FROM R TO SIEVERT

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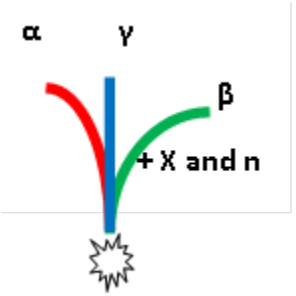
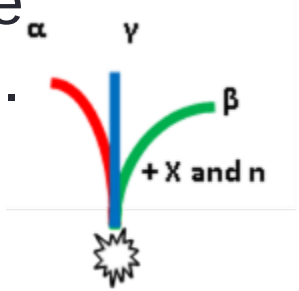


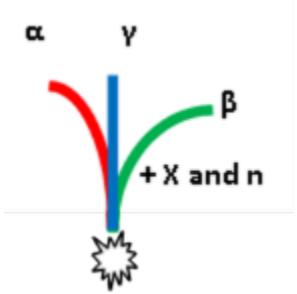
My role

- It started a very, very long time ago (1978) when I was effectively a new grad.
- I worked for the National Radiological Protection Board
- NOT a regulatory body
- Purely an advisory body to government
- But very closely tied to the relevant UK regulator, the Health and Safety Executive (HSE)
- My departmental boss was heavily involved in working out the concept of the sphere as reasonable object to develop operational quantities, i.e. ambient dose equivalent as a substitute (mostly) for roentgen and directional dose equivalent as a substitute for beta dose rate in rads.
- My role was to look at the practical implications



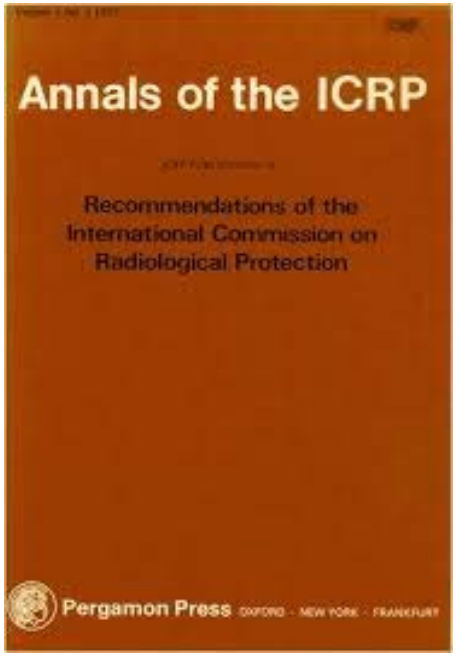
Why did we convert in the UK?

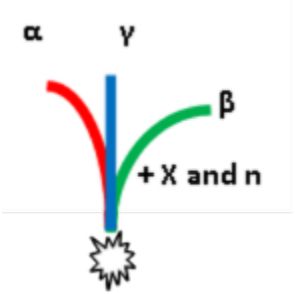
- The UK was very active at the time in ICRU
- Europe was clearly going to convert.
- We had already gone on to SI units in science. I was one of the first school pupils to always work in metres and kilogrammes but all younger than me knew nothing of pre-SI, such as ergs (and inches)
- Engineering was going metric, except for aeronautical engineering – that's still mostly in inches
- The UK was having a "boldly going" moment anyway.
- Many people wanted some sort of universal "Index of Harm"



Specifics

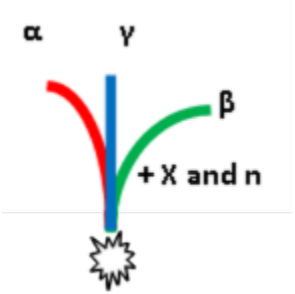
- A legal obligation to use SI units in health protection
- ICRP publication 26, which introduced the concept of effective dose in sieverts (Sv)
- Euratom Basic Safety Standards (The UK was a member of Euratom long before it became a member of the EU) We were legally obliged to enact the 1976 standards by 1980
- These used the sievert





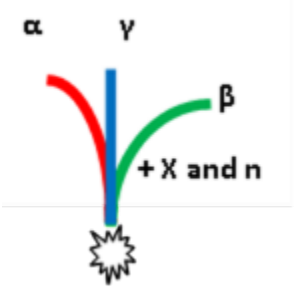
Leading Agency for conversion in the UK

- Scientifically, the National Radiological Protection Board.
- We also had the BCRU, the British Commission on Radiation Units, with members from the National Physical Laboratory, the Central Electricity Generating Board and academia
- It is important to realise that at that time the UK nuclear programme was run apparently as a research exercise, with a relatively low commercial focus.



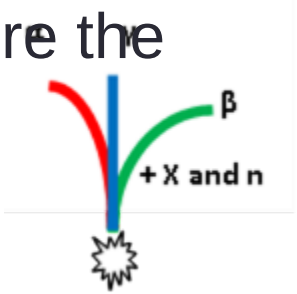
Legislative driver

- The 1985 Ionising Radiations Regulations were the first to be in sieverts.
- Issued by the Health and Safety Executive, a UK government body
- Mandated by the Health and Safety at Work Act, 1974



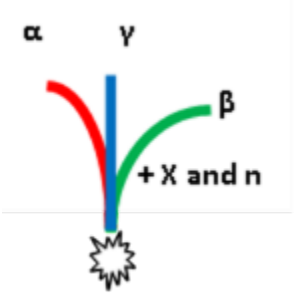
Implementation strategy

- In the late 1970s and early 80s there was a series of papers basically looking at the conversion for photon radiation from R to sphere quantities in Sv
- ICRU 39 in 1985 produced the outline definitive data for the quantities ambient dose equivalent, directional dose equivalent and individual dose equivalent penetrating and superficial.
- In 1987, for example, we published a paper “Current and Future Instrument and Dosemeter Designs to Measure the New ICRU Radiation Quantities”
- Manufacturers quickly saw the opportunities to make money by producing equipment designed to measure the new quantities



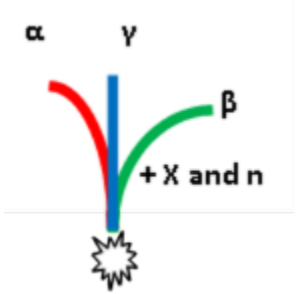
Standards and calibration laboratories

- Rapidly adopted to the new quantities
- Stayed with air kerma or exposure reference X and gamma radiation chambers
- Used conversion coefficients to ambient and directional dose equivalent, rather than changing to an ambient and directional secondary standard, which are not that easy to make and were not available
- ISO4037 lists these for nuclide, filtered and fluorescence X-ray qualities
- Calibration sheets and standard reports modified accordingly



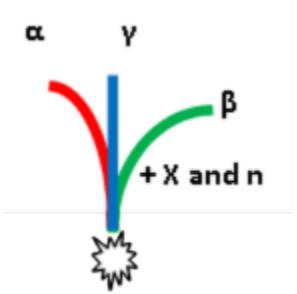
Large users

- Most saw the merit of having instruments reading directly in the relevant quantities, rather than just using conversion factors between R, rads and rems to the legal reporting quantities.
- Far fewer mistakes!
- So the decision then became:
  - just change the legend to Sv
  - Or also modify the energy response to match the sphere based quantities



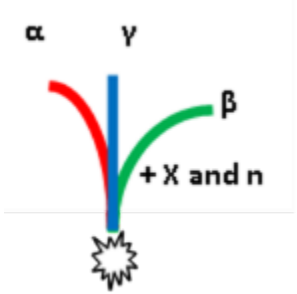
The process – displayed reading

- When the instrument was due for testing (14 month test interval), make the conversion.
- For log scaled instruments with units specified on the dial (popular in the UK), fit a new meter or change the meter scale. Some were easy to change, some required a great deal of care.
- For linear scaled, switch rage instruments, usually 0 to 3 and 10 (dual markings) or 0 to 5 (single scale) on the dial with no units specified, change the top plate or, more simply, stick on a new set of ranges on a vinyl
- For better quality instruments, adjust slightly.
- 100R = 1.04 Sv for H*(10) and Cs-137 gammas



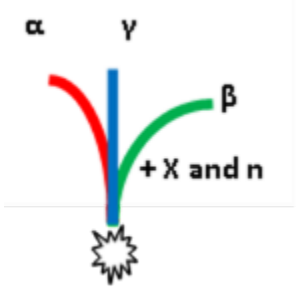
The process – energy response

- Most people lived with what they had because:
  - Most ion chambers over-responded in the right area in terms of R. This meant that the under-response in terms of ambient dose equivalent (cap on or slide shut) and directional dose equivalent (cap off or slide open) was tolerable. This was mainly because aluminised plastic was used as the end window
  - Older energy compensated GM detectors used United Kingdom Atomic Energy Authority designed filters which, again, tended to over-respond in the 50 to 150 keV region in terms of R. This meant that the under-response in terms of ambient dose equivalent was tolerable

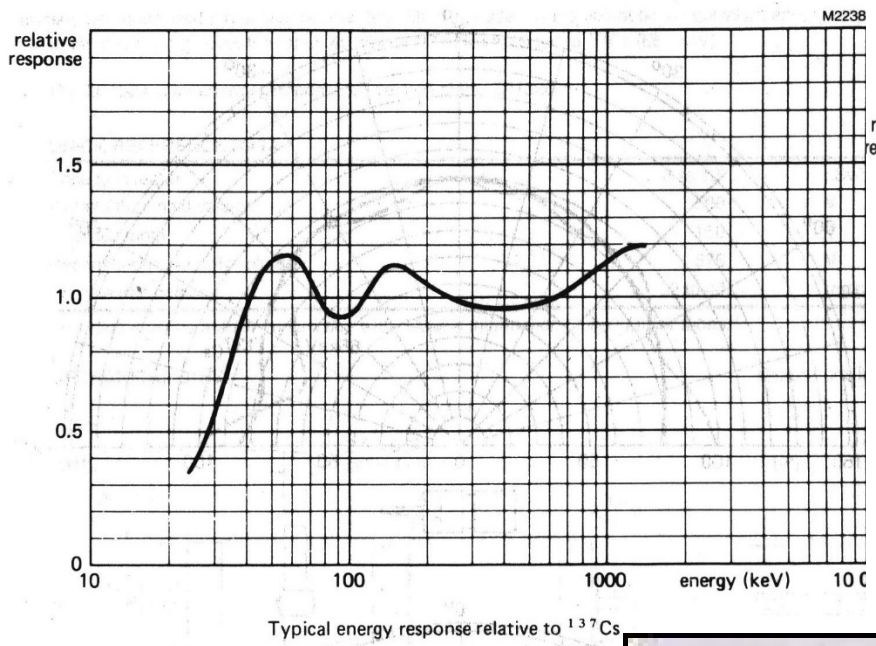


Energy response 2

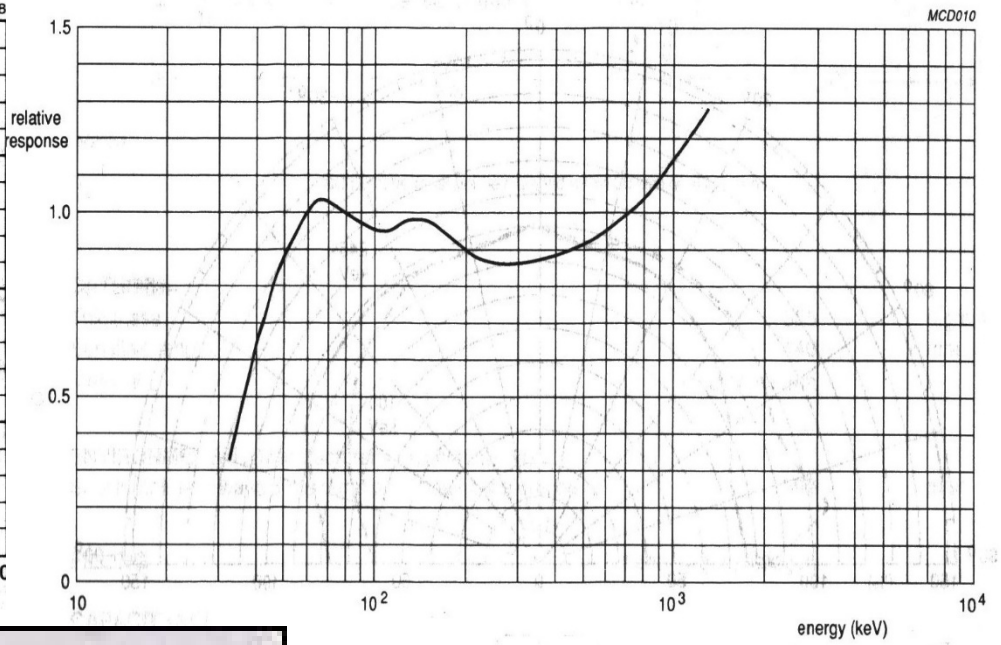
- New GM instruments had more accurate Philips (Mullard) energy compensation filters.
- A few had replacement detectors fitted as the errors at lower energies were larger
- New production switched to ambient dose equivalent designs on the same base GM, e.g. from the ZP1313 to the ZP1314, both based on the ZP1310.
- Ambient dose equivalent ones are easier to make – the 50 % wider gap and slightly thinner filters make it easier to get good polar responses over a wide range

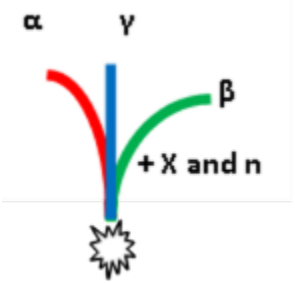


On left, exposure, on right, H*(10)



Typical energy response relative to ^{137}Cs



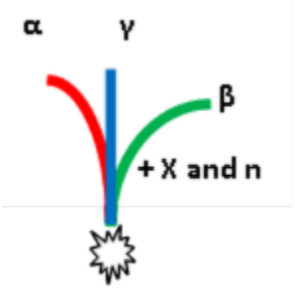


Energy response 3

- The Eberline RO-2 was the exception – very common, relatively popular and expected to have a long life
- Kits were made available. These included:
  - New range vinyl
  - A 1 mm thick aluminium stick-on for the slide to get the attenuation of 1 g/cm^2 of tissue for both photon and beta radiation
  - An aluminium band inside the chamber and an aluminium back plate, both 0.5 mm thick, to enhance the response in the 30 to 200 keV region

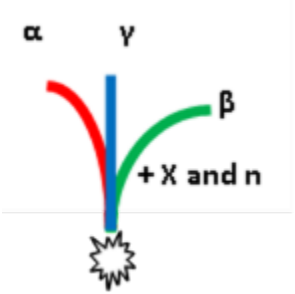
While these were being fitted, the collector diameter was reduced to about half the original, improving the beta response, and an extra connector and clip fitted to increase the not really adequate original 9 volts to 18 volts

Subsequent designs used the same approach



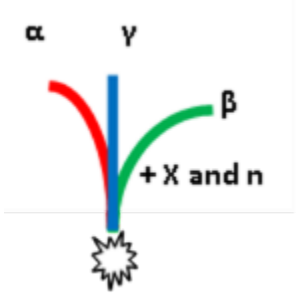
Costs

- About 2 hours to modify the instrument
- Main problem is regluing the ion chamber foil
- Many were modified to use a push-on clamp ring and conducting gasket
- Cheaper in the long run
- Parts were about 10 % of a new instrument
- No real problems EXCEPT hybridisation. The case bottoms can be swapped between instruments easily so
- Exposure based instruments with modified slides
- Modified chamber instruments with original slides



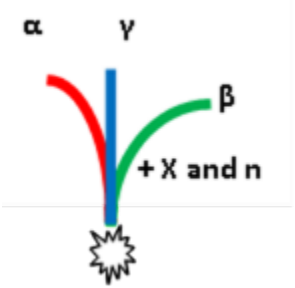
And at broadly the same time

- Changed from curies to becquerels
- A less arithmetically convenient change
- Sensible people rounded limits
- e.g. 10^{-4} microCi/cm^2 became 4 Bq/cm^2, not 3.7
- But operational limits were usually expressed in counts per second anyway
- Very few instruments were ever marked in Bq/cm^2
- A recognition that there is no such thing as a Bq meter and the fingerprint or nuclide vector generally has to be taken into account



Advice from UK experience

- Prepare forms, procedures, notices well in advance
- Parallel measurements for the previous 3 months or so
- Define mega, kilo, milli, micro etc. on forms. Don't let people chose
- For "old" data, always quote both. People will worry about corrupt conversion for waste records etc.
- Lots of training at appropriate level.
- Credit card sized summary card
- There will be mistakes!
- From The Day, new units only. Otherwise people will hang on to the old.
- New RP staff should be trained to be bi-lingual



The card

SI UNITS FOR RADIATION PROTECTION

RADIATION DOSE — REM TO SIEVERT

10	µrem	–	0.1	µ Sv
100	µrem	–	1	µ Sv
0.75	mrem	–	7.5	µ Sv
1	mrem	–	10	µ Sv
2.5	mrem	–	25	µ Sv
5	mrem	–	50	µ Sv
10	mrem	–	100	µ Sv
100	mrem	–	1	mSv
500	mrem	–	5	mSv
1	rem	–	10	mSv
5	rem	–	50	mSv
10	rem	–	100	mSv
100	rem	–	1	Sv

Sv	to	rem	× 100
mSv	to	rem	÷ 10
µ Sv	to	mrem	÷ 10

rem	to	Sv	÷ 100
rem	to	mSv	× 10
mrem	to	µSv	× 10
µ rem	to	µSv	÷ 100

Use the same Factors for gray (Gy) to rad and rad to Gy

QUANTITY ACTIVITY

NEW UNIT BECQUEREL = 1 dis. per sec.

No. of Ci × 3.7×10^{10} = No. of Bq

No. of Bq × 2.7×10^{-11} = No. of Ci

PREFIXES FOR UNITS

SUB MULTIPLES			MULTIPLES		
10^{-3}	milli	m	10^{3}	kilo	k
10^{-6}	micro	µ	10^{6}	mega	M
10^{-9}	nano	n	10^{9}	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f	10^{15}	peta	P
10^{-18}	atto	a	10^{18}	exa	E

SI UNITS FOR RADIATION PROTECTION

ACTIVITY – CURIE TO BECQUEREL

1 Bq 37 Bq 37 kBq 370 kBq

27 pCi 1 nCi 1 µCi 10 µCi

3.7 MBq 37 MBq 370 MBq 3.7 GBq

100 µCi 1 mCi 10 mCi 100 mCi

37 GBq 370 GBq 3.7 TBq 37 TBq

1 Ci 10 Ci 100 Ci 1000 Ci

DERIVED LIMITS (DL 'S)

FOR SURFACE CONTAMINATION

µCi cm^{-2}		* Bq cm^{-2}
10^{-5}	—	0.37
10^{-4}	—	3.7
10^{-3}	—	37
10^{-2}	—	370

* SOME ESTABLISHMENTS MAY USE A ROUNDING CONVENTION

DERIVED AIR CONCENTRATION (DAC)

EXPRESSED AS Bq m^{-3} (see ICRP 30)

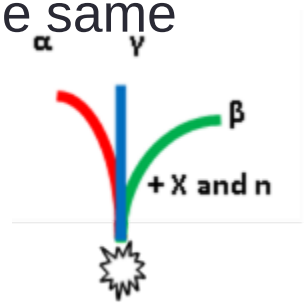
TO CONVERT µCi cm^{-3} to Bq m^{-3} :-

No. of µCi cm^{-3} × 3.7×10^{10} = No. of Bq m^{-3}

U.K.A.E.A. - HARWELL

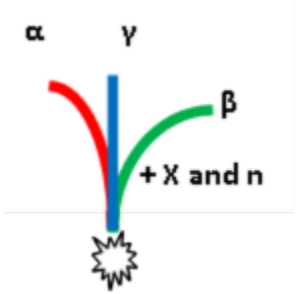
Education

- A long, slow, hard process!
- Many people thought they understood roentgens, rads and rems. They rarely did, to any depth
- For the Radiation protection Advisors (= certified health physicist), a series of training courses which explained:
  - What the new quantities were
  - The simplification = 100 R is close to 1 Sv difference, so the new numbers will differ mainly by factors of 10 and 100
  - where readings would differ more than the rescaling factor, e.g. 1 mR/h would become 14 µSv/h
  - And the very useful fact that ambient dose equivalent would predict the maximum dose accumulation rate on a dosemeter at the same point in space



For the workers

- Kept simple
- Change building by building, so no Sv/R mixture if at all possible.
- Concentrate on the 1 Sv = 100 R major change
- Allude to the fact that there would also be other differences. For example, for UKAEA glove boxes containing Am-241, 10 mR/h wouldn't change to 100 µSv/h, it would probably go to 150 µSv/h
- A detailed list of where the problems occurred and how these were dealt with is available.



Metric all the way?

- In the UK we still run on miles and pints of beer.
- All butchers etc. are bi-lingual
- Building materials can be asked for in feet or metres
- People still talk about miles per gallon even though we buy fuel in litres
- Most people work in centigrade. I have to do the sums to convert to Fahrenheit. But some still think summer = 70^0
- Property is often in acres but sometimes in hectares
- People can be either 5’11” or 1.79 metres
- And 11 stone 5 lbs (159 lbs) or 72 kg