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When Windscale burned

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16–20 minutes

"Don't be so silly lad," Yorkshire-born Leonard Owen, chairman of the production pile design committee, told Terence Price, newly-recruited to Harwell in 1947. "Two tons of air go up chimney every second. Can't filter that."

Price had been calculating the consequences of a fire in the pile and the dispersal of unfiltered coolant air contaminated with radioactivity. Price took his fears to John Dunworth, responsible for Harwell's reactors including BEPO (British Experimental Pile 0), prototype of the piles, and thence to Sir John Cockcroft, director. Cockcroft, off to the USA, returned convinced filters were needed; but by then the two huge pile chimneys were well advanced. Which is why the Windscale chimneys, long an icon of UK nuclear activity, achieved their unique shape with massive filters atop instead of built into the base. *Cockcroft's follies*, Sir Christopher Hinton's office dubbed them.

Ten years later, on 8 October 1957, No 1 Pile (on the far left in the image), commissioned in 1951, caught fire and blazed furiously for two days.

The world's first atomic accident to make newspaper headlines occurred in northwest England in the county now called Cumbria, on the coast of the Irish Sea. The two tall concrete chimneys, over 400 feet (120m), with curious square bulges near the top, were already one of the world's most familiar symbols of atomic energy. From the top on a clear day one could see Scotland, 30 miles (50km) away. They were ventilation stacks for the air that cooled their adjoining graphite piles wherein atomic alchemy was turning uranium into plutonium for Britain's first atomic bomb. Two tons of hot air each second blasted through the graphite and up the stacks, 40 feet (12m) in diameter. The gale-force draught, over 20mph (32km/h), swept 100 megawatts of heat from each pile, designed between them to yield 100kg of plutonium a year.

"The Windscale accident of 1957 is the equivalent of a wartime battle," wrote Sir Alan Cottrell in a forward to the historian Lorna Arnold's *Windscale, 1957: Anatomy of a Nuclear Accident*. "All the same basic elements are there: misjudgements, professional rivalries, brilliant improvisation, desperate decisions and heroic actions, all wrapped in a cloud of uncertainty as dense as any fog of war". Cottrell, for decades now Britain's most eminent metallurgist, was deputy to Harwell's chief metallurgist, when the accident happened. He had contributed crucially to the success of the two piles by developing the aluminium alloy in which each uranium slug was wrapped to seal in dangerous radioactive gases formed by its transmutation to plutonium. This alloy was burning, releasing those gases into the airstream.

When the accident happened I was in the area awaiting demobilisation from National Service. I recall some speculation about troops being sent in, but the news was competing with *Sputnik*, the USSR's pioneering spy-in-the-sky satellite, for attention in the village pub. I was sent on a short course at Newcastle University to learn some nuclear physics.

Tuohy's story

Another decade would pass before I was introduced to Tom Tuohy, the ebullient Irishman who played a lead role in the two-day drama at Windscale. By then he was a senior executive of the UK Atomic Energy Authority, government agency for all aspects of atomic energy. In 1957 he had been deputy to Gethin Davey, a Welshman, usually known, as HG, general manager of the sprawling Windscale Works which refined plutonium. But Davey, sick with 'flu, was persuaded by colleagues to go home at a critical stage in the firefighting. A few hours earlier Davey had telephoned Tuohy, home at nearby Beckermet nursing wife and family, also sick with 'flu: "Come at once, Pile No 1 is on fire."

"I told wife and kids to stay indoors and keep all the windows closed." In what I would learn was a characteristically cavalier gesture, Tuohy then flouted standing orders and discarded his radiation badge, so no-one could tell him he'd exceeded permitted radiation dose limits and lay him off work. He went immediately to the top of the pile and peered down vertical inspection holes on the concrete pile cap, into the graphite pile core. He could see the bright glow from the fire near the pile's discharge face. It would spread over the next few hours. His inspections suggested about 120 of the horizontal fuel channels filled with uranium slugs were ablaze. Windscale process workers were sweating away with steel rods, trying to shove burning fuel cartridges, distorted by heat, out of the conflagration.

From the colour of the flames Tuohy believed temperatures must be approaching the melting point of steel. He continued inspections throughout the night. Around dawn he had carbon dioxide gas pumped into the core to try to quell the inferno but it had no dramatic effect. There were signs, however, that the fire was abating. Now Tuohy began to fear that the thick concrete biological shield that protected him and the rest of the world from the core's intense radiation might begin to collapse.

Earlier Tuohy had agreed with his peers on site that if it came to the worst water must be used to drown the fire. It raised serious risks of exacerbating the damage – for example by creating an explosive mixture of watergas and air. But time was running out, Tuohy told his fire chief where to position the hoses, two feet above the fire. He remained in the pile while water began to flow, gently at first. Initially, nothing happened. He switched off the blowers that had been keeping temperatures tolerable for the fire-fighters but were also fanning the flames – and watched the fire die. Five hours later he was reporting to his boss that the fire was out – though his fire chief kept water flowing for the next 30 hours. The pile structure, so sternly tested, survives to this day.

Tuohy returned home to reassure his sick family. He was in his late-30s.

Half-a-century later, aged 86 and still living in Beckermet within sight of the factory, he was boasting to me that he still enjoyed 20:20 eyesight.

Radioactive plumes

It was far from the end of the story, however. The filters – *Cockcroft's follies* – had failed to prevent two major releases of radioactive debris. The first, on October 10, carried the activity northeast of Windscale; the second, carried it southeast over England and thence to western Europe. The primary concern was iodine-131 and contamination of milk drunk by young children. In collaboration with the local manager of the Milk Marketing Board, it was decided to ban distribution of milk from 17 farms in the Windscale area. The UKAEA paid farmers £60,000 for the milk they dumped. Cattle and sheep prices were not affected, however. One long-term consequence has been a much sharper focus on dose limits for public exposure to specific radioisotopes.

"They always go back to Windscale," I was told by Glenn T Seaborg in Washington DC a decade later. In 1969 Seaborg, who had discovered plutonium and wrote the rulebook for handling it safely, was chief nuclear adviser to the US government. As chairman of the Atomic Energy Commission he was planning a campaign of "sober rebuttal" to counter the growing anti-nuclear sentiment sweeping east from California – his home base. He cited the hysteria expressed by Sheldon Novick's *The Careless Atom* alleging that, atom-happy, the US was courting great danger. Rumours circulated that the Lake District – a great tourist attraction – would be uninhabitable for 200 years.

What went wrong?

What had gone wrong at Windscale? Lorna Arnold's painstaking analysis, begun over three decades after the accident when hitherto top secret government papers had been published, concludes that the precise cause of the fire is still not clear, but may become clearer when the pile itself is eventually dismantled. It might have been the failure of one of the 70,000 sealed slugs of uranium; or failure of a similar cartridge making tritium. Whatever the cause, the evidence she has assembled suggests the government may have been too hasty in blaming those in charge of the pile on that fateful day. As Arnold concluded: “After an accident which had become inevitable, they had acted with outstanding courage, resourcefulness and devotion to duty. Yet their actions had been publicly blamed, at the highest level, as contributing materially to the fire.”

The government asked Sir William Penney, one of the three nuclear knights managing the UK nuclear programme (the others were Hinton and Cockcroft) and customer for Windscale’s plutonium, to conduct an urgent inquiry into the accident. In only 10 days a team of five interviewed 37 people, some repeatedly, conducted some experiments, and examined 73 technical exhibits. “Some witnesses must have been mentally and physically exhausted,” sympathised Arnold. “They had just been through a traumatic experience, unsure whether an incalculable disaster could be averted.”

Penney reported on 26 October – 16 days after the fire was extinguished. The 31-page report reached four conclusions:

- The primary cause of the accident had been the second nuclear heating on 8 October, applied too soon and too rapidly.
- Steps taken to deal with the accident, once discovered, were “prompt and efficient and displayed considerable devotion to duty on the part of all concerned.”
- Measures taken to deal with the consequences of the accident were adequate and there had been “no immediate damage to health of any of the public or of the workers at Windscale.” It was most unlikely that any harmful effects would develop. But the report was very critical of technical and organisational deficiencies.
- A more detailed technical assessment was needed, leading to organisational changes, clearer responsibilities for health and safety, and better definition of radiation dose limits.

The UKAEA wanted the government to publish Penney's report in full. The government decided otherwise. In the words of prime minister Harold Macmillan, it had "been prepared with scrupulous honesty, even ruthlessness." He took the view that it was sufficiently critical of the UKAEA to severely shake public confidence in the national nuclear programme. It elected to keep the report itself secret, even from Hinton, now head of the electricity industry, but publish a white paper. Macmillan was acutely aware of the impact the Penney Report could have on his freshly negotiated nuclear pact with the USA.

Instead, the public would receive an expurgated version of the accident and its consequences, couched in non-technical language, and stressing that such an accident could not possibly occur in the new nuclear reactors coming on-load for plutonium production, precursors of commercial nuclear power stations. *Cmnd. 302 (HMSO November 1957)* had an introduction by Macmillan himself, attributing the accident partly to inadequacies in the pile's instrumentation and partly to faults of judgement by (unnamed) operating staff. One consequence inevitably was media speculation about the "culprits", leading in at least one case to the naming of someone who was absent throughout the crisis.

One man who had been present throughout was Ronald Gausden, pile group manager, in charge on the fateful day fire broke out. Lorna Arnold wrote her book, she has told me, because she believed Gausden and his fellow pile operators were unfairly fingered by the inquiry. As the UKAEA's official historian when time to publish under the 30-year rule approached, she persuaded the government to release the Penney Report and all other papers relevant to the accident in one tranche, instead of dribbling them out and risking further misunderstandings.

Gausden himself, 36 at the time of the accident and deeply affected by his experience, had moved on. He took his three years' experience at Harwell

followed by ten at Windscale to the newly-created Nuclear Installations Inspectorate in 1960. This body, charged with licensing and regulating the

UK's nuclear stations and factories, was a direct outcome of the accident. Starting as a principal inspector he rose to become the UK's Chief Nuclear Inspector in 1976; and from 1978-81 also director of hazardous industries at the Health & Safety Executive. Gausden was awarded a CB on his retirement in 1982.

Penney Report

Welcoming the release of the 1957 government Windscale documents, the then UKAEA chairman John Collier said: "Operation of the Windscale piles taught us many lessons and the 1957 fire triggered off a complete reorganisation of our nuclear safety programme. It led to the setting up of the UK Nuclear Installations Inspectorate… A new safety culture was born out of the Windscale fire which highlighted faults that have been corrected, making nuclear power operations safe and effective. We learned important lessons from the 1957 fire and these have been taken up by the nuclear industry worldwide."

Collier went on: "We welcome the disclosure of the files as an important addition to the nuclear debate and an indication to people of the many improvements to nuclear safety made since the 1950s."

The white paper faithfully summarised the findings of the accident caused by the so-called "maintenance operation". This was, in fact, Windscale's eighth Wigner release, in 1957 still a novel and little-understood annealing operation on irradiated graphite, in a pile built before it was known and which was manifestly under-instrumented for the purpose.

Penney's inquiries found no evidence of unauthorised experiments (widely alleged at the time of the fire) or of manufacture of undisclosed weapon-related materials, often alleged to be the real reason for "suppression" of the full report.

The full report does, however, provide a more vivid picture of the dangers faced by the factory:

Observations from the top of the pile, through the east inner inspection hole, revealed an obvious glow on the pile rear face at 1846; at 1930 the *flames were much brighter, at 2000 they were yellow and at 2030 they were blue.*

At about this time the use of water was first considered. Two hazards had to be examined: first the danger of a hydrogen-oxygen explosion which would blow out the filters, second a possible criticality hazard due to replacement of air by water. The management were informed, however, of the danger of releasing high temperature Wigner energy if the graphite temperatures were to rise much higher than 1200°C. It was thought that this might well ignite the whole pile.

Penney concluded that the primary cause of the accident was a second nuclear heating, carried out when parts of the pile were still rising in temperature. It was "too soon and too rapidly applied."

His report says by far the most likely chain of events was that the rapid rise in temperature of the aluminium-clad fuel (natural uranium) due to the second nuclear heating caused failure of one or more fuel cans. "The exposed uranium oxidised and gave further release of heat, which, together with the rising temperature occasioned by later Wigner releases, initiated the fire." A second possibility "which we cannot entirely reject is that a lithium-magnesium cartridge failed because the second nuclear heating triggered off pockets of Wigner energy at a time when the general level of temperatures throughout the pile was high. The oxidation of the lithium-magnesium could have added further heat and initiated the fire." But Penney rejected the possibility that the source of the fire was an isotope cartridge other than the lithium-magnesium type. His report pieced together a detailed account of the course of an accident which began "in the region of the pile just below the middle plane and towards the front."

David Mosey, in a critical appraisal of seven 'classic' accidents (*Reactor Accidents: Institutional failure in the nuclear industry*), characterises Windscale as a situation which lacked clearly defined safety responsibilities and authority. "When the accident occurred the several responsibilities of the Chief Safety Officer, the Group Medical Officer and the Windscale Health Physics Officer were not clearly defined."

Mosey, British-born, spent 30 years with the Canadian nuclear industry, mostly in safety-related posts. He concluded that, at Windscale, as with a number of other reactor accidents, the operating staff cannot be described as well supported by their organisation. "Even allowing for the benefits of long hindsight, it seems a particularly conspicuous oversight to give charge of a demonstrably tricky and unreliable operation to an individual without providing anything in the way of formal written guidance aside from a memo of less than a hundred words."

Archive image of the Windscale Piles Windscale