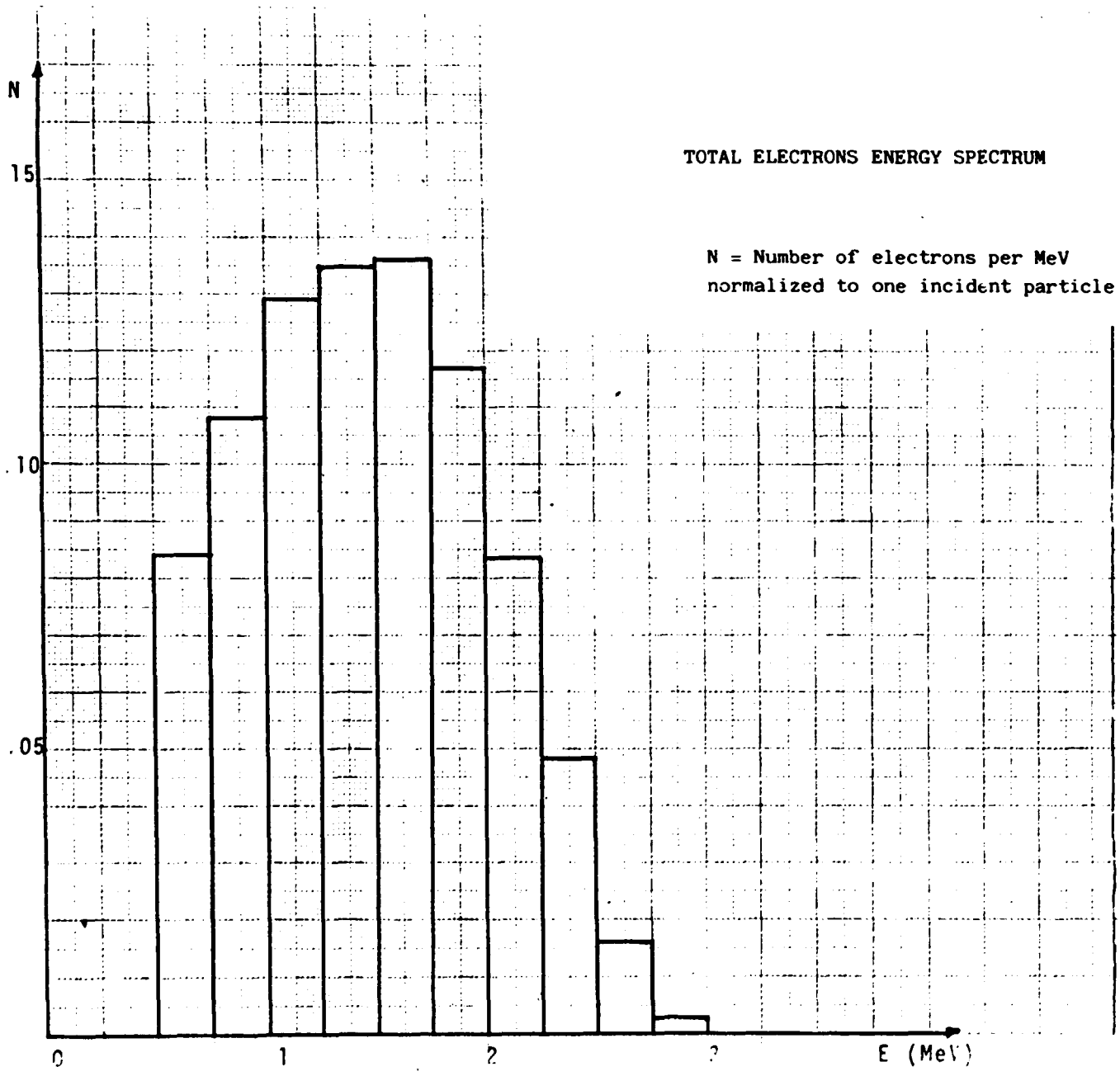
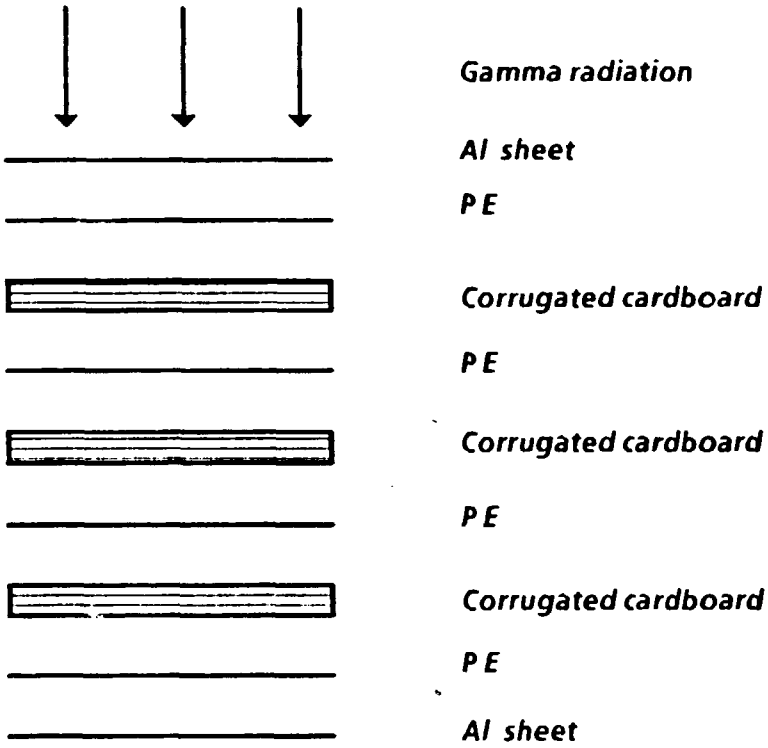
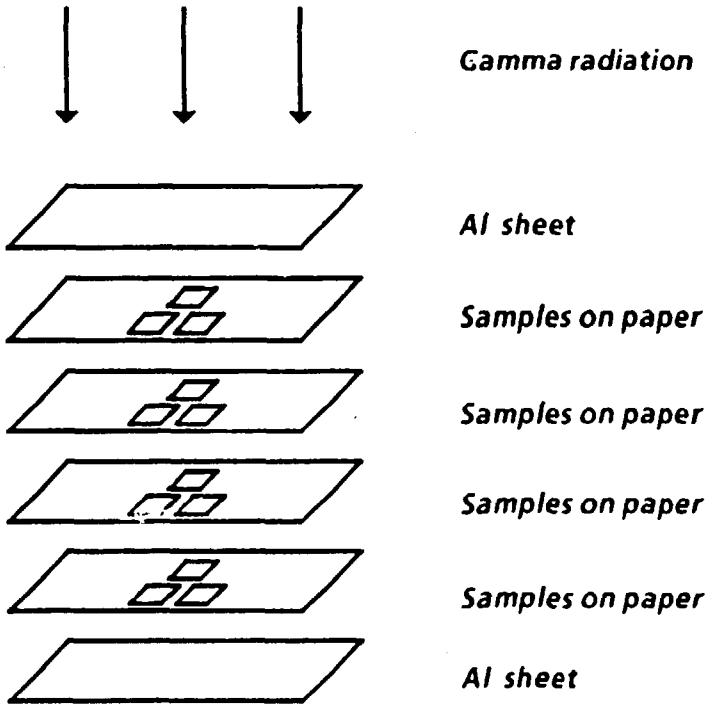


Fig.1 - Calculated mean energy of electron beam

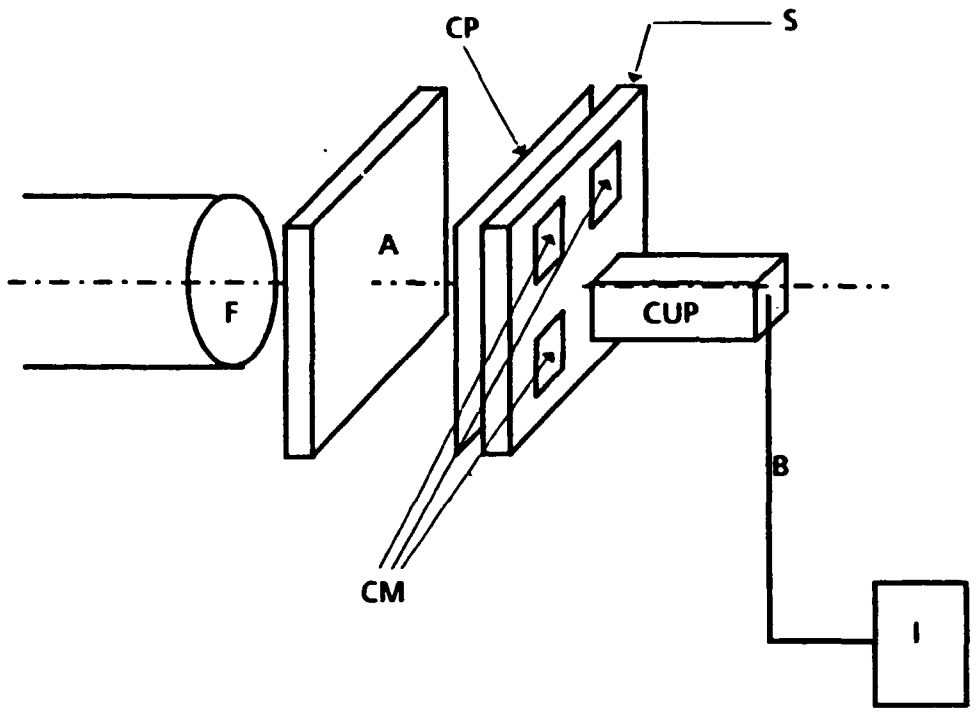


a) Package for irradiation of P E supported coatings (section)



b) Package for irradiation of steel supported coatings (view)

Fig. 2 - Packages used for gamma irradiation



F = Output electrons window
A = Absorber
CP = PE supported coating sample
S = Sample holder
CM = Steel supported coating samples
CUP = Faraday cup
B = RG 58 Cable
I = Remote charge integrator

Fig. 3 - Sample holder for electron irradiation

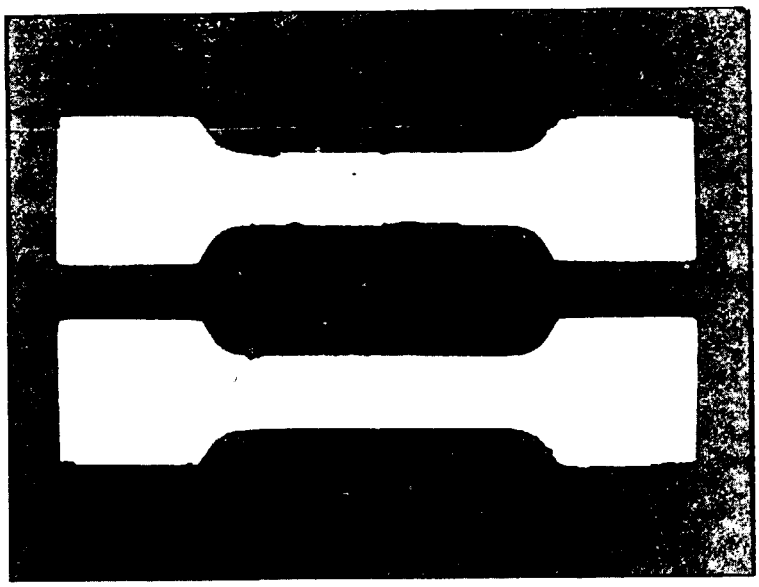


Fig.4 - Shaped coating piece for tensile strenght measurements

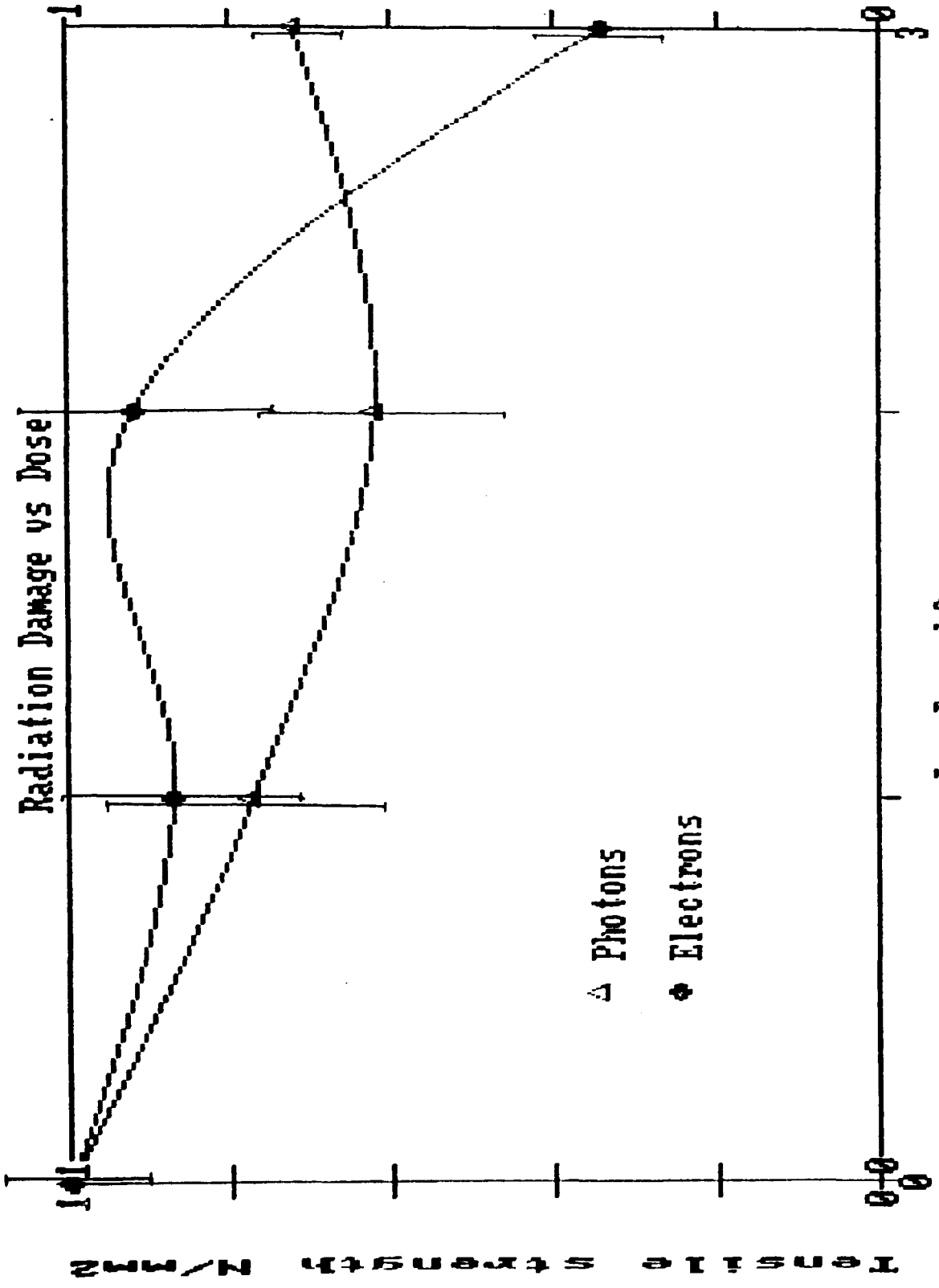

Radiation Damage vs Dose
Tensile Strength N/mm2
Log Dose kGy
Photons
Electrons
1
0
3
0.0

FIG. 5

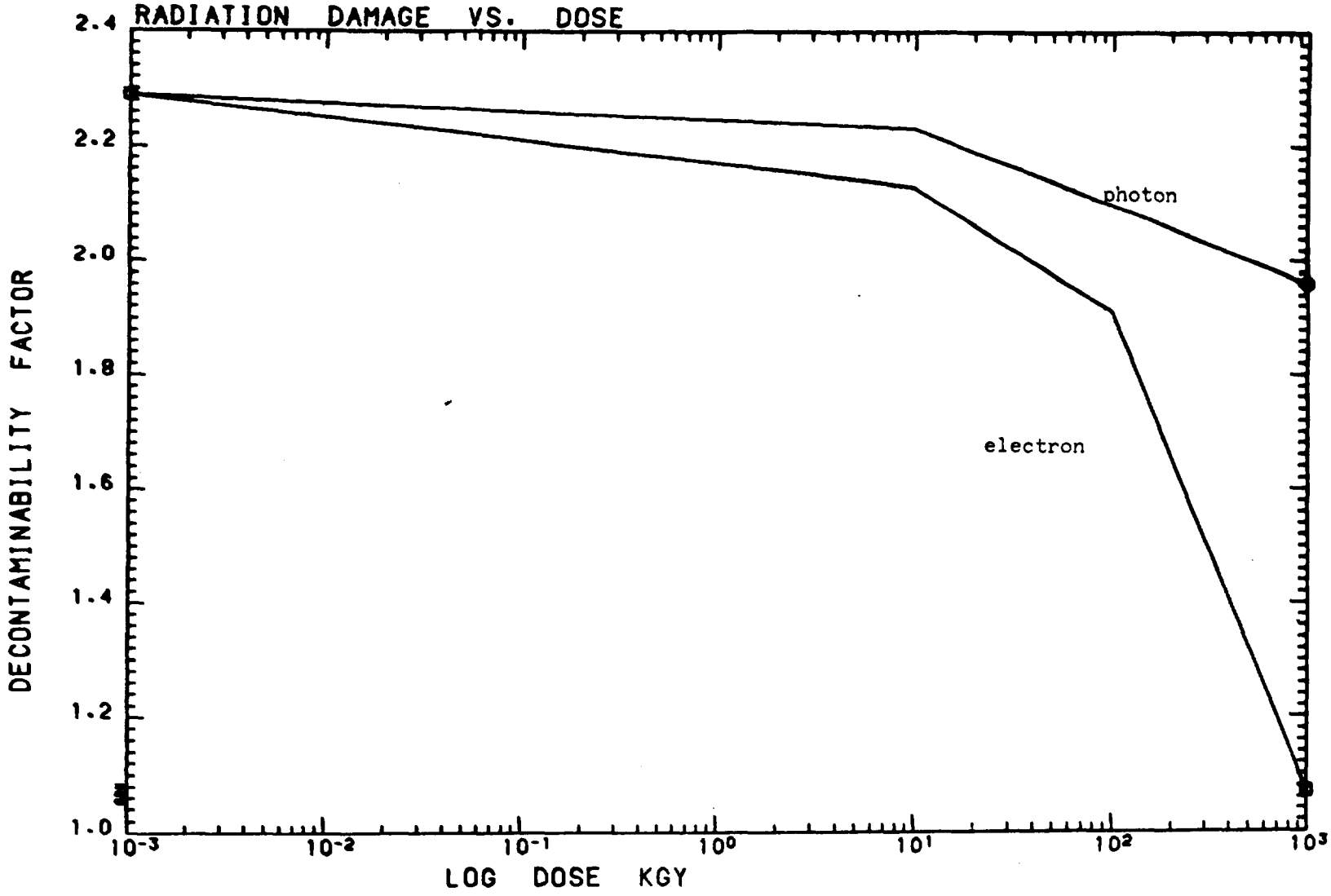

RADIATION DAMAGE VS. DOSE
DECONTAMINABILITY FACTOR
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
photon
electron
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
LOG DOSE KGY

FIG. 6

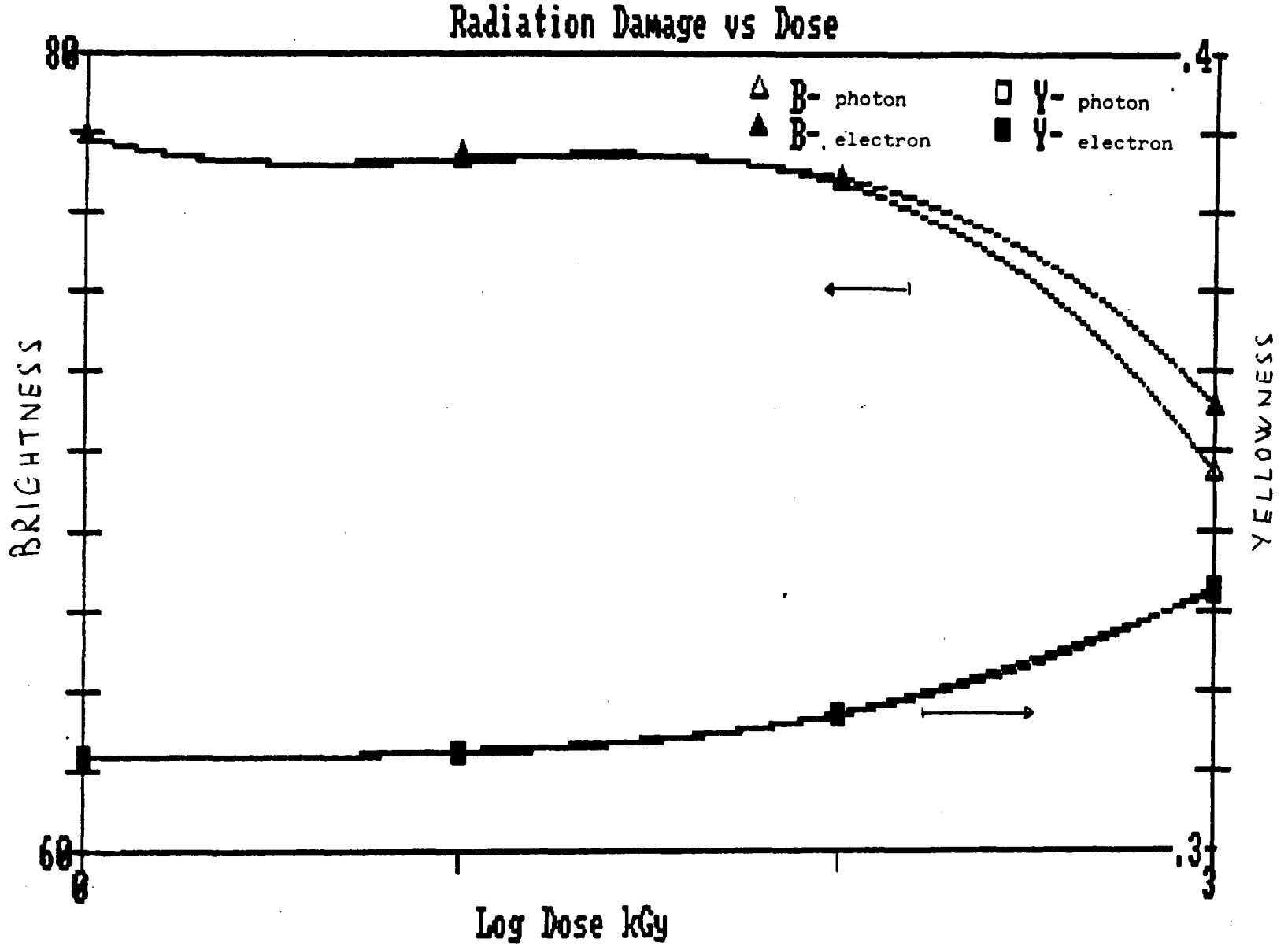

Radiation Damage vs Dose
80
60
.4
.3
BRIGHTNESS
YELLOWNESS
B- photon
B- electron
Y- photon
Y- electron
0
Log Dose kGy

FIG. 7

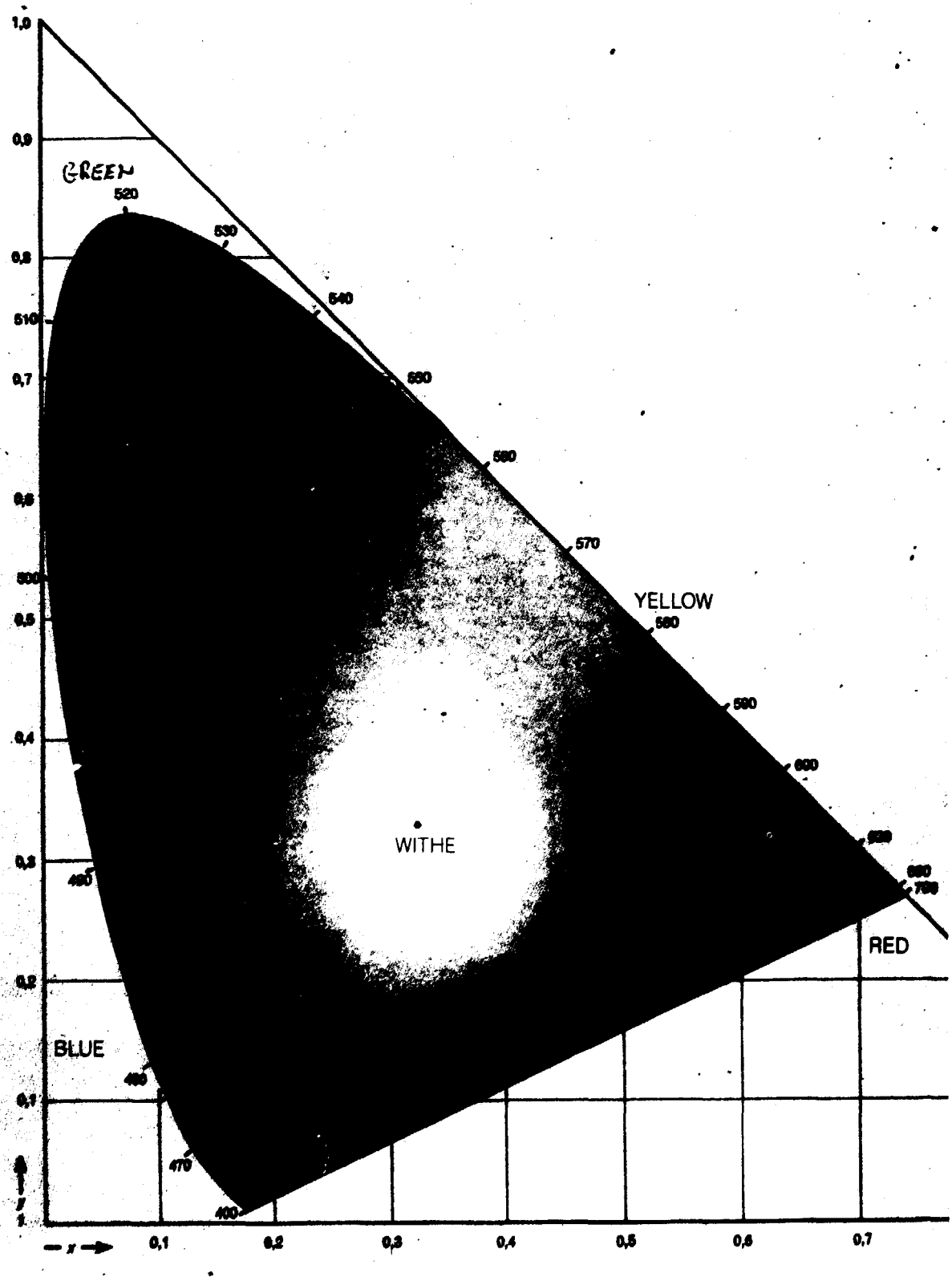

GREEN
YELLOW
RED
BLUE
WITHE
520
530
540
550
560
570
580
590
600
620
700
490
470
400
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1,0
— x —

Fig. 7-bis -

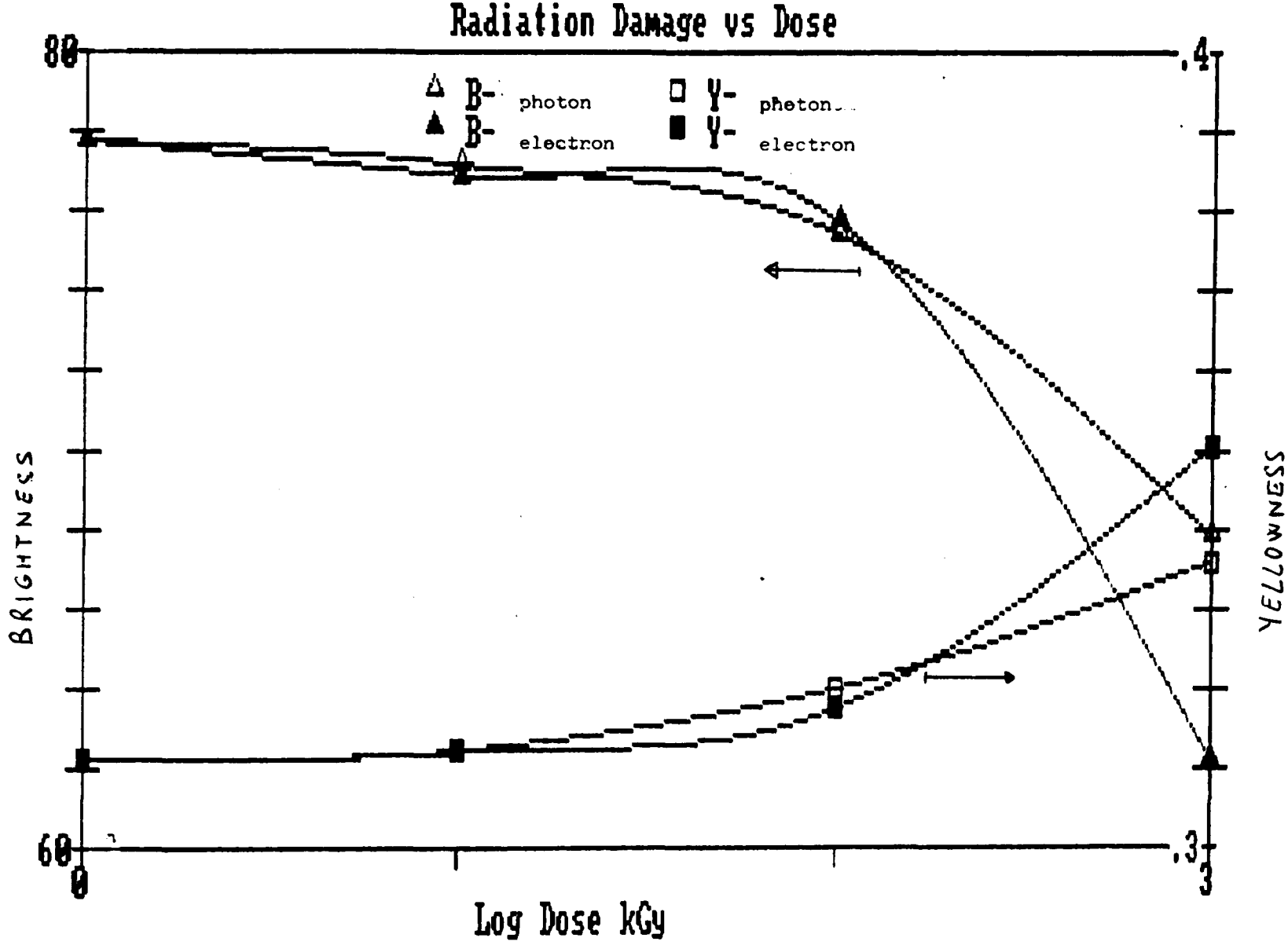
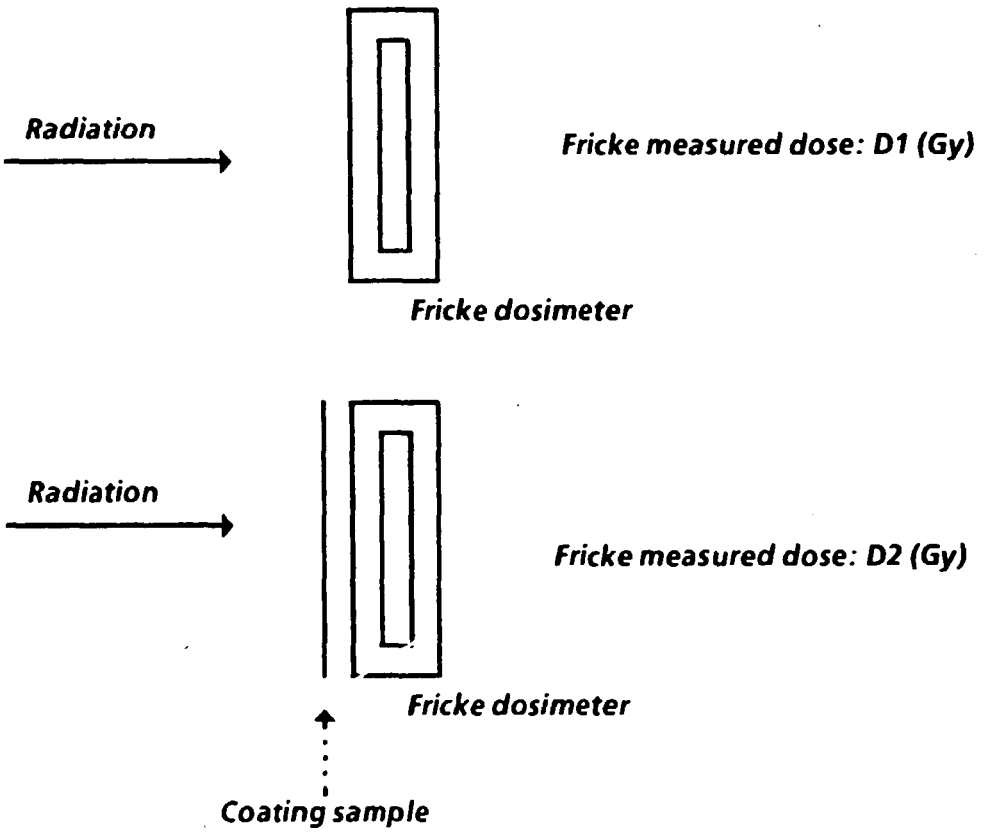

Radiation Damage vs Dose
80
60
0
.4
.3
3
B- photon
B- electron
Y- photon
Y- electron
BRIGHTNESS
YELLOWNESS
Log Dose kGy

FIG. 8



m1 : mass of Fricke solution (kg)
m2 : mass of coating sample (kg)

Energy - loss in the coating sample : $\Delta E = (D1 - D2) \times m1$ (J)

Dose absorbed in the sample : $DS = \frac{\Delta E}{m2}$ (Gy)

Fig. 9 - Outline of dosimetric differential measurement on free coating film

LIST of TABLES

NOTE: All the plots are referred to dose absorbed in FRICKE dosimeter.

Table I - Tensile strength vs received dose

	ZERO	10	100	1000 Kgy
electron	1.00±.17	.87±.17	.92±.20	.34±.08
photon		.77±.19	.62±.19	.72±.11

Table II - Decontaminability vs received dose

	ZERO	10	100	1000 Kgy
electron	2.29±.20	2.13±.15	1.91±.10	1.07±.13
photon		2.23±.17	2.10±.12	1.96±.12

The values reported are the aritmetic mean of the decontaminability to Co-60 and to Cs 134

Table III - Hardness vs received dose

	ZERO	10	100	1000 KGy
electron	11.9±4.1	10.5±0.7	9.5±2.9	10.9±5.0
photon		8.3±1.4	10.4±3.1	9.3±1.5

Table IV - Brightness vs irradiation dose on PE supported coating

	ZERO	10	100	1000 KGy
electron	77.87±.10	77.30±.11	76.85±.04	71.11±.14
photon		77.36±.12	76.71±.10	69.44±55

Table V - Yellowness vs irradiation dose on PE supported coatings
(x of CIE Scale $\times 10^4$)

	ZERO	10	100	1000 KGy
electron	3117±.6	3125±.6	3171±.7	3322±1.1
photon		3123±.5	3169±1.1	3329±2.5

Table VI - Brightness vs irradiation dose on steel supported coatings

	ZERO	10	100	1000 KGy
electron	77.75±.04	76.86±.02	75.72±.25	62.22±.60
photon		77.15±.11	75.41±.04	67.86±.14

Table VII - Yellowness vs irradiation dose on steel supported coating
(x of CIE Scale * 10^4)

	ZERO	10	100	100CKGy
electron	3112±.5	3121±1.5	3174±1.1	3507±16.0
photon		3123±.6	3200±.1	3360±1.1

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