Modelling a commercial cobalt-60 tote irradiator using the Monte Carlo code egspp, and validation using a real-time dosimeter

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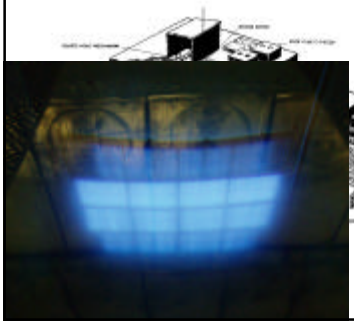
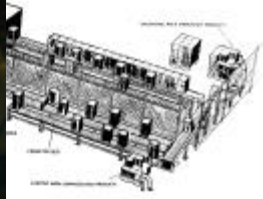
Introduction: Motivation

- Modelling of a full-scale gamma irradiation facility
  - Monte Carlo modelling is not used very widely in UK radiation processing industry, compared with companies overseas
  - NPL project with REVISS Services (UK) Ltd and Isotron plc, to investigate benefits of modelling a full plant
  - Nordion JS-9600 plant at Bradford selected
- Validation of approach using Real-Time Dosimeter data to confirm Monte Carlo code predicted dose rates
  - RTD originally built at NPL several years ago, uses VHS tape to record output from ion chamber dosimeter after signal processed through radiation resistant electronics
  - Recently modified and improved
- How necessary is it to model the full facility – conveyor details etc?
  - Examples of dose maps with/without full details
  - Egspp used as this enabled fairly intuitive entry of extremely detailed geometry

Nordion JS-9600

- Overview:
  - Up to 3 MCi cobalt-60 in source rack with 16 modules of 42 source





Real-Time Dosimeter

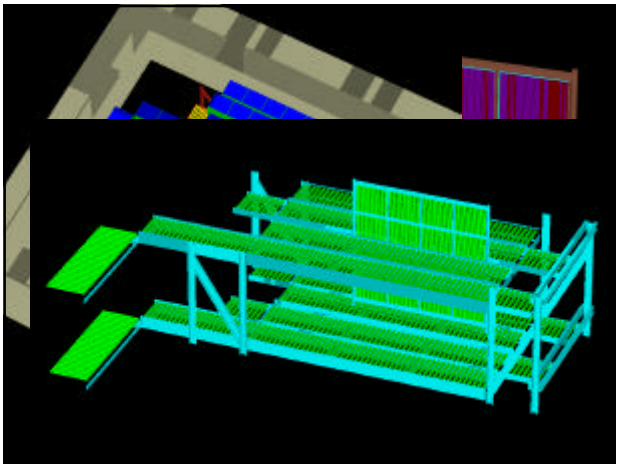
- Battery-powered
- Sensors:
  - Ionisation chamber, response ca
    with 300V DC supply from onbo
  - Calibrated thermistor
- Radiation-hard electronics
  - Mainly valves rather than transis
- VHS tape deck
  - Recorded signals from ionisatio
    signals, on 1mm wide audio trac

EGSnrc/egspp:

- Egspp: New C++ front end for EGSnrc Fortran back-end
  - Has full state-of-the-art electron/photon tracking of EGSnrc but controlled using simpler input file
- Intuitive text-based geometry and source handling
  - Distribution includes reasonably powerful 3-D geometry viewer, can be used to identify/eliminate geometry errors
  - Can handle huge numbers of geometric entities, sources
  - Advantageous to use scripts to generate repeated elements
- Still contains a few bugs and issues:
  - Full-up simulation deposits dose in ~17000 regions
  - Up to five million regions created, mostly redundant as a result of nesting and combining geometry units
- Calculated dose delivered to 1809 regions – 27 “dosimeters” in 67 totes
  - Slight mod to output just to print results for non-zero doses, otherwise output up to millions of lines long
  - Script then extracted doses only from dosimeters

Modelling: Geometry

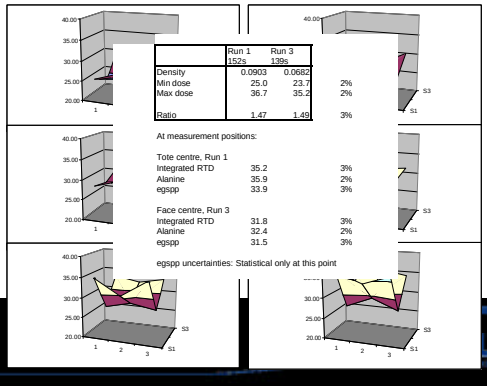
- Object: Create the full irradiator, exploring how well this could be done with egspp
  - Build totes, source rack, conveyor frame and rollers, concrete shield
  - Source rack complete with dummy pencils; each pencil assigned an individual activity
  - Scripts used (Fortran) to generate repeated geometric and source units
    - Dosimeters
    - Totes
    - Source pencils
    - Conveyor rollers
- Investigate whether simplifying geometry would cost significantly in accuracy
- Confirm results of calculations with RTD



Measurements:

- RTD travelled around cell five times:
  - Run 1: 152 seconds, density 0.0903 g cm^{-3}
  - Run 2: 146 seconds, mixed densities
  - Run 3: 139 seconds, density 0.0682 g cm^{-3}
  - Run 4: 139 seconds, density 0.0682 g cm^{-3}
  - Run 5: 159 seconds, data not used
- Data from Run 1 and Runs 3 and 4 (combined) were used
  - Run 2: Product of different densities in vault.
    - This situation is what we might call "future work"!
  - Run 5: RTD VHS rollers radiation damaged: Signal degraded

Results:



	Run 1 152s	Run 3 139s	
Density	0.0903	0.0682	
Min dose	25.0	23.7	2%
Max dose	36.7	35.2	2%
Ratio	1.47	1.49	3%

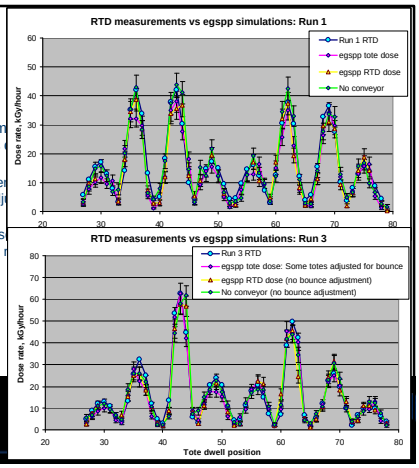
At measurement positions:

Tote centre, Run 1		
Integrated RTD	35.2	3%
Alanine	35.9	2%
egspp	33.9	3%
Face centre, Run 3		
Integrated RTD	31.8	3%
Alanine	32.4	2%
egspp	31.5	3%

egspp uncertainties: Statistical only at this point

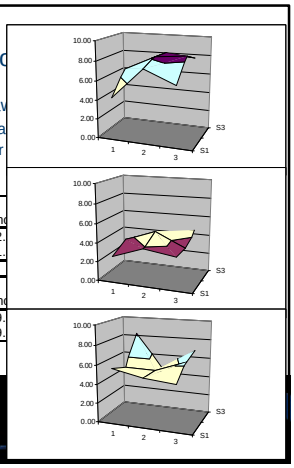
Results:

- Dose rates:
  - Initial runs prom
    measurements
    adjustments
    - Height of ce
      opposite adj
      vault!)
    - Position of s
      rebound on



Results with conveyor remo

- Removal of the conveyor takes av
  - Calculated overall doses significa
  - For this type of irradiator, vital for
    capture these effects



- Run 1:

Cycle time 152 s	Conveyor: With	Withe
Max dose	36.7	42.
Min dose	25.0	31.

- Runs 3/4:

Cycle time 139 s	Conveyor: With	Withe
Max dose	36.7	39.
Min dose	25.0	29.

Summary:

- The new egspp Monte Carlo code has been successfully used to simulate a complex gamma irradiator
- Predicted dose rates are a close match within uncertainties, with directly measured dose rates and overall doses
- Inclusion of the conveyor system in this type of irradiator, is imperative if good agreement with measured doses is required

- The NPL real time dosimeter delivers results good enough that validation of the Monte Carlo approach to modelling these irradiators can be carried out
- Temperatures were also recorded, but a significant part of temperature increase was due to close proximity to warm concrete and warm air above source rack
  - Cumulative dose did not follow temperature curve

Further work:

- Could use these models to establish behaviour of plants for routine process control, investigating statistical process control application
- Examine behaviour of delivered doses under conditions including mixed loads
- Investigate improvements to irradiator conveyor design

References

1. I Kawrakow and DWO Rogers: *The EGSnrc Code System: Monte Carlo Simulation of Electron and Photon Transport* NRCC Report PIRS-701, November 2003
2. JP Sephton PHG Sharpe, RDH Chu, KPJ O'Hara, F Abdel-Rehim, A Abdel-Fattah: *Dose mapping of a 60Co industrial rradiation plant using an electronic data recording system, static measurements and mathematical modelling* Rad Phys Chem 76 (2007) 1820-1825

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