

**Long Range Science: personal reminiscences of the Daresbury Synchrotron Radiation
Laboratory**

by John S. Reid

The first chapter was penned in 1994, when I had been going to the Daresbury Laboratory for over 10 years as a visiting scientist, usually in the company of Dr Moreton Moore of Royal Holloway, Dr John Pirie from Aberdeen and at least one other member of our Aberdeen group. For a period of years the other member was Dr Stephen Clackson. The second chapter was written in 1997.

In disciplines traditionally associated with a University Laboratory, an increasing amount of scientific research was being carried out in the 80s and 90s at national, central facilities like the Daresbury Laboratory. Such facilities attracted an international clientele of researchers to some large device, perhaps a telescope, a nuclear reactor, a large laser or a particle accelerator, which in turn supported a clutch of special experimental stations. Today the central facility for scientific research is even more common.

*The purpose of our work over this period was to develop apparatus suitable for energy dispersive diffuse X-ray scattering and make measurements with it. No-one else was doing such work at Daresbury at the time and in its own way it was a pioneering venture, though not novel enough to merit keeping some quite large pieces of apparatus in our historical scientific instrument collection. One monochromator described in John S. Reid & Gordon J. Milne "A Simple Variable Wavelength X-ray Monochromator" *Journal of Applied Crystallography*, vol. 21, pp 992 - 993 (1988) is in the collection. On the whole this record supplements other X-ray diffraction equipment in our collection, illustrating another side to the X-ray scattering work carried out at Aberdeen.*

What was it like to come out of the University laboratory and undertake research work at a central facility? Early in my career, I had made many visits to the Harwell Atomic Energy Research Establishment to use neutron scattering facilities associated with one of their reactors and analyze the results. The Daresbury experience was different in detail – it was some two to three decades later and a different place - but the laboratories had sufficient in common that the flavour of such places comes through in this account.

Chapter 1

The visit

It is about 370 miles, door-to-door, from Aberdeen University to the Daresbury Synchrotron Radiation Laboratory. In a noisy Transit van, laden with equipment, the journey takes a good 8 hours. Since you are joining us at the beginning, I'll warn you that there will be little time or inclination for any other useful activity on the day. We shall follow the routine of the journey, take it slowly, enjoy the scenery and prolong the gossip stops at two or three motorway cafes along the route.

Three of us are heading for an academic laboratory that is too big, too complex and too expensive for any single University to house. It is a multi-million pound blend of precision mechanics and computer controlled electronics that offers x-ray and ultraviolet facilities far beyond anything else available in the country. To the public, if not to many an academic, it may seem a wonderland of science, a simile the more appropriate since Daresbury is the village in North Cheshire where Lewis Carroll was born.

By mid-evening of our journey there, the hilly countryside of the North on either side of the motorway gives way to panoramic sheets of sodium street-lighting fading into the distance. Manchester looms. We shall soon be turning off the M6, speeding towards Runcorn & Chester along the M56 before being greeted by the first real sign that our destination is close, the A56 to Daresbury & Warrington. Now it's but a mile and a quarter along the A56 before the turn off into the twisty Keckwick Lane and, at last, the lab lies only a few hundred yards down the hill.

From autumn until spring it is dark when we arrive. Over the brow of Keckwick Lane, the lights of Warrington and Runcorn twinkle as far as the eye can see, except in a blank sector where they are hidden by the gigantic tower of the Nuclear Structure Facility at the edge of the Daresbury site. We back the van up to the door of the hostel, check the register for our room numbers, pick up our room keys and leave our luggage. We're in. A quick phone home confirms our safe arrival. Leaving the van by the front door is an unpopular crime. We drive onto the main site, where security will lift the barrier as if we are old friends. Park beneath the NSF tower, have a quick look over the familiar surroundings before rounding off the evening with a visit to Daresbury's *Ring of Bells* inn. I usually return to a long soak in one of the two baths in the hostel.

The hostel itself runs to over 50 bedrooms in two, separate, 2-storey, mid-century brick houses with early 1970s flat-roofed extensions. It nestles on a hillside terrace at the

edge of a small wood overlooking the Daresbury site. The rooms are clean and neat, with soft towels and too much heat. They're all much the same: about ten square metres into which fit a wardrobe, wash-basin, firm bed, small bedside cupboard and oak-finish desk with one working chair and one easy chair. Plain walls with no pictures and a mottled grey-brown wall-to-wall carpet create a neutral atmosphere that is pleasant enough for a short and busy stay. There will be no time to appreciate the finer points of life in the coming days.

The two separate hostel buildings are named Hinstock Mount and High Firs. They are run as one. For the visitor, the hostel really has only three rooms: the bedroom-study, a dining room (in Hinstock Mount) and a main lounge (in High Firs). The lounge has fifteen overly soft seats, ranged in front of a TV and usually occupied more by the remnants of the day's newspapers than by bodies. In our line of work there are few opportunities to snatch even a short spell here. In times of major equipment breakdown, refuge can be sought in one of two smaller lounges, normally empty, though even on these occasions the scientific library or the computing facilities on-site keep us away. The main public room in the hostel is the dining room, used for breakfasts only: 7.30 - 8.30, weekdays, 8.30 - 9.00 weekends and holidays.

Breakfast is worth getting up for and will detain us in the hostel for another paragraph, though we are impatient to set out. Breakfast at home is a snack rather than a meal; prepared by myself, eaten either standing or sitting but in either case while not fully awake, and cleared away mostly by myself. At home there are no papers, no TV and only enough talk to clarify the domestic arrangements of the day. I'm glad to say that at Daresbury there are also no papers or TV at breakfast, but we usually find time for three-quarters of an hour of civilized conversation on the progress of the work, changing social customs, sport, wildlife habits or other topics of mutual interest. Breakfast is one of the times during the day when the whole group will be together. At breakfast you run your eye over fellow guests and greet old acquaintances. You watch the cats sport on the grassy bank outside the tall windows, or the birds and squirrels in the trees beyond. Breakfast is a meal, beginning with juice, coffee and a choice of cereal stirred with a pot of yoghurt (my own choice). A large slice of thick ham, hand-cut from the joint, eaten with Wensleydale cheese and an apple, is a tempting second course on weekdays. No doubt it is offered as an alternative to the cooked breakfast taken by many but the hungry may take both. If this sounds greedy, remember that this will be the only meal of the day that will provide food you would recommend to your friends. Replete, a leisurely toast and choice of marmalade, honey or jam is washed down by more coffee. The day has begun or, if you have just come off night-shift, it will be time for bed.

Don your coat and grab your gamp, it may be after midnight before we're back and the weather could well change by then. On to the site, with a slight pause near the top of the concrete-stepped path leading down hill from High Firs. A panorama greets us. Over the bracken and brambles to the left, a distant line of tall pylons is the first conspicuous mark on the horizon. Next, the dark silhouette of a broad, sandstone tower that begs us to guess its use. I failed, until a walk up to its base some two miles away in the village of Norton, followed by a browse of historical books, revealed it as an important water tower in the famed nineteenth century North Wales to Liverpool aqueduct. Impressive though it is, for me it is surpassed by the monolithic Nuclear Structure Facility tower that blocks the line of sight only 100 metres away. Within the tower's massive concrete walls stands a 20 million volt Vander-Graaf generator, insulated with sulphur hexafluoride gas. Like the water tower, it is elegant, functional and on the limit of the achievable. Perhaps it is only in imagination of purpose and refinement of technology that it exceeds the Norton tower. The generator accelerates ion beams whose interactions with selected targets probe the secrets of nuclear structure, representing an aim and achievement that is truly twentieth century. From this momentary reflection, one's eye soars over the low, extended, half-hidden buildings at its base that form the rest of the Daresbury site, to the raked clouds rising from some of the seven giant cooling towers of the distant Fiddler's Ferry power station. The almost invisible plume from the adjacent 400 foot chimney adds to the atmosphere its weekly voluminous tonnage of carbon dioxide and sulphur dioxide. Behind the nearby Bridgewater canal, two railway lines and the restless, roaring expressway to Runcorn and Widnes, stretching to the right lies a sprawl of houses, services and the remains of once great manufacturing industries. Specks of detail recede into the ever present haze. Low trees beside us finally cut off the view. This is England, wrought by the hand of man.

As we walk down the steps past the crab apple trees, the panorama eclipses. A shining reflection from the Mersey estuary and the taught bow of Runcorn Bridge come into view behind the NSF tower. I search for the correct Yale key on the hostel key-ring and we enter through the perimeter fence gate. Circumventing the NSF buildings, we drop down to the synchrotron radiation complex, heading for the nearest door of the outer hall. If you were to look at a photograph of the approach, all would appear silent and empty of people. We meet no-one on the way but all is not quiet. We hear the increasingly forceful throb of a heavy-duty motor hidden within the compressor blockhouse. *'Hearing protection must be worn'* announces a notice on the blockhouse door. Daresbury is strong on safety notices. We walk past an insistent hissing coming from the vent of a 7 metre high liquid nitrogen reservoir. Ice 300 mm thick covers the pipework at its foot, though the weather is not cold. *'Asphyxiant gas NITROGEN keep this area freely ventilated at all times'*. A swirl of wind does it for us. Open the nearby un-named grey-green double doors and we are standing in the outer hall. *'No*

smoking', 'No drinking', 'No eating' is posted in graphic detail. 'For security reasons video cameras are operating in this area', and out of curiosity I scan the distant roof to locate them.

The building may have looked inconspicuous from the High Firs path but it can now be seen to resemble an aircraft hanger of useful dimensions. The plan of its layout is not obvious. Stacked two-storey Portakabins on the right, housing biological support laboratories, suggest a shortage of space, yet large stores, discarded equipment and pieces being assembled for commissioning lie spread around behind fenced-in areas. What did you expect? We have, after all, come in the back door. Under the roof of the outer hall are the more distant experimental stations, more distant that is from the synchrotron radiation source, on beamlines 7, 8 and 9. The hall also houses support rooms and dark rooms, the linear and booster accelerators that feed the synchrotron and an instrument room of synchrotron control electronics. These utilities were not separated from the remainder by design but by the accident of being placed in a set of buildings constructed for a completely different machine, the high-energy proton synchrotron NINA. NINA was dismantled in the mid 1970s.

For all its size, the hall is quite a noisy place. An untuneful chorus of extractor fans vent from the hutches and Portakabins into its interior, providing a background whirr of motors and a rushing of air. Two bands of tall, wire-reinforced frosted windows run the length of the building on either side but fail to provide enough light during the day. Powerful roof lights with domed reflectors make up the deficit. Also up in the roof, two 25-ton travelling cranes span the 30 metre width of the hanger. We proceed towards station 7.6, dipping under the long stainless steel vacuum pipe that carries the intense x-ray beam to its destination, and to our destination, 80 metres from the source. The pipe is chest high, about 250 mm in diameter, flanged together in sections with fittings protruding at frequent intervals. It is both vacuum tight and x-radiation tight. If it were to fail, pneumatically driven shutters would seal the entrance of the pipe in milliseconds and the entire x-ray producing synchrotron beam would be dumped.

Though station 7.6 looked small from the back door, it is a commodious, end-of-line experimental area. It consists of a yellow-painted steel hutch about 5 m high by 4m wide by 6m long, with an adjacent control room of an odd shape but some 40 square metres in area. We check that the previous users have left and I open the door with the key. The control room has thin wooden walls, a corrugated Perspex roof and large Perspex windows on three sides. On two of these sides, most of the windows are covered with posters advertising to passers-by the science carried out within. *The Daresbury Photon Microprobe for Trace Element Analysis* [Warwick University and Amsterdam]; *X-ray Topography of Dislocation*

Motion in Ice [Birmingham]; *X-ray Topography of Diamond* [Royal Holloway]; *Energy Dispersive Diffuse X-ray Scattering* [Aberdeen].

There are no concessions to aesthetics anywhere. Services are brought in 3 m high at roof-top level along an open metal service channel: electricity, water, telephone, computer local area network, nitrogen gas, vacuum exhaust, beam-line warning lights and emergency shut-down control cabling, all visible for ease of access. Seven fluorescent tubes provide a good light. The furniture consists of 3 desks and a table, one 19-inch rack of electronics and two monochrome Selanar computer terminals. Tables of X-ray Emission Energies and Electron Binding Energies for the Elements adorn the walls. A thermo-static fan heater for cold nights looks down idly from near the ceiling above the station operator's position.

Our immediate task is to set up in the yellow steel hutch the equipment that we have designed at home and brought with us. I fetch the van and, with permission, drive it into the outer hall. One of us locates an abandoned trolley while the other finds a broom to sweep out dust, dropped screws and scraps of paper left by our predecessors and several groups before them. We decant trolley loads of boxes, fill our Dewar with 30 litres of liquid nitrogen and, subsequently, our x-ray detector from the Dewar. The detector will take at least six hours to cool properly.

Within the yellow steel hutch are two pieces of hefty apparatus known as '*the double-crystal camera*' and '*the white-radiation camera*'. Neither of them looks anything like a camera, nor have they a single lens between them. The description *camera* is used because x-ray sensitive photographic film or plates can be placed on these devices to record the x-rays scattered by centrally mounted crystal samples. Our work does not use photographic film but instead the cooled x-ray detector that supplies electronic signals for digital recording. The double-crystal camera will therefore serve us only as a moveable mechanical platform. Two tall racks of electronic motor-drivers provide the pulses necessary to step an assortment of motors on both cameras. We turn off the white-radiation camera, for it will be no use to us, and concentrate on moving the double crystal camera into an appropriate configuration on which to mount our equipment.

It will take about twenty-four hours to set up our apparatus. Parts, some weighty, must be bolted together; our own motors and electronics installed and supplementary wiring connected onto the patchboards in both hutch and operating room. These patchboards are at either end of permanent cabling that runs through metal-clad, radiation-blocking channels conveying signals and control voltages between hutch and operating room. The apparatus within the steel hutch must be entirely remote controlled, for the radiation dose there can

reach lethal levels. We align the station's laser to the x-ray beam using pin-holes in x-ray sensitive paper; set up our component parts by optically surveying with this laser and then more finely, to an accuracy of about 0.1 mm, with the x-ray beam itself. Likewise, our specimens are oriented by a combination of laser beam and x-rays, aiming for an accuracy of one-hundredth of a degree.

The final parts of our sample chamber are assembled, a small Christmas tree of vacuum fittings bolted to the chamber lid and the vacuum pump switched on. There is an anxious watch to see whether our x-ray transmitting vacuum window, only one fortieth of a millimetre thick covering a slit 700 mm long by 12.5 mm high, will hold against atmospheric pressure. At long last we are ready for the main purpose of our mission, to test our innovations in the apparatus since the last visit and to record diffuse x-ray scattering intensities from a new sample. I will certainly find it a pleasure to spend less time within the hutch. Its off-white painted walls reflect the light from six, long, fluorescent tubes and, when needed, four high-powered quartz-halogen floodlights. It is not easy to hold a conversation across the width of the hutch above the noise of rushing air and the roaring motor of the extraction fan installed to remove the harmful ozone created by the x-ray's ionization. Working inside a steel box is not a recipe for a quiet life.

The safety procedures for evacuating the hutch preparatory to admitting the x-rays are by now familiar. The loud click of a heavy-duty relay confirms that the search initiation switch beside the door has been rotated; the urgent beep-beep of a warning siren cuts through the roar of the fan; press search button 'A' on the far side of the apparatus, button 'B' on the end wall and retreat to escape the penetrating siren; swing the weighty steel door to until it closes with a solid clunk, steel against steel, and press the large door-side button to activate the interlock. The lights within turn blue and anyone still inside who has failed to notice from this cacophony of sound, rapid motion of personnel and flashing of lights that the working area has been sealed has twenty seconds to press one the fist-sized yellow buttons on the wall to isolate the whole beamline. All this for an area scarcely larger than a modest domestic living room. It sounds even noisier at 4 O'clock in the morning. After that, another green button activates a hissing pneumatic shutter which allows the beam into the hutch. Even now the x-rays have not emerged from the confines of their stout stainless-steel pipe, for they have to pass yet another pneumatic 'fast shutter' that can be opened for preset times from 0.1 seconds to many days, upon the press of a final button.

We sit back in the chairs of the operating room, glance at the synchrotron beam current monitor, the x-ray beam ionization gauge reading, the flickering green light from our detector electronics that shows all is well as incoming x-rays arrive at an acceptable rate. It's

pretty noisy here too, with the whirr of cooling fans in the electronics rack, the reverberation of their cabinet and the penetration of outside noise but it matters little: we are ready to go.

Two days have passed. I am sitting in the hostel bedroom with the windows open on a cold October night, writing this at 2 am. Hailstones are drumming on the flat roof. Any sane person would be in bed, which is where I went in mid evening. Where I should be just now is attending the apparatus, but lightning has struck the site and a serious control system fault knocked out any immediate prospect of a synchrotron beam. Just when you think you've seen every possible reason for the system to fail, a new one appears. One aspect of working at Daresbury is a necessary asynchronism between our biological clock and the real world.

Another aspect is that we have no private life to speak of: a telephone call home now and again or a glance at the daily newspapers reminds us of the 'normal' world outside; otherwise attention to day-to-day matters is as consuming as it would be on an Atlantic yacht race or an expedition to a distant land; the minutiae of fending for oneself being replaced by the minutiae of the experiment. Is the alignment problem solved? Is the crystal suffering radiation damage or moving on its mounting? Are there still problems with background scattering, data storage or post collection computation? A score of changing questions always awaits attention.

The daily shenanigans of politics, the adrenalin of the sporting world, the horrors of the day's catastrophic news occupy little conscious time for the experimenter at work. Such normally important considerations as whether today is a week day or a weekend or a public holiday are scarcely observed. One notices the inescapable signs of the seasons: in spring, the ever-present birdsong from the budding young trees near the path; in summer, the ripening corn in adjacent fields, the 'pick your own strawberries' signs, the holiday traffic on the Bridgewater canal disturbing the hopeful, copiously equipped, canal-bank fishermen; in autumn, the ripening brambles around the hostel or the efflorescence of fungi through the grass; in winter, the frost and the smell of unventilated, industrial England on a windless day breathed in front of a backcloth of vertical cloud-forming steam plumes from the Fiddler's Ferry cooling towers. Aside from the continual roar of the trunk road traffic, society's myriad daily developments impinge little on the scientist at Daresbury.

I work from lunch time to early evening, and all night. At night there is a greater chance of making an error, a greater opportunity for uninterrupted thought and uninterrupted attention to the experiment; the night shift should be taken by the project leader, not, as I believe frequently happens, by the least experienced. The accompanying schedule is work, sleep, work, sleep, two periods of each every twenty-four hours. This requires a dedication to

the cause verging on a passion. Big science, or at least big scientific facilities, need a generous supply of the passionately committed who can walk to work through the night air at 12.30 am with a spring in their step and a sense of imminent achievement. Such people must be motivated, skilled and knowledgeable. In my experience, they are in quite short supply.

The night following the lightning strike, all was back to normal. After midnight I went out as usual into the cool, almost still air with the sense that for a few nights every year something special was on offer, a modern adventure in science. I paused at the top of the concrete steps to scan the band of anonymous, twinkling yellow lights stretching from hillside to hillside, the double row of red beacons climbing the tall Fiddlers Ferry chimney, the cooling tower plumes lit from below, now raked seaward. Cassiopeia was almost overhead; the road traffic stilled to the passing whoosh of a single vehicle, scarcely noticeable above the light rustle of nearby birch tree leaves. I walked slowly down the steps between the squat rectangular guiding lights to meet the man-made sounds of the giant NSF ventilating fans and the nitrogen hissing, motor chugging synchrotron site. The experiment was indeed an adventure, as was the whole synchrotron radiation complex, a synthesis of mankind's curiosity, understanding and ability.

There was time that night between readings to emerge from the isolation of our experiment and walk round 'the ring'. The ring is the source of all power for the experiments. What you can see is a ring of shining bright steel, surrounded by magnets, tapped by many sensors and pumped all the way round to the highest vacuum attainable. I have only once seen this visible ring, for in normal operation the radiation levels behind the thick concrete walls protecting us from it are life-shorteningly high. Threading the centre of this ring of expensive hardware lies the actual ring of power, a very high energy electron beam travelling within an ace of the speed of light. Unlike mythical rings of power, this ring is real and large, 100 metres in circumference. The travelling electrons are invisible until they are bent by magnetic fields; at the bends they glow in these fields, with a brilliant and blinding blue light whose spectrum extends through the ultraviolet into the region of hard x-rays. This is synchrotron radiation. From each magnet designed to bend the electron beam, a rod of 'light' emerges, straight as a laser beam and almost as narrow. Along these powerful beams of ultraviolet and x-rays that emerge at tangents from the ring, the users' experiments are arranged, each cutting off a slice of the synchrotron radiation for their own use. To walk round the ring is to walk round these radiating lines of experimental stations. At present there are twelve active lines hosting around 30 experimental stations.

Our station, 7.6, is the most distant one from the ring. If we could walk along the beam pipe back towards the source, it would take a good minute. Since this journey is

impossible due to various intervening barriers and walls, we must take a much longer route between station and source. Outside our station is a line of Portakabins, essentially large brown boxes serving as adjacent laboratories. Our Portakabin is 3 m by 10 m, the size of a small mobile home, containing two photographic darkrooms for processing film used with the x-ray cameras and a central room for film drying and microscopic examination. We sometimes use one of these darkrooms for developing x-ray 'topographs' to characterize our samples but tonight we can skirt this Portakabin and head out across the empty space at the centre of the hall. Our station being in the outer reaches of the outer hall, it is not uncommon to find pieces of apparatus parked nearby, some presumed abandoned in transit, others temporarily plugged in for off-station commissioning. Today there is a large vacuum vessel of unusual appearance sitting almost centre-stage on the concrete floor adjacent to our Portakabin. Its chamber, two and a half metres high by one metre in diameter, has a conical top bristling with connectors and gauges. Standing on four tubular legs, it looks like a cartoon version of a small spacecraft. Disappointingly, 'NASA' is not boldly stenciled up its side but only the number '2'. What and where is '1'? Since there is no-one around to solve this small mystery, we walk on past another liquid nitrogen dispenser, an improbable hissing stainless steel tank on wheels with a long flexible tube emerging from its base to trail on the floor. I have a fleeting vision of a giant, hungry, robotic anteater. Well, this is a break from the serious stuff.

We can look in to the operating rooms of the outer stations on lines 8 and 9. A few are empty, either working under computer control or not in operation; some have one or two people sitting with a keyboard in front of them surveying a computer screen; the protein crystallographic station has five. Five people at 3 am! Either its very hot science or they have a huge research group. At least the stations in the outer hall are large enough to take such a number. Once in the inner hall, as the beamlines converge towards the ring the crowding of stations becomes reminiscent of birds' nests on a sea cliff, and the background comparably noisy from the mechanical chatter of vacuum pumps and cooling fans. Users of the innermost stations work in open-plan, without enjoying the privacy of a control room.

Each beamline is the product of man-years of thought, planning and construction. Looking over the beamlines, there is a mind-boggling amount of detail to be seen; one can only home in on the half familiar. Nonetheless, merely to have browsed amongst the state-of-the-art hardware used in some of the modern research techniques that we teach to our advanced students is worth more than weeks spent in a University library.

On a quicker return journey to our equipment, my eye catches some of Daresbury's many multi-coloured warning signs found above doorways or stuck onto doors, walls and

cabinets of equipment: *'Injected Beam On', 'Stored Beam On', 'Magnet On. Do Not Open Door', 'Radiation. No Access to Linac or Booster Roof Except Under Permit To Work', 'Caution Laser Operating', 'Delicate Instruments Keep Off', 'Radiation Notice. This is Lead Loaded Perspex Window Not To Be Changed For Glass or Ordinary Perspex Under Any Circumstances', 'Danger X-RAYS Press Emergency Beam Off', 'General Evacuation. If a WAILING SIREN is heard you should collect Personal Belongings and go to the Staff Car Park'*. Contrary to the impression given by all these dire warnings, the Daresbury Laboratory is not a hazardous place to work in. Hazards are well confined to areas occupied only by apparatus, with users excluded by strict safety procedures. For example, users are not required to register as Radiation Workers, as is required in many University x-ray laboratories.

Another night on our experiment brings some progress and some setbacks. We are, after all, developing a technique and though the idea can be good, to make something work you need the right geometry, the right adjustments, the right shape of aperture, the right metal, the right adhesive, the right sealant, good workmanship and a myriad of other details all right. You then have to know what to do with the result.

It is even more important that the design and operation of the synchrotron has been 'got right'. The synchrotron operations staff work round the clock from a console in the main control room housing a bank of instruments and monitors. Once the electron beam has been established, the synchrotron flies mainly on auto-pilot but, unfortunately, a breakdown is not a rare event. Normally, the stored electron beam is refilled twice a day, at 8 am and 8 pm, with synchrotron radiation being made available to users at some time between 9 and 10 O'clock. On occasions, the stored beam, which decays with time, is kept for 24 hours. This is what one can hope for. Sometimes, when the experiment is in full swing, without any warning a faint click can be heard from a box near the ceiling of our station and a glance up at the illuminated hutch lights shows the 'X-RAYS ON' sign is off. One's disappointment is confirmed by the beam status monitor showing *'Beam Lost. Refill ASAP'*; frustration is brought on by a variety of more alarming messages, one of the worst of which is *'Klystron failure. No Beam for at least 3 Days'*.

One of the pleasures of a week at Daresbury is talking with people we know there, about their own work and prospects in the subject. A few of the Daresbury staff have strong links with Physics (or Natural Philosophy) at Aberdeen, others we have come to know through the years. Chance meetings with fellow crystallographers or former students are not uncommon. These meetings are the more valuable because we share a problem with others at

Aberdeen: as a small group in a small department, located at the periphery of the University network in Britain, we have too little personal contact with like-minded academics.

With the passing of time, our allocated five days of beam for this visit has almost expired. There has been little in the way of routine in our programme and we have had to draw on our reserves of stamina to keep up the intensity of application. Those present during the day have worked from after breakfast until after midnight, with little time off. At 6 am on the final morning we call it a day, push the keyboard aside and reach into the toolbox for the Allen keys and spanners. What took more than 24 hours to align to great precision is dismantled in minutes. Three of us can repack and reload the Transit van in two hours, clearing the station by the required 8 am. Over a hundred of our data files have to be transferred from the station computer to the mainframe and thence to Aberdeen. Over a hundred spectra have to be laser-plotted for later perusal. All the files have to be backed-up on magnetic tape, requiring a visit to the site's computing complex, located conveniently near. Unlike any University computer centre I have been to, users are allowed access to the main computing operations room to mount magnetic tapes and retrieve printer and plotter output direct from the machines. Daresbury's implicit treatment of its users as intelligent and responsible individuals does much to promote good relations with the laboratory - it's a pity, though, about their canteen!

At times, it is necessary to spend the remainder of the final day recovering from lack of sleep, and the upset of our biological clocks, before it is safe to make the long drive North. No more Kendal Mint Cake at 5 am to keep up blood sugar levels. This can be a day to catch up on the data processing more easily than can be done at home. Whatever the activity, it is a day to review the broad achievements of the visit and re-enter the real world. I'm glad to say that there have been achievements on every visit we have made to Daresbury, including the one when the klystron failed.

Chapter 2

Return to Daresbury, 1997: not the official log

Three years have now passed since I went to Daresbury to do any experiments. I can't really believe it's that long, but the lab book doesn't lie. This time it's different. No noisy Kenning Van Hire diesel Transit full of equipment, hopping the traffic and the motorway service stations in a full day's drive. This time it's the train, with only a suitcase of equipment, lab-books, results of previous work, coffee mug, calculator, ear defenders and some specimens. I originally thought I would go with only a few diamonds in my pocket but

if experience is worth anything it teaches that we should be prepared for contingencies at Daresbury. My small packet of natural diamonds contains specimens rarer than most you will find in the local jewelers. The local jeweler, though, would not give much for these. They have been specially selected for their interesting defects and unusual growth sectors. Moreton Moore, the principal investigator on our research trip, is bringing some well-studied natural diamonds and some synthetic diamonds with interesting properties of their own. We'll be choosing two or three specimens and exploring the nature of these defects by 'reciprocal space mapping'. That's the official title of the project but to the less initiated, it's diffuse x-ray scattering.

The train is time-tabled to leave at a civilized 0910 hours. Aenea's been on holiday all week trying to use up her leave allowance. The weather has turned the worst we've had for months. A gale from the South East has continued for over two days, with driving rain and local flooding. She's reluctant to get out of bed to chauffeur me to the station. I'd be the same. Last night the wind continued its tile rattling blasts and I woke up several times to look at the clock. It wasn't particularly the wind that woke me but the memory that the previous night we'd had a power cut, which meant the morning alarm failed to go off. None of us woke up until 0915, making Hamish very late for school and leaving me thinking that if I'd slept in until 0915 I'd have missed today's *Devon-Scot* rail service from Aberdeen to Plymouth.

We left home in plenty of time. The gale still blew straight off the North Sea. Passing a new housing estate in Cove, the advertising flag-poles were bent bow taught in the wind, flags not fluttering but trembling stiffly. Almost every traffic light was green right in to Joint Station and we arrived in plenty of time. This happens only when you've already left plenty of time. The train was at the platform and I walked passed the big diesel engine "Institution of Mechanical Engineers 150th Anniversary 1847 - 1947". Verbose name, but very appropriate. I'd given a talk earlier in the year at their 150th anniversary celebrations, and Robert Stephenson, railway building son of railway pioneer George Stephenson, was the first president of the I.Mech.E. With a name like that, the engine might even be new. Aenea left me to go home to her interrupted sleep. Lucky thing. I found my reserved seat on this Virgin Train and put the suitcases up on the rack, diamonds and all. Mustn't forget them.

The train was pretty empty. Looking around, most table seats were reserved. It left on time and headed down the gale swept coast. The grey North Sea was at its greyest. Surging waves crashed against the rocky shore, in places sending spray over the top of the low cliffs. Bays all the way to Stonehaven and beyond were white fields of breaking rollers and windblown spume. We sped south through a grey November landscape, past grey slate roofs,

grey wet roads, a grey haze under grey clouds. No rain was falling but fields and buildings were sodden. The Esk was testing its banks as it tumbled and swirled with an urgent rush to reach the sea. Beautiful Lunan Bay was a spume-streaked spectacle. They'll be more agates washed up on its beach this week.

Stonehaven - Montrose - Abroath: we stopped at them all for a few more passengers. By Dundee the wind had moderated. We crossed the 'new' Tay bridge that has sat for more than a century beside the blackened stumps of the 1879 disaster, when in weather worse even than today's the longest bridge in the world gave way only a year and a half after it had been built. All lives were lost one wild December night as a crossing train plunged into the inky darkness of the waters below. Today, we rolled smoothly over to Newport, still under leaden skies. At Leuchars, that odd stop in the countryside with its usual line of taxis waiting to take passengers to St Andrews, as many people seemed to depart and get on as at Dundee. Next stop Kirkcaldy, *'Alight here for the Fife Coastal Path'* - not today. Just enough view out of the window to see that the University of Dundee has a substantial School of Engineering and Mining next to the station. You learn something every day. We trundled at a modest pace along the north shore of the Forth, past wet, sandy beaches, sheltered waters and the almost empty harbours of Burnt Island with their sky-raked cranes waiting for work. Under clearing skies we stopped briefly at Inverkeithing, *'Alight here for the Fife Coastal Path'* in case you missed it at Kirkcaldy, to catch a glimpse of the sun. Finally, through a few tunnels and cuttings before we reached the highlight of the rail trip to Edinburgh, that eighth wonder of the world, the Forth rail bridge. What a piece of Victorian engineering! It used to be just 'The Forth Bridge' in my youth, when you queued for the ferry beneath its massive girders in days before the road bridge was built alongside. Plenty of its girders are rusty but there were men at work behind extra strong sheeting engaged in the task of Sisyphus re-coating the flaking surface. Finally, we reached Haymarket and Waverley stations, where we paused to change from diesel to electric.

The seat next to me was filled by an elderly gent with a stale smell who wanted to face forwards, as I'd been doing all the way down. At Waverley the train always goes out backwards and fortunately the ticket inspector assured him it would stay that way until Birmingham. He moved to the other side and his smell moved out of range. As we went West, the grey skies returned and in truth it never really got properly light. As we outpaced traffic on the M74, I was glad not to be driving 370 miles through clouds of spray seen through a smeary windscreen, headlights on all the way. The train journey had its own stresses, though, and I could have done without the noisy young kids behind me whom I'd gladly have defenestrated had the windows been of the opening type. Maybe it was just the

time of the week but I arrived at Warrington Bank Quay after about six hours with an irritating headache.

A Daresbury Laboratory car was waiting for me and I recognized the driver and his comfortable Citroen at once. Dark suit, leather gloves, conspicuously turned out better than most of his customers, he had made a profession out of a job. Could it be at least three years since I was last taken by him from Manchester airport? Surely it must have been more recently. The car, he said, was not the same - just the same model. He took me swiftly to the hostel to receive a friendly welcome from the Manageress, Sheila Conwell. "*I thought it must be you*", she added, "*when I looked at the bookings*". It really was three years since I'd stayed in the hostel. I guess she remembered me as the pest who wanted a board under the mattress for many years. I haven't needed that since they got new beds a few years ago. Phoned Aenea, who'd recovered from the unwelcome break in her holiday rest. Went to 'A block' to go through the new routine of getting a site pass. Security is taken more seriously these days. I even watched the 'safety video' (again), as requested. Dial 3333 in case of emergency. Visited the library to catch up on publications not in our own palace of learning any more. Went to the canteen for the evening meal. They've changed its times but the dreaded '3 Gates Services' catering company have still got the licence. "*The Company that Cares - 3 Gates Services are proud to be managing the staff Restaurant at Daresbury Laboratory. Our main objective is to provide you with good food and service in a friendly atmosphere*". Someone must have spoken with them because they're clearly trying harder: table cloths now, bottled mineral water on the table and a choice in the menu. They've taken down their BS5750 notice, though. The staff are friendly and the atmosphere good. The only thing they fall down on is the food, which is still canteen quality and you wouldn't want to serve it to your guests. Pity, really.

I had a rest to try to clear my head and was roused from a doze by Moreton knocking on the door. He'd arrived at 1945 from Royal Holloway with Gregory, Grzegorz Kowalski, from Warsaw and Mina from Tehran. We repaired to the 'Ring of Bells' for a news over a drink and, for them, a pub dinner. I'd last been with Gregory in Seattle 15 months ago. Mina is Moreton's new research student of a couple of months. She spoke English with an excellent English accent, due, she said, to the efforts of her mother who, as an English teacher in Tehran, had taught her at home since she was very young. Impressive. Many a second generation immigrant couldn't match her diction. The 'Ring of Bells' flourishing new extension was comfortable but with an exhausting few days ahead we retired early. I turned down the radiator in the perennially overheated bedroom (no. 45), set the alarm and soon fell into a dreamy sleep, interrupted on a few occasions by the unaccustomed noise of night-time traffic.

Breakfast at the hostel was as good as ever - even better in fact. Supplementing the choice of cereal, ham, cheese, fresh fruit, yoghurt, wholemeal rolls, a cooked selection from bacon to hash browns, coffee, plain tea or herb tea were several bowls of delicious compote, grapefruit, prunes or apricots. Mrs Conwell was doing us proud. Breakfast was still by far the best meal of the day. There was good sense in this since we went down to the lab at 9 in the morning and were seldom back before 1 am the following morning. Not the sort of regime you want to start on a quick cup of coffee and a slice of toast. Having enjoyed Mrs Conway's fruits, we took ourselves down to station 16.3 to meet Steve Collins, the stationmaster, whom we all knew except Mina, for a run through the station's operation. Only Gregory had had a short trial at the equipment when it was being commissioned last year. It was new to the rest of us.

16.3 is one of Daresbury's 'flagship' stations. It's a commodious 'end-of-line' station, one of a cluster of 5 stations on their newest and most powerful beamline. I had been eyeing up its potential ever since the plan to build it was mooted several years ago. It's been equipped at a cost of several hundred thousand pounds with the best custom built apparatus and the latest controlling software. In the station control room are a couple of good Pentium PCs running Windows NT, one for controlling the equipment and one for data processing, and a Silicon Graphics workstation. You don't find out how to get the best out of such a facility in a couple of hours. Steve spent the day with us, in spite of an irksome cold that he'd willingly have gone home to nurse. Steve is a good man to have around. Very competent, conscientious and enthusiastic, without being single-track. His cheerful optimism is infectious and we felt this session was going to go well. We selected an x-ray wavelength of 1 Ångström, aligned the beam, mounted one of Moreton's synthetic diamonds and by a combination of luck and judgment aligned it remarkably quickly. Steve is still writing the station manual so we scribbled like mad to note down the commands that would move anything we might want to move, count x-rays we might want to count, set electronics we might want to set and process the results in the way we wanted results to be processed. True, the PCs had some on-line help but it was primitive and nothing beats a good demonstration.

By the time midnight came we had made enough preliminary measurements to realize we were ready to set off an overnight run that would scan the scattering in fine detail over a small area of 'reciprocal space'. We'd all get a good night's sleep after all. This was certainly different from station 7.6 I'd used before, which needed continuous manning for 24 hours a day, or the next best thing. Eight hours on and four hours off was my own timetable then. A full night's sleep seemed a soft option by comparison. We set up the scan, doubled checked all the parameters, confirmed all the motors that should have moved had moved, and retired at

about 1 am. The x-ray beam had been beautifully stable all day. We kept our fingers crossed that it would last until 8 am, when it was due to be dumped and replaced. Locked the station, and so to bed.

We came back at 9 am to find that the overnight run couldn't have gone better. It was all too good to last. Our luck ran out in the morning. When changing the beam-size, one of the eight slit controlling motors didn't move as asked. Lines of FAILED messages scrolled up on the terminal. We took the short cut and phoned Steve Collins, hoping he wasn't out doing the Saturday morning shopping. He was at home nursing his cold. We recommended a good dose of malt whisky. He recommended we recover the old motor settings from a previous file and try setting the motors individually to their previous values. It wasn't that easy, because the motors were set in pairs and setting one motor sometimes caused another motor to move out of position. Gremlins were abroad. Somewhere in the racks of electronics and hidden bundles of cables electronic noise was being picked up. It could have been a no-win situation but after a while we did get the motors where we wanted them to be. The electronics support group had been called by Steve not many days before and their earlier suggestions clearly hadn't worked. They'd come back on Monday. Meanwhile, we could live with it.

Daresbury's experimental stations have developed over the years around a central electron accelerator that is 100 metres in circumference. Daresbury is not a compact place. Numerous concrete walled and concrete floored passages take the visitor from station to station, room to room. There's always more than one quite different way to get between any two places some distance apart. A dedicated nerd could probably make sure he never went the same way twice over a whole week. Since I was last here, many walls have been adorned with A0 size professionally produced colour posters describing the work of the lab. It's a great improvement. Some posters near us hid the ageing cream painted walls and distracted from the lime green concrete floor with its rust red scratch marks. I read a few of them: *'The Importance of Ozone and Pollutants'*, *'Keeping the Samples Clean'*, *'Sending Electrons around the Bend'*, *'Cementing Relationships'* (about powder diffraction studies of the atomic structure of cements) and *'Liquid Analysis in the Pipeline'* (about solid/liquid interfaces and corrosion inhibitors). A few display cabinets show some of the crucial pieces of technology that make the whole place work. One display near us is at the site of the first synchrotron radiation experiment that was built to use the radiation from the high energy proton synchrotron NINA that operated here in the 1960s. A young Ian Munro, then at Liverpool University, played a crucial part in building and operating that first experiment, which harnessed the brilliant UV emission of NINA. Ian, well-known to us at Aberdeen and a times a visiting Professor, unveiled the plaque on 4th July 1997 to mark 30 years of synchrotron radiation work, just before he retired as Head of Synchrotron Radiation Research at the lab.

The equipment alone in Daresbury makes it a place of continual visual excitement. Adding a little spice to every viewpoint is the lab's great variety of safety notices. The place is a class A site for collectors, if there is such a breed - so much so that attention saturation must be not far away. Each experimental station has 3 clips of sheets waving in the breeze at its door: '*Station Notices*', '*Area Risk Assessment*' and '*Experiment Risk Assessment*'. If all this information were to be assimilated in detail, you would expect a common sight to be a door with a cluster of people outside leafing through the paperwork. I haven't seen one yet. SRS Station 16.3, Materials and Magnetic Diffraction, Area Risk Assessment form begins with a summary of at least 13 categories of Hazards and Control Measures. On top of the un-social hours payments that we don't get paid for working at Daresbury, perhaps we should be asking for hazardous working environment compensation. The hazards include potential exposure to radiation, to laser light, to liquid nitrogen, to beryllium, to vacuum, to remotely operated moving equipment, to the overhead crane, to high voltage and ..., and I can't think of all 13 but I'm sure they're recorded on the notice. No mention is made of the hazard of reduced blood sugar levels at 3 am. I guess it's really a legal matter of the lab being able to turn round and say '*We told you so*' if an accident occurs but the real safety prevention measure is the responsibility, experience and common sense of experimenters like us who use the facilities.

Near the coffee room beside the main synchrotron operators' room, where we repaired to from time to time for a mental break as much as mug of coffee, is a notice board filled with press cuttings concerning the lab. It is almost overflowing at the moment. Many cuttings quote John Walker, recent Chemistry Nobel Prize winner from the Cambridge Molecular Biology Laboratory who has come to Daresbury to experiment for the past 10 years. I was going to say '*like us*', but perhaps our science hasn't been as high profile. John Walker shared the prize for his study of the enzymes in cells used to form ATP, the crucial energy generating chemical that keeps us warm, and most other living organisms warm as well. Other clips described the promotion of 'Diamond', the name for the replacement synchrotron that most of us would like to see built here at Daresbury over the next few years but over which the Research Councils are dragging their feet. It seems to be a rarity to find a collection of administrators with any significant vision. One gem of reporting buried in the cuttings on the board, from the Sunday Times 26th Oct. 1997, seemed to confirm scientists' misgivings over the accuracy of what appears in the press: '*Once the structure of a molecule is known, biochemists will be better equipped to design new drugs to tackle the illnesses they create*'. Was the reporter struggling to comprehend, or was he just careless with his copy?

Back at the experiment, data collection generally went pretty well. It wasn't, though, a matter of confirming what we already knew because the pattern of scattering we were finding

was not what we expected. The experiment may be over in four days but the head scratching will last very much longer. The synthetic diamond showed much more structure than we had expected. The natural diamond that we mounted afterwards showed much less. Nitrogen is a common impurity in diamonds that can have a large effect on some of their useful properties. In the synthetic diamond, we believe the nitrogen is diffused throughout the specimen in isolated atoms or at most in very small groups. In the natural diamond, we believe that the nitrogen has over a period of millions of years diffused and clustered together into small impurity platelets an atom or so thick, the oversized nitrogen atoms wedging open the natural carbon crystal structure in places. That is the current belief, but the scattering we found did not confirm such a simple distinction. The natural diamond we sampled proved more cursed than expected. First it was harder to align accurately, suggesting it had enough variations in growth to orient different parts slightly differently. Here we fell foul of using a tool almost too accurate for the job. Angles can be set to better than one thousandth of a degree on the apparatus and the scattering probed in detail almost as fine. If the crystal has major misoriented sectors then their scattering can fall out of the field of view of this microscopically fine probe. Whether that was happening was for us to consider at leisure later. More pressing was our failure on Sunday night to be able to close the hutch interlock on the door that kept the x-rays around the apparatus out of the control room. No interlock, no experiment. Steve couldn't help us here. If all else fails, call the ever helpful synchrotron operators. They have seen many problems in their years. A deputation left the flight control deck (the synchrotron flies on auto pilot much of the time). A confab around our offending hutch door quickly produced the answer. One of the safety interlock relays at the door hinge was sticking. It needed dismantling and lubricating. Meanwhile, a modest tap with a lead brick should do the job. It did and we were away again. There are times for the high tech fix, and other times.

Lab staff were conspicuous by their absence at the weekend, not unnaturally. Come Monday morning I had a good chat with Pat (Broadhurst), Ian's former secretary, who gave me a very up-beat account of Ian recovering from the pressure of his final stretch at the lab and enjoying the science in Japan's Institute of Molecular Sciences. Caroline has just joined him for 5 months or so which, apart from having to retire to do so, should be a great experience for them both. I heard that most of their animals had been disposed of, but a few favourites are being kept. I enjoyed another chat with Manolis in his old office in the computing section. Manolis always seems to me to combine expertise with both common sense and vision, a combination that's done the lab a lot of good. He's regretting that increasing amounts of computing effort are being spent providing data for administrators rather than directly supporting the science. At least he never seems to forget what the purpose of the lab is. I had breakfast on Monday with Denis Greig, newly appointed as our external

examiner in Aberdeen and here to join his group for several days on beam-line 6. He was in good form and it seems a pity I'll have to dampen his enthusiasm for science next week by sending him a couple of envelopes of exams for scrutiny. The following morning Roger Cowley joined him at breakfast, just before Roger took over from us on 16.3. It's a good few years since I've spoken with Roger and it was good to do so again. He's still in relaxed mood despite heading up the Clarendon for several years now. Roger and I have worked in neighbouring fields for a very long time, the difference being that Roger is one of the outstanding physicists of our generation. I suspect Roger's achievements will be under appreciated by posterity and given different circumstances it would be no injustice to find Roger's name where John Walker's is today. What would Physics be like now in Aberdeen if we'd had someone of such exceptional talent in the Chair?

Our four days on station 16.3 were almost up. Outside it had been dull and grey throughout the time. The last of the autumn leaves still clung to the trees or covered the path to the hostel in dark brown slippery patches. The crab apple trees beside the perimeter fence hung heavy with this year's crop. The grass was permanently damp, the low hills in the distance permanently invisible, a folded brolly permanently in hand as we walked to and from the High Firs hostel. In the station, though, there was plenty of light. We'd all worked well together and on the final night's run we'd coaxed a wonderful plot of a diffuse scattering spike from our reluctant natural diamond. It was time to call a halt and look forward to next February's sequel.

John S. Reid