The Atomic Bomb Connection

The redundant Pyro Building P6 at the Ministry of Supply Works, Valley was used in 1942-1945 to house test equipment in an attempt to establish the feasibility of producing the isotope U-235 on an industrial scale. It was estimated in 1942 that it would take 10-15Kgs of U235 to make a bomb which would explode with a force of 1,800 tons of TNT.

U-235 had never before been produced on an industrial scale and if this could be achieved we may be able to produce two atomic bombs per month in two years time. Building P6 was the test unit for a team of scientists of the highest order located in Oxford University's Clarendon Labs, Birmingham University, ICI at Billingham, Liverpool University and Metropolitan Vickers at Trafford Park, Manchester, ICI Widnes and Runcorn and the Cavendish Laboratory at Cambridge.

Fission is discovered in Berlin.

In the 1930s scientists strived to discover the structure of the atom. Some Europeans who sought to achieve this were Enrico Fermi in Rome, the Joliot-Curies in Paris, James Rutherford at the Cavendish, Niels Bohr in Denmark and two groups located in Berlin. When James Chadwick discovered the neutrally charged neutron in 1932 it was identified as the ideal projectile for nuclear reactions as there was no Coulomb barrier to its neutral charge and it approximated to the mass of the proton. One of the Berlin groups was led by Otto Hahn, Fritz Strassmann and Lise Meitner and they were located at The Kaiser Wilhelm Institute for Chemistry at Dahlem. The Institute of Chemistry opened in 1912, as one of the first two Kaiser Wilhelm Institutes in Dahlem. It had three self-contained departments. Its founding director, Ernst Beckmann, headed the Inorganic and Physical Chemistry Department, with Richard Willstätter heading the Organic Department. In 1915, Willstätter became the first scientist from the Kaiser Wilhelm Society to receive a Nobel Prize, awarded for his clarification of the structure of chlorophyll. The third department, for radioactivity, was headed by Otto Hahn und Lise Meitner. It was subdivided into sections for chemistry and physics. On July 14th 1938 Lisa Meitner, who was an Austrian of Jewish extraction, fled Berlin via Holland and took up a newly created post at the Nobel Institute for Physics in Stockholm, Sweden. She had worked at KWI since 1912, mainly with Otto Hahn and from 1929 with analytical chemist Fritz Strassmann.
The experiments were continued by Hahn and Strassmann. The story of Hahn's discovery began in 1938 with a report by Irène Joliot-Curie that bombarding uranium with neutrons had resulted in the production of a radionuclide of thorium, which they later speculated was a transuranium element similar to lanthanum. The astounded Hahn told Irène's husband, Frédéric, that such a thing was nonsense and that he would perform an experiment to prove as much. On 17th December 1938 in the process of duplicating her work, Hahn and co-worker Fritz Strassmann discovered that, among other things, three isotopes of barium had been produced. This was incredible because the mass of barium is about half that of uranium. No known reaction could explain such a huge change in mass. Hahn, realising that as a chemist he was treading in the domain of physics, did not offer an explanation but instead, on 19th September 1938, he sent a letter to Lisa Meitner describing his findings and asking "Perhaps you can suggest some fantastic explanation".

On Holiday in Sweden

Lise Meitner was spending the New Year Holiday with her nephew Otto Robert Frisch, who was a noted physicist, in Kungalv on a walking holiday. They discussed the letter from Hahn and came to the conclusion that the nucleus of the Uranium atom had split into two pieces (later found to be Barium and Krypton). They described their conclusions in a paper which was received by Nature magazine on 16th January 1939. They calculated that this fission generated a huge 200MeV of kinetic energy and should be observable in an ionisation chamber. When Frisch returned to Copenhagen on January 13th, 1939 he performed the experiment in an ionisation chamber in Niels Bohr’s laboratory and generated 70 MeV per fragment. He discussed the findings with an American biochemist William A Arnold who was working with George de Hervesey and asked him what term biologists used to describe the process of cell division. He was told binary fission and he used the term nuclear fission or fission in his description of his experiment.

Nuclear Fission Is Reported

Between Hahn-Strassmaan announcing their findings in Naturwissenschaft on 21st December 1938 and Meitner-Frisch writing their conclusions in Nature nuclear fission became common knowledge in the scientific community. Niels Bohr publicly announced the discovery of fission at a physics conference in the George Washington University in Washington DC on 26th January 1939. Frisch had confided in his mentor after he had confirmed his calculations in Bohr's own laboratories. The room emptied quickly as the scientists rushed out to find the equipment to repeat Frisch's experiment. The news of the discovery of nuclear fission echoed around the world. Perhaps transmutation WAS possible?

The problems with Fission

On February 5, 1939 Niels Bohr gained a crucial insight into the principles of fission - that U-235 and U-238 must have different fission properties, that U-238 could be fissioned by fast neutrons but not slow ones, and that U-235 accounted for observed slow fission in uranium. At this point there were too many uncertainties about fission to see clearly whether or how self-sustaining chain reactions could arise. Key uncertainties were: The number of neutrons emitted per fission, and the cross-sections for fission and absorption at different energies for the uranium isotopes.

The Frisch-Peierls Memorandum

In March 1940 Robert Otto Frisch was working at Birmingham University with Rudolf Peierls. Robert was staying in the Frisch house, along with Rudolf's wife Genia and their children. They were both enemy aliens and had to report to the local Police Station on a daily basis. The apocryphal story has them being kept waiting by the police while they whiled away the time by calculating how much Uranium 235 would be needed to achieve a critical mass (the amount needed for a large explosion). They wrote their calculations on a cigarette packet and used their Slip Sticks (slide rules). They were amazed to find that their calculations indicated a mass of 1 kilogram. This result, if true, indicated that an atomic bomb was feasible if sufficient amounts of the isotope U-235 could be separated from U-238. They spoke to their Department Head, Mark Oliphant and began drafting a report on their findings this became known as the Frisch-Peierls Memorandum. This Memorandum was forwarded to Henry Tizard and caused the formation of the Maud Committee.

The Maud Committee

The Maud Committee was assembled to determine what steps we should take to hastily manufacture atomic bombs. In the light of the Frisch-Peierls Memorandum it seemed that such a device was possible for use in the present war and it was also thought that the Germans probably were intending to make such a device and were possibly more advanced than ourselves in such an enterprise. The Maud Committee consisted of four present or future Nobel Laureates and two Hughes Medal winners. In general terms The Maud Report could be summarised as follows. At that time it was identified that the fastest way to achieve an atomic bomb would be by utilising the uranium isotope U-235. This had never been produced on an industrial scale and there could be no bomb without this refined isotope. The recommended way to separate it would be by the gaseous diffusion process and the world authority was Franz Simon a pioneer of cold temperature physics. If experimentation showed that U-235 could be produced on an industrial scale factories could be built to produce enough to manufacture three bombs per month in two years time. The cost would be £95 million (this was when a Spitfire cost £8,000).[1] [2]

The Gaseous Diffusion Process

There were a number of methods to separate U-235 from U-238 but the one favoured by the Maud Committee was the gaseous diffusion process to be provided by Franz Simon and his Clarendon team. The basic principle was to put a gaseous form of Uranium (Uranium Hexafluoride or Hex) in a heated chamber and force it against a very fine meshed membrane. The output would be slightly enriched at the top of the membrane with U-235 which has a lower atomic weight than U-238. This slightly enriched output would then be used as the input to the next of hundreds ......

Tube Alloys is Formed

It was identified in the Maud Report that it was theoretically feasible to make an atomic bomb. There was also the probability that the Germans were ahead of us in the knowledge necessary to build one. The major question was would it be a weapon useable in the current conflict?

In 1941 we were on our own and almost broke financially and the prospect of the enormous cost and loss of industrial production which could be used in more pressing areas was the *Judgement of Solomon*. It was decided to form an enterprise which was code-named Tube Alloys, This would be tasked with establishing if it was feasible to produce fissile material on an industrial scale at a price which made it a useable weapon in the current war.

There was an over-riding priority which was the U-boat war in the Atlantic. The Germans were sinking more shipping than we were building (400,000 tons in one month) and it was probable that we would starve if we could not find a method to defeat the U-boat. We believed the way to defeat them would be by the perfection of centimetric radar and all of our most talented scientists were being used to make this effective and they could not be spared.

Ironically the German and central European scientists who were not cleared to work on radar could work on the atomic bomb and Tube Alloys employed them to fulfil such a role. The Tube Alloys project was launched with the highest level of priority and secrecy probably with the feeling that our expatriate Germans were not of the same calibre as Eisenberg and Hahn.

The Tube Alloys Project

The Tube Alloys project was spread over a number of locations some of which were Oxford University's Clarendon Labs, Birmingham University, ICI at Billingham, Liverpool University and Metropolitan Vickers at Trafford Park, Manchester. In the early days James Chadwick was involved before he went to the USA to be the leader of the British Contingent on the Manhattan Project. The head of this project was Wallace Akersand his CEO was Michael Perrin. The Head of the technical section was Rudolf Peierls and his deputy was Klaus Fuchs. Chadwick ran a department at Liverpool University which housed Europe’s first cyclotron which was partially financed by his Nobel Prize money for the discovery of the neutron. In the early stages of Tube Alloys Frisch calculated cross-sections and Josef Rotblat and John Holt also worked there. The Clarendon housed Franz Simon and his cold temperature physics team who had done the original theoretical work on the gaseous diffusion process. Birmingham University had Rudolf Peierls working for Mark Oliphant and ICI at Billingham and Widnes were involved in the initial work on the production of Hex, ingots of uranium and heavy water.

There were eventually 70/80 scientists of various grades involved but the hub was the Clarendon. It was decided to build four prototype gaseous diffusion machines and the contract was awarded to Metropolitan Vickers at Trafford Park in Manchester at a cost of £150,000. This contract required the building of a single cell unit, a double cell unit and two ten cell units. Each of the cells in the first stage units could weigh up to three tons. It was intended to run the two ten cell units in series making a twenty cell unit weighing about 60 tons. The combined efforts of the project were to test the theory in the units when completed by Metro-Vick.

Choosing Rhydymwyn

The physical size of the units and their great weight precluded the use of any buildings in the Clarendon. There were also no units of sufficient size on the Trafford Park Industrial Estate or particularly height where a 20-24 feet clearance was needed. ICI suggested that the redundant Pyro Building P6 at Rhydymwyn may fit the bill. A number of other sites were inspected before the virtues of P6 prevailed. Although constructed to manufacture Pyro mustard gas it was never fitted out with the manufacturing machinery. It was large enough, had all of the required services readily available, was accessible by all the research and manufacturing sites, and was located in a secure, guarded enclosure.

Wallace Akers the leader of the Tube Alloys project telegrammed from the USA and instructed that all preparations should be made to make P6 ready for installation of the gaseous diffusion units. During 1941 a great deal of work was carried out on the building to make it ready. This included an enhanced power supply, the filling of air channels, the installations of a new air conditioning system from Andrews, changing the internal lay-out to provide, offices, laboratories and outside storage for hex.

During this period, except for the Commonwealth, we were on our own and we now know that we were the only party making progress with the practical possibility of refining enough fissile material to make an atomic bomb. .....

Work Starts at Rhydymwyn

The internal layout of P6 was changed to reflect the needs of Tube Alloys. This included the insertion of partition walls, the building of physics and chemistry workshops, a glassblowers laboratory, the building of a 24 ft lift, the fitting of new air conditioning, the sealing of half of the building as a secure unit, the construction of external storage and the provision of a safe to store any Hex in. Access to the building was to be limited to one guarded entrance and all of the staff were to be strictly segregated from the other site workers. Two hostels were fitted out at Maes Alyn and Bryn Bellen for the use of the 70/80 scientists, many of whom would be transient. A pool of 10 young female laboratory assistants was recruited from a national base for testing some of the equipment. It appears there was a great deal of testing if the glass spheres blown on site were maintaining their vacuum. When the gaseous diffusion cells were delivered they were installed as one two stage unit and one twenty stage unit configured from two ten stage units in series. It is believed that the single stage unit was installed at the Clarendon. The initial run-up period of the units was dogged with bad engineering practices by Metro-Vick and delays caused by the need to locate rare materials and parts. This may also have been the result of skilled craftsmen being called up or a lack of appreciation of the fine tolerances necessary in such machines. ICI at this time were working on the production of Hex and in the short term fluors were used to test the prototype diffusion process. The major problem was the membrane technology but this was eventually resolved by the use of sintered nickel. During this period the experiments taking place in a redundant poison gas factory in a tiny village in north Wales was at the cutting edge of one of the most important developments in the whole of history. It must have seemed to the scientists to be like Camelot. The British Government were providing unlimited funds to conduct pure research in the most glamorous field of physics.

The Quebec Agreement

In August 1943 Great Britain, the USA and Canada signed the Quebec Agreement which committed the future development of an atomic bomb to take place in North America out of the range of German bombs and closer to the greater resources available there. This resulted in the British contingent of 23 scientists (mainly of foreign birth and education) travelling to North America to help with the Manhattan Project. There were two types of atomic bombs possible, one by the use of Plutonium and the other by Uranium and both were being developed in North America. There were also four methods of separating fissile material from Uranium and all four were being developed in the USA. The British had concentrated on the gaseous diffusion method to develop a Uranium bomb.

There was a massive effort in the USA to build a gaseous diffusion plant, this was located at Oak Ridge, Tennessee in a bespoke building called K-25 which covered about 100 acres.

In December 1943 Peierls and Fuchs travelled to the New York and went to a meeting with Groves and the Manhattan Project leaders on the gaseous diffusion project. They were in difficulty with the initial design and welcomed their input which was not acted upon.

Fuchs and Peierls worked as consultants for the Kellex Corporation at Columbia University designing the K-25 plant at Oak Ridge. In January Peierls left to go to Los Alamos to run the Theoretical Section

and lead the British contingent. Fuchs stayed at Kellex until the Spring when he went to Los Alamos to lead the section working on the lens system for the Plutonium Bomb and he is credited with the design of the initiator for that device.
None of the British contingent were ever allowed to visit any fissile material production plants or made aware of which productions methods were finally decide upon.

Tube Alloys at Rhydymwyn 1943-1945

When Fuchs and Peierls left for the USA Harold Schull Arms and Nicholas Kurti took over at Rhydymwyn. Work continued on the gaseous diffusion process but at a slower pace as the momentum in the project had swung to North America. The test equipment was all collected and moved to Harwell and Didcot in 1945 and P6 became a general storage facility. At the end of the war despite agreements including a modus vivendi between Roosevelt and Churchill that neither side would use atomic weapons without mutual permission the USA attempted to frustrate our attempts to develop our own device device by excluding us from the processes used in the separation of fissile material. They further obstructed our access to uranium and suggested we may not qualify for the sorely needed Marshall Aid if we had sufficient resources to build an Atomic Bomb.

The Legacy

In the post war world we believed that we must have the Atomic Bomb to be able to sit at the top table and we were still considered ourselves to be a major power, if a somewhat parlous one. There was no problem in designing it, anyone could do that as the process of fission was public knowledge and we knew that both the Uranium and Plutonium devices worked as they had been demonstrated at Hiroshima and Nagasaki. The problem was the immense amounts of money, people, industrial resources and materials necessary to produce weapons grade material. The situation in the UK was that we were broke, our industry was battered and the returning troops were seeking a better life under a Socialist government. Although we had scientists who had been involved in the design of the US devices many of them stayed in the USA or did not want to continue in that field. There was also the fact that knowledge in the Manhattan Project was compartmentalised so it was difficult to put together a full picture, although Klaus Fuchs seemed to have a remarkably wide knowledge.
The simplest device to make was a uranium bomb but even if we aimed for a plutonium device we would still need a system for uranium enrichment to feed the reactor to breed the plutonium.
In 1946, in secret committee, Clement Attlee chaired a meeting which pledged the UK to making an atomic bomb as soon as possible. The key element in this would be the construction of a gaseous diffusion enrichment plant at Capenhurst in Cheshire. The cost would be £100 million and it would utilise 5% of the nation’s electricity production.
Capenhurst produced the fuel for the reactor at Calder Hall which produced most of the plutonium (the rest came from Canada) for the bomb detonated aboard HMS Plym at Monte Bello on 3rd October 1952.
This was a staggering achievement, as the bomb was built by civil servants on shoe-string, in a country struggling to survive the second world war, in thirty years. It was perhaps the last great achievement of this country and it could not have been done without the wartime efforts of a few young men and a handful of young girls at Rhydymwyn.

REFERENCES

[1] Wikipedia - Maud Committee

[2] Atomic Archive - Maud