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Minutes from
The DOE Lung Intercalibration Committee Meeting
Idaho Falls, Held May 2&3, 2000.

DOE Lung Intercalibration Committee Meeting 2000

Approximately 40 participants from the United States of America, Canada, France, and Belgium (including suppliers from Canberra, PGT, Eurisys) attended the meeting held in Idaho Falls, May 2-3, 2000.

Opening address - Rick Cummings

Rick briefly mentioned DOELAP and the accreditation process. The process seems similar to Canada now. Failure can lead to serious consequences. DOELAP is trying to increase the lung library (fission product) and start the thyroid intercomparison program in 2002.

Gary Grothaus (chairman) is retiring soon and he was instrumental in setting up accreditation programs. This will be his last workshop. Tracy Jue will take over from Gary, when he finally leaves. She will also take over Rick=s role as program administrator in the future.

Martial Huver (France, Eurisys Mesures). The new counting system at Cogema

The system consists of four Eurisys HpGe detectors 8 cm diam, 25 mm thick, 0.8 mm C window, LN cooling, 60 hr holding time. Detectors not in centre of Dewar, but offset to outside edge. This allows them to be put close to each other. The system can be used for lung and WBC

Large counting room (2.3 x 2.3 x 2.3 m) with graded shielding. Pb lined with Cu as the last layer. Automatic LN filling. Forced air ventilation with Rn free air. Local background 7 to 10 uRad/h

Detectors can be run independently or summed (this gives best MDA). The system was calibrated with the LLNL phantom using B-series overlay plates and ^{235}U, nat U, ^{241}Am, ^{239}Pu, ^{152}Eu, ^{137}Cs

Resolution is 320 to 390 eV at start of spectrum and 2200 eV at end of spectrum for individual detectors. For the summed spectrum the resolution values range from 350 eV at 7 keV to 2400 eV at 1500 keV range.

Efficiency curve showed. Background 1800 secs in empty chamber with spectra summed. MDA in empty chamber: 3 Bq for Am-241, 2249 Bq for Pu-239

Using a person, 7.3 Bq U-235, 14 Bq Am-241, 14.6 kBq Pu-239, 9.1 Bq Cs-137, 81.7 Bq K-40 (1800 secs).

Detection limit changes with CWT. MDA calculated from 8.8sqrt(R*B)/E*I*T where: R=FWHM, B=mean background counts (cnts/keV). MDA for U-235 varies from about 2 - 9 Bq from 1.5 to 4.5 cm.

Conclusion. The new Ge system is as good as the previous phoswich system. Benefits from high resolution for identification. System is more flexible (can do WBC)

Jean Loius Genicot (SCK.CEN, Belgium) Background reduction

Background in chamber is always highest when the person is in the chamber. The MDA with empty chamber or blank phantom will underestimate the MDA. When detector volume increases, so does the background. This means the MDA rises. Detector thickness should be optimised for the energy of collection. Ideal thickness is when the thickness of the detector captures most of the photons.

Shielding can affect the continuum, and graded shielding is not always an advantage. Cu can add to the continuum as shown in an empty chamber test (54,000 sec) with 2 and 3 mm thickness, so Pb only is good for U-235.

Independent detectors (not just a summed array) are necessary to test for heterogeneity; otherwise you are just adding background counts and no signal.

Four effects, environment, volume/thickness of detector, shielding, position (number of detectors)

Other work has shown that shielding is unnecessary when using the small Si detectors.

Future work: detector jacket, CdZnTe 1mm, Si 1,2,3 mm, thin HpGe, compare storage well with shielded room for background.

See HP March 1999 for Background interpretation.

David Groff (Canberra) BeGe detectors in Accuscan-II for low energy photon emitters.

Similar properties to the French system for FWHM. BEGE 50% vs Traditional 50% coax gives better efficiency. Of course, this is not necessarily a valid comparison for lung counting. Canberra promotes these detectors for both lung and WBC counting.

Lung counting goals summarised (not new). ACT-II system reviewed. Cannot be used for WBC as efficiency is low, and FWHM gets very poor. Dual purpose count system reviewed (KAERI system). This now replaced by Accuscan-II with two 8 cm diameter BeGe ($200,000 US). Energy range is 10 - 15000 keV. LLNL phantom used for lung calibration. Standard RMC-II phantom for WBC calibration.

As lung counting, subject sits on stool leaning forward on stationary detectors for 1800 sec. CWT calculated from height and weight (or manually entered from ultrasound)

Compare two BeGe (50 cm^2) to four LeGe (28 cm^2) (shield 5,000 kg instead of 16,000 kg).
Both detectors systems are 2 cm thick Above 300 keV BeGe is more efficient than LeGe system

Region	BeGe	LeGe	
U-235	130	40	total counts in region for 1800 sec count.
Am-241	230	49	
Am-241	0.78	1.15	%counts/gamma emitted
U-235	0.77	0.96	
Am-241	14	4.7	MDA using Currie formula in Bq based on CWT of 2.25 cm
Th-234	130	47	
U-235	7.5	3.4	

Advantage of this system is that can be used as WBC with a scanning detector configuration for 5 min count. Can also be run in MCS mode.

MDA=s are <370 Bq for fission products (i.e., ^{60}Co, ^{137}Cs).

Tim Lynch (PNNL) - Coincidence summing with ^{152}Eu/^{241}Am lungs.

1500 lungs counts per year for Am and Pu at his site.

Four 7 cm x 3 cm PGT detectors with Be windows. Detectors on long arms and calibrated with LLNL phantom with summed output. Four detectors are in a horizontal plane and not adjusted from person to person. Gives reproducible geometry. Used ^{241}Am, natU, ^{235}U lungs (#516, 557, 550) for gold standard. Calibration takes 18 measurements.

Now want to use ^{241}Am/^{152}Eu lungs phantom for calibration as it will cut down on the number of counts. (17, 26, 40, 45, 60, 122, 344 keV lines used) Only need five measurements as a base curve. Calibration curve looked OK. Did cross calibration with Am, and U phantoms. Am and Th results 5 to 10% high. ^{235}U was 25 to 30% higher at 185 keV. Seemed like coincidence summing was responsible for the deviation.

Examples of how sum peaks are formed: 122 + 45, 122 + 345, 122 + 773 etc
This leads to Anew≅ peaks at: 167, 367, 900, 689, 595 keV

Did further checks with other phantoms and found the same things. Question, do we want to correct for this?

Concluded that coincidence summing can affect accuracy of low energy lung counting; therefore, should calibrate with single nuclide sources, and that the effect is geometry (system dependent) and activity dependent. Discussion suggested that the PNNL electronics could be responsible as literature results and other lab=s data seem to refute this finding. May also have something to do with detector thickness.

Dave Hickman (LLNL) Mixed oxide lung counting using ACTII detectors.

Detector size: 7 cm x 2 cm. Lung set contains Pu-238, Am-241, U-235, U-238 (1,192; 323; 2.12; x nCi). Many of the X-rays overlap. Measure Am-241 at 60 keV, U-235 at 186 keV, Pu-238 is hard

Using LLNL phantom (CWT=2.56 cm). Resolution ~0.35 @17, 0.46@60 keV, 0.63 @122 keV
Pu high energy counts often missing if amount is low. Need to improve resolution to separate the x-rays and see the Pu x-rays directly. Can also try to de-convolute the spectrum using standard shapes and stripping techniques.

Using Abacos which has multiplet analysis and interference correction. The first fits a number of peaks to a user defined region and relies on the FWHM to be well known. The Gaussian sensitivity factor can be a nuisance and results in too many peaks being identified. LLNL uses a Gaussian sensitivity if 40 and Joel Webb at the CEMRC uses 80.

The second is a weighted linear least squares solution. Not well documented by Canberra.

Experimental results show measured to actual ratios are (measured/actual) 1.49, 1.39, 1.8 (CWT ~1.5, 2, 2.7) with no correction. Above 3 cm the ratios increase up to 7 for 17 keV. With correction the ratios are 0.95, 1.94, and 1.72 (4 cm is highest CWT). Above 3 cm the Abacos software fails and does not treat peak as a multiplet. The corrected values are obtained with the interference routine. U-235 does not contribute much to 17 keV multiplet, main problem is Am-241.

Things might be improved if there was a capability for FWHM calibration at each CWT instead of just a single curve.

Steve Allen (Cameco). Lung counting system replacement.

Steve reviewed Cameco=s role in uranium industry, history of lung counting, showed pictures of existing equipment, described calibration and analysis routines, and showed two commercial proposals. The advantage of the front and back detectors allows him to identify surface contamination easily. How will this be done with a front mounted system (Ge)?

He asked the assembly for advice on the replacement criteria based on some concerns that he identified during the presentation. Two vendor proposals were presented to the assembly.

Questions asked: diameter (70 or 80 mm), thickness for 185 keV, bed or chair, surface contamination identification, LN or mechanical cooling, optimal detector mounting, analysis software, movement

problems of detectors (warm or cold), and dose limit is 4 mg.
Discussion pointed out that the LLNL phantom could not be used to calibrate for posterior lung counting because of the absence of the scapulae and results from that type of calibration for low energy applications should be treated with suspicion.

Election of New Chairman

Four names were proposed as Gary Grothaus= replacement: Joel Webb, Tim Lynch, Tracy Jue, and Govind Rao. It was pointed out that Joel Webb was not a valid candidate and spirited discussion followed. Finally, the objection was withdrawn and Joel=s name was allowed to stand. Voting was by secret ballot amongst the committee members.

The successful candidate was Tim Lynch. Tim Lynch addressed the assembly to discuss the next meeting. Tim proposed the next meeting be held in May 2001. Bob Keys suggested it might be better to wait for a couple years. Representatives from ORNL and RF indicated they would talk to their management about possibly hosting the next meeting and get back to Tim. Tim indicated the meeting could also be held in Richland.

David Hickman (LLNL) LLNL=s new wound counter.

The wound (not lung) counter is simply a small NaI detector attached to a portable MCA and laptop. The unit is much smaller than the one described at the Bioassay conference some years before.

The MCA is a Canberra Inspector and Genie PC is the analysis software. Excel is used for data collection and reporting. With different detectors, the counter can also be used for thyroid counting.

Data steps: QC count, personnel count, background count.

Activity is calculated using a wound depth correction factor $0.882e^{-0.294D} + 0.016e^{-0.125D}$ at 17 keV where D = depth in mm and is user entered. First coefficient include most of inverse square effect, second is mostly just attenuation, especially as distance increases beyond 4 cm.

Depth and efficiency errors are propagated.

Advantages of the system include: portable, simple, efficiency determined at time of measurement, computations archived, can explore the effects of depth on activity, other radionuclides can be evaluated if they have energies similar to standards.

Milan Gadd (Rocky Flats) Lung counting at the Rocky Flats sites.

Rocky Flats is in a closure mode and is being decommissioned at about 50 years of operation as of 1992. Expected close 2006. It used to make warhead parts.

There have been a number of contamination incidents at the site with detectable lung burdens. Mostly as a result of fire incidents.

Although it was recognised that Pu could not be measured in the lung, a lung counter was justified on the basis of enriched uranium. June 1964 saw the system on line, and routine counting began in 1965.

Calibration was with the REMAB phantom with no CWT correction. Phoswich was the main counting system, although others were used experimentally (Gas proportional, SiLi).

1965: Pu fire - 400 people counted and 25 were >16 nCi. Lung counting was more sensitive than urinalysis at that time.

1969: GeLi used for evaluation. Two detectors on the chest and one on the liver. A second shield was installed Another fire in 1987. Rocky Flats was US first site to use germanium detectors for lung counting

GeLi were 1000mm2. MDA was 1.4 MPLB at 52 keV.

Pictures of early electronics showed walls of modules with paper tape and teletypes.

1970's GeLi in routine use, third and fourth shields put in place. Fourth shield now in MAYAK (Russia) GeLi=s replaced by planars. CWT correction begun and ultrasound work also. Masonite sheets were used on the REMAB phantom to simulate CWT. Detector was placed under the armpits.

1980's LLNL phantom used for calibration for 2000mm^2 x 20 mm thick Ge detectors. Dental chair used. 5,500 counted in 1984. Organ pipe detectors introduced. Eight detectors per room, but only six used. It was a problem to keep them running.

1994 equipment failing so that only one room could be kept running. Ortec 70 x 30 detectors acquired with C-fibre windows. Four used, two per lung.

Two rooms in routine use, 30 min count, four detector array, MDA for CWT 3.36 cm: 0.5 nCi U-235, 0.2 nCi Am-241, 0.7 nCi U-238. 3.29sig used to calculate MDA.

Now doing 2,500 count per year. A mixture of lung, routine, new hire, termination, skull, liver, wound, etc. counts.

Joel Webb (CEMRC) Evaluation of Ge detectors by experimental and Monte Carlo approach.

The experimental work was performed at CEMRC and MCNP done at HML. Both projects were done independently. Joint work sent to Health Physics for publication.

Used the 8 cm diameter 2 cm thick BeGe. Simulated efficiency for 2,3 and 4 detector arrays.

Background was measured using a BOMAB phantom. OK for comparative measurements of background. All data normalised to the 7 x 2 cm detectors.
Pictures shown of detector placement and it is clear that only three of the large detectors would be needed based on LLNL phantom.

Efficiency and background plots shown. MDA of 3 and 4 large Ge detectors is about 20% better than the four-detector array (70 x 20). Surprisingly the 2-detector array is about the same. At 185 keV there is a small improvement.

MCNP shows thickness immaterial at <60 keV. Larger diameter is better. Similarly, thickness does not impact MDA at low energy. The large diameter improves MDA by about 15%.

	CEMRC 70x20	2 BeGe	3BeGe	4 BeGe
U-235	2	2	1	2

Idealised MDA (Bq) for LLNL phantom with CWT of 1.7 cm and no K-40.

Tracy Jue (RESL) DOELAP multi use counting fixtures.

Tracy showed pictures of the lung verification equipment for BOMAB, lung and thyroid phantoms that we saw on the tour and described the techniques used: direct counting, Dr^2 capability, planchet counting, gravimetric, etc.

Didier Frank (IPSN ,France) SiLi detectors and their In Vivo application and MCNP work.

Ge for low energy x-rays measurements is hard: LN cooling, need heavy shielding, difficult to use large area, not very portable, high Dl

Need an alternative semiconductor that operates at room temperature. The Si detector was chosen for further study. Two projects identified: lung counting and wound counting.

These detectors have low E and need a multi readout electronic system with low noise characteristics. A collaboration was set up 1995-1998 a metrological study, 1998-2000 the technical feasibility. First attempt was a hybrid system (nucl inst meth a380 371-375 1996). Worked on improving resolution and background reduction.

Background of Si is lower that Ge by a factor of 1.5 to 1.7. LLNL phantom was efficiency mapped to optimise position of Si detectors. Si can go to 600 cm2 and reach a Pu-239 MDA of 2000 Bq. (RPD 1999 83(4) 309-315) This reference gives MDA for other applications.

Still have to improve resolution <1.5 keV), integrated electronics, thickness. In collaboration with Canberra a 16-element detector was built (1296 mm2 total area). Also built a 64-element detector. Cooled by Peltier cooling to keep the temperature constant. Resolution is about 1 keV. Acquisition

set-up has been designed for the elements and testing is underway at this time.

Conclude that there is high potential for lung and wound measurements. The detector has been demonstrated as being technically feasible. There will be a paper in RPD in 2000 on 2D and 3D applications. Si is limited by its energy response. CdTe detectors will be looked at.

MCNP work. In Vivo calibrations.

Physical phantoms are limited in their application as they are often single sized, organs are fixed etc. This can be solved using a virtual phantom created from existing voxel phantoms (Norman, Visible Man). Want to take advantage of advances made in PV-wave to create an MCNP file. PV wave will be used to create an anthropomorphic phantom for MCNP input.

CT images used to create numeric phantom, create phantom sources, image processing, source creation, detector positioning, creation of MCNP file, calculation and visualisation of detector spectrum. MCNP is limited in the number of vowels that can be used, so the images must be reduced so there is some loss of resolution. Of course, it simplifies the model and reduces the calculation time.

Detector creation looks simple and there are procedures for detector positioning in 3D space. Looks easy.

Optimised voxel coupling (i.e., grouping of similar characteristics and reduces calc time by a factor of 6 for rough res or 336:12 for high res), resolution and energy of detectors (uses expt data to enter resolution into MCNP), intrinsic efficiency correction of MCNP results (I.e., obs/cal - varies with energy)

Compared experimental and measured results for LeGe with LLNL virtual phantom and Am-241 activity and the results were within 15% at 59.5 and 20% at 26.3 keV.

Now using the visible man voxel phantom for future studies. Still working on LLNL phantom validation. Principal problem is segmentation of the phantom.

Mac Ennis (LLNL) Gammavision at LANL

FWHM set to about 4 channels at 0.15 keV/ch. Low energy range set to 300 keV. High-energy range set to 0.4 keV/ch to get up to 3.3 MeV. No simple way to sum detectors and as gains are slightly different LANL uses an external program to do a gain shift, sums, and exports back to GammaVision for analysis. The mechanism of summing was explained in more detail.

There was a Pu-238 incident (nose swipe was high for one person). 17.4 keV had an interference at 16 keV, 20.8 keV had poor shape, but results were found to be good. Spectrum (2,000 sec within 24 hr of incident) showed small peaks above background - subject had Pb apron over his hair. CWT correction performed.

Counted person 10 times at 4,000 sec per count and then summed all the spectra. Pu clearly seen. Lung burden estimated at 38 ∀ 20 nCi from first count. 41 ∀ 6 nCi from sum analysis. Individual detector data not analysed at this time, so there is no information about distribution. He is currently undergoing chelation therapy. Looks like Type S material. He will be monitored for some time to come. Urine bioassay will probably be the method of choice for dose estimate.

Peter Olsen asked if the person would be willing to travel to different counting sites for analysis but as the man is undergoing chelation therapy it is not certain if this will be a useful exercise.

Conclude: GammaVision worked well for LANL, some functions are not well automated, but software is evolving quickly. LANL will be obtaining Rennaissance32 from EG&G as a replacement code.

Peter Olsen (PNNL). Technological improvements and overcoming adversities in DOELAP lung production.

Lung phantom production was unstable due to a composition change in the material in 1998 due to a ban on the use of Freon. Lungs shrank 2-3 mm with a deviation of up to 10% in response (measured at PNNL). But, the buyer rejected them.

New materials had to be identified. Many tests tried, but everything shrank (including Henry Spitz=s supplier, but he has a stockpile of the original materials). Foamex XDS-272 (RSD>s new material offered by Mark Basic), but cannot add solvents to the mixture. The new foam gives higher gas pressures when foaming.

Finally, 5.25% $CaCo_3$ (this is more than before but is the same as the original Anderson spec) worked. Attenuation of this material agrees with ICRU data at 17 keV. 0.26 g/cc is target density.

Radiochemist (Sam Glover) at WSU has left and gone to U. of Pittsburgh. Both would like to continue in the validation program. So now it is uncertain where the lung flash can be sent for analysis. Second method is to use Dr^2 as an alternative method for validation. When it's working the way its supposed to, Peter will be able to create Reference Lung phantoms. No supplier can meet the performance specs of the S-100 board for the TTL pulse out. The third alternative is to count the lung phantom and determine the activity at two different laboratories.

XCOM1.3 used for attenuation calculations. Last two columns are total attenuation with and without coherent scattering. Last column is most important as nobody can measure the coherent scattering.. Great agreement (<2%) between new TEM and ICRU 44 adult (healthy) lung tissue.

Other findings. PNNL moulds 2% smaller than the original moulds. Wanted to do laser machining to scoop out moulds, but it did not work. One set of original moulds available that could be used (had to be modified for higher foaming pressure - increase size of vent hole). Has to be decontaminated by

a 3-step process after each lung set is manufactured. Original positives missing, presumed lost.

A new mixing gun will be used to combine PartA and /PartB. Leftovers can be added to another shape for validation. There is no cleaning as the mixing cylinders and spout are disposable. Mixing is very thorough as it folds over itself 48 times. Part A is chilled to slow down the reaction as foaming is fast. This is a good improvement as there is now 1.5 min to dispense the mixture for foaming.

Joel Webb (CEMRC) Effect of 657 m cosmic ray shield on In Vivo measurements

This is a work in progress, not much data but lots of pictures of WIPP. Background radiation is terrestrial, cosmic and the subject. Shields work well on terrestrial, but the cosmic goes straight through (fortunately very few interact with the shield). Cosmic is dominated by high-energy protons and neutrons. They interact with the atmosphere to produce a shower of muons (pion decay) that has high energy. They add to background through capture, decay, ionisation and collision.

What changes happen if muons are removed (reduction of 100,000 in WIPP mine). Single detector lung counter in shadow shield design 10cm Pb shield with graded liner (built from Pb bricks, Cd sheet, and stainless steel sheet). Used 8 x 2 cm Ge detector. Measured shield empty, BOMAB, 3 subjects, and KCl bottle. 30 min count time. Detector was placed in the middle of the sternum. Repeated measurements on the surface.

Found a factor of 10 reduction in background (46 to 2.4 MeV) for empty chamber. For a human, the reduction was much less.

keV range	empty	BOMAB	Human	KCl bottle	Reduction in MDA
3-9	127	140	37	39	7.1
9-25	11.2	11.9	5	4.4	2.5
25-250	8.2	8.3	2.8	2.4	2
250-1500	9.5	9.3	2.8	2.3	1.9
1500-3000	44.6	61.3	30	51.5	10.7

Background for lung count, background reduction 3.5 - 6.4. MDA=s reduced by a factor of approximately 2. Discussion pointed out that background reduction could be due to removal of equipment (i.e., counts underground compared to counting room on the surface). So perhaps the good improvement would be less.

This work points out that lung counting seems to have reached the limit of sensitivity with current technology.