8 Personal Recollections

8.1 Biological radiation science – Associate Professor Roger Martin

The radiation facilities and availability of radioisotopes at ANSTO, and previously the AAEC, proved to be a valuable resource for radiobiologists and other university researchers involved in radiation research in the biomedical sciences. AINSE's overall brief in facilitating access to these resources provided important support for these research activities.

A critical early development in providing support in this area was the initiative of the inaugural Scientific Secretary, Bill Palmer, in organising the first of the AINSE Radiobiology Conferences. The records indicate that Dr George Watson, the Chief of the Health Division at AAEC, was an important contributor to this initiative, which followed the inauguration of AINSE Radiation Chemistry Conferences several years earlier.

Unfortunately the program for the first AINSE Radiation Biology Conference held in the AINSE theatre is no longer available, however, it is recollected that 47 scientists from universities, the AAEC and other institutions, attended.

Following this inaugural Radiation Biology Conference, meetings were organised biennially until the 13th Conference in October 1991 at the AINSE Theatre at Lucas Heights. The first 13 conferences were dedicated to radiobiology but as indicated in Table 19, from 1993, combined meetings were held with scientists from other radiation science disciplines. In particular, the AINSE Radiobiology and Radiation Chemistry Conferences were merged. For the first ten years the average number of papers presented was about 25. The significant increase of submitted papers for the 7th conference in 1979 necessitated the introduction of poster sessions, which became a permanent feature at subsequent conferences.

In an attempt to provide more exposure for poster presenters, Ron Cooper at the first combined meeting in 1993 introduced the practice of 2 - 3 minute oral presentations, in which authors presented their posters. These later became called 'Poster Blitz' sessions in 1998 and 2000. At the first combined meeting, the organisers deliberately avoided separating chemistry and biology into different sessions, and the heterogeneity was especially evident in the poster sessions. Table 19 focuses on the biomedical science components of the combined meetings.

The highlight of AINSE-sponsored conferences, in all radiation science disciplines, was undoubtedly the International Congress of Radiation Research, held in Brisbane in August 2003. Indeed, this could reasonably be inserted at the end of Table 19 between the 2000 and 2006 entries. ICRR2003 was a great success, putting Australian radiation research 'on the map'. Over 1,000 delegates attended the four-day meeting.

AINSE radiobiology conferences provided an important forum for the scientists involved in AINSE-supported research, and in retrospect also provided an interesting record of the research activities. For the most part, recipients of AINSE research awards and fellowships take the opportunity to report their progress at AINSE conferences. In reviewing the historical development of the scientific activities associated with the disciplines now embraced by the Biomedical Science and Biotechnology Specialist Committee, the proceedings of the AINSE radiobiology conferences provide the information to build a picture. Indeed it is interesting to follow the changes and developments in the areas of interest. In addition to this overall scientific perspective, browsing through the proceedings of the AINSE Radiobiology Conferences, one is struck by the number of prominent Australian scientists who participated.

At the second conference, in 1969, 25 papers were presented. The presenters included two prominent medical researchers; namely Dr Donald Metcalf from the Walter and Eliza Hall Institute and Dr Paul Vincent, who later became the Director of the Kanematsu Institute in Sydney. Other prominent Australian biomedical scientists who participated in AINSE Radiobiology Conferences include

- Dr M A S Moore (3rd; 1971) from the Walter and Eliza Hall Institute in Melbourne who went on to a prominent career in the USA
- Dr Jim Peacock (4th; 1973) from CSIRO Plant Industry, who became the Chief Scientist (2006 - 2008) after a prominent career at CSIRO

Table 19. AINSE Radiobiology Conferences

RB conf #	date	Total (posters)	Invited Overseas speakers	Mammal (+drosoph)	Bacterial	DNA Rad chem	Ecolog Epidem	Nuclear Med	Other Clinical	Free rad biomed	Miscell (dosimetry methods)	NCT*	Special themes
1	Nov 67	22											
2	Nov 69	25		6 (2)	5		2	2	7		1		
3	Nov 71	25		10 (1)	9		1	1	2		1		
4	Oct 73	24		8 (1)	5				3		8		
5	Oct 75	23		7 (2)	5				2		6		
6	Nov 77	26		10	5		4	1	2		4		
7	Aug 79	38 (9)		15 (2)	8		5	1	3		3		
9	Aug 83	43 (21)	1	24	5		4		5		5		
10	Aug 85	36 (12)	3	19	7		6	1			3		
11	Aug 87	37 (11)	1	17	5		4	1	1		4		Food Irradiation (5)
12	Sep 89	35 (9)	-	19	3		6		1	4		3	Non-ionising radiation (2)
13	Oct 91	46 (13)	1	23			1	2	2	1	7	6	Apoptosis; Low Doses (5)
14A; MAC	Feb 93	42 (29)	6	13		6	2	5		3	4	9	Nuclear medicine; NCT; DNA radiation chemistry
14B; MEL	Nov 94	33 (16)	3	8		3	3	5	1	3	8	2	Nuclear medicine
15 Rad96	Nov 96	44 (23)	3	10		3		7	4	9	7	4	DNA radiation chemistry
16 Rad98; MEL	Nov 98	51 (17)	3	4		3	5	8		27	4		Free Radicals in Biomed
17 Rad 2000	Nov 00	30 (8)	5	9		5	5	2		3	6		
18 Rad2006; SYD	Apr 06	44 (16)	-	8			3	4		5	24		Medical dosimetry

*neutron capture therapy

- Charles Geard (2nd; 1969, 3rd; 1971, 4th; 1973) who pursued a successful career at Columbia University in New York, where he is currently Associate Professor
- The late Dr G S Hodgson (4th; 1973) who was Director of Research at the Peter MacCallum Cancer Centre until his retirement in 1995
- Professor Chev Kidson (5th; 1975, 6th; 1997), the then Director of the Queensland Institute of Medical Research
- Dr Jenny Graves (5th; 1975) who is currently Professor of Genetics at the Australian National University and a renowned expert on marsupial genetics and the molecular biology of X chromosome inactivation
- Professor Martin Tattersall (7th; 1979) a prominent medical oncologist in Sydney
- Dr Richard Gibbs (10th; 1985), then a PhD student at the Cancer Institute in Melbourne (now Peter MacCallum Cancer Centre), pursued his career in the USA where he made a prominent contribution to the Human Genome project (DNA sequencing)
- Professor John Kerr (University of Queensland), who is acknowledged as the first scientist to describe apoptosis, was an invited speaker at the 13th conference, at which apoptosis was a major theme
- Dr Michael Fenech (9th, 11 - 13th) who with Alec Morley (8 - 11th) is credited with the development of the micronucleus assay.
- Dr Norman Swann of the ABC Science Unit gave the speech at the conference dinner at the 10th meeting in 1985.

None of the above notables could be described as radiation scientists, but their participation in the AINSE conferences reflects the engagement of Australian radiation researchers within the wider research community, and the facilitation of that engagement by AINSE. Analysis of the contributors (presenters and chairpersons) indicates the importance of the AINSE radiobiology conferences as a forum for Australian researchers engaged in biomedical radiation research. Many scientists were regular contributors over a long period of time, as is evident from Table 20. The best example is Professor Martin Lavin who has attended all the AINSE radiobiology conferences since 1975. Drs Donald MacPhee and Janus Gebicki are other examples of university researchers who have had the benefit of AINSE radiobiology conferences over an extended period, as did Professor Peter Parsons and Dr Y A E Bick. Moreover, what Table 20 does not show is the large number of graduate students for whom AINSE conferences were their first conference experience. Of course some of these, like Paula Imray and Bill Diver continued participation at the postdoctoral level.

Table 20 also shows that the radiobiology conferences were a valuable forum for AAEC/ANSTO scientists, Keith Brown being a good example. Dr Keith Brown, Dr Des Davey and Dr John Clouston were part of a significant radiobiology enterprise at AAEC under the leadership of George Watson who, as noted above, was instrumental in the organisation of the first radiobiology conferences. He is recorded as convenor of the 3rd radiobiology conference in 1971, and it seems likely he was scientific convenor of the 1st and 2nd conferences, but there are no records to confirm that assumption. George Watson also participated in the 11th conference in 1987, as a retiree.

The steady decline of radiobiological research at ANSTO during the 80s was punctuated by a very active research effort in Boron Neutron Capture (BNCT), lead by Professor Barry Allen and centred around the thermal neutron beam he developed on the MOATA reactor. This effort peaked in the early 90s, and provided many contributions to AINSE conferences, and supported a number of AINSE postgraduate students. The closure of MOATA, and Barry's later departure from ANSTO, brought the program to an end.

The consistent participation of Ross Jeffree from the Environmental Science Division of AAEC/ANSTO is notable, and perhaps suggests that the AINSE radiobiology conferences may have been the only national forum for presentation of research in the specialised field of radioecology. Similarly, Michael Izard, Pam Wills and John Twining from AAEC/ANSTO have been frequent participants.

Table 20. Frequent Contributors to AINSE Radiobiology Conferences

Name of Presenter	Affiliation	Details of Conference Participation	
		Total	Conference Numbers
Martin Lavin	QIMR	15	5-18
Keith Brown	AAEC/ANSTO	11	2-11 & 13
Roger Martin	Peter MacCallum, Melbourne	11	8, 10-18
Barry Allen	ANSTO, St George Hospital, Sydney	10	9-15; 17 & 18
Janus Gebicki	Macquarie University	10	5-6, 10, 12-13, 14B-18
Donald MacPhee	La Trobe University	9	3-11
Ross Jeffree	AAEC/ANSTO	8	8-12, 14A, 16 & 17
Paula Imray	University of Queensland	7	3-7, 9 & 12
Barry Lee	The University of Melbourne	7	2-3, 6, 8-11
Ian Radford	Peter MacCallum, Melbourne	7	9-11, 13, 14B, 16 & 17
Djunia Bick	University of Tasmania	6	2-4, 6, 7 & 9
Des Davey	Health Division, AAEC/ANSTO	6	2, 7-9, 11 & 13
Ruth Moore	Peter MacCallum, Melbourne	6	4, 6-9 & 13
Bill Diver	La Trobe University; Peter MacCallum	5	4-6, 9 & 11
Sir Ernest Titterton	The Australian National University	5	6-9 & 11
Bob Anderson	University of Auckland, NZ	4	14B-17
P R Bates	University of Queensland	4	9-11, 13
John Clouston	AAEC	4	2-4 & 6
Michael Fenech	Flinders University; CSIRO	4	9, 11-13
M E Izard	AAEC/ANSTO	4	5, 7, 14A & 15
I S Jenkinson	St Vincent's Hospital, Sydney	4	3-5 &
A Morley	Flinders Medical Centre	4	8-11
Peter Parsons	La Trobe University	4	2, 6, 10 & 11
Dennis Podger	CSIRO, Molecular Sciences, Sydney	4	6, 8-9 & 11
Michael Westerman	La Trobe University	4	3, 4, 7 & 10
J R Twining	ANSTO	3	10, 12 & 14B
Pam Wills	AAEC/ANSTO	3	2, 6 & 11
George Watson	AAEC/ANSTO	5 (+ 2?)	1 (?), 2 (?), 3, 4, 6, 8 & 11

Table 19 also illustrates the changing trends in the topics of interest for the earlier radiobiology conferences. The radiobiology of bacterial systems and the advantages presented by the genetics of *Drosophila* attracted some attention but gradually gave way to mammalian systems particularly with the emergence of strong groups such as those lead by Professor Martin Lavin at the Queensland Institute of Medical Research (QIMR). Dosimetry has been an ever-present component, albeit commonly with only one or two papers, but in the last few combined meetings it grew steadily, especially in the medical physics context, until Radiation 2006 for which is was the major theme.

The first combined meeting, entitled 'The First Australian-Asian Conference on Radiation Science and Nuclear Medicine' was held in 1993 at Macquarie University.

All previous 13 meetings had been held at Lucas Heights. Even though the meeting returned to Lucas Heights in 1996, the 13th conference in 1991 hosted the last of the traditional evening poolside barbecues. It is also amusing to note other attempts to drag the somewhat austere venue upmarket, with some judiciously arranged partitioning at Lucas Heights conference facilities and also the creation of 'The Bamboo Room' within the AAEC canteen for the conference dinners (9-11).

Roger Martin is Associate Professor, at the Peter McCallum Cancer Centre. He is the recipient of 23 grants from 1994 to 2007. These have been in two distinct areas of research. One involves development of DNA-binding radioprotectors for use in cancer radiotherapy, and in particular mechanistic studies using pulse radiolysis, in collaboration with Associate Professor Bob Anderson. The other concerns DNA damage by DNA ligands labelled with Auger-emitting isotopes, specifically ^{123}I and ^{124}I, and their potential use in radioimmunotherapy.

8.2 History of radiation chemistry in Australia from 1960 - Associate Professor Ron Cooper

Early days

In 1960 Don Stranks returned to Australia from a position at the University of Leeds which was one of the foundation centres for radiation chemistry in the United Kingdom. The Leeds Chemistry Department was headed by F S (Fred) Dainton (later Baron Dainton), the others being Manchester headed by Baxendale (Bax) and Newcastle upon Tyne, headed by Joe Weiss. Harwell had groups led by Bill Wild and Arthur Charlesby which investigated basic processes and industrial applications.

In Australia there was little activity except at the AAEC where David Sangster (who trained with Wild at Harwell) led a group active in the area of radiation dosimetry. There was some activity in radio/radiation chemistry at the University of New South Wales led by Jim Green, and John Hawke was active in the Pharmacy Department at the University of Sydney.

Stranks recruited PhD students from Leeds to come to Australia and encouraged them to take up radiation chemistry studies. In 1961 Gerald Laurence accepted a position at the University of Adelaide and Ronald Cooper accepted a position at the University of Melbourne. This Leeds connection was enhanced later by the appointment of Jim O'Donnell to the University of Queensland and Rod Willix to the University of Western Australia. Peter Airey, who joined the staff at AAEC, was a Leeds postdoctoral fellow under Dainton. Later, Ken Busfield arrived at Griffith University, Harry Sutton started research at DSIR in New Zealand and the 'Leeds Mafia' was thus installed!

Radiation Chemistry thus began at the various centres with no structured national linkages. AINSE's role as a national coordinator began as a result of an informal meeting organised within the 1962 ANZAAS Congress held at the University of Sydney. In the tea room within the Department of Pharmacy, a small group of chemists met to present their researches to one another. Present were John Hawke, Jim Green, Doug Moore, David Sangster, Ron Cooper, Norman Barker, Ralph Matthews, and students Rawson, Shah and Cattell.

This informal meeting later came to be known as the 'Zeroth' AINSE Radiation Chemistry Conference. The participants expressed a desire to meet annually to help the subject grow in Australia. Subsequently, AINSE provided the facilities and travel support to enable this to occur.

1968 Radiation Chemistry Conference at AINSE

From left: Harry Sutton, New Zealand; Jim O'Donnell, (QLD); Peter Airey, AAEC; Fred Dainton; Doug Moore, (SYD); Ron Cooper, (MEL)

At this time, AINSE research grant opportunities and the use of Lucas Heights facilities were draw-cards for the subject. In those days AINSE research awards provided direct grants to universities which meant that they could set up their own facilities. For universities without intense gamma sources the gamma pond at Lucas Heights was the only accessible irradiation facility. Many AINSE research awards had air freight components because samples were flown from capital cities to Lucas Heights and back again. For example, the polymer chemists in Brisbane had cryogenic problems with some samples which had to be shipped, irradiated and then returned all at 77K - liquid nitrogen temperature.

The subject grew slowly and facilities were sparse. The overall focus for the decade 1960 -1970, was the use of gamma irradiation and the determination of stable products. Mechanistic implications of unstable intermediates were examined in polymer samples by ESR or by scavenging experiments in solution chemistry. Was it ions or free radicals which were important controllers of the chemistry? This meant access was required to large (kilocurie or greater) ^{60}Co or similar sources, for example the ^{137}Cs at the University of Sydney. The University of Melbourne initially had access to a Megacurie facility at Dandenong where Westminster carpets had a ^{60}Co source sterilising goats-wool bales imported from Pakistan. ICI at Ascot Vale had kilocurie sources for their industrial radiation program run by Hans Battheard. The company was generous in allowing the University of Melbourne use of that facility. Later they gave spent (500 curie) cobalt rods to the

University of Melbourne to boost its source. They also vigorously contributed to AINSE's radiation chemistry conferences and boosted thoughts of industrial applications of radiation chemistry. Their famous 'failed' formaldehyde synthesis was a lesson in no matter how good the chemistry; the market place is a fickle arena.

Another source of radiation for chemists was neutrons. Don Stranks and collaborators built a rig to undertake neutron irradiations in the small training reactor MOATA at Lucas Heights. The topic of these studies was the effect of damage caused by recoil of atoms subsequent to neutron capture - the Szilard Chalmers effect.

The University of Adelaide

the University of Adelaide was an early radiation research centre. AINSE President Denis Jordan, in the Chemistry Department, undertook studies on the radiation effects on DNA. Gerald Laurence joined the staff in 1961 and studied photochemical, radiation and Szilard Chalmers recoil reactions in fluorocarbons. The small AAEC reactor MOATA was used for these studies. Later when the 1.3 MeV accelerator was commissioned for pulse radiolysis, Laurence and his student Andrew Thornton produced a computerised data acquisition and analysis system for this national facility. Later studies in Adelaide were concerned with the radiation destruction of pesticides in natural waters.

The University of Melbourne

Ron Cooper established a radiation chemistry group early in 1961 and initially studied energy deposition in gases by ion current measurements. This led to the measurement of fundamental 'W' values used in dosimetry calculations for gases. When the gamma sources were installed at the University of Melbourne, the program turned to measuring the decomposition products in fluorocarbon gases. Using selective scavengers for radicals and ions the intermediate reaction entities could be identified and accurately assayed.

Don Stranks with two well dressed students, Ron Cooper & Gerald Laurence!

Following a sabbatical leave at ANL he turned his attention to pulse radiolysis experiments in gases. The university funded the purchase of a Febetron 706 nanosecond pulsed electron beam source. This was used for a long series of measurements of the fundamental processes in irradiated gases. Results included absolute emission yields from halogen-atom rare-gas systems; and first detection of the rate constants for the reactions of subexcitation electron reactions. These studies were conducted in cooperation with M C Sauer at ANL where a picosecond linac enabled ultrafast transients in irradiated gases to be observed. In conjunction with plasma physics groups in Australia, absolute rate constants for pressure dependent ion-ion and ion-electron recombination were measured for the first time. Theoretical studies of the decay of plasmas formed during radiolysis were undertaken in collaboration with theoretical physics group at ANL led by R L Platzmann's protégé Mitio Inokuti. An AINSE student, Manuela Burgers, undertook the calculations accessing the CRAY system at the Lawrence Livermore labs from her desk in the University of Melbourne. The collaboration between the University of Melbourne and ANL continued for 25 years with many PhD students spending some time in Chicago during their doctoral studies.

Late in Ron Cooper's career, collaboration between ARPANSA, ANSTO and the Technical University of Delft in the Netherlands resulted in unique measurements on the production and stability of luminescent defects in various solid oxides of interest in nuclear waste storage applications.

The University of Queensland

Research began with the arrival of Jim O'Donnell at the University of Queensland in 1964. Jim completed his PhD in Dainton's Department at Leeds in the United Kingdom in 1962 under the tutelage of Professor Ken Ivin on the chemistry of poly(alkene sulfones). Jim's PhD research included, in part, a study of the radicals formed on irradiation of some polysulfones. Subsequently, Jim spent a postdoctoral year at the Polytechnic Institute in Brooklyn in New York with the well-known polymer chemist Herbert Morawetz, where he studied solid-state polymerisation. This was his introduction to radiation chemistry, which later became one focus of his research.

Soon after his arrival in Queensland, Jim O'Donnell, through AINSE, established a collaboration with David Sangster that lasted 30 years. Jim published numerous papers on the radiation chemistry of polymers over this period, Jim and David wrote the widely used textbook, *Principles of Radiation Chemistry*, in 1970.

Jim O'Donnell was always keen to involve others in his research. In the 70s he, David Hill and Peter Pomery, two other University of Queensland physical chemists, formed the Polymer Chemistry and Radiation Group, the first focused polymer research group. As well as these researchers, other radiation polymer chemists were attracted to other Queensland universities, including Ernie Senogles to James Cook University (1964), Ken Busfield to Griffith University (1976) and Graeme George to the Queensland University of Technology (1983). Queensland became a nationally recognised centre for polymer radiation chemistry with a strong international reputation.

Jim O'Donnell died in 1995 after a lifetime of research in polymer science, including significant contributions to his profession through The Royal Australian Chemical Institute (RACI), the International Union of Pure and Applied Chemistry (IUPAC), the Pacific Polymer Federation and AINSE. In 1996, Jim O'Donnell (posthumously), David Hill and Peter Pomery were jointly awarded the AINSE Gold Medal for their studies of the effects of high-energy radiations on polymers and radiation-induced polymerisations.

More recently, a new generation of polymer scientists with interests in radiation chemistry have been appointed at universities and other institutions in Queensland. Currently, the major areas of research are radiation-induced polymerization and grafting of polymers for biomedical applications and the development of new low-energy electron beam resists for use in manufacture of the next generation of computer chips. Queensland remains Australia's major national centre for polymer radiation chemistry.

While the major focus of radiation chemistry in Queensland has been on polymers, other chemists have also utilised the facilities available through AINSE in their research. For example, Martin Lavin from the Queensland Institute of Medical Research has studied the applications of radiation chemistry in biomedicine, and Paul Bernhardt's team at the University of Queensland and Richard Keene and his PGRA scholar, Bradley Patterson, at James Cook University, carried out pulse radiolysis studies of oxidation-reduction reactions in inorganic complexes.

The University of Sydney

Don Napper, University of Sydney, had been working for several years on emulsion polymerisation which looks simple but was proving to be quite difficult to understand. Basic mathematical equations had been postulated by Harkins, Smith and Ewart but nobody had managed to solve them. Bob Gilbert was giving an in-house seminar on quantum theory when Napper recognised that a set of equations, which he said were solvable, had the same form as the Smith/Ewart equations. This realisation led to a long and fruitful partnership.

Don Napper and Bob Gilbert were unable to explain some of the new experimental results obtained by PhD student Brian Hawkett. Radiation initiation provided a model-independent means of examining this directly since radiation caused no further initiation after the system was removed from the source. It was found that there was a thermal reaction initiating polymerisation in addition to that due to radiation. This underlying thermal reaction complicated the kinetic analysis. However, the radiolysis results subsequently enabled a series of research workers in the group to build up a comprehensive and quantitative interpretation of emulsion polymerisation. Radiation chemical techniques proved to be indispensable in resolving some of the outstanding problems in emulsion polymerisation of monomers and in the unequivocal evaluation of some of the kinetic parameters. Napper and Gilbert were awarded an AINSE Gold Medal in 1993.

The gamma source used in this work has had a top-up of ^{60}Co and an improved system of dilatometry measurement. It is still being used by present researchers 27 years later and producing useful and unequivocal data.

University of New South Wales

Professor Jim Green studied the implications of positronium decay.

Jack Garnett had an expanding program of polymer research which had strong connections with local industry. The curing of thin films as surface coatings, using low-energy electron beams was a significant advance.

Norm Barker used iodine to scavenge and assay free radical yields in irradiated hydrocarbons.

Mervyn Long investigated tritium uptake and damage to organic compounds.

Rob Burford examined the use of radiation in producing new polymer products with novel rubber-like properties.

Macquarie University

John Hawke studied hot atom reactions in gases subjected to reactor irradiation and caesium β-radiation.

Jan Gebicki had a major program studying the effects of radiation on proteins. The role of organic peroxides in the ageing process of cells was a biologically important issue. The program had strong links to New Zealand workers particularly Christine Winterbourne at Christchurch.

University of Wollongong

Anatoly Rozenfeld has an extensive program developing solid state radiation monitors for micro domain radiotherapy.

Universities in Perth

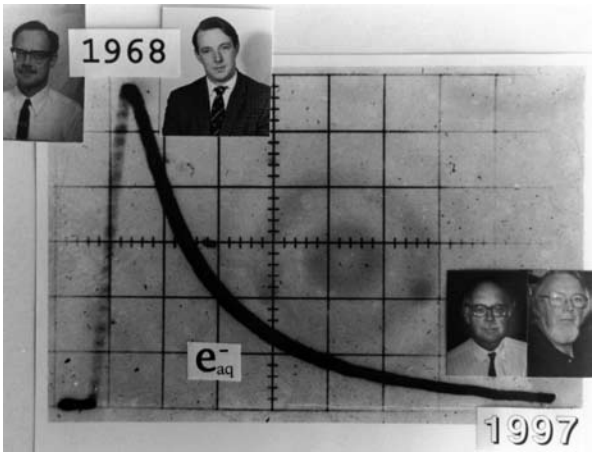
Terry Quickenden, the University of Western Australia, who had a long association with AINSE, studied the radiolysis of ice and, in particular, the light emission from various crystalline forms. In collaboration with David Sangster (ANSTO) and Colin Freeman from the University of Canterbury NZ, they published many papers on the nature of luminescent defects. They used the AINSE Febetron at Lucas Heights for this work.

Rod Willix at Curtin University of Technology worked on polymers for some time.

Australian National University

Alan Sargeson used the AINSE pulse radiolysis facility together with Jim Sullivan (ANL) to investigate oxidation-reduction reactions of coordinated ligands.

Geoff Lawrance (University of Newcastle) used the AINSE pulse radiolysis facility to generate the solvated electron or the OH radical which then reacted with in coordination complexes giving them unusual valences.



Production and decay of the solvated electron in pulsed e-beam irradiation of water

Scale: 1 division= 1 Microsecond or 4.15 years!

AINSE Facilities

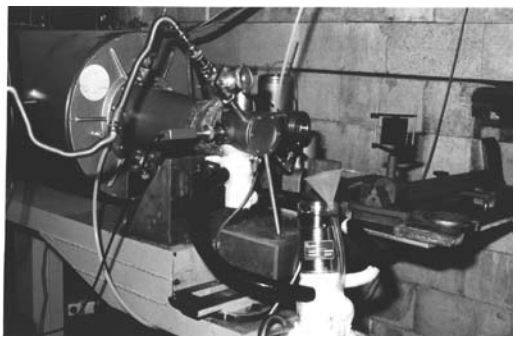
A major contribution to the National facilities resulted from two separate visits to ANL. First, in a short working visit to ANL, David Sangster saw what a powerful tool pulsed radiation source could be to Australian studies. Secondly, Ron Cooper had a sabbatical year to visit ANL. On his return from ANL and on 6 March 1968 he, together with David Sangster and a research student from the University of Melbourne set up the 1.3 MeV electron accelerator at Lucas Heights and successfully observed the production and decay of the solvated electron in the microsecond time regime. This technique opened up the field to the direct observation of various radical and ionic intermediates important in the reaction mechanisms of radiolytic processes. It did more than this; the radiation chemistry of water was by now fairly well understood. The main reacting primary species produced by irradiation were the solvated electron-reducing agent and the hydroxyl radical (oxidising). These species were found to be produced in reliable and known yields. Thus the field of free radical and redox chemistry was opened up to direct observation of the intermediate reactions. The technique was in immediate demand and time on the accelerator was at a premium.

The accelerator was decommissioned by ANSTO in mid 1997 and the facility relocated to ARPANSA in Melbourne where a 25 MeV linac was adapted for the purpose. Interestingly this linac, installed at ARPANSA, came from Toronto where John Hunt used it to conduct the first picosecond pulse radiolysis experiments.

The Febetron

AINSE extended the pulse radiolysis facilities in 1973 by purchasing a nanosecond pulsed electron beam instrument. It worked on the field emission principle hence Febetron - and had a 3 nanosecond pulsed electron beam with a controlled variable energy up to a lowly

0.6 MeV - sometimes nicknamed a 'Feebletron'. It had a large dose capability, 12 joules, and was especially useful for the study of atmospheric gases and solid surfaces. Its short pulse facility was very important since it gave scientists a chance to look directly at atoms and molecules in the excited states produced directly by irradiation. The work done by Terry Quickenden from the University of Western Australia on ice luminescence contributed to the recent studies of the emissions from comet tails. It was installed at ANSTO and used mainly by Western Australian, as well as Melbourne and AAEC workers. It was decommissioned to liberate research space for ANSTO/CSIRO and relocated to the University of Melbourne. It was assembled in the basement laboratories of the School of Chemistry where a similar instrument was already operational. It was operated on AINSE's behalf for some years when surprisingly ANSTO research scientists working on the solid state waste containment program were knocking on the door requesting access to the instrument. Measurements of the stability of crystal lattices to radiation damage were made for the first time on this instrument. The instrument was finally decommissioned in 1996 when Ron Cooper retired.



Febetron with ice luminescence detectors

AINSE Conferences

The first structured AINSE conference was held in 1963, 34 attendees heard 16 papers on chemical and biological topics. Subsequently the radiation biology area grew and each discipline had a its own conference.

The radiation research area grew from 66 attendees at the 1971 conference with 40 papers presented, to 75 attendees with 52 papers presented at the 1983 conference. Significant was the large contingent of overseas guests who reflected the international regard which Australian radiation research was attracting. In 1993, at Macquarie University, AINSE hosted the first International Conference - the First Australasian-Asian Conference on Radiation Science and Nuclear Medicine. This attracted 95 participants who presented 82 papers. There were twelve distinguished overseas participants representing most Asian countries as well as the USA and the United Kingdom.

From this time onwards there has been a decline in radiation chemistry projects supported by AINSE. The reasons are many but changing focus, expansion of the radiation biology/ oncology areas, and retirement of senior group leaders in Melbourne, Sydney and Brisbane were contributing factors. Following the death of Jim O'Donnell in Brisbane, David Hill carried on the polymer group studies until his retirement in 2006. The Radiation 2000 Conference held in November at AINSE had only had 25 papers on Radiation Chemistry and at the 2006 Radiation Conference held at the University of Sydney only twelve papers were presented on Radiation Chemistry. By 2004 only four radiation chemistry proposals were funded by AINSE.

The bright-spark ending the era of radiation chemistry was AINSE's hosting of the 2003 12th International Congress of Radiation Research in Brisbane at which there were over 1000 attendees presenting 930 papers. There was a substantial medical flavour to the conference, however, radiation science was well represented. This was AINSE's first venture into running major international conferences and was a scientific and financial success despite some nervous moments as international warfare and disease epidemics threatened its existence. The Conference surplus was used to establish a scheme for international student travel awards.

Since the first official radiation AINSE Conference in 1963 there have been many international visitors to AINSE and member Universities and affiliated research institutions. Special collaborations have been evident with visitors from Japan, USA, Canada, the United Kingdom, Russia, the Netherlands, Germany, New Zealand, Indonesia and China.

Contributions to AINSE by radiation chemists

Over these fifty years a number of radiation chemists have provided an exceptional contribution to AINSE: five have been AINSE President; six have been awarded AINSE Gold Medals for research excellence; and three have been made Honorary AINSE Fellows.

Photo taken at the 12th AINSE Radiation Chemistry Conference in 1984 Front Row, from left: Winzor (QLD) Warman (Delft) Young (ARPANSA) Gordon (Argonne) Cooper (MEL) Sangster AAEC, ? (AAEC), John Boas (ARPANSA)

8.3 Neutron scattering - Dr Trevor Hicks

The centre for neutron-scattering in Australia is at Lucas Heights and its form has been shaped by the researchers and their organisations, the AAEC, and its replacement ANSTO, the ARC and AINSE over five decades.

From the point of its inauguration in 4 December 1958, AINSE has collaborated with the AAEC to provide neutron-scattering facilities for Australian condensed matter researchers. In 1959 AINSE approved funding for a technician, Denis Cato, to assist Terry Sabine, the Harwell-trained neutron scatterer appointed by the AAEC, to lead the neutron effort, and also to build a single-crystal diffractometer to supplement the powder and single-crystal instruments planned by the AAEC.

From the start, AINSE provided research grants, credits for the use of facilities at Lucas Heights and funds for travel and accommodation. The AINSE 'process' was unique, particularly in the area of neutron-scattering, it certainly predated and probably provided a model for other such schemes overseas, such as a similar but more restricted support scheme operated at Harwell in the late 60s. The first service institute for external use of neutron beams was the Institut Laue-Langevin in Grenoble which was first operational in the early seventies.

HIFAR achieved criticality in 1958 and attained full power during 1960. By 1961 the celebrated powder diffractometer based on a naval gun mount, along with the AAEC single-crystal diffractometer were operational. The responsible group leader was Terry Sabine who had returned from gaining experience with British neutron scatterers at Harwell. He was joined by David Browne, imported from the Metallurgy Division at Harwell, Suzanne Hogg as computer programmer, and two technicians.

The first crystal structure study in Australia, largely carried out on the AINSE single-crystal instrument, was of *p*-diphenylbenzene, and involved collaboration between the University of Western Australia through AINSE, and Terry Sabine. The work was published in 1961 in *Nature* under the names of Clews, Maslen, Rietveld and Sabine[3]. Apart from being the first neutron diffraction study from Lucas Heights, it was also significant because of the association with Hugo Rietveld, then a PhD student at the University of Western Australia, whose least squares refinement of powder neutron and x-ray diffraction data Terry Sabine was later to promote as 'The Rietveld Method', and which remains today as the premier analysis tool for powder diffractionists.

The collaboration with AINSE-sponsored institutions involved provision of neutron diffraction facilities at Lucas Heights and also the provision of equipment and personnel by universities. An early example of this is a simple variable temperature liquid nitrogen cryostat for the powder diffractometer, designed by Trevor Hicks and fabricated by the Department of Physics workshop at Monash University (Figure 10).

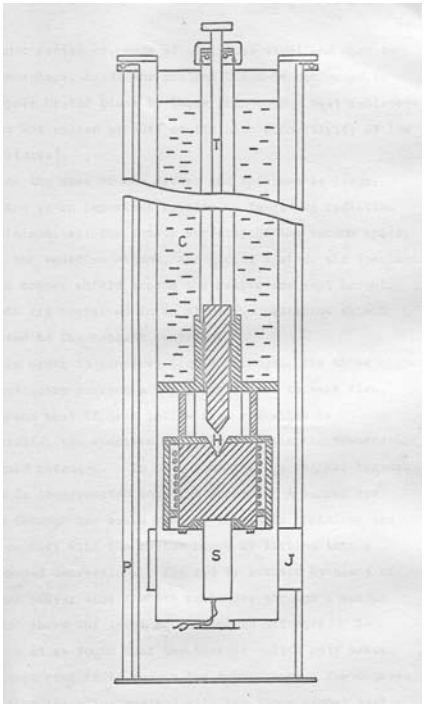


Figure 10. Liquid nitrogen cryostat designed and made for the neutron powder diffractometer in the Department of Physics, Monash University in 1963.

Later, Gordon Cox, who had recently joined the neutron-scattering group, and assembled the first primitive triple-axis spectrometer on HIFAR by the simple expedient of mounting a single-crystal diffractometer on the arm of the second powder diffractometer (6H) (Figure 11).

I remember spending a night with this 'beast' manually resetting the angles after each counting period. In addition to the second powder diffractometer there was a variable wavelength total cross-Section spectrometer associated with the name of Brian Hickman built for the specific purpose of looking at defects in beryllium oxide (BeO), at that time a favoured material for prospective power reactors in the Australian context. I understand that it played a significant role in the rejection of BeO for that purpose.

AINSE took the decision to put more troops on the ground. In November 1965 David Wheeler, with considerable equipment and scientific experience from Harwell was appointed as a Research Assistant. Peter Lloyd was appointed as a Technician in April 1966. In August 1967, Dr Frank Moore, a former DPhil student of the famous Oxford crystallographer, Dorothy Hodgkin, was appointed a staff scientist and leader of the new AINSE Neutron Diffraction Group. In April 1968 Roy Ebdon was appointed as a Technician.

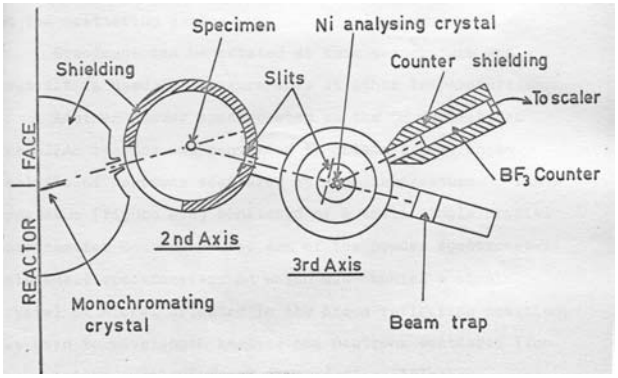


Figure 11. Powder spectrometer converted to triple-axis spectrometer

The purpose of the new group was to expand the suite of equipment available for AINSE users. This included much needed ancillary equipment such as magnets and cryostats as well as a further single-crystal and a polarised neutron diffractometer.

New units brought into operation in 1968 were a second single-crystal diffractometer (2TanA) and a small-angle spectrometer for the measurement of excitations (magnons) in ferromagnetic materials. Figure 12 shows Frank Moore and David Wheeler with the original single-crystal and gun mount powder diffractometer. The powder diffractometer, which overhangs the spent fuel rod storage, sports a new electromagnet.

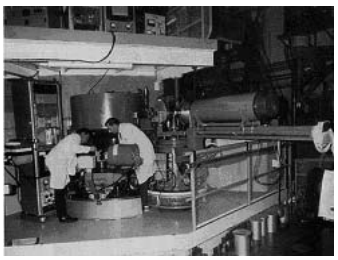


Figure 12. Frank Moore and David Wheeler working on one of the single-crystal diffractometers. The 4H1 powder diffractometer, based on a naval gun mount, in the background

Meanwhile there were further staff appointments in the AAEC neutron-scattering group which was focused on the development and operation of the new triple-axis spectrometer. This, perhaps, was the most ambitious instrumental development at Lucas Heights at that time. Triple-axis spectrometers were the workhorses for the measurement of all types of excitations in condensed matter the measurement of which is the province of neutron-scattering alone. Arthur Pryor, from the AAEC and Margaret Elcombe, from Cambridge joined the AAEC neutron-scattering group particularly for this instrument. Arthur Pryor was later to continue his interest in lattice vibrations by joining the laser uranium-enrichment program. In 1970 Chris Howard joined the group and Gordon Cox left for a computing career.

This period also saw the initial development of LONGPOL (the long wavelength polarisation analysis diffractometer) in the 70s. At that time it was one of only three instruments worldwide with polarisation analysis capability and the only one on a medium flux reactor. While the concept came from Monash University, the building was undertaken by David Wheeler and the AINSE neutron diffraction group. Figure 13 shows the early instrument for which the detector setting was not automatic but had to be physically manoeuvred from angle to angle. This instrument's first task was to directly observe the glassy nature of the magnetic structure in the archetypal spin glass Cu-Mn, something which the instrument at The Institut Laue-Langevin (ILL) was not capable of at the time.

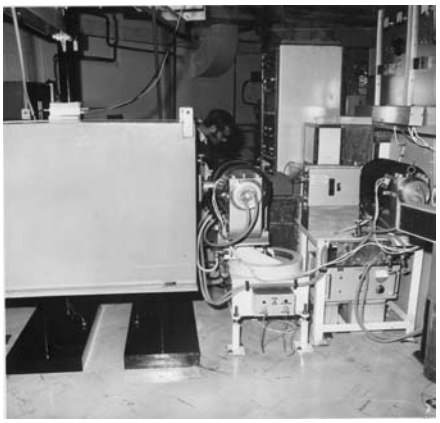


Figure 13. The original LONGPOL in about 1974

At this point Terry Sabine left the AAEC to join the New South Wales Institute of Technology which was to become the University of Technology Sydney (UTS) and David Wheeler left for the Institut Laue-Langevin. Cliff Ball was appointed as Leader of the ANSTO x-ray and Neutron Diffraction Group and Lindsay Davis was appointed to assist Frank Moore. The AINSE neutron diffraction group maintained its strength of four (including two technicians) while that part of the AAEC still doing neutron-scattering shrank to two (Margaret Elcombe and Chris Howard with no technicians). From 1977 to 1980 Chris Howard was the only AAEC staff member doing neutron-scattering as Margaret Elcombe was in administration. At that time the AINSE neutron diffraction group outnumbered the AAEC group 4 to 1.

AINSE was still able to develop LONGPOL which after the demonstration of its usefulness needed more intensity to maintain its competitiveness. There was no money available for new shielding so Bill Palmer and I scoured the junkyard near stores to find a piece of discarded shielding which could serve. That found, the AINSE group carved out a space for the monochromator assembly and punched through a new hole below the original for the exit beam. Such was the improvisation of that time. Figure 13 shows LONGPOL installed on the new more intense beam with the scavenged shielding.

In this period one of the most important instruments was commissioned on HIFAR. That is the High Resolution Powder Diffractometer (HRPD). For its construction, Chris Howard relied very heavily on the AINSE group because of its capability for technical backup. Unlike x-ray patterns, for which the peak intensity falls off with angle, neutron patterns have peaks of similar intensity at all scattering angles. Because of this, more peaks can be collected as long as they can be resolved at high angles.

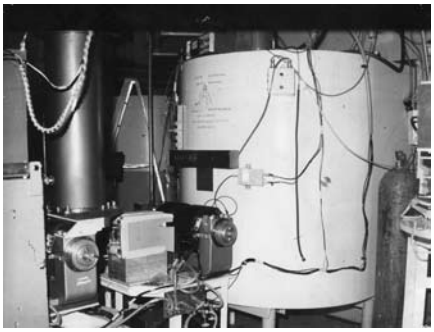


Figure 14. The second LONGPOL on a higher intensity hole with the curved scavenged shielding.

The history of this period would not be complete without reference to the Australian Neutron Beam Users' Group (ANBUG), then representing about 80 Australian neutron scatterers (including some marginal users and some overseas) in 1998 but now with over 300 members.

During the late seventies and the eighties ANBUG lobbied the AAEC for improved facilities and staffing for neutron-scattering at Lucas Heights. In addition there was a realisation that for neutron-scattering to be useful in new areas, including soft matter and applied areas, the spectrum of neutrons available had to be widened towards longer wavelengths. This had already been done on all HIFAR's sister DIDO-class reactors overseas. This resulted in ANBUG's parallel push for a cold source in HIFAR.

ANBUG prepared submissions to government relevant agencies. One of these was a submission to The Australian Science and Technology Council (ASTEC) which, in its 1985 report `Nuclear Science and Technology in Australia', recommended that $10m be spent on HIFAR refurbishment and neutron beam instrumentation. Meanwhile ANBUG felt itself a strong enough organisation to host the International Neutron Scattering Symposium, a satellite of the International Crystallography Congress, in Sydney in 1987.

Things have looked up in the last ten years or more. It is hard to pick the exact point because it all happened so gradually. Certainly Margaret Elcombe coming back to the group in the early 80s was important as was the decision of ANSTO and AINSE to proceed with AUSANS at the end of that decade. It seems to me however that about 1986 was significant for the turn around because there was significant discussion in the AAEC about refurbishment of existing and development of new instruments. Much of this was prompted by the ASTEC report. Unfortunately the amount recommended would not cover the cost of a cold source.

ANSTO also increased the number of personnel in the ANSTO Neutron Scattering Group at various times with interfacing and computer technicians. After the transfer of AINSE neutron-scattering staff to ANSTO in 1993 ANSTO continued to increase the number of scientific personnel.

In this period, AINSE was able to assist with further capitalisation of the neutron instrumentation through its access to ARC funds. Previously some ARC funds had flowed to particular instruments via personal ARC funding to individuals in universities but with the advent of the Infrastructure Grants, AINSE, as an university organisation which represented most universities, was able to tap these funds for the development of neutron instrumentation for university use. This has helped ANSTO in its role as supplier and operator of the neutron-scattering instrumentation.

During 1997, Federal Government plans for a replacement research reactor were announced. Broad specifications indicated that the reactor envisaged would be similar to that proposed to the Research Reactor Review by ANSTO a few years previously. The neutron-scattering community was delighted.

Significantly, at all phases in the development of the reactor, ANSTO consulted widely in the scientific community including the formation of a Neutron Beam Facilities Consultative Group representing scientific associations, CSIRO, AINSE and industry. The group advised ANSTO on the range of science and technology appropriate for the new neutron source and the suite of instruments which would be needed. The group also specified the level of staffing required to operate the new facilities effectively. This certainly promises to be a new era in Australian neutron-scattering and will hopefully bring Australian facilities up to the standard of other medium-flux reactor sites.

In these recollections I have outlined the various influences which have shaped Australia's National Neutron Scattering Centre. In the long run, if maximum effectiveness is to be obtained from the new OPAL reactor facilities, these influences need to be recognised.

The discrete AINSE group, while it existed, was vital for the survival of neutron beam research in Australia. Its existence also allowed for consideration of interests beyond the confines of the AAEC/ANSTO. Now that the evaluation of neutron beam proposals has been transferred to ANSTO's Bragg Institute it is hoped that the broader interests of the neutron beam community continue to be recognised.

* *Trevor Hicks holds an honorary research fellowship in the Department of Physics at Monash University.*