1957 The Windscale Fire

It is an ill wind that turns none to good

Thomas Tusser

One morning in early October I arrived at the lab. to find a note on my desk asking me to phone Dr.Dunworth. It was a little unusual to be chased by the Division Head so early in the morning. I felt a little apprehensive as I dialled the number, and wondered what I had done wrong! The phone was answered by his secretary, who said that Dunworth wanted to see me in his office NOW! As I walked the short distance to his office, I could think of no reason why he should want to see me urgently. I knocked and entered the office and found that John Simmons was with Dunworth. They both looked very glum and serious. I must have looked worried, for Dunworth, in his very polite and courteous manner, asked me to take a seat. He then began to ask me a series of questions about the 'Linear Rise Calorimeter' that I had designed in 1956. This had been given to the Windscale Works only two months before. He told me that the Physics Group at Windscale had not yet managed to get the system working, and then asked me to estimate how long would it take ME to get the calorimeter operational.

The system was very complex, and had many parts. I could only give one answer. If there was nothing missing, and no damage, then perhaps one day would be enough. Dunworth turned to John Simmons, as if for confirmation. John said that he believed that the apparatus was intact, but there seemed to be a problem with the control system.

Dunworth went very quiet, as if having to make an important decision. He then dropped a 'bombshell'. He told me that during a routine procedure to release 'Stored Energy' from the Windscale BPP1 reactor, the core had overheated and was on fire! He quickly stressed that the responsibility for the fire lay with the Windscale engineers. However, there was little doubt in his mind that an enquiry would follow, and difficult questions would be asked! He did not want any blame to fall on Harwell, because OUR apparatus for measuring 'Stored Energy' was not operational!

Dunworth then asked me if I was prepared to go to Windscale immediately to get the system working. Almost before I had agreed, he had lifted the phone and was ordering a car to take me there. Was ten minutes long enough to collect my things? It seemed that I had little choice, he had already decided!

His final words to me were on the question of security. The 'news' had not yet broken, so he thought that it would be best to keep quiet about it for the time being. He wished me luck, and a safe journey. John Simmons said that he would phone Windscale to let them know the estimated time of my arrival. As I left the office alone, the two Johns had already returned to their conversation about the 'Fire'. They were two very worried men. I thought that I would not like to be in their shoes when the truth leaked out!

I ran back to my office, and quickly decided what I needed to take with me. I emptied the contents of my brief case onto my desk and replaced them with some essentials. A folder containing a few

papers and drawings, a notepad, two graphite samples, and a few small hand tools. I had been caught out once before, in a strange 'lab', when I could not find something as simple as a pair of tweezers! The ten minutes was more like twenty before a colleague came to tell me that a car had arrived to collect me. I grabbed my coat and the brief case and was half way out of the door, before I told him that I would be away for a few days. He seemed very surprised, but did not have a chance to ask me where I was going. I was already on my way.

The official car was waiting at the main door, complete with driver! A very attractive young lady in a green uniform. She was very quick to realise that I did not have the status of her usual passengers, and began to grumble about the very long journey at such short notice. I thought that she would not have dared to behave in such a way if she had been driving John Dunworth! However, when I told her that I had no more notice than she had, she calmed down and we began a more normal conversation. It seemed that the driver was already prepared for an overnight stay, which I guess was standard practice. However, I was not prepared, and had to ask her to drive to Reading first so that I could pick up an overnight bag. She was not at all pleased as it would add at least an hour to our long journey.

When we arrived at my home in Caversham, I tried very hard to be as quick as possible. I think I was in the house for less than five minutes. I just grabbed a few clothes and a toothbrush, stuffed them into a bag, and was out of the door before my bewildered mother could ask too many questions.

When at last we were on our way, we discussed the journey, the route, and the likely time of our arrival at Windscale. It was almost 300 miles, and nearly always took 10 hours! At that time there were no motorways, and the only bypass that I can remember was the new one around Preston. Most of the main roads went through the middle of towns, and it was just a matter of luck that decided how long one was delayed in negotiating the busy areas. Once we were settled into the journey, the driver asked me why I was going in such a hurry. I replied that I had to repair some equipment that was required urgently. She then gave up the questions, realising that she would get nothing more. However, I had the feeling that she already knew that something important was happening.

I remember little about that journey. I know that we stopped a couple of times to eat, but where I do not know. The girl knew the route well, all the shortcuts, and where it was good to stop. We seemed to make good progress. I believe that she may have thought that I was asleep, but I was only deeply immersed in thinking about the task which lay before me. I could only hope that they had not made too much of a mess of the assembly. I was also very worried about the fire, and of course the cause. I remembered the incident in 1952 when the BPP1 reactor had an unscheduled release of 'Stored Energy'. That caused a dreadful panic, but no harm was done. We were just a bit shaken by being caught out by an unexpected event. A fire was something else! I could not understand how it could happen, or what the consequences would be.

It was about 8pm when we on the final approach to Windscale. Only then did we discuss exactly where we were going. The driver, by now quite tired, was keen to head straight for the Greengarth hostel where we could get temporary accommodation. I felt like that too, but I had agreed with John Simmons to go directly to the Windscale main gate to pick up a message which would tell me what to do. When we arrived at the gate, I went into the police lodge, and was given a single sheet of paper. It just said 'Phone me', a number, and was signed Brian Kelly. The policeman had already lifted the phone and handed it to me. I dialled the number and it was answered almost immediately. Brian said that someone would pick me up in a few minutes. I went out to the car and told the driver

to go on to the hostel alone. She asked if I would be returning the next day. I said that it was very unlikely, thanked her and said goodbye.

Within a few minutes a police car picked me up and took me to the building which housed the Physics Support Group. As we travelled the short distance, it was obvious that there was a lot of activity. Lots of people about, many vehicles around the Reactor building, and lots of flashing lights. I asked the policeman what was happening, but he only replied grumpily that he did not know, and that no one would tell him anything. Brian was waiting at the door of the building. He just said hello, and shook me by the hand, and led the way to a large laboratory. Here I was confronted by Joe Bell and Harry Bridges, two very senior physicists.

If it were not so serious I think that I would have laughed. I had never before seen such a sight. Three white and very strained faces. They looked as if they had not slept for a week, and the bottom had dropped out of their world. Which in a way I suppose it had! They seemed as if they did not know what to say. After a long pause it was Joe who broke the ice.

He asked me what I knew of the present situation. I replied that I had only been told that there was a fire in the reactor. He said that it was still on fire, but fortunately it was not their problem! However, he expected a lot of 'stick' when it all got into the newspapers. He promised to fill me in with the detail, but later when we had more time. Joe stressed that our first priority was to get the 'calorimeter' working, and asked Brian to describe the problems that they had experienced.

It seemed that everything started in the expected manner, but when the temperature rose to about 200 degC, the control system went berserk! At this point they had always switched the system off, for fear of causing some damage. They had checked the wiring, and all the individual components many times. Everything appeared to be correct. After several attempts they admitted that they were beaten. Just one thing that Brian had noticed when he last inspected the calorimeter. Some of the surfaces inside the vacuum system were coated with a thin grey deposit! They had taken a sample of the material, and sent it for analysis, but were still waiting for a reply.

The system was 'cold', so we removed the top from the vacuum chamber. The grey deposit was very obvious, coating the cooler surfaces around the calorimeter. I said that it looked like tin or lead which had evaporated in the vacuum. However, this could only come from a hot source, that is the calorimeter itself. I asked if they had made any modifications to the calorimeter or its surrounding supports. Their reply was unanimous; No changes had been made to any part of the system. I asked Brian to open the calorimeter so that we could inspect the inside. While he was doing this, I told them that I had seen a similar effect before when solder was used on hot parts within a vacuum system. Even 'hard' solders often contained impurities like tin and lead, and I had found it necessary to purchase a high purity silver solder to avoid this type of problem. When the interior of the calorimeter was exposed, I peered down at the two graphite samples, which were the object of the test. The light was poor so I had to ask for a lamp. An anglepoise was soon fetched from an adjacent room, and the interior of the system was flooded with light.

It was then that I saw something that filled me with dismay! I could hardly believe what I was seeing. Around the centre of one of the graphite samples was a fine hair line crack. This had not been visible in the dim light, but was now very obvious. I asked where the sample had come from. It was Brian who replied. These were only unirradiated samples to test the system. He had found them in MY desk drawer at Harwell! I bent forward and removed the suspect sample. A simple twist and the graphite cylinder divided into two parts, exposing three small holes in the interior. The three men were horrified when I told them that this was a failed experiment, that I had carried out the year

before. The three holes were filled with tin, lead and zinc, in an attempt to calibrate the temperature of the system using the latent heat of fusion. However, this had been a disaster, for I had not allowed for the fact that graphite was porous, and the tin had evaporated into the vacuum chamber. The thin metal film caused leakage between the power circuits and the sensitive thermocouple inputs which measured the temperature. This made the electronic control system unstable, and the apparatus unusable.

There was a long and ominous silence while they struggled to take in what I had revealed. Joe looked quite cross and was eager to shift some of the blame onto me. I quickly pointed out that I had been on holiday in Austria when the apparatus had been removed from my laboratory. Also, the offending sample had been in the top draw of my desk, which was locked! Brian very sheepishly admitted that it was John Simmons who had located the key in an adjacent drawer, and found a glass topped specimen box containing the sample. I was only negligent in that I had not labelled the box!

[I have often wondered why they chose a date when I was absent to remove the apparatus from Harwell? On reflection, I believe it was a deliberate decision by John Simmons. I had been in close contact with Brian Kelly, and had many discussions with him about the apparatus. Indeed only a few weeks before I went on holiday, I had given a demonstration to Brian, and had detailed talks with J.Mounsey, who was to look after the electronics. I can only think that John wished to hand over the equipment himself, without me being involved!!]

After hearing my explanation, there was another long silence while they seemed to sink deeper into despair. A very tired Joe again broke the ice. He just wanted to know how long it would take to clean up the mess, and how we should proceed. I said that I thought that it would take about half a day. I suggested that we first heated the calorimeter, under manual control, to about 450 degC. This would drive the metal deposits, out of the calorimeter, to the cooler parts of the vacuum system. We could then clean any residual material away using tweezers and cotton wool. A very delicate operation! Joe considered that we were all too tired to undertake such difficult work. It was now quite late, so he suggested that we got some sleep, and returned for an early start in the morning. Brian offered to take me to the Greengarth hostel where he had already booked me a room. As we left the lab, Joe expressed his thanks, and seemed extremely pleased that we could possibly have the system working by the following afternoon.

As we drove the few miles to the hostel, Brian told me the sad story of what had led up to the fire: Two days ago they had started a routine 'Anneal' of the No.1 pile. This had been done many times before, and was an established procedure. With the air cooling system switched off, the reactor was started, and the core allowed to heat up to the critical temperature at which the 'Stored Energy' would begin to be released. At this point the reactor was shut down, and the temperature was allowed to rise as the energy stored within the graphite moderator was released. At first everything seemed to be going according to plan, but the next day the temperature was still rising, and the engineers were beginning to be concerned that something was wrong. However, the temperature was still not above safety levels, so the anneal was allowed to proceed. It was in the early hours of that morning that a 'Radiation Alarm' was triggered, showing that radioactive material was leaking from the reactor. This was soon followed by other alarms on the Windscale site. This had looked like a burst fuel element, but it was strange that this could happen when the reactor was shut down! Tom Hughes the engineer responsible at that time, took the very unusual decision to look inside the reactor core. This could be done from the 'Charge Face' of the reactor, by withdrawing one of the shielding plugs, which exposed four fuel channels. The core of the reactor was glowing red hot! He did not

need any measuring device to tell him that this was far too hot, and was a disaster. The plug was replaced and he quickly called the Reactor Manager, Tom Tuohy, for assistance. At this point there seemed to be a lot of indecision about how to cool the reactor core. They were afraid that if the cooling fans were started, it could make matters worse, by blowing oxygen onto the already overheated uranium fuel. Brian said that was all they knew at that time. He did not say, but I got the feeling that they had been excluded, and the engineers had taken charge of the situation!

When Brian left me at Greengarth it was already very late. I felt completely strained and exhausted, and was only too happy to flop into bed. However, I slept little that night, as my mind was continually thinking about the fire, its cause, and the consequences.

In the morning Brian collected me early and we were in the lab by 9 am. As the others had not arrived, we set about preparing the apparatus for the heating run to purge the metal deposits. This took longer than I had expected. It was nearly 11 am when we finally got the temperature up to 450 degC. I switched off the power and left it to cool. I knew that it would be at least an hour before it would be cool enough to release the vacuum and open the system.

While we were waiting Joe arrived. He had been into the reactor building to find out what was happening. The good news was that the reactor core was now cooling. The fire was not completely out, but it was now under control. The bad news was that they had to use water to smother the fire. This was a very desperate step. Something that they had tried to avoid. Air cooling was out, because it could fan the flames, and would blow radioactive debris out of the chimneys. During the night they had attempted to pump carbon dioxide into the core, but this had proved difficult and was unsuccessful. The problem with water was that it had to go somewhere. There was no way to stop it from leaking into the fuel processing pond, and from there it would eventually overflow into the Calder river. At this time it was not possible to tell how serious the fire had been, but Joe thought that it would be a long time before the reactor could be used again.

The calorimeter had now cooled, so I released the vacuum and opened up the system. The purge had been very successful. Most of the grey deposit had been driven from the region of the calorimeter, and had deposited on the cold walls of the vacuum chamber. The fine wire thermocouples and their silica insulation were almost clear. After only half an hour of delicate cleaning, I thought that we were ready to try a dummy run. We decided to use two brand new unirradiated graphite samples that had been prepared that morning. It was with a great deal of apprehension that we started the run, and enabled the electronic control circuits. The temperature began to rise at the predetermined rate, everything was stable, and seemed to be behaving in a perfectly normal manner. I had complete faith that everything would be all right, but I thought the others had stopped breathing! When we came close to 200 degC, the conversation diminished to a whisper, while the onlookers waited for the signs of instability that they had seen so many times before. At 250 deg it was still behaving perfectly; A look of relief came over the members of the group, and they all started talking at once. Even Joe, who had looked so crestfallen, now had a smile on his face. When we reached 300 deg, with still no trouble, Joe was convinced that we had licked the problem. He was very keen to abort the run, and start again with an irradiated sample. It was way past lunchtime, and as we had to wait for the system to cool, he suggested that we used the time to get something to eat.

It was some two hours later before we were ready to start a real run with an 'active' sample which contained 'Stored Energy'. Brian agreed to operate the system himself, and after a hesitant start, had the system running. All he had to do now was to measure the temperature every few minutes. The

'Stored Energy' would be displayed on a strip-chart recorder, which was the output from the differential wattmeter. As it was all going well, the rest of us retired to an office area in the corner of the lab, knowing that we would have a long wait before the run ended.

During lunch Joe had gathered some more news about the fire. It seemed that the fire was completely out by midday, and the panic was now over. However, the highly radioactive water which had put out the fire, had flowed into the fuel storage pond as he had predicted! Then the pond had overflowed, leaking the highly dangerous liquid into the Calder river! As all the radiation alarms on the site had been triggered, it meant that radioactive materials had also been emitted from the reactor chimney. It was an extremely nasty incident, and would have very serious repercussions. Although the fire had spread radioactive materials over a wide area, it had not been a nuclear accident, and no one had been hurt. One very unpleasant fact emerged, that the reactor core had contained Lithium in some of the fuel channels! This has a low melting point, and burns in air. It also releases hydrogen when in contact with water!!

After three hours the run was over, and Brian came to tell us that it was a complete success. The 'Stored Energy' release was plainly visible on the recorder chart which he spread out on the table. Joe was very pleased, and thanked me for sorting out the problem so promptly. He agreed that the trouble which had been caused by the 'bad' sample, was just an unfortunate accident. Now that we had the system working, it was unlikely that this would become an issue in any subsequent enquiry. However, he certainly expected to pick up some of the blame for the fire!

It was now quite late, and Joe suggested that I should stay another night, and return to Harwell in the morning. He promised to arrange transport to collect me from Greengarth. I said my goodbyes, and Brian took me back to the hostel, where we spent a long time talking about the events of the last few days.

Before I retired for the night I was given a message that a car would pick me up at 7 am! I was a little peeved at having to get up so early, but it did mean that I would arrive at Harwell at a reasonable hour. I was ready and waiting before the car arrived. It had a driver, and one passenger who I did not know. He seemed rather put out at having to share the car with me. I don't think that we exchanged more than a dozen words on that long journey.

When I arrived back at Harwell, I found John Simmons waiting for me. He had been briefed by Joe Bell about all that had happened, but he still wanted a 'post-mortem' on the events. It seemed that a lot of decisions had been taken in the short time that I had been away. An enquiry was to be held to investigate the cause of the fire, and no doubt to apportion blame! Also John had been directed to set up a new 'Wigner' group to study graphite, and in particular 'Stored Energy'. As from that day I had a new job. John just could not stop talking about it, and I had another very late night.

What happened in those few days was a disaster for Windscale. The No.1 pile was completely destroyed, and would never work again. The No.2 pile was closed down pending a decision that would follow the enquiry. It was never restarted!

The loss of Plutonium production was no longer a problem. The new reactors at the adjacent Calder Hall began working in 1956, and being 'dual purpose', could provide Plutonium and generate power for the 'Grid'. A scheme that was much more acceptable to public opinion. The wasteful Windscale reactors blew a 100 Megawatts apiece straight up the chimneys!!

It may have been a stumbling block for Windscale, but it was certainly a stepping stone for me. I was launched into the most exciting phase in my career. The next few years proved to be a most enjoyable and memorable experience.

In Retrospect

The truth is rarely pure and never simple. Oscar Wilde.

Looking back from today (April 2000), the whole issue is clouded by many conflicting reports. This was inflamed in 1997 when the government decided to release papers relating to the fire, which had been kept secret for 40 years. This produced a new rash of reports and comment, much of it ill informed, and some which was pure nonsense!

The original enquiry blamed lack of instrumentation. In particular there were not enough thermocouples installed in the reactor, so the engineers did not have a good appraisal of the temperature distribution. This was believed to have led to a situation where the high temperatures, which caused the fire, went unobserved.

When the reactor operates normally, the generation of heat in the fuel channel would be symmetric, and peaked at its centre. With a flow of cooling air along the channel, the maximum temperature would be displaced to the outlet end. i.e. the 'hot' end. It is at this point that most of the temperature measuring sites would be chosen. However, most of the Wigner energy is stored in the cooler regions of the graphite moderator. i.e. the peak of energy storage would be displaced towards the 'cold' end of the channel. During a Wigner 'Anneal' the conditions are different; There is no air flow, and there is no nuclear heating. Therefore the stored energy released would then result in a maximum temperature which was displaced towards the inlet end of the channel, where the temperature measuring instrumentation was either sparse or even absent!

One major item, missing from the findings of the original enquiry, was the presence of Lithium in some of the fuel channels. The reason for this, we must assume, was for the production of Tritium, which would be required for the fusion weapons programme. Lithium has a melting point of only 186 degC, which is much lower than the normal working temperature of a uranium fuel element. It also burns readily in air, and decomposes water to release hydrogen!! Not a pleasant material to have in a reactor core! One may well ask why this fact was missing from the report of the official enquiry.

Of course there was a lot of blame implied, but the worst example of this was in a recent TV documentary. This blamed Harwell for ignoring warnings from American scientists about the effects of radiation damage in graphite. Eugene.P.Wigner had predicted many changes, including the 'Stored Energy' which was to give so much trouble. However, Harwell was well on top of this problem. On the 1st of January 1949 I joined a new group, under the direction of T.M.Fry, which was set up to study these problems. In fact it was called the Wigner Group!! It is ironic that the group was disbanded in 1956!!

In 1998 Ronald Gausden died. He was the overall manager of the Windscale site at the time of the fire. In 1952 he had been in charge of the reactor control and instrumentation, and in my mind he was the one person who was responsible for the disaster in 1957. However, at the time of the fire I did not hear his name mentioned once! His obituary claimed that 'HE successfully tackled a nuclear reactor fire like that at Chernobyl', and makes him the hero of the hour. He certainly received a lot of promotion in subsequent years!

Note that if the Windscale fire had been a 'meltdown' like Chernobyl, I would not have gone within a hundred miles of the place!!

Of course it is easy to criticise in retrospect, from the comfort of ones armchair, without the immense pressure that the engineers were under at the time of the fire. However, it is without doubt that there was a lot of indecision, and even panic which 'fuelled the flames'. I believe that many wrong decisions were taken, which prolonged the fire, and resulted in the widespread distribution of highly radioactive fission products over the region. Trying to tackle the fire from the 'Charge Face' was a bad idea. With shielding plugs removed it was necessary to have positive ventilation, which blew air from the working area onto the already red hot core! This would have turned the core into something like a blacksmiths forge!

Once Tom Hughs had observed the core to be red hot, I believe that the correct action would have been to seal all the air vents to the reactor, to cut off the supply of oxygen. (It should have been obvious that this was NOT a nuclear 'meltdown' like Chernobyl!) Then the reactor core could have been flooded with carbon dioxide, from the top of the containment vessel. It was reported that a tanker containing 25 tonnes of liquid carbon dioxide had arrived at Calder Hall that day. This should have been more than enough to fill the the reactor vessel, and stifle the fire.