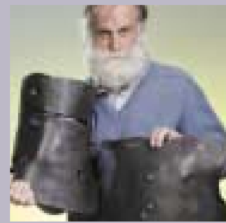
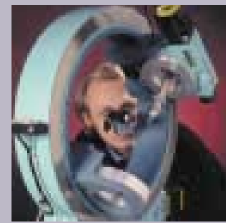
Australian Government

ansto

fiftyyears





Introduction by Minister Peter McGauran

2003 is a significant milestone for ANSTO and the Australian research and development community, as it is the 50th anniversary of the passing of the Atomic Energy Act, 1953.

One of the activities ANSTO has undertaken this year is to produce its 50th Anniversary Booklet, which celebrates its past, present and future.

Since its inception, ANSTO's work has gone through a tremendous evolution. The one constant, however, has been its commitment to maximising the benefits from its facilities and know how for Australia's and the world's sustainability, health and economic development.

ANSTO is a crucial part of Australia's science and innovation infrastructure, as its facilities provide essential capabilities to industry, research and development bodies and a range of educational institutions.

ANSTO's research focus and collaborative relationships – with educational bodies and other publicly-funded research organisations – will continue to identify ways in which the lives of all Australians can be enhanced.

The recent launch of the Bragg Institute was another great milestone for ANSTO. A tribute to the father and son team of William and Lawrence Bragg, the Institute is at the forefront of research and development in neutron scattering and the use of x-rays.

The replacement research reactor, a state-of-the-art facility, will keep Australia virtually self-sufficient in nuclear medicines and enable the development of new therapeutic and diagnostic substances. It will also allow ANSTO to expand its commercial capability and further contribute to the economic development of Australia in areas such as biotechnology, sustainability, engineering, materials, nanoscience and environmental science, as well as contributing to history and archaeology.

An objective of ANSTO is to turn good science into good business for its clients, global partners and stakeholders. With this in mind, processes have been put in place to fast track some commercial ventures.

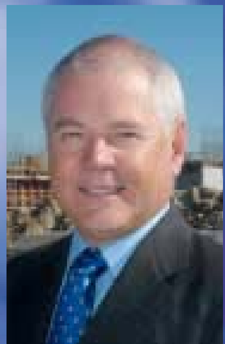
Given the enthusiastic workforce and the investment in facilities, ANSTO will underpin socioeconomic development in Australia for many years to come.

Yours sincerely

The Hon Peter McGauran, MP
Australian Science Minister

Australian Nuclear Science & Technology Organisation

Letter from Chairman, Ian Blackburne



At 11.15 pm on 26 January 1958, at ANSTO's Hi Flux Australian Reactor (HIFAR), the process of criticality, a self-sustaining chain reaction which splits atoms, was achieved.

This was the first nuclear chain reaction conducted in the southern hemisphere and a milestone in Australian history. It was a step that would ultimately make Australia a world leader in the application, research and development of nuclear based science and other technologies.

Since that first chain reaction HIFAR has operated safely and efficiently throughout its history and continues to do so.

Fifty years on, although many people know about important medical procedures that employ radioactive materials, their knowledge of the widespread uses and benefits of other nuclear-based services in our daily lives is more limited.

Even a quick browse through this booklet should go some way towards changing that understanding.

ANSTO works in the development and application of new knowledge and expertise, important to sustainability, the environment, human health, national security and the economic development of Australia.

Our replacement research reactor – Australia's largest scientific investment, due to go live late in 2005 and ultimately replacing HIFAR – will unlock knowledge associated with biotechnology, engineering, materials, nanoscience and environmental science.

It is our scientists themselves, however, in tandem with our advanced technology, who are at the heart of our success. A reflection of the respect in which they are held is that during 2002-03 some 447 of their papers were published in scientific journals or presented to conferences.

In a knowledge-based organisation such as ANSTO, staff are integral to delivering excellent outcomes so that together science and business can build Australia's economic strength.

ANSTO has a number of important partnerships with Australian industry, particularly with the national and international mining industry. We specialise in handling and treating ores and wastes, minimising the impact mining has on the environment.

One of ANSTO's greatest achievements is its support for students. This manifests itself through its work experience programs, as well as access to facilities and expertise – either directly or through the Australian Institute of Nuclear Science and Engineering (AINSE).

ANSTO is internationally recognised for its innovative applications of nuclear science and technology. The future for ANSTO is a positive one and Australians should be inspired by the contribution it is making to all our lives.

Yours sincerely

Dr Ian D Blackburne, Chairman

01. Replacement Research Reactor on its way

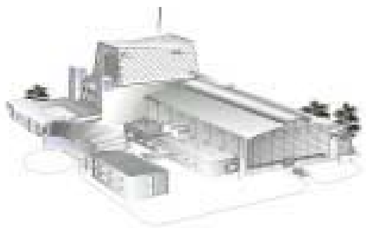
Above, construction going well at the Replacement Research Reactor, and below a 3D representation of the finished building.

Scientists in the ANSTO Radiopharmaceuticals research & development laboratory using precision remote handling controls. They are performing radiochemistry inside heavily shielded 'hot-cells'.

Construction of the research reactor (RRR) to replace the HIFAR (High Flux Australian Reactor), operating since 1958, is now well advanced.

When completed in 2005, the new reactor will be a low power, high flux pool reactor using low enriched uranium fuel. The reactor will be a multi-purpose facility for radioisotope production, irradiation services and neutron beam research. Its compact core has been designed to achieve high performance in the production of neutrons.

The reactor building will contain all the nuclear systems as well as the reactor and service pools. The reactor pool houses the reactor core and reflector. The service pool is alongside it, and will be used to store or handle fuel, radioisotope targets and silicon that need to be moved into or out of the reactor pool. These materials will be transferred between the pools via an open canal to enable manipulation of underwater items.



The reactor building will serve as a containment and protect the reactor from external elements and events.

A modern, more efficient reactor will allow us to expand our work in the development and application of new knowledge in many areas that are vital to Australia's future, such as agriculture, industry and manufacturing, minerals and energy, construction, human health and the environment.

HIFAR's performance limitations, compared with more modern reactors, indicate that it is approaching the end of its useful life. It will be taken out of service in 2006, following a successful parallel operation period with the RRR.

Neutron beams are used for strategic research into materials, providing an understanding of their structure, properties and behaviour, enabling development of improved materials and a wider range of applications. Neutrons generated in research reactors are scattered by atoms in the material being probed. The scattering pattern reveals the sample's molecular structure. This technique is called neutron scattering.

Irradiation is treating materials with varying levels of radiation. This gives them special qualities which make them useful in industry and science.

Radioisotopes are atoms that undergo radioactive decay at a known rate. They have a range of beneficial uses in medicine, industry and the environment.

ANSTO 1950 → The first critical years

All elements exist in different forms called isotopes. If you dig a lump of, say, sulphur out of the ground it will be made up of sulfur 32, 33, 34 and 36 (the only difference between them is the number of neutrons they have). Most isotopes are stable, but others are radioactive and emit radiation – hence the term radioisotope. Some radioisotopes occur naturally (for example, carbon 14 used in radiocarbon dating); others are made artificially (such as the americium 241 used in smoke detectors).

Making a radioisotopes in a reactor involves adding neutrons to what's known as a precursor. Neutron-rich radioisotopes are made inside the HIFAR reactor, neutron-deficient ones are produced in our cyclotron in Camperdown by bombarding a precursor with charged particles.

Half-life is the time it takes for half the atoms in a quantity of radioisotope to decay. For polonium 214 it's 0.00016 seconds, carbon 14 takes 5,730 years and uranium 238 takes 4.5 billion years.

The year was 1953: the FJ Holden was released, 'From Here to Eternity' picked up four Oscars, and the Australian Blue Ensign was confirmed as our national flag. It was also the year we came into being as the Australian Atomic Energy Commission. By the end of 1955, land at Lucas Heights in Sydney had been cleared and construction of our research reactor was underway.

HIFAR (High Flux Australian Reactor) started up or, to use the technical term, 'went critical' on Australia Day 1958. By the end of that year – while HIFAR was still being tested – our scientists were making radioisotopes.

Radioisotopes are an invaluable tool in agriculture, industry and medicine, particularly because we can use them to follow what's going on inside solid objects. Being able to make our own was more than a matter of national pride: they're expensive to import, overseas suppliers didn't necessarily make the ones we wanted and some are difficult to bring out here because of their short half-life.

Because HIFAR wasn't yet running at full power, we began with the radioisotopes that are relatively easy to produce, such as sodium 24 and phosphorous 32. It's not surprising in a country like Australia, whose economy depends so heavily on the land and where the climate is so harsh, that many of these first radioisotopes were snapped up by agricultural scientists studying such things as whether plants use more or less fertiliser in drought conditions.

Now at ANSTO (we became the Australian Nuclear Science and Technology Organisation in 1987) we produce a dozen or so different industrial radioisotopes, supplying 98 per cent of the Australian market.

Being effectively self-sufficient is a huge boon to our economy because, not only are we keeping the entire supply chain within Australia, but we also export our radioisotopes, mainly to South East Asia and the UK.

One of the most common uses for our industrial radioisotopes is checking things such as pipelines for internal defects, a technique called gamma radiography. In pipes it involves putting a radioisotope, such as ytterbium 169, on little gadgets that trundle along inside and wrapping photographic film around the joins. If the seal is not perfect, a small amount of radiation will escape and expose the film. The wings and engines of aeroplanes, even the welds at Telstra Stadium, are tested using this technique.

Radioisotopes can also be used as tracers to monitor the flow of molten iron through a refinery or waste through sewage treatment plants. They can reveal where solids build up in pipes or where sediment is deposited in an estuary. And they can be used to track the movement of pollutants through the air or termites underground. Radioisotopes can even be embedded in the walls of furnaces in power stations to measure the rate at which they deteriorate.

The source of these radioisotopes, HIFAR, has run virtually continuously for 45 years, giving us a capability in nuclear science and technology that's second-to-none.

We'll be building on this proud tradition with the Replacement Research Reactor (RRR), due for completion in 2006. Not only will the new facility allow us to produce a larger quantity of radioisotopes more efficiently, but the RRR will ensure ANSTO scientists stay on the cutting edge of scientific research.

02. Looking at the world on a molecular scale

The description of our world on the molecular (or nano) scale can provide Australian industry with solutions to problems and give it a competitive edge when it comes to developing new products and improved services.

ANSTO has specialist knowledge and skills in molecular structure and dynamics that we are using to assist industry. Based on X-ray, neutron and electron scattering, our knowledge and skills are in the enabling areas of advanced materials science, physics and chemistry.

- We have worked with research and industry partners to determine the shape of polymer molecules in injection moulded polypropylene products (such as margarine tubs and car parts) and to understand the influence the molecular shape has on the mechanical properties of the product.

  Commercial moulding of polypropylene is a complex process. Temperature, pressure geometry and other factors all need to be considered. ANSTO applies sophisticated technology to make sure the process perfectly suits the product.

  For example, glass fibres can be added to the polypropylene to give it added strength, or mica flakes can help give fire protection to special cables (important in a bush fire-prone country like Australia).

  The new knowledge gained from these investigations is being incorporated into sophisticated computer software that is used for the design of injection moulds.

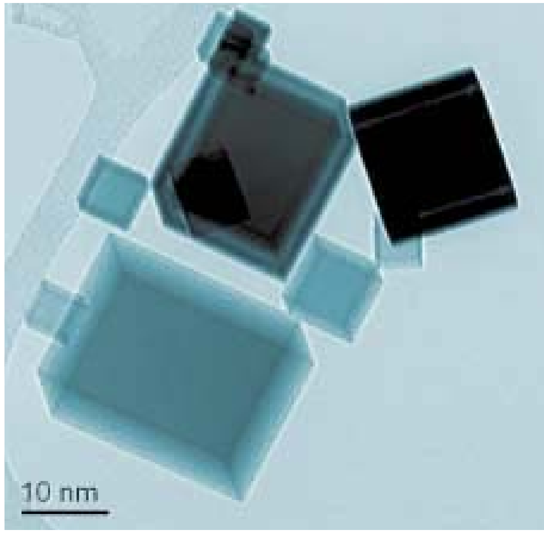
- The growing demand for lighter, stronger materials for the automotive and aeronautical industries is driving the development of nanocomposite materials. We have investigated the molecular architecture of nanocomposites fabricated from clay 'platelets'.

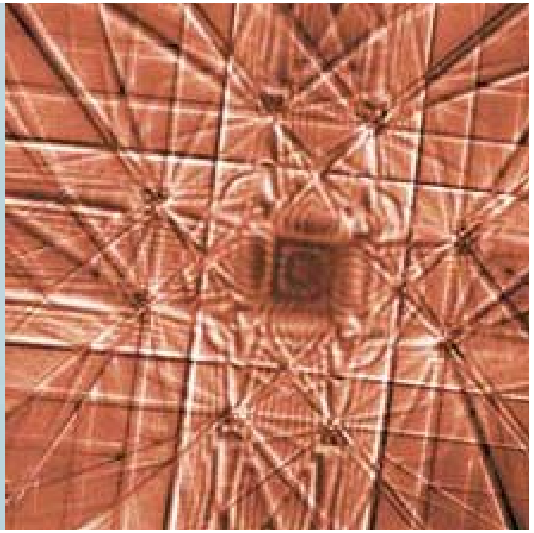
  The clay platelet is an exquisite crystal structure that gives the clay very special properties. For example, if water is able to penetrate the galleries between the clay platelets then the bulk clay can swell dramatically.

- Australia is one of the top bauxite and alumina producers in the world. The raw bauxite contains alumina and impurities such as silicates and organic matter. ANSTO is exploring ways to improve the efficiency of bauxite mining or alumina processing. The goal is to provide an industry partner with important information that will reduce the concentration of the organic matter in the re-fining of alumina (this is known as the Bayer Cycle).

- The efficiency of oil exploration and recovery is critically dependent on the porosity of the rock the oil is captured in. We are investigating the interaction of drilling muds (complex fluids containing polymers, clays and solvents) with oil-bearing rock to understand the molecular interactions of the mud with the pores, particularly those interactions that can lead to pore blockage. This will lead to more efficient oil recovery.

The "nanocubes" on the left are tiny crystals of magnesium oxide as seen under the electron microscope. The scale-bar represents 10 nanometeres, or 10-millionths of a millimetre! The scattered electrons produce the pattern on the right which can be used to provide information on the internal structure of the material such as the arrangement of the atoms within the crystals.





About X-ray, neutron and electron scattering: X-rays, neutrons and electrons are different forms of electro-magnetic radiation that can be scattered from the atoms and molecules to provide valuable inform-ation on the internal structure of objects that make up our world (plastics, metals, ceramics, etc).

These radiations can also be used to explore our natural world and assist with the development of new drugs and medical procedures for human health, for example, as well as leading to a better understanding of our environment (the structure of bacteria, trees, soil, minerals etc).

Each radiation has special properties that make it most suitable for a particular application.

Very small, intense beams of X-rays can be generated using a synchrotron and are therefore particularly suited to the study of tiny samples of proteins, for example. The typical sample can be very small (a millionth of a metre in dimension) and the X-ray gives a clear image of the structure, particularly for heavier atoms (carbon, nitrogen and the lighter metals - but not lead!).

Neutrons, on the other hand, are generated in larger, less intense beams and are used to investigate the structure of objects containing many light atoms (hydrogen, for example), or very heavy metals (lead – though not cadmium), or magnetic materials. The typical sample for neutron scattering studies can be quite large (a hundredth or thousandth of a metre in dimension) and the neutrons can therefore see deep inside objects. Since electrons have a negative charge they can only be used to study the atomic or molecular structure near the surface of an object.

Nanocomposite materials are composites of inorganic and organic materials. They are a class of extraordinary materials with properties that are superior to conventional microscale composites, exhibiting novel and significantly improved physical, chemical, and biological properties.

Nature makes fabulous nanocomposites, and scientists are trying to emulate such processes. The abalone shell, for example, has alternating layers of calcium carbonate and a rubbery biopolymer; it is twice as hard and a thousand times tougher than its components.

ANSTO 1960 → Building our independence

Prototype Technetium 99 generator used to make TC-99m, which is still the most widely used radioisotope in nuclear medicine.

From top, a patient undergoing a kidney scan, early radioisotope manipulation inside a 'hot cell' (done through glass that is 35% lead) and above a rectilinear scanner (radiation detector), scans the organ of interest – in this case the brain – and maps out the distribution of radioactivity in the brain. The patient has been injected with a radioisotope from ANSTO.

On 26 January 1960, two years after ANSTO's reactor got going and the same day that Sir MacFarlane Burnet was named the first Australian of the Year, HIFAR was brought up to full power and our scientists set to work reducing our reliance on expensive imported radioisotopes.

One of the first made in large quantities was cobalt 60. This has many applications in industry, but it was also used for radiotherapy, where a controlled dose of radiation is used to knock out cancerous cells.

Teletherapy machines, as they were known, contained a lead pot full of cobalt 60. Once the machine was in the correct position, a shutter in the pot was opened and a beam of radiation shot through the patient's body into the tumour. These machines are now largely replaced by very high energy x-ray type machines that treat localised cancer.

By the time many cancers are discovered, however, they are beyond the reach of externally directed beams. Courtesy of decades of dedicated research, there are now drugs incorporating radioisotopes which release their radioactive payload right into the tissue being targeted. Radioisotopes like these tend to be relatively long-lived so-called beta-emitters whose radiation doesn't go beyond a confined area.

Those used in diagnosis are very different. They emit radiation strong enough to penetrate from within the body to the outside, where special gamma cameras and other such imaging devices are waiting. Diagnostic radioisotopes are selected for their short half-lives as part of minimising radiation doses to the patient.

Radioisotopes for treatment and diagnosis are made in our reactor in the south of Sydney, and at the National Medical Cyclotron in Camperdown, close to Sydney's CBD. ANSTO is unique in that it produces isotopes from both its cyclotron and reactor.

Many of the radioisotopes made in the cyclotron are applied straight away in imaging techniques such as PET (Positron Emission Tomography), which uses fluorine 18, and SPECT (Single Photon Emission Computer Tomography) using iodine 123, thallium 201 or gallium 67.

Put simply, these scans involve incorporating a radioisotope into a substance which is then taken up by a specific part of the body. For example, diagnostic radiopharmaceuticals which target the heart, skeleton and brain are in routine clinical use.

Because it's only a matter of hours before many diagnostic radioisotopes lose their radioactivity, ANSTO has a highly efficient distribution system, but even that isn't always fast enough. For example, the radioisotope used in over 80 per cent of medical procedures, technetium 99m, has a half life of 6 hours.

Fortunately, our scientists were quickly onto the problem. By June 1968, the same month Prime Minister John Gorton was visiting Australian troops in Vietnam, we'd adapted an existing technology and released it onto the Australian market.

The basic idea is that the parent radioisotope, molybdenum 99, is placed in a specially designed container (which looked deceptively like a small heavy Esky) where it gradually decays to technetium 99m over a week. It was quickly nicknamed 'The Cow' because of how some technetium 99m can be 'milked' every day. A new, improved version of 'The Cow' is now marketed by ANSTO as a Gentech® Generator.

ANSTO is the premier supplier of medical radioisotopes in Australia: we make 17 different medical radioisotopes in our reactor and 4 at the cyclotron. As our expertise has grown, so has the number of people we've been able to help. We estimate that last year some 550,000 people received a nuclear medicine service.

ANSTO researchers are involved in a very exciting new area of cancer treatment using radioisotope tagged molecules. This provides a 'double whammy' of the chemotherapy effect of the molecule and the radioisotope to enable better cancer treatment.

ANSTO scientists are also involved in new tools for early evaluation of treatment using radiopharmaceuticals which have both a diagnostic and therapeutic effect. In this way it is possible to evaluate the likely response to a particular treatment before undertaking the treatment itself.

Many countries still rely on cobalt 60 for radiotherapy, but in Australia linear accelerators started taking over at the end of the 1960s. These machines produce a controlled dose of x-rays on demand.

03. Hip technology

Manufacturing hip and knee joints may not be what the community expects from ANSTO.

We have, however, begun a commercial partnership with Australian Surgical Design and Manufacture (ASDM), a manufacturer of prosthetic devices.

While initially sourcing much of their technology overseas, ASDM intends bringing much of the manufacturing cycle back to Australia, and ANSTO is helping them meet that goal.

Complex shaped knee and hip joints are formed by casting which can result in pores and other undesirable microstructural defects. Hot isostatic pressing (HIPing), applies heat and high pressure at the same time and in all directions. When castings are HIPed, the defects are removed, producing a fully dense component – improving the strength, flexibility and fatigue life of the component.

ASDM processed around 1,500 knee joints during 2002 to 2003 using ANSTO's HIP technology. This is expected to increase greatly over the coming years.

ANSTO's certified laboratory status, along with our ability to provide mechanical testing and characterisation of these components, has enabled the ASDM knee technique to meet the United States Federal Drug Administration Standards.

The manufacture of artificial body parts is an unusual spin-off of ANSTO's know-how, originally developed for making nuclear wasteform ceramics. ANSTO is also involved with ASDM in a number of other development projects.

04. Migrating sands and sediments

Pollution and erosion of our coastal zone is an ongoing subject of ANSTO collaborative research into the movement of sands and sediments. We have been using 'tracer techniques' to study off-shore processes at MacMasters Beach on the NSW Central Coast and migration of contaminated muds at Homebush Bay in Sydney.

- The impact of storms on the coast line is of major interest to Australia, and climate change is expected to lead to an increase in their frequency and intensity. The movement of sand off MacMasters Beach, during storm events, has been studied using a radioisotope labelled sand tracer. ANSTO is working with the NSW Department of Land and Water Conservation and the University of Sydney Coastal Studies Unit on this project.

  Labelled sand was deployed at various depths more than half a kilometre off-shore, and the location of the tracer was monitored before and after storms for a period of one year. The role of 'mega rips', storm waves and currents in beach erosion are more clearly understood as a result of this work.

- Together with the Sydney Olympic Park Authority, ANSTO is investigating the transport of cohesive sediments in Homebush Bay over a 12-month period. These 'muds' were contaminated by industry that previously existed in the area.

  The dispersion of the labelled muds is studied using special 'tracer' techniques. The results are being used to evaluate computer models of transport processes in Homebush Bay, developed with the University of NSW Water Research Laboratories. The aim of the research is to provide the Authority with a tool for the sustainable management of the wetlands surrounding the Bay.

Tracer Techniques

Tracers are materials which can be measured with high sensitivity and which behave in all essential respects like the system that is being studied. Tracers may be radioactive or non-radioactive: eg. water in the environment can be studied using radioactive tritium.

The labelling of sands and muds is quite complex. For the sand migration study off MacMasters Beach, glass particles incorporating the radioactive tracer iridium-192 were used. The particle size was designed to match that of the sand. The distribution of the tracer is monitored with a detector deployed on a sled from the research vessel.

All studies using radioactive tracers are fully approved by the licensing and regulatory authorities following input from major stakeholders.

The Homebush Bay investigation used the non-radioactive tracer indium. The cohesive sediments were labelled in the laboratory, sampled at intervals up to one year after deployment and examined using a neutron activation technique in ANSTO's HIFAR research reactor.

05. ANSTO air pollution studies offer clues to climate change

A Radon measuring site at the southern tip of the Hong Kong island.

Is air pollution in Asia influencing climate change? As part of a program known as the Aerosol Characterisation Experiment (ACE), ANSTO scientists are at the forefront of an international effort to answer this question.

Like greenhouse gases, aerosols are believed to influence climate. Atmospheric aerosols are very fine particles suspended in air that can originate from the dispersal of material at the earth's surface or by reaction of gases in the atmosphere.

The aerosols include sulphates and nitrates from the burning of fossil fuels, organic materials from the oxidation of volatile organic compounds, soot from fires, and mineral dust blown in the wind. Natural aerosols include sea salt and volcanic dust.

It is known that increased burning of coal and other living matter raises the concentrations of sulfate and soot particles in the air. These particles are thought to scatter more sunlight back into space, influence cloud formations, and alter the amount of atmospheric material deposited into the Pacific Ocean. Scientists have theorised that these factors could cause localised cooling, and affect the amount of rainfall and associated agriculture, as well as marine life.

ANSTO scientists are collecting samples from filters at five selected sites to observe the outflow of air pollution from the Asian continent. They are located in Hong Kong, Manila (the Philippines), Hanoi (Vietnam), Sado Island (Japan), and Cheju Island (South Korea).

Using ANSTO's facilities, accelerator-based nuclear techniques of analysis are being applied to obtain over 25 different elemental and chemical species from hydrogen to lead, including carbon, sulphate and soil.

Accelerator-based nuclear techniques of analysis use very fast proton beams from particle accelerators that pass directly through samples. In doing so they stimulate x-rays and gamma rays from the material being analysed. From the response we can determine characteristics of the samples and understand their composition better. In the case of air pollution, this is important because we can fingerprint its sources. If we understand where pollution comes from we can better manage it and apply valuable resources more effectively.

ANSTO 1970 → Right on target

At left, close up of the gun base, slightly modified, which gave good angle control for the powder diffractometer detector. Below shows the layout of the powder diffractometer. The cylindrical shield on the end of the long beam holds the neutron detector. The smaller instrument below was used for studying single crystals. Below right, the original powder diffractometer. The sample is located between the two poles (conical shaped items) of the electro-magnet. The neutron detector is in the long cylindrical shield, and a typical electronics rack is on the left.

Making radioisotopes isn't the only thing you can do with neutrons. Here at ANSTO we also use them to look at the structure of things.

When it comes to developing high-performance materials, such as superconductors, heat-resistant ceramics and nanocomposites, understanding the relationship between composition and structure is essential. A tiny shift in the way atoms are arranged can mean a big variation in physical properties. Take diamond and graphite, for example: they're both pure carbon, but their atoms are organised quite differently.

One of the instruments we use to do this work is called a powder diffractometer. We built our first one in the late 1950s from an army surplus gun mount that was driven through a car gear box. While it might sound crude, this device was ideal for us because it had a very precise pivot mechanism.

We controlled the diffractometer, and collected and collated our data, with purpose-built electronics. Back then you couldn't simply walk into a shop and buy this kind of thing, so we had a team of people who tailor-made our electronics from scratch.

This powder diffractometer was so accurate and reliable that our scientists were still doing world-class research with it when Australians got to watch colour television in 1975 – and the papers they wrote are still referred to today. It was finally superseded in the early 1980s by a custom-built, computer-controlled instrument that takes 24 measurements simultaneously.

While basic research is a fundamental part of our work, we also take on jobs for industry: testing welds for instance. Welded metal contracts as it cools, and that produces stress that could pull the join apart. Because neutrons penetrate into steel we can use them to detect these stresses.

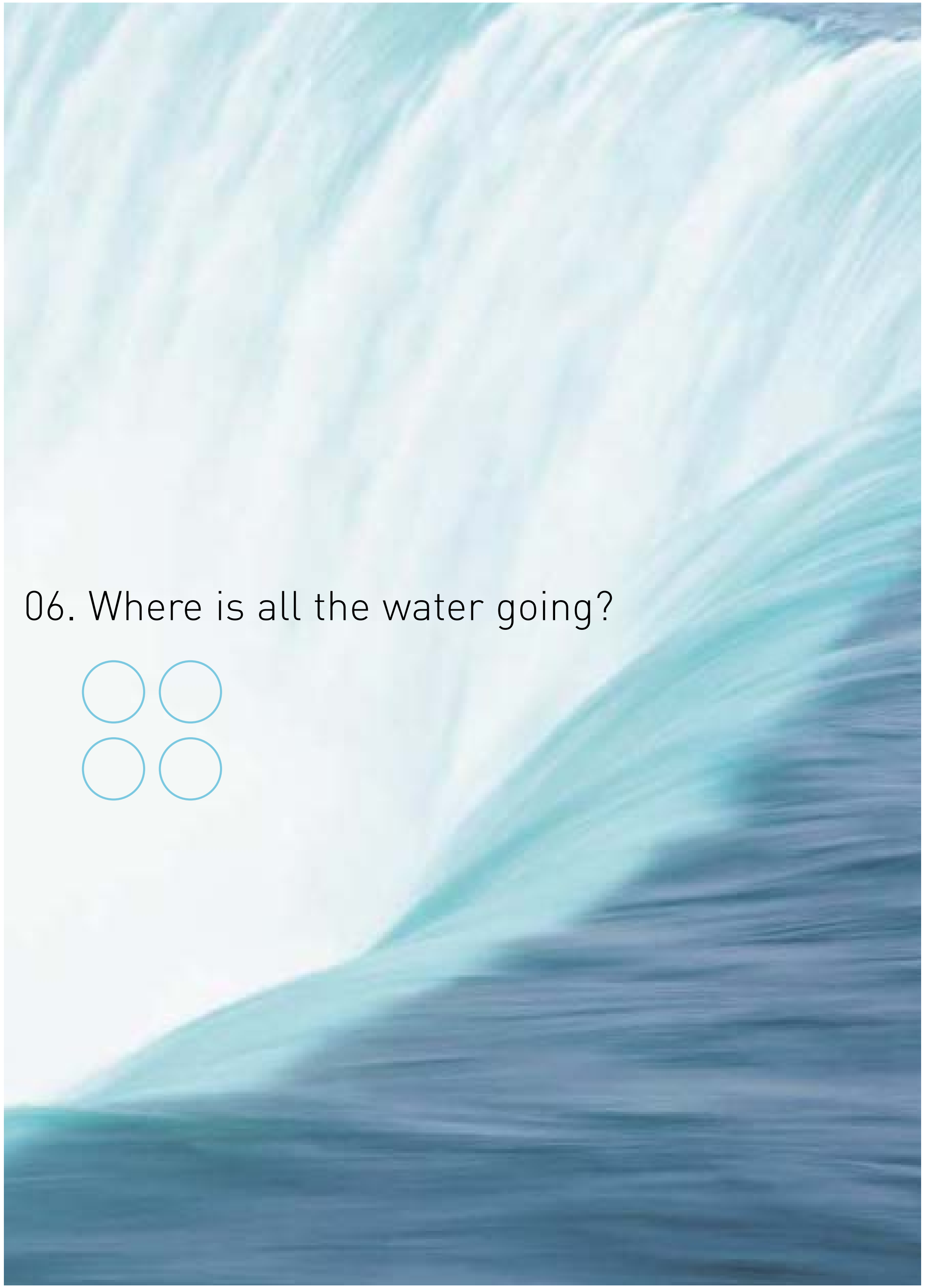
Neutrons are also the only tool we have for accurately pinpointing the smallest atom, hydrogen. ANSTO was asked to check out a new breed of lightweight nickel-hydride battery for electric cars. By finding out where the hydrogen atoms were joined to the nickel, we are helping to improve the efficiency of such batteries.

But we don't just look at physical structure; we also use our neutron beams to tell which way a magnetic field is pointing. This doesn't mean telling one end of a bar magnet from another; with neutrons we can see how each molecule in a magnet lines up. This is important because magnets are strongest when all their molecules line up properly – and the demand for smaller, stronger, more resilient magnets is growing all the time.

When the Replacement Research Reactor (RRR) is built we'll have access to more neutrons than ever before because the RRR will have three times the flux, or flow of neutrons, than HIFAR. The neutron beam instruments – we plan to build eight – will produce more intense beams of neutrons and be freer of contamination by gamma radiation. Also, for the first time, we'll have cold neutron beams. These are perfect for studying delicate biological molecules and their interactions and will be a boon for medical research.

To 'see' the structure of something, we fire a beam of neutrons in and watch for the way they bounce back. The neutrons pass in between the atoms unless they collide with the nucleus in the middle of one. If they do, they don't fly off randomly, but deflect down a specific pathway. Because different structures create different pathways, looking at how the neutrons were deflected lets us know the structure of the sample.

Neutrons are the ideal tool for this job because they're small and can get right into the spaces between atoms even in dense material such as lead. They have no electric charge, so they don't get moved around by negatively charged electrons, but they are magnetic, hence usable for the study of magnetic fields.



06. Where is all the water going?

Above, Honours student, Meredith Thomas, taking a borewater sample from alluvial flats adjacent to the river.

ANSTO, together with the NSW Department of Land and Water Conservation (DLWC), has investigated the loss of up to one-third of the volume of the Macquarie River into alluvial aquifers downstream of Narromine in Central West NSW.

Aquifers are geological formations (rocks, sediments) that hold water. These can be tapped by bores and used as a resource.

The long-term sustainability of using groundwater for irrigation in the area is also under investigation as part of the NSW Water Sharing Plan. Narromine is about 460 km from Sydney, near Dubbo. The land is predominantly used for cotton and grain crops, due to irrigation from the river and a large number of high yielding groundwater bores.

DLWC developed a model of how the water was leaking from the river and invited ANSTO to use nuclear expertise to fill in the picture. The project utilised stable and radioactive isotopes to determine the source and ages of groundwater near the cropping area and assessed the suitability of the water for use in irrigation.

Using nuclear tools such as tritium and carbon-14 dating, ANSTO set about accurately quantifying the amount of water lost from the Macquarie River to the alluvial aquifers in the buried valley adjacent to the river south-west of Narromine. This work was critical in demonstrating that a stream of mainly river water was extending up to 20 km west of Narromine at depths from 30 down to 100 metres – an enormous amount of water.

The source of the water was proven using the stable isotopes of water while the age was determined using the naturally occurring radioactive isotopes. We were also able to delineate the main zones of river water leakage through the use of geophysical surveys to reveal where the water flows underground.

The value of this work is enormous. It provides a sound basis for sustainable irrigation using groundwater in the region, while also demonstrating that the loss of water from the river and extraction for uses such as irrigation has established a new groundwater balance. Additionally, the volume of extractable water resources in the alluvial sediments can now be better determined since the improved understanding of the bedrock topography provides more accurate dimensions of the buried valley.

ANSTO 1980 → Caring for our environment

Modern mining operations the world over manage potentially environmentally damaging waste using techniques pioneered by ANSTO scientists in the 1980s.

It all began with abandoned mine workings at Rum Jungle in the Northern Territory. This was the first commercially viable uranium field in Australia. Between 1954 and 1971, 2,700 tonnes of yellowcake was produced. This may not seem like much, given Ranger churns out around 5,000 tonnes a year, but at the time Rum Jungle was one of the richest sources of uranium in the world. There were also reasonable amounts of copper and other metals such as lead, silver and zinc.

Unfortunately, containment systems for trapping run-off from the mines were often swamped during the wet season. Highly acidic water loaded with dissolved metals sloshed through the surrounding bush and into the nearby East Finniss river with devastating effects on the aquatic ecosystem. Back then, attitudes to the environment were not what they are now and this regrettable situation persisted for some time.

To pin down the source and impact of the contamination, ANSTO scientists did a full-scale ecological survey of the area in 1973. Although it might sound a bit strange at first, one of the most important things we achieved was unlocking the mysteries of what goes on inside heaps of dirt and rocks.

It was common-place at open-cut mines like these to simply dump the overburden (material dug out on the way to the main ore body) in a large pile, without any thought of future problems.

After making many careful measurements, we found that these overburden heaps were the source of most of the pollutants. This was because they contained high levels of iron pyrite, or 'fools gold'.

The problem of acid mine drainage is not unique to uranium mines. Iron pyrite is commonly found in mineral deposits including copper, gold, iron ore and coal.

The idea of pouring acid onto a pile of ore and capturing the metal-rich liquor draining out the bottom has been exploited since ancient times. The technique is called heap-leaching and is now used mostly to extract metals from low-grade ore.

In 1987 'The Year My Voice Broke' won Best Film at the AFI awards, while we too had a coming-of-age. On 27 April, the Act of Parliament which created the Australian Atomic Energy Commission was abolished and we became ANSTO; the Australian Nuclear Science and Technology Organisation.

When iron pyrite comes into contact with oxygen from air and water it oxidises, producing acid and making any other metals present more soluble in water. This kind of pollution is known as acid mine drainage and, if left unchecked, would continue contaminating rivers and groundwater for decades, even centuries.

Our scientists were the first to came up with ingenious ways of measuring the processes going on in the overburden heaps. These revealed what was controlling the rate of production of the pollution and therefore what could be done about it.

The best solution at Rum Jungle was to put a covering of soil on the overburden heaps. It was in three layers (clay, sandy loam and gravelly sand) and the whole lot was contoured and revegetated to stop it eroding.

In 1982, a year before the Franklin River in Tasmania was saved from being dammed for hydroelectricity, the Northern Territory government began constructing this cap system along with the other remediation measures – it took them four years of hard work. Our environmental monitoring of the site continues and has provided many valuable lessons over the years.

The know-how gained from our work at Rum Jungle in the 1980s is still the basis of 'best practice' techniques used to manage acid mine drainage around the world. ANSTO scientists continue doing cutting-edge research for the mining industry; protecting our environment, our future, for generations to come.

07. New waste reduction technology

The treatment of highly acidic Intermediate Level Liquid Waste (ILLW) from radioisotope manufacture is a technological challenge that will benefit organisations around the world.

ANSTO has recently developed novel inorganic sorbent materials (materials that have no carbon in them) that are unique in being able to extract most of the radioactive components from historical ILLW and concentrate it into small amounts. This pre-treatment technology represents a viable option for the management of ILLW.

The sorbent materials developed at ANSTO act like atomic scale sieves. Most of the radioactivity in IILW can be concentrated onto these sorbents (or 'sieves'), leaving behind lightly contaminated liquid which is easier to manage.

Once the small volume of sorbent is saturated with radioactive components, it can be heated to temperatures between 800 and 1300˚C, producing ceramic material that won't dissolve in water, making it suitable for long-term storage in a waste repository.

This technology represents an effective, simple technique to deal safely with the wastes arising rom medical isotope production. In the future, the separation and concentration of valuable medical radioisotopes may also be facilitated using processes such as this.

The sorbent materials are also extremely effective in extracting small amounts of radioactivity arising from lead and polonium in minerals processing circuits in the mining industry.

Chemist, Chris Griffith, measuring the efficiency of sorbents at extracting radioactive species from solution.

08. Radioecology study to benefit tropical nations

A Northern Territory radioecology study recently completed by ANSTO scientists will substantially improve environmental risk assessments in tropical nations across the world.

The research is part of an international collaborative research program initiated by the International Atomic Energy Agency and the United Nations Food and Agriculture Organisation in a wide range of countries such as Russia, USA, Greece, Syria, Vietnam, China, Pakistan and Bangladesh.

More countries in the tropics are expected to utilise nuclear energy in the next few decades, so key information to improve environmental risk assessments is vital.

ANSTO chose Douglas Daly Research Farm, about 250 kilometres south of Darwin, to carry out the experiment. Because similar soils predominate right across the tropics, other countries will be able to use the Australian data to help predict the impacts of any potential environmental releases from unplanned nuclear activities.

A radionuclide is a radioactive isotope of an element. It reacts chemically in exactly the same way as the non-radioactive isotope of that element (ie the stable isotope) but its nucleus is less stable and tends to decay radioactively into some other element.

Trace amounts of short-lived radioactive elements were injected into Blain and Tippera soils, where sorghum and mung bean crops were grown. The research monitored the uptake of the radioactive materials over several growing seasons in order to determine how the plants accumulated radioactivity from the soil (a form of bioaccumulation).

This study showed that most radioisotopes in this tropical environment behave in a similar fashion to those studied in temperate regions, although zinc-65 showed relatively higher bioaccumulation. The work also related the transfer factors of radionuclides from soil to plants to the chemistry of the radionuclides and the properties of the soils.

Until this study was undertaken, there was virtually no relevant information on the behaviour of radionuclides in tropical Australian soils and crops, as research has been restricted largely to the temperate regions.

ANSTO 1990 → Counting atoms for science

Archaeologists dating ancient rock art, police monitoring the supply of illicit drugs, environmental scientists measuring greenhouse gases and international organisations making sure countries stick to the nuclear non-proliferation treaty – they all turn to our world-class particle accelerator, ANTARES, for answers.

ANTARES (the Australian National Tandem Accelerator for Applied Research) is internationally recognised as one of the best instruments of its kind, primarily because of the skill and ingenuity that went into its construction.

In 1988 our scientists travelled to Rutgers University in the US and collected the accelerator that was to be the foundation of ANTARES. Once home, they began souping it up: refurbishing equipment, adding new pieces, and overseeing construction of a brand new building to house it all. By August 1991, just before the official opening, ANTARES was detecting the radioisotope carbon 14, which is the basis of carbon dating.

Anything that's taken up carbon from the atmosphere, and is less than 50,000 years old, can be radiocarbon dated. This includes organisms that were once alive, and their products (such as shell, wax and pollen).

Our instrument is so sensitive that we confidently work with samples containing just 20 micrograms of carbon, and we are working to decrease this still further. Only a handful of facilities around the world can do this: most require at least 300 micrograms of carbon. Because getting the carbon out destroys the original sample, our facility is very popular with those who simply can't gather big samples or who are custodians of valuable historic artefacts.

ANTARES handles thousands of samples a year, but they're not all for radiocarbon dating. ANSTO is accredited by the International Atomic Energy Agency to check samples from around the globe for tell-tale signs of nuclear testing, such as iodine 129 and uranium 236. Since our equipment can find one atom of uranium 236 lurking in a million million other uranium atoms, it's difficult to hide them from us.

We also use ANTARES' ion beams for investigating the surface of materials and finding out what they're made of. It's a bit like shining a torch onto something and seeing what colour light bounces back, but we're looking for what particles and types of radiation are created when the ions react with the sample. Because the beam of our 'torch' is barely as wide as a human hair, we're able to look at things in incredible detail.

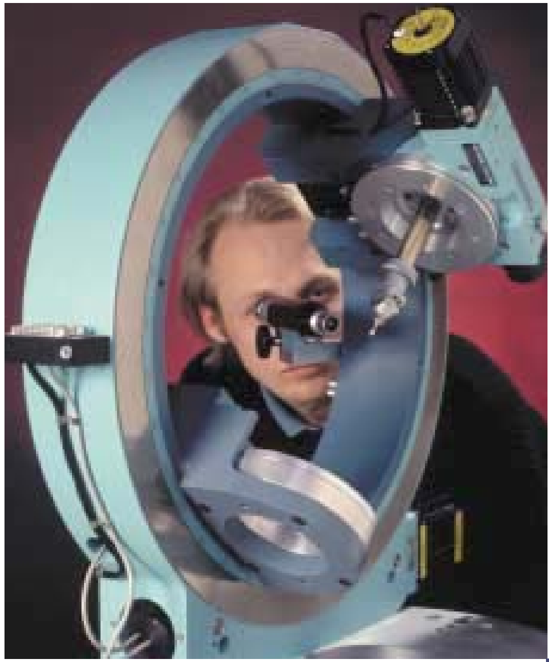
Our dedicated team is always on the lookout for new applications of tandem accelerator technology and jumps at the chance of designing an instrument to make it happen. The future for ANTARES is, quite literally, a work in progress.

Examples of work done using ANTARES:

- A crown thought to belong to the first Holy Roman Emperor, Charlemagne, was confirmed to be of about the right age by analysing wax securing precious stones to the metalwork.
- Dating illicit drugs to find out when they were harvested lets police know if they've been moved quickly to market or stockpiled first, and therefore how much is yet to hit the streets.
- ANSTO undertook radiocarbon dating of rock paintings on Vanuatu, adding to the scientific knowledge of human migration in the Pacific and Indian Oceans.

Carbon dating works on the principle that plants take in carbon 12 and the radioisotope carbon 14 from the atmosphere during photosynthesis. Animals who eat the plants (or who eat other animals who have eaten plants) will also pick up the carbon. No more carbon is absorbed after death so the ratio of the isotopes changes very slowly over time as the carbon 14 decays.

09. Materials research of the future



Part of a four-circle diffractometer which collects data from single crystal samples. This allows scientists to determine the detailed atomic structure of the material (i.e. the relative positions of the atoms with respect to each other). Slight changes in the structure can lead to large differences in the properties of the material, such as its strength and electronic or magnetic characteristics.

By scattering neutron beams, ANSTO scientists and engineers are building a future in materials research with a modern high performance facility that probes atomic and molecular structures.

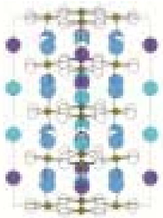
New materials that display exotic and exciting properties - potentially of great benefit to mankind - are discovered in chemistry, physics, materials science and engineering laboratories every day. To exploit this potential, scientists must have a complete understanding of crystal structures and interactions on an atomic scale – as in, very small!

Many materials either are crystals or are made up of them. Anything from sugar, salt and sand to diamonds and rubies to metals and ceramics. Even mud and bones.

There is no better way of probing these structures than neutron beam scattering. However, the method requires that neutrons be generated in a nuclear fission reaction and then cooled sufficiently so that their interaction with atoms and molecules can provide information about the way materials are arranged and how neighbouring atoms influence each other.

As a result of neutron beam research there have been advances in our understanding of the influence that internal structure has on material properties. For example, there have been improvements in magnetic materials for such things as small electric motors and read/write heads for computer disks; catalysts for improved efficiency in chemical production; and ceramics for the encapsulation and storage of radioactive wastes.

ANSTO's replacement research reactor (RRR) will provide a more powerful and versatile source for neutron beam research than the ageing HIFAR reactor. The design and construction of the neutron beam facility is being undertaken within ANSTO's Bragg Institute and in close consultation with the Australian research community.



Atomic and Molecular Structures

Atomic structure is the arrangement of elements at the atomic level (ie. atom to atom).

When atoms are brought together they stick together (bond) in ways which are specific to the elements and the surrounding atoms. Some prefer angles, some prefer straight lines and some go in for spirals (like DNA, the core atomic structure of all living creatures).

Molecular structure is the arrangement of the atoms as they form a molecule – from simple ones such as water (always bent) or carbon dioxide (straight), to more complex ones like alcohol (zigzag – which explains it all, really) or benzene (6 fold ring). Then there are very complex ones such as vitamins and proteins (a folded and coiled long piece of string).

Each molecule has its own particular atomic arrangement or structure when in isolation.

To determine an individual structure we need to have the material in crystalline form – in which many millions of identical molecular units stack up like bricks in 3-dimensions. We can then scatter neutrons from them in a systematic way and analyse the data to determine the arrangement of the atoms within each unit.

Many materials change structure when their environment changes, which affects the properties of the material.

10. What is Sol-Gel technology?

Sol-gel is a technique for producing ceramic or glass materials at low temperatures. A fluid containing nano-sized particles is produced (a sol) which sets to form a gelatine-like solid (a gel). The gel can be further heat-treated to obtain ceramic or glass materials.

These materials can be used in areas ranging from biotechnology, telecommunications, protective coatings, nanotechnology, environmental monitoring and waste clean-up.

ANSTO is researching how the sol-gel technique can produce microscopic particles for the controlled delivery of therapeutic drugs to specific sites within the body. This may help avoid side effects that can arise from standard (uncontrolled) delivery. Apart from making for happier and ultimately healthier patients, it can save on doctor-time and costs (for both the individual and the community as a whole).

In biotechnology, ANSTO's research into how to make porous ceramic 'cages' for immobilising biological species such as bacteria and enzymes has potential for use in biocatalysis (e.g. fermentation) and environmental monitoring and remediation (making polluted sites clean).

Potential commercial applications exist for ANSTO and Australian industry in the form of new ways to engineer thin films on plastics, metals and glass to provide protection against abrasion and corrosion, or to modify the optical properties of the substrate (e.g. by depositing anti-reflection layers on lenses).

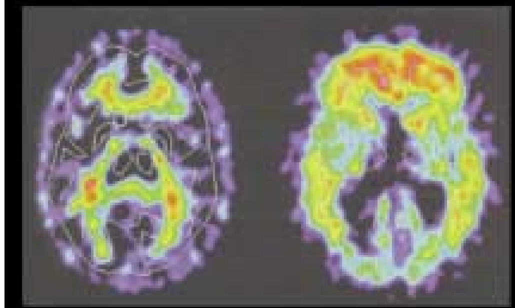
ANSTO is developing its unique intellectual property with appropriate research & development partners, generating valuable income for Australia.

'Porosity' refers to the amount of pores (or open space) that materials contain, and how much liquid or gas can be stored within them.

Nanotechnology refers to materials that can be engineered on the 'nanoscale' (one nanometre = one millionth of a millimetre) through molecular-level control of their synthesis.

11. Helping people with degenerative brain diseases

Amyloid Imaging with PET



Normal brain Alzheimers disease

ANSTO makes a major contribution to the community by producing radioisotopes, the substances that are at the very core of Nuclear Medicine. We provide nearly all of the radioisotope needs of medicine in this country.

ANSTO's scientists are continually looking at ways to better harness the power of radioisotopes, which has uses not only in combating cancer and Multiple Sclerosis, but also degenerative brain conditions such as Alzheimer's Disease.

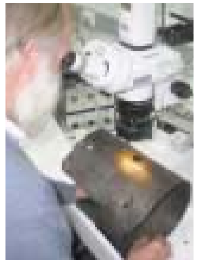
ANSTO has contributed to the development of technology that allows different patterns of a protein in the brain (beta amyloid) that precipitates out in Alzheimer's to be clearly imaged.

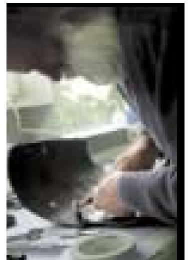
The precipitating protein has been labelled with a small amount of a radioisotope. Early studies in humans are very encouraging. PET imaging (positron emission tomography) cameras have shown uptake of some of these compounds in the brains of Alzheimer's patients but not in healthy volunteers.

It is hoped that these scans for amyloid will be an accurate diagnostic test for Alzheimer's and be able to show who is going to suffer from it before they have symptoms. The test will probably work on people as young as 40 who have the disease. Currently, there is no reliable diagnostic test for very early Alzheimer's when treatment is likely to be most effective.

This disease affects approximately 2% of individuals at age 65, with the prevalence increasing every decade after this such that 10% of individuals aged 75, and 20% of those aged 85 are affected.

By 2040 the number of Alzheimer's sufferers in Australia is expected to triple and the costs associated with their care will approximate 3% of GDP. ANSTO's work will therefore impact positively on the entire community by reducing health costs and providing medical solutions.





12. The secret life of Joe Byrne's armour

The Kelly Gang visited ANSTO in 2003. Or, to be more accurate, the armour of gang member Joe Byrne paid us a visit.

The armour of Ned, Joe and the gang are an iconic part of Australian history. Forged steel, that unforgettable helmet – just a slit for the eyes – lumbering, almost falling towards you.

The stuff of which folklore is made.

But what has the armour got to do with all the science that goes on at ANSTO?

The story started with the National Museum of Australia. They decided to put on an exhibition of heroes and villains from around the world, called Outlawed! The World's Rebels, Revolutionaries and Bushrangers.

When the NMA took stock of its exhibits, they realised the armour worn by Joe Byrne was going to be the star attraction. The museum thought this was a great opportunity to prove or debunk some of the theories surrounding the armour. Through their contacts in the University of Canberra they discovered that ANSTO would be the perfect place (the only place in Australia) to do this scientifically.

Over the years numerous debates have emerged about what kind of metal was used to make the armour (ploughshares being a favourite nomination – perhaps donated or stolen) and where it was made (in a blacksmith's forge or a bush campfire).

ANSTO scientists were assigned the tasks of revealing some of the armour's long-held secrets. The following analytical techniques were used:

- Neutron diffraction: this process provides information on how the atoms are deformed in the crystal lattice of the armour as a result of heat treatment or being worked with a hammer or something similar.
- Metallography: areas of the armour that had been scuffed bare while on display were polished without mechanical deformation, etched in acid (which revealed the processing history of the steel) and then replicated with cellulose acetate film.
- X-ray fluorescence: x-rays from radioactive sources were used to generate characteristic radiation from elements within the armour, confirming the alloy content of the steel. Lead detected at some places indicated where bullets had ricocheted off the armour – the armour obviously did the job it was designed for!
- X-ray diffraction: this process is similar to neutron diffraction. The x-rays interact with the crystal structure near the surface, whereas neutrons examine the bulk of the material.

Using these techniques (which examine the crystal structure of materials), ANSTO scientists were able to show that the armour was probably made from plough shares and that it was forged in a low temperature (bush) fire, not a blacksmith's forge.

If you would like to receive online newsletters discussing ANSTO's science and technology, please send your email address to enquiries@ansto.gov.au and put Subscribe in the subject line. You can also phone (02) 9717 3770 to let us know your details. If you are interested in receiving local news on ANSTO please also provide your postcode. You can be removed from these databases at any time. They are not given to third parties.

www.ansto.gov.au

ANSTO is the Australian Nuclear Science & Technology Organisation

PMB 1
Menai NSW 2234
Australia
T. 61-2-9717 3111