1957 The Shielding Group

I have looked at the heart of a nuclear core,
And I found no malice there,
But beware, for there lies a Demon,
Entrapped by the width of a hair.

At the beginning of 1957 I found myself in a curious situation. The Wigner group had been wound up at the end of 1956, and most of the remaining members had been transferred to the Shielding group, under the direction of John Simmons. I had not completed the work that I was doing on the 'Linear Rise Calorimeter', and John was very keen that it should be brought to a satisfactory conclusion. I continued the work as if nothing had happened, without knowing that John had not obtained permission.

At first everything continued as before, and I was unaware of any difference, except that all my colleagues were involved in other work. I was quite used to working on my own, so I hardly noticed the changes. By the beginning of April I had the new system working, and was able to measure the 'Stored Energy' in graphite to an improved level of accuracy. I was exceptionally pleased as it was a very complicated piece of apparatus, and it all worked well. It had taken me over a year, from the basic idea conceived by John Simmons, to the reality of an operational system.

We saw little of the Division Head, John Dunworth, unless he wanted something.

However, he did occasionally wander round the labs. and chat to his staff. Maybe he did this when he was bored, or more likely when he wanted to find out what we were all doing! So the day arrived when he wandered into my lab. As always he was very polite, enquired how I was getting on, and then asked me to explain the work that I was doing. I thought that this must be some sort of test, and tried desperately to give a good impression. My explanation took so long that he had to sit down while I completed the description. He then asked a lot of questions, and I showed him the results that I had already obtained. I believe that he was very impressed, and he thanked me as he left the lab.

A few minutes later a friend came into the lab. closed the door, and asked what Dunworth had said to me? It seemed that he had gone straight from me to John Simmons and they were having a row! I had to wait nearly an hour before John came to tell me what had happened. He sheepishly told me that Dunworth had been cross because my work had been continued without permission. However, Dunworth thought that it was a fine piece of apparatus, and should be given to the Physics Support group at the Windscale works, who had need of it.

So that was that! From that moment I had to stop what I was doing, and join the others in the Shielding Group. Everyone thought that this was a huge joke, and John Simmons was a little embarrassed by what had happened. However, he did get his way, and the 'Linear Rise Calorimeter' had been completed.

Shielding

The Shielding work seemed to be a bit of a mystery, and still does! There were a lot of people working on this project, and there seemed to be little in the way of a programme. We were to study the attenuation of radiation in various shielding materials, which I suppose would enable the design of better shields. There was even a completely separate group, manned by members of the Royal Navy, whose purpose seemed to be very obscure! I believe, but did not know, that their work was to develop new light and compact shields for nuclear powered submarines.

Our work was centred on 'Lido', which was a 'swimming pool' reactor. The reason for this arrangement was that, as the core of the reactor was quite small, it could easily be moved within the bounds of the pool. This would enable us to set up a shielding experiment, and when ready, move the reactor core into the required position. This may sound like a fanciful idea, but I believe that it was a sound one, and had many advantages. As the Lido reactor is a little unusual, I will describe it in some detail.

Lido

This was a 'light water' moderated thermal reactor, which is similar to the one built at Oak Ridge in the USA. It consisted of a small core composed of about 2.5 Kg of Uranium 235, in the form of thin plates clad in aluminium. A fuel element was approximately 10 cm. square and 60 cm. long, being made up a stack of equally spaced plates. The fuel elements were contained in a vertical rack, making an assembly measuring about 50 cm. square by 60 cm. high. The core, and its control system, was suspended from a bridge across the top of a water tank, in which the reactor core was immersed. The water, which was demineralised 'light water', was held in an concrete tank with an open top. This covered the core to a depth of about 6 metres, and served as moderator, coolant, and as a shield. The remaining part of the shield was the concrete wall of the tank. The bridge could be moved on rails along the length of the tank, and the reactor could be moved across the width of the bridge. This enabled the reactor to be placed at any point within the tank. The tank stood some 8 metres high, and measured about 10 metres long by 4 metres wide. In the wall of the tank there were several measuring holes, and two large bays into which shielding assemblies could be built. The reactor was controlled by an operator from a control position on the bridge.

Most reactors are exceeding dull to look at; About as exciting as a block of concrete. However, Lido was an exception; You could see the core in the water, and if the lights were low, the blue glow of the Cerenkov radiation was plainly visible; An awe inspiring sight! However, no matter how pretty it looked, it was not a good place for a swim!

One problem that this reactor shared with any swimming pool was that the surface of the water continually accumulated dust and debris from the surrounding environment. If no preventive action was taken the water surface soon became coated with a layer of scum. This not only looked unattractive but also contaminated the water which would eventually come into contact with the reactor core. One of the engineers came up with a simple but elegant solution which proved to be very successful. This consisted of a shallow wedge shaped tray which floated on the surface of the water. The narrow end of the wedge oscillated up and down, allowing water to leak into the tray and skimming the scum from the surface. A flexible hose connected to the tray removed the contaminated water. I believe that this was 'invented here' and subsequently became used in more conventional swimming pools!

The experimental shielding assemblies were to be quite big, and would be built on a huge trolley. This could weigh many tons and when complete could be moved, on rails, into the test bay in the wall of the 'Lido' tank. The trolley was a large and very complicated piece of engineering; a bit beyond our experience. The design was put out to tender, and an external firm selected. When the design was completed, they sent the drawings to John Simmons for checking, before the device was manufactured. John was a little overwhelmed by the number, and complexity, of the drawings. He decided that we could not take the responsibility for the checking. It was then decided to give the same engineering company another contract to check the drawings! (I never knew the result of this, or even if the trolley was ever constructed.)

While we were waiting for the trolley, we were busy preparing the many forms of radiation measuring equipment that would be required. These included small activation detectors, many forms of neutron counters, ionisation chambers, fission chambers, and the associated electronic equipment.

John, anxious to get some work underway, asked me to set up a system of measuring the neutron flux and gamma ray profile in the water of the 'Lido' tank. This proved to be quite difficult, as the equipment had to operate under six metres of water. I was very familiar with the counters and the electronics required to make the measurements, but had no experience of working with equipment in water of any depth! However, it soon became obvious that my long association with vacuum systems would be an invaluable asset.

Another hurdle, insisted on by John Simmons, was that any container that I designed to enclose the counters, had to have a minimum effect on the radiation that we were trying to measure. This limited the choice to a few materials, mainly plastics. I had certainly never made a vacuum system using plastics. However, I soon decided on a design of a container that was simple and dismountable. I had already ruled out the use of adhesives, or even welding the plastic, which I had been warned was difficult.

The successful container consisted of a polythene tube fitted with a plug at each end. The plugs were made of nylon or polystyrene, and were machined to be a good fit in the tube, but not a friction fit. The seal was a standard rubber 'O' ring fitted into a groove in the plug.

The next problem was how to get a cable into the container? My first thought was to extend the polythene tube all the way to the surface of the water. However, this was a clumsy solution; It would have been inflexible and difficult to manage. As most of the cables that I would be using were available with a PVC sheath, I decided to try the cable in the water with no additional protection. I realised that even a small pin-hole in the cable sheath would be a disaster. However, after a few tests I was convinced that it was a good solution. The cable entry to the container was made using a modified vacuum seal which also used an 'O' ring. This never gave me any trouble, and was a complete success.

The Naval group also tried this technique, but adopted a standard cable entry gland that was used in electrical wiring boxes. These were really designed to keep out the rain, and not to work under water! They had many disasters.

My only failure was when I made a container to fit a large ionisation chamber. This was about 15 cm. in diameter, and I had some difficulty in finding a suitable plastic tube that was strong enough. At the first attempt the container collapsed in the water, and caused considerable damage. This had to be redesigned to include a sleeve within the tube, to provide additional strength.

Some of the counters required a 'pre-amplifier' that was adjacent. In fact, in most cases it needed to be less than one metre from the counter. This of course also had to be located under water! The amplifier was quite large and contained valves! (vacuum tubes). This used high voltages and generated a lot of heat. For this reason a metal container had to be used to dissipate the heat. Pure aluminium was chosen to reduce the effect of the neutron activation of the metal. As this has a half-life of only 2.3 minutes, it was safe to handle one hour after being removed from the tank. Aluminium alloys are a much harder material, and easier to use. However, they contain copper which, having a half-life of over 12 hours, does present an activation problem! The container required four cables. One at the bottom to connect to the counter, and three at the top; Two to carry power supplies to the 'pre-amp', and one to pass the counter output to the counting electronics. Despite the high voltages, and the heat generated by the 'pre-amp' this container never gave any trouble!

(N.B. Although 'Transistors' were available at this time, they had not yet moved into the area of counting electronics. This was to happen a few years later.)

One further problem encountered with the underwater equipment, was that it was often necessary to connect different counters to the 'pre-amp'. This required an underwater connector! This was solved quite elegantly using a similar construction to the plastic containers. The plug and socket of the connector were each fitted through the centre of a nylon rod which would fit into a slim polythene tube. Again 'O' ring seals were used to keep the water out. While the lower end rod had a shoulder to prevent it sliding completely into the tube, the upper end did not! It was therefore possible to slide the tube upwards to break the seal, and expose the plug and socket inside. This was a very simple but successful device!

The next step was to decide how to mount the counter in the water. It would have been simple to fix the counter position, and move the reactor in order to take measurements at different distances. However, moving the reactor while in operation was forbidden on safety grounds, and it would waste a lot of time to shut down the reactor between each measurement. This was solved by suspending the counter from a temporary bridge which could be placed across the top of the tank. This was a wooden structure about one metre wide, with a hand rail at each side. Standing on this, above the water, one felt very vulnerable!

The counter and its cables were suspended from a 'fishing rod' mounted in a horizontal position across the bridge. This consisted of a steel tube which could slide through bearings, and move the counter along the axis of the tank.

On one side of the tank, and close to the top, was a protected walkway which gave access to the reactor bridge. From here a short ladder allowed access to the temporary bridge. Also located on the walkway was the rack of electronics which was required to make the measurements.

On the other side of the tank there was no protection! Here it was sometimes necessary to walk along the wall of the tank. The wall was about 60 cm. wide with a steel railway line running along the centre. The rail was part of the mechanism which allowed the reactor bridge to move along the length of the tank. On one side of the wall was the tank, with the reactor plainly visible below the surface of the water, and on the other side an 8 metre vertical drop to a concrete floor!! It was no problem to walk along the wall, which had ample width, but the 'exposure' of this position was quite frightening. It is interesting to note that, in later years, a platform and hand rail were fitted to this side of the tank!

In order to use the reactor it was necessary to book time. This was arranged at a weekly meeting of users, where one had to bid for a particular time slot of 2 or 4 hours. The meetings were usually quite amicable, and rarely ended in dispute. It was also a good time to find out what other users were doing, and glean information about their techniques. It was surprising how frank they all were about their failures and disasters! When the time was booked it was necessary to fill in a short form giving details of how the reactor should be set up: The position in the tank, the operating power level, and any special facilities required. The temporary bridge had to ordered well in advance as it required a crane, and driver, to set it in position.

One problem that I encountered very early in my measurement programme, was due to the stability of the reactor power. It was of little use taking a series of measurements, over a period of several hours, if the reactor power level changed during that time. Of course it would have been possible to have a reference measuring device, so that the results could be corrected for the variations in reactor power level. However, this would add another layer of complexity to the equipment, and take more time. A better approach was to ensure that the reactor power remained constant! When I raised this problem with the reactor manager, I was told that the degree of stability that I required was difficult to achieve in practice. He took me onto the reactor bridge and showed me how the power level was controlled. The operator manually changed the position of a control rod in the reactor core, using a small lever that controlled an electric motor. Pushing the lever to the right raised the control rod, and increased the power. Pushing the lever to the left lowered the control rod, and reduced the power. An ionisation chamber fitted to the reactor measured the power level, and the result was displayed on a meter. The operators job was to try and keep the power constant by moving the lever. As the reactors response to the movement of the control was slow, it was quite easy for an experienced operator to find the balance point where the power remained more or less constant. However, it would then slowly drift away, and a correction was required every few minutes! As one would expect, the stability was as good as the operators concentration! In practice the power level wandered up and down in a random fashion, and if he was distracted by other tasks could be a long way from the desired level. I made the obvious suggestion to the reactor manager, that a simple automatic control would solve this problem. The deviation from the desired power level could be used to drive the control rod. I was told that they had considered this option, but had not decided on how it should be done. About a week later I was invited to the reactor bridge by one of the engineers who had devised a solution to the control problem. He confessed that this was just a trial, and was not 'legal'. When the control system was switched on the power was remarkably constant, and maintained this state easily. The control rod was cycling up and down with a small amplitude, at a period of about one second. A human operator could not possibly attain this degree of control. I made a few measurements over the period of one hour, using a neutron counter, and declared this new system to be a triumph. The engineer was exceptionally pleased, but the reactor manager was less enthusiastic. He confessed that this had to be submitted to the 'Reactor Safety Committee', and had doubts about the outcome. I pleaded with him, and was allowed to use the system for my next series of measurements, which were without doubt the best measurements that I ever made. A month later the reactor manager called me to his office, and told me that the Safety Committee had decided that the automatic control system was not safe. Unfortunately this did mean that use of the system was forbidden until safety tests had been carried out, and a full analysis undertaken. I was warned that this could take months! It did not happen during my time on this project!!

I remember little of the results obtained during this time, as they were quite unremarkable and behaved as one would expect. Only one series of measurements showed a feature of interest: A plot of gamma ray intensity against distance from the reactor core. This did not behave in the expected manner, which should decrease steadily as one moved away from the reactor. Instead there was a pronounced hump in the curve. It was quite reproducible but defied explanation. At first I thought that it may be due to convection currents in the water, which could move the suspended ionisation chamber from its expected position. However, checks of the position, using a special telescope which we adapted to look under the water, showed that this was not the cause. My colleagues, who thought that these results were hilarious, could offer no explanation!

My work in the 'Shielding Group' was interesting, but I must admit to being very uncertain about where it was leading. I was convinced that this feeling was shared by many other members of the group. I was quite relieved when we were overtaken by the event of the Windscale fire, and I was transferred to more essential work.

Following the Windscale fire in October 1957, John Simmons and I were instantly transferred to work on Stored Energy; the cause of the fire.

Ron Dugdale took over the Shielding work, and eventually produced a report on the measurements we had made. This did contain a description of my 'Fishing Rod' equipment, and I did get an acknowledgement.

'Attenuation Studies in the LIDO pool' A F Avery and R A Dugdale
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