

## Chapter Two: October 1941 to Quebec, August 1943

The American atomic programme received vastly increased funding in the autumn of 1941 and was beginning to overtake Britain's. Also, the American programme didn't have competition for resources like the British programme had. In Britain, manpower and scientific research were being channelled into investigating radar and making ammunition. There was little to spare for nuclear research. The technical know how was there but there were insufficient funds available to make use of it. Making a uranium separation plant in Britain would have been strategically risky as the plant would have covered a significant area and would have been an obvious target for German bombing raids. Britain's atomic programme began to suffer. In the war Britain had a number of dramatic military reverses during 1941. Churchill 'had much else on his mind, therefore, during this period, and what he needed from his advisers on the atomic issue was a firmly unanimous view.'<sup>1</sup> There developed a harmful split over whether the bomb should be built in Britain. Lord Cherwell and James Chadwick wished the bomb to be built in England. However, John Anderson 'backed by some scientists, believed that to build a plant of the size required in wartime Britain was impracticable, and moreover there was the risk that the plant might be bombed.'<sup>2</sup>

Resources were a headache. The British team thought it was crucial to 'establish a world monopoly in the raw material required' for tube alloys.<sup>3</sup> Sir John Anderson felt a survey for

---

<sup>1</sup> Edmonds, R *The Big Three: Churchill, Roosevelt and Stalin*, London, Hamish Hamilton, 1991, p. 399

<sup>2</sup> Edmonds, R *The Big Three: Churchill, Roosevelt and Stalin*, London, Hamish Hamilton, 1991, p. 399

<sup>3</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, *Minutes of a Meeting of the Council held on Tuesday 18<sup>th</sup> November 1941 at 10am*, National Archives, p. 2

uranium and other raw materials ‘could probably best be made by the Department of Scientific and Industrial Research.’<sup>4</sup>

Keeping any new developments in the atomic programme a secret was an incredibly complex issue as there was so much material that was published about physics. Technical journals didn’t present too much of a problem as measures had been already put in place to censor their articles during wartime. There was however, less chance ‘of exercising control through the Ministry of Information over articles of a purely speculative kind in the popular press.’<sup>5</sup> Regarding patent matters<sup>6</sup>, it was felt keeping all patents a secret might give enemies ‘a means of discovering that we regarded this work of special secrecy and importance.’<sup>7</sup>

Due to the favourable reports from Britain on producing a nuclear weapon, a decision by the United States to proceed with a full nuclear programme was taken on 6 December 1941 and was announced to the uranium researchers in the Office of Scientific Research and Development. This was on the eve of Pearl Harbour. The attack from Japan further convinced the U.S that an all out effort for an atomic bomb should be made the highest military priority.

The Allied programme picked up speed during the winter of 1941 and into the spring of 1942. Britain sent a delegation of scientists to the U.S to see the progress made on research in

---

<sup>4</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, *Minutes of a Meeting of the Council held on Tuesday 18<sup>th</sup> November 1941 at 10am*, National Archives, p. 2

<sup>5</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, *Minutes of a Meeting held in the Lord President’s room, Great George Street, 16<sup>th</sup> January 1942*, National Archives, p. 3

<sup>6</sup> Patents are intellectual property rights for inventors. An inventor takes out a patent to stop anyone else stealing his or her idea. Patents relating to such world changing inventions, such as the patents taken out by the French scientists on their design for a heavy water reactor, were bound to be controversial. The design for an atomic reactor had such wide industrial implications that it would be difficult to assign intellectual property rights to one person or country.

<sup>7</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, *Minutes of a Meeting held in the Lord President’s room, Great George Street, 16<sup>th</sup> January 1942*, National Archives, p. 3

February and March of 1942. This was led by Wallace Akers from I.C.I and included the French scientist Hans Halban, who conducted heavy water research for a uranium pile. The British suggested Halban should go to the States to continue his work on heavy water and take the 165 litres available in Britain with him. James Conant rejected this on the grounds that amounts of heavy water needed for a reactor would be too great compared to graphite as a moderator. 'Objections were also raised on security grounds insofar as Dr. Halban was not a British or American national.'<sup>8</sup>

Rudolf Peierls and Francis Simon visited the United States in spring 1942 and were impressed with the scientific knowledge and funding on the American programme. However, the pair made a bad impression on the American diffusion experts. 'They seemed to assume the superiority of their approach; Peierls lectured rather than conferred.'<sup>9</sup> They suggested Britain should think again on collaboration with the U.S as there would be military and economic benefit. America would soon be far ahead of Britain and Britain would need to act fast if she were to influence the American programme. There also began investigations as to whether graphite could be used as a cheaper and speedier moderator than heavy water for plutonium production which would sideline the British heavy water research.

In March 1942, Anderson and Bush discussed information exchange. 'Each was satisfied with the progress of interchange for the time being, but with the technical situation so fluid, neither

---

<sup>8</sup> Gale Reference Library, Harry S. Truman Library, *History of United States-British and Canadian Atomic Relations, March 2<sup>nd</sup> 1949*, p. 8

<sup>9</sup> Hewlett, R.G and Anderson, O.E *The New World*, Pennsylvania State Publishing, 1962, p. 260

was ready for a final commitment.<sup>10</sup> This was another opportunity to stitch the two countries' atomic programmes together that was left to drift.

By June, the British experts were turning their thoughts to the wider implications of atomic energy. What would the world do with the technology if and when it became a reality? The utilisation of nuclear energy either as a weapon or for power would require 'a special and powerful system of international control.'<sup>11</sup> International control could not be effectively provided for 'by any general solution covering other fields in which British and American inventions have been temporarily pooled for war-time use.'<sup>12</sup> During the war, there would have to be an agreement between Britain and the U.S.A 'specifically for nuclear energy inventions.'<sup>13</sup> Regarding control of nuclear energy after the war, the tube alloys council made possibly the understatement of the century saying atomic technology might have 'far reaching considerations of policy'<sup>14</sup> for the world.

That same month, Winston Churchill visited Washington. His visit concerned the operation of the war effort for 1942-1943. On the agenda was the programme for Tube Alloys. Churchill was enthusiastic over British progress at the Hyde Park discussion on 20 June. 'Mustering his ample powers of persuasion in the intense heat of the summer afternoon, Churchill urged that the two nations pool all their information, work together on equal terms, and share the

---

<sup>10</sup> Hewlett, R.G and Anderson, O.E *The New World*, Pennsylvania State Publishing, 1962, p. 260

<sup>11</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, *Note by the Directorate of Tube Alloys 5<sup>th</sup> June 1942*, National Archives, p. 1

<sup>12</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, *Note by the Directorate of Tube Alloys 5<sup>th</sup> June 1942*, National Archives, p. 1

<sup>13</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, *Note by the Directorate of Tube Alloys 5<sup>th</sup> June 1942*, National Archives, p. 2

<sup>14</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, *Note by the Directorate of Tube Alloys 5<sup>th</sup> June 1942*, National Archives, p. 2

results.<sup>15</sup> Roosevelt said the American programme was doing well but a positive result would only be found if there was a successful test of the chain reaction. A decision was needed about where the full scale production plant for uranium should be built. It was jointly decided for safety and security reasons the plant should be built in the U.S. Churchill 'offered the help of British scientists, and asked in return that Britain share fully in the technical information which might be gathered from the American experience.'<sup>16</sup> Churchill was aware of further intelligence linking Germany with the production of heavy water and the fear that Germany was winning made the Allies work much faster. 'Atomic bombs in German hands would almost surely paralyse Britain and bring resounding victory to the Nazis in Russia. With such a possibility in the background it could not be safe to suspend any effort that promised results.'<sup>17</sup> No written record exists of the discussion on atomic weapons but Churchill would have interpreted the discussion as a promise for full collaboration. The letter that Vannevar Bush wrote to Sir John Anderson seemed to back up this interpretation. Bush told Anderson that when it became possible to compare the British and American atomic programmes 'we will find that these interlink closely, and that such conflict or unnecessary overlap as readily evident then can easily be adjusted.'<sup>18</sup> Bush added that he was 'much encouraged'<sup>19</sup> by the progress that had been made and there was no hint in this letter that any problems lay beneath the surface.

---

<sup>15</sup> Hewlett, R.G and Anderson, O.E *The New World*, Pennsylvania State Publishing, 1962, p. 261

<sup>16</sup> McNeill, W.H *A Survey of International Affairs 1939-1946, America, Britain and Russia: Their co-operation and Conflict, 1941-1946*, London, Oxford University Press, 1953, p. 186

<sup>17</sup> McNeill, W.H *A Survey of International Affairs 1939-1946, America, Britain and Russia: Their co-operation and Conflict, 1941-1946*, London, Oxford University Press, 1953, p. 186

<sup>18</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, Program of Research on Tube Alloys in the United States, *Copy of letter (with enclosure) 19<sup>th</sup> June 1942 from Dr. Bush to the Lord President of the Council*, National Archives, p. 1

<sup>19</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, Program of Research on Tube Alloys in the United States, *Copy of letter (with enclosure) 19<sup>th</sup> June 1942 from Dr. Bush to the Lord President of the Council*, National Archives, p. 1

Fully expecting to be included in the American decisions, the Tube Alloys Consultative Council expressed the belief that it was ‘urgently necessary that action should be taken to merge the work on fast neutrons.’<sup>20</sup> British knowledge already gained in this field could then be ‘placed at the disposal of the United States, in order that the British method of separation might be given a fair trial.’<sup>21</sup>

In summer 1942 the American project transferred from the authority of the scientists to the direction of the military under the Military Policy Committee. On 17<sup>th</sup> September, General Leslie Groves was appointed leader of the project. He was chosen because he was an expert in construction and would be invaluable in the creation of Los Alamos and its infrastructure. Groves was strict on secrecy. He didn’t like collaboration with the British and gradually Britain was effectively closed out of information exchange on atomic research and development. ‘The British had thought that the American project was already too subdivided for efficient progress but Groves was clearly determined to go much further in that direction.’<sup>22</sup> Groves used the argument that Britain had only concentrated on research and had not made any progress in weapons production. Therefore, she was not helping the immediate war effort and not entitled to any information regarding the production of the bomb. Groves stated the British themselves ‘had provided us with numerous precedents for rejecting their argument for, as Conant pointed out, they had not told us of a secret bomb disposal method, or of several

---

<sup>20</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, *Minutes of a Meeting held in the Lord President’s Room, Great George Street, 29<sup>th</sup> July 1942*, National Archives, p. 1

<sup>21</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, *Minutes of a Meeting held in the Lord President’s Room, Great George Street, 29<sup>th</sup> July 1942*, National Archives, p. 2

<sup>22</sup> Gowing, M *Britain and Atomic Energy 1939-1945*, London, Macmillan, 1964, p. 150

other of their developments in which we were interested, because, they said, this knowledge would not assist our military effort.<sup>23</sup>

Roosevelt told his Secretary for War, Henry Stimson, that Churchill and he had discussed atomic research only in very general terms. As such, Stimson proposed information should only be passed to the British as strictly necessary. 'Roosevelt concurred, though he suggested that sometime in the near future he and Stimson ought to speak with the Prime Minister.'<sup>24</sup> It followed that the Manhattan Project organisers decided no information should be divulged to the British that was not of immediate military value to them.

The U.S was highly suspicious of Britain's overtures for a joint programme during 1942 and thought that Britain wanted to gain all the nuclear information for when the war was over and use it for her own commercial gain. Britain was suspicious of the U.S as Britain believed the U.S wanted a post-war nuclear monopoly over other nations. Groves and Bush had discussed limiting information to the British due to the rapid progress the American teams had made. Their case had some merits. Now the U.S had committed to a full effort for the bomb it was doing most of the work, estimated at 90%. Britain had not investigated electro magnetic separation or the graphite pile. 'Reinforcing these considerations were the more rigid security arrangements that would prevail now that a weapon was in sight... It would be unfair to compartmentalise American scientists while allowing their English counterparts to travel about picking up information from all projects.'<sup>25</sup> Britain would obviously not have the funds available to contribute in a large way to the atomic programme. Groves was concerned that

---

<sup>23</sup> Groves, L.R *Now It Can Be Told*, London, Andre Deutsch, 1963, p. 129

<sup>24</sup> Hewlett, R.G and Anderson, O.E *The New World*, Pennsylvania State Publishing, 1962, p. 264

<sup>25</sup> Hewlett, R.G and Anderson, O.E *The New World*, Pennsylvania State Publishing, 1962, p. 265

Britain would receive a huge amount of technical information from the U.S ‘while practically none beyond preliminary laboratory data would pass from the British to us.’<sup>26</sup>

Also because the Americans were so far ahead of Britain by the summer of 1942, they were less than enthusiastic about Britain being part of the programme as it was doubtful of the benefits collaboration with Britain would bring. For example, the British had been researching the gaseous diffusion method of separating uranium. The U.S had been working on this but also on ‘three additional methods: electromagnetic separation, centrifugal separation and the production of Plutonium’.<sup>27</sup> Groves has said if it weren’t for suspecting post war commercial aims of the British, information exchange may not have been affected. ‘Negotiations broke down not because of American policy, but because the British refused to accept our view that collaboration should be for the purpose of winning the war – not for post war purposes.’<sup>28</sup> This argument is highly doubtful as Groves himself is famed for being security minded. Compartmentalisation was a useful tool for blocking Britain’s access to the programme. As soon as the military were given power over the enterprise there was no stopping the security measures. Information was bound to be restricted unless the President directed otherwise, which in part explains why Churchill was determined to negotiate with Roosevelt in secret. Bush apparently told Francis Simon that the British team could not be accommodated in America as another plant would divert valuable resources, especially rubber, away from the American production plants. Simon wrote to Akers, surmising the real reason to be ‘that the army people want to run the thing 100% American or something similar’.<sup>29</sup>

---

<sup>26</sup> Groves, L.R *Now It Can Be Told*, London, Andre Deutsch, 1963, p. 126

<sup>27</sup> Pierre, A J *Nuclear Politics*, London, 1979, p. 30

<sup>28</sup> Groves, L.R *Now It Can Be Told*, London, Andre Deutsch, 1963, p. 130

<sup>29</sup> AB 3/102, Clarendon Diffusion Papers: Prof Simon Correspondence, *Simon to Akers, 16/9/42*, National Archives, p. 2

There could be an explanation for the wariness of America. Britain signed an agreement with the Soviet Union on 29<sup>th</sup> September 1942 which promised sharing of technical information relating to weapons production. There was an escape clause allowing some information to remain secret but this would not have allayed the Americans' distrust of British motives regarding the bomb. This agreement was not disclosed to the Americans when it was first made. The agreement is all the more startling considering Churchill's staunch anti-Soviet stance.

Because the American response to Britain's suggestion of collaboration had been less than enthusiastic, in autumn 1942 Churchill commissioned a report to assess the cost of Britain developing a programme of its own. The results were not good. 'After three or four years of war Britain was fully stretched with regard to materials, engineering equipment of all kinds and technical manpower...Britain also lacked engineers of every description.'<sup>30</sup> The economic cost of building an atomic plant and the drain of manpower and scientific resources would have had a major impact on the war effort. 'The construction and operation of even a pilot plant was beyond the nation's wartime capacity'.<sup>31</sup> Also, if Britain and the U.S developed independent programmes, this would have created a post-war diplomatic headache over control of atomic power. The results suggested a further diplomatic mission to the Americans was necessary. Rudolf Peierls wrote to Francis Simon about the difficulty of keeping in contact with the American theory group. He said that it was 'very disappointing that after we have gone out of our way to put all material that might be of the slightest use to the American team

---

<sup>30</sup> Roberts, F *60 Years of Nuclear History: Britain's Hidden Agenda*, Oxfordshire, John Carpenter Publishing, 1999, p. 15

<sup>31</sup> Pierre, A.J *Nuclear Politics*, London, Oxford University Press, 1972, p. 32

at their disposal<sup>32</sup> the Americans had not sent anything in return. Peierls said there would be no value in him travelling again to America unless ‘a system of written communications’<sup>33</sup> could be established between the teams.

Wallace Akers went to the U.S in October 1942 to find out why information exchange was grinding to a halt. Groves told Akers information exchange was governed by security rules and ‘under the existing agreements, I had no authority to extend the established rules of collaboration.’<sup>34</sup> Groves, along with Bush and Conant had suspicions about Britain’s motives. ‘They took deep root during the discussions with Akers, whom Bush, Conant and Groves all took to be an Imperial Chemical Industries man at heart, more interested in nuclear power plants than a bomb.’<sup>35</sup> Rudolf Peierls wished to go to America to study research into possibilities of fast neutron fission in November 1942. He was informed that he ‘would not be allowed to do so unless he was prepared to remain on the American team for the duration of the war.’<sup>36</sup> Again, the reason given for this was secrecy. ‘Akers was not impressed by Groves’ argument that security demanded this arrangement and said that Chadwick would not come under such conditions. Peierls would probably take the same attitude.’<sup>37</sup> The increasing security restrictions in the Manhattan Project played a huge role in the information go-slow. ‘These

---

<sup>32</sup> AB 3/101, Clarendon Diffusion Papers: Simon Correspondence with Kearton, Appleton etc, *Peierls to Simon, 19/10/42*, National Archives, p. 3

<sup>33</sup> AB 3/101, Clarendon Diffusion Papers: Simon Correspondence with Kearton, Appleton etc, *Peierls to Simon, 19/10/42*, National Archives, p. 3

<sup>34</sup> Groves, L.R *Now It Can Be Told*, London, Andre Deutsch, 1963, p. 129

<sup>35</sup> Hewlett, R.G and Anderson, O.E *The New World*, Pennsylvania State Publishing, 1962, p. 271

<sup>36</sup> Gale Reference Library, Harry S. Truman Library, *History of the United States-British and Canadian Atomic Relations, March 2<sup>nd</sup> 1949*, p. 13

<sup>37</sup> Hewlett, R.G and Anderson, O.E *The New World*, Pennsylvania State Publishing, 1962, p. 269

regulations cut down, and after 1 May 1943 practically cut off, the flow of information to the British.’<sup>38</sup>

Akers wrote to Conant on 15<sup>th</sup> December 1942 for a proper explanation as to why there had been no information from the American teams. Akers admitted that the pace of the U.S programme had moved on to ‘pilot or even larger scale operations’<sup>39</sup> whereas Britain was still at the experimental stage. However, Akers bitterly protested against Groves’ plan to separate the theoretical physicists into a camp of their own to keep ideas secret. He argued military progress would ‘certainly be seriously retarded, if not worse, unless considerable freedom of exchange of opinions between the British and American theoreticians can be restored.’<sup>40</sup> He said it had always been the wish of both the U. S and British teams that ‘Professor Chadwick and Dr. Frisch should visit America’<sup>41</sup> to discuss their part in the work. Akers argued the time factor was another reason Britain should be given information as a combined effort for the bomb would be quicker. Rallying against increased compartmentalisation, he protested ‘the division of the work into watertight compartments can be carried to the point at which inefficiency may be considered to outweigh the gain in secrecy.’<sup>42</sup>

The U. S found out about Britain’s agreement with the Soviet Union on weapons development just after Christmas 1942. The administration had been kept in the dark over the agreement.

---

<sup>38</sup> McNeill, W.H *A Survey of International Affairs 1939-1946, America, Britain and Russia: Their co-operation and conflict, 1941-1946*, London, Oxford University Press, 1953, p. 235

<sup>39</sup> CHAD 1 28/2, S1 Project Relations between America and Canada, *Akers to Conant, 15/12/42*, Churchill Archives Centre, p. 1

<sup>40</sup> CHAD 1 28/2, S1 Project Relations between America and Canada, *Akers to Conant, 15/12/42*, Churchill Archives Centre, p. 4

<sup>41</sup> CHAD 1 28/2, S1 Project Relations between America and Canada, *Akers to Conant, 15/12/42*, Churchill Archives Centre, p. 3

<sup>42</sup> CHAD 1 28/2, S1 Project Relations between America and Canada, *Akers to Conant, 15/12/42*, Churchill Archives Centre, p. 6

‘The situation was serious, Stimson observed. This agreement endangered the future of any new weapons confided to the British.’<sup>43</sup> Due to security concerns, Roosevelt approved draconian security measures and restricted exchange of information on 27<sup>th</sup> December. Information was only to be divulged to other countries if it was to have an effect on the outcome of the war. As Britain was not able to produce plutonium or uranium 235 in quantities sufficient to have an impact on the war, information was restricted accordingly. The British were to receive no information on the work being conducted at Los Alamos. Most of the Tube Alloys project was to be withheld from the British, however, the Americans expected the British ‘to continue to proffer such useful information as they possessed.’<sup>44</sup> The Conant memorandum communicated to the British ‘crucially marked the intellectual transformation of nuclear weapons from a short-term military factor to a political and diplomatic bargaining chip.’<sup>45</sup>

The correspondence between the prominent British scientists in the primary documents sheds light on the increasing unease they experienced during diplomatic delays. Francis Simon wrote to James Chadwick on 20<sup>th</sup> January 1943 expressing the hope that Britain might yet build its own production plant for uranium. This had been previously ruled out as impossible. ‘When we took this decision we were thinking in terms of at least 5,000 machines. As it seems now certain that the maximum will be about 1,000 machines, the situation should be reconsidered.’<sup>46</sup> In addition, Simon pointed out that if a production plant were to be built in England ‘then of course the Americans have, according to their own rules, to give us again all

---

<sup>43</sup> Hewlett, R.G and Anderson, O.E *The New World*, Pennsylvania State Publishing, 1962, p. 268

<sup>44</sup> Gowing, M *Britain and Atomic Energy 1939-1945*, London, Macmillan, 1964, p. 157

<sup>45</sup> Hershberg, J.G *James. B Conant: Harvard to Hiroshima and the Making of the Nuclear Age*, Stanford, Stanford University Press, 1993, p. 174

<sup>46</sup> CHAD 1 19/8, *Simon to Chadwick, 20/1/1943*, Churchill Archives Centre, p. 1

information on all types of plants<sup>47</sup> which would include military applications, meaning ‘full information on everything on the bomb side of the project’<sup>48</sup>. If the Americans refused ‘then it is quite clear that the whole thing was a pretext.’<sup>49</sup>

If Britain was to construct its own uranium separation plant, this was estimated to cost £70 million and would take at least three and a half years to start production.<sup>50</sup> Therefore it was a matter of great difficulty for the British Government ‘to decide if they are justified’<sup>51</sup> in taking technicians from wartime programmes already underway. If production at the British plant could not be started during wartime, university and industrial experts would want to be engaged on other projects more immediately useful to the war effort ‘and they probably ought to be so used.’<sup>52</sup> Additionally, if the Canadians felt unable to proceed without American assistance, the British Montreal team were to be brought back to the United Kingdom when laboratory space was found to accommodate them. If the Canadians decided to proceed on a project with Britain without help from the U. S it was thought best to build any plants in Britain. Canada would be ‘difficult without high priority for plant and materials from [the] USA.’<sup>53</sup> Apart from these problems, even if the British built a full scale separation plant, the Americans would hand them no information if it was felt the British plant would not influence the outcome of the war. If Britain made a full scale separation plant, this would use the

---

<sup>47</sup> CHAD 1 19/8, *Simon to Chadwick, 20/1/1943*, Churchill Archives Centre, p. 1

<sup>48</sup> CHAD 1 19/8, *Simon to Chadwick, 20/1/1943*, Churchill Archives Centre, p. 1

<sup>49</sup> CHAD 1 19/8, *Simon to Chadwick, 20/1/1943*, Churchill Archives Centre, p. 1

<sup>50</sup> AB 1/700, Independent British and Anglo-Canadian Effort - Organisation, Tube Alloys Project, *Program in Absence of American co-operation*, 8<sup>th</sup> July 1943, National Archives, p. 1

<sup>51</sup> AB 1/700, Independent British and Anglo-Canadian Effort - Organisation, Tube Alloys Project, *Program in Absence of American Co-operation*, 8<sup>th</sup> July 1943, National Archives, p. 1

<sup>52</sup> AB 1/700, Independent British and Anglo-Canadian Effort - Organisation, Tube Alloys Project, *Program in absence of American Co-operation*, 8<sup>th</sup> July 1943, National Archives, p. 1

<sup>53</sup> AB 1/700, Independent British and Anglo Canadian Effort – Organisation, Tube Alloys Project, *Program in absence of American Co-operation*, 8<sup>th</sup> July 1943, National Archives, p. 2

diffusion process and I.C.I would have to supply most of the senior technical staff<sup>54</sup> for this. Given the Americans' deep suspicion of I.C.I this would almost certainly mean no information would be forthcoming from the American teams.

Churchill became seriously worried in February 1943. He was concerned at the U.S being told all the progress that Britain had made, yet Britain was not receiving any information in return. On 27<sup>th</sup> February Churchill asked Harry Hopkins, Roosevelt's secretary, to clear up the misunderstanding and send information. 'As the telegrams to Hopkins were sent, hopes rose once more that they would be followed by speedy action. But again there was silence.'<sup>55</sup> Hopkins eventually replied that the Americans were not aware of breaching any agreements and was evasive about why information exchange had been curtailed.

The policy of restricted interchange meant the British were being pushed out quickly as technical progress was too rapid in America for the British team to keep pace. Churchill knew of the huge costs to Britain of mounting an independent push for the bomb. However, he was adamant the British would not be left out of the project. If collaboration was halted, the Montreal group could not continue, reliant as they were on the United States for materials. If Britain was to conduct her own nuclear programme, this would have been dependent on stopping other war work and getting priority for materials and manpower. 'This was a very big proviso indeed: in the summer of 1942 it had already been necessary to trim the demands of the services because Britain's manpower resources did not match up to her programmes.'<sup>56</sup>

---

<sup>54</sup> AB 1/700, Independent British and Anglo Canadian Effort – Organisation, Tube Alloys Project, *Memorandum of 5<sup>th</sup> July 1943*, National Archives, p. 2

<sup>55</sup> Gowing, M *Britain and Atomic Energy 1939-1945*, London, Macmillan, 1964 p. 159

<sup>56</sup> Gowing, M *Britain and Atomic Energy 1939-1945*, London, Macmillan, 1964, p. 163

There would also be trouble of post-war control of atomic energy arising from two separate programmes. The cost of a production plant and trained engineers was daunting.

On 25<sup>th</sup> May 1943 Lord Cherwell told the Americans the reason Britain wanted information on production of the bombs was to aid Britain in acquiring nuclear weapons after the war. Bush was amazed Cherwell admitted the reason Britain wanted nuclear information was for post-war purposes. Bush 'maintained that delivery of information to the British for after-the-war military purposes was a subject that needed to be approached on its own merits, for one reason, because it was tied to long-term international relations.'<sup>57</sup> That said, Cherwell pointedly denied British interest in commercial use of atomic energy. Cherwell also stated that if America did not give the information on production as requested, Britain might have to divert some of the war effort into finding this out for herself. He hoped it would not come to that seeing as it was an unwise use of energy during the struggle against the Nazis. This was a clever diplomatic ploy by the British, hinting they may try and find information out independently. America then knew it could not keep all the information by itself. If Britain had diverted war time energy into replicating American research, this would have weakened Britain in the struggle against Germany. America knew that it could not afford to have a weakened ally.

When Cherwell said Britain might make a bomb independently, this was probably bluff. Britain was in no position to divert extra manpower and resources to a project which was already being carried out in the U.S, with no guarantee it would help win the war and not even an assurance that the bomb would work. The sheer cost of making atomic bombs would have been prohibitive during wartime and there was still a multitude of technical problems to be

---

<sup>57</sup> Hewlett, R.G and Anderson, O.E *The New World*, Pennsylvania State Publishing, 1962, p. 273

effectively negotiated. Assembly of the weapon still had to be finalised. A huge problem was still in the way ‘notably that of bringing together two subcritical masses at a speed which would avoid pre-detonation – the danger that the bomb would fizzle rather than explode.’<sup>58</sup> The British had come up with only tentative suggestions of the cost for building a full scale production plant for uranium. These figures were ‘regarded as largely guess-work.’<sup>59</sup> For instance, just the research programme used to run an isotope separation plant ‘might cost £2-3 millions.’<sup>60</sup>

Nevertheless, the efforts behind the scenes were still focused on exploring all avenues. Akers wrote to Michael Perrin, the Tube Alloys secretary, on 23<sup>rd</sup> July. He noted the position with the U.S was constantly changing and was anxious ‘lest we should be landed again, or rather continue to be landed, in the same sort of stale-mate position as occurred after Casablanca.’<sup>61</sup> Akers also denied to Perrin that the idea of a British independent programme was bluff, although duplicating the work would be ‘a wicked thing to have to do in the present state of the war.’<sup>62</sup> Even so, considering there had been little positive information from the Americans for some time, Akers reported impatience at Britain’s hesitation to start an independent project. The longer the delay, the more unsound it looked and ‘the postponement of the decision to undertake independent action has steadily become less and less reasonable.’<sup>63</sup> Akers also noted the dangers of letting the Americans buy up all available stocks of uranium oxide as

---

<sup>58</sup> Clark, R.W *The Greatest Power on Earth*, London, Sidgwick and Jackson, 1980, p. 154

<sup>59</sup> AB 1/700, Independent British and Anglo Canadian Effort-Organisation, *Summary of increase in work needed if Tube Alloys was to be realized without U.S help*, National Archives, p. 1

<sup>60</sup> AB 1/700, Independent British and Anglo-Canadian Effort-Organisation, *Summary of increase in work needed if Tube Alloys was to be realized without U.S help*, National Archives, p. 1

<sup>61</sup> CHAD 1 28/2, Relations between Britain, America and Canada: General Policy, *Akers to Perrin*, 23/7/43, Churchill Archives Centre, p. 1

<sup>62</sup> CHAD 1 28/2, Relations between Britain, America and Canada: General Policy, *Akers to Perrin*, 23/7/43, Churchill Archive Centre, p. 3

<sup>63</sup> CHAD 1 28/2, Relations between Britain, America and Canada: General Policy, *Akers to Perrin*, 23/7/43, Churchill Archives Centre, p. 5

this would damage any chance of a British independent project. 'We, therefore, seemed to be slipping, if we had [not] already slipped, into the position that we could not go ahead with any large scale work even if we wanted to, for lack of material.'<sup>64</sup>

There was a conference in London held between the U. S and Britain to sort out the mess of Tube Alloys on 22<sup>nd</sup> July 1943. Churchill, John Anderson and Lord Cherwell represented Britain. Henry Stimson, Vannevar Bush and Harvey Bundy represented the U.S. Churchill stated that on three occasions he had talked to Roosevelt about atomic power and they had both agreed verbally there should be a full information exchange between Britain and the United States. The United States could not stake sole claim for all information on atomic matters. Churchill framed his argument in terms of national security. If the U.S and Britain did not co-operate 'Germany or Russia might win the race for a weapon they could use for international blackmail.'<sup>65</sup> Again he emphasised Britain was not interested in commercial issues but was vitally interested in all available information as it would have repercussions for Britain's future independence and an impact on winning the war.

Attempting to finalise an agreement, John Anderson was sent as an envoy to Washington to clear up the issue. 'He was quick to see the American point of view and to disabuse their minds of certain well-rooted suspicions.'<sup>66</sup> The Americans were impressed with his knowledge of science and hands on approach. He managed to dispel any suggestion that Britain was out for commercial gains and successfully got collaboration back on track during his discussions

---

<sup>64</sup> CHAD 1 28/2, Relations between Britain, America and Canada: General Policy, *Akers to Perrin*, 23/7/43, Churchill Archives Centre, p. 9

<sup>65</sup> Hewlett, R.G and Anderson, O.E *The New World*, Pennsylvania State Publishing, 1962, p. 276

<sup>66</sup> Wheeler-Bennett, J *John Anderson: Viscount Waverly*, London, Macmillan, 1962, p. 294

with Vannevar Bush and James Conant, notwithstanding Conant's unwillingness to fully cooperate.

On 20<sup>th</sup> July, Roosevelt had cabled Bush to 'renew' information exchange with the British. This was coded before transmission and sent as 'review'. This may have been accidental but it could also have been deliberate as it meant that Bush had a stronger hand to bargain with at the conference of 22<sup>nd</sup> July than was intended by the President. Bush's tough stance got big concessions from Churchill and necessitated the Quebec Agreement. Part of the diplomatic fog originated from Roosevelt not discussing what he'd agreed with Churchill with his own advisors. As Sherwin has argued: 'Roosevelt listened attentively when any of his atomic energy advisers offered their views, but he acted decisively only in consultation with Churchill.'<sup>67</sup>

The Quebec Agreement of 19<sup>th</sup> August 1943 was a general and loosely worded agreement on collaboration. As such, it left much room for different interpretations of its terms, storing up future problems. The agreement was simple for such a complex and divisive issue as the control of atomic power. The agreement stated there should be complete interchange of information between Britain and America on nuclear weapons. The two governments agreed not to use nuclear weapons against each other and the two governments also agreed not to use the weapons against another state without gaining consent of the other party first.

The agreement was especially important for Britain's programme because research into tube alloys in Britain could now continue and be given much needed funds for further experiments. Also, when British scientists returned to continue Britain's own nuclear programme after the

---

<sup>67</sup> Sherwin, M.J *A World Destroyed*, New York, Vintage Books, 1975, p. 88

war, their knowledge was much more developed because of their time involved in the Manhattan Project. However, the transfer of many eminent scientists and resources to the Manhattan Project from Britain 'was to close down entirely all work in the U.K on the electromagnetic process and to reduce almost to nothing the nuclear physical research.'<sup>68</sup>

Though most of the British experts were then asked to work in America, an Anglo-Canadian team was also at work in Montreal. It was developing a heavy water pile for plutonium production. This was based at the Chalk River site. By September 1944, 40 Canadian experts and the same number of British scientists were working on this project. This was a fair clue that Britain would be aiming for her own nuclear weapons after the war, as this project was separate from the Manhattan Project. This reactor was the development of the 'boiler' which had promises of nuclear energy as power rather than a weapon. However, slow neutron reactions in a heavy water pile would also create plutonium and therefore fissile material for atomic weapons.

Strangely, the Americans were more worried about Britain's economic interest in the use of atomic power than the obvious military significance of possessing the atomic bomb. The Americans asked for only one British concession on the military applications of nuclear technology while making the Quebec Agreement; the use of the bomb against a third party had to be jointly agreed. Clause five of the agreement practically gave the U.S a monopoly over commercial rights of atomic energy. The British experts were mortified to hear of Churchill's concession. One of these was R.V Jones, a boffin and a good friend of Churchill's, who argued 'it appeared to me that he would never have signed away Britain's birthright in the post-war

---

<sup>68</sup> H.M Treasury, *Statements Relating to the Atomic Bomb*, H.M.S.O, London, 1945

exploitation of atomic energy had he fully appreciated the potential.<sup>69</sup> Jones also said Churchill's disclaimer was 'a magnificent gesture that could put us in a very awkward position after the war.'<sup>70</sup> The opposite view is taken by Clark, who states 'Churchill had no alternative. Bush's fight for review instead of renewal certainly made his task more difficult.'<sup>71</sup> It must be remembered Churchill had to act fast to gain any agreement at all, and the Americans were not enthusiastic. This frantic period of negotiation must have been especially galling for Churchill, considering Britain had previously been ahead in atomic research and had been a big spur to the American programme. The concession can be looked at cynically as a desperate act but it was framed as a trade off. Churchill used the argument that since the U.S had spent more money in research and development, it should reap the benefit of future rewards.

Another hugely important consequence of paragraph five of the agreement kept Britain frozen out of information on production. The agreement said information should be fully exchanged between those experts working in the same area of the project. This was a polite acknowledgement of Groves' compartmentalisation policy. Groves could then argue that as the British were not immediately working on production problems concerning the bomb, they didn't need to know the information. Groves has argued that America was lucky with the terms that the British accepted. The U.S was 'fortunate that the British were not aware of the President's instructions of July 20, fortunate that the President's directions to Bush were garbled in transmission'<sup>72</sup> and also lucky that Bush had negotiated skilfully to protect the American national interest.

---

<sup>69</sup> Blake, R and Louis, W.R (Ed) *Churchill*, Oxford, Oxford University Press, 1993, p. 438

<sup>70</sup> Jones, R.V *Most Secret War*, London, Hamish Hamilton, 1978, p. 474

<sup>71</sup> Clark, R.W *The Greatest Power on Earth*, London, Sidgwick and Jackson, 1980, p. 151

<sup>72</sup> Groves, L.R *Now It Can Be Told*, London, Andre Deutsch, 1963, p. 136

Britain may not have been much concerned about the commercial issues of nuclear technology because of the size of the Empire. In 1943, Britain still had a large enough empire to supply much of the resources and manpower it needed. The U.S would have been keen to compete in this respect and gain more in resources for herself. Essentially, Britain gave a blank cheque to the U.S over future commercial interest of atomic energy. This could have arisen from Churchill trusting Roosevelt. Most probably it was Churchill making a desperate but necessary concession in a bid to keep up with nuclear development. The threat of being frozen out of the nuclear age would have been enough for the most hard minded of politicians to give big concessions, especially under the strains of total war. The Quebec agreement would have been distasteful to many Americans because it was concluded in secret. This cut out the possibility of the agreement being open to debate and amendment. Therefore, it would have been 'most unlikely that formal agreement, open to such debate, could ever have been reached in terms as favourable to Britain.'<sup>73</sup> Roosevelt and Churchill found it easier to agree due to the deteriorating position of Roosevelt's atomic advisers. Sherwin argues 'Bush and Conant appear to have lost a large measure of their influence because they had used it to oppose Churchill's position.'<sup>74</sup> The bomb was not a certainty but Roosevelt 'nevertheless consistently chose policy alternatives that would promote the postwar diplomatic potential of the bomb if the predictions of scientists proved true.'<sup>75</sup> Roosevelt liked the idea of the 'two policemen' of Britain and the United States having control of atomic energy. Roosevelt, according to Sherwin, did not believe there would ever be an effective international system for the control of the atomic bomb and he 'intended to take full advantage of the bomb's potential as a post-

---

<sup>73</sup> Bertin, L *Atom Harvest*, London, Secker and Warburg, 1955, p. 76

<sup>74</sup> Leffler, M.P and Painter, D.S *Origins of the Cold War*, London, Routledge, 1994, p. 83

<sup>75</sup> Leffler, M.P and Painter, D.S *Origins of the Cold War*, London, Routledge, 1994, p. 79

war instrument of Anglo-American diplomacy.<sup>76</sup> The decisions of this period in the war, being taken at the top and in secret make interpretation of the facts intriguing. ‘This decisionmaking procedure and Roosevelt’s untimely death have left his motives ambiguous. Nevertheless it is clear that he pursued policies consistent with Churchill’s monopolistic, anti-Soviet views.’<sup>77</sup> If Roosevelt had lived, Britain could certainly have utilised the Quebec Agreement more than she did.

Britain gained much from the agreement. She was to be given partial information on the electromagnetic method of isotope separation, with information on the fundamental physics of the bomb to be decided at a later date following discussions between Chadwick, Peierls and the Americans. The field of research where Britain gained the most was the diffusion process. There was to be very full information exchange ‘on all sections of this project in the field of scientific research and development.’<sup>78</sup> The British and American groups researching heavy water were also to fully exchange information on the role of heavy water in chain reactions. This would additionally include ‘information on the properties and methods of separation’<sup>79</sup> of plutonium. Ordnance issues were to be ‘considered by the appropriate military authorities of both countries’<sup>80</sup> who would then decide on the best course of action.

Information exchange was further formalised with the setting up, on the suggestion of John Anderson, of a Combined Policy Committee. This helped formulate the joint venture and kept

---

<sup>76</sup> Sherwin, M.J *A World Destroyed*, New York, Vintage Books, 1975, p. 89

<sup>77</sup> Leffler, M.P and Painter, D.S *Origins of the Cold War*, London, Routledge, 1994, p. 80

<sup>78</sup> AB 1/585, Quebec Agreement 1943, Lord President Negotiations, *Tube Alloys Provisional Memorandum on Interchange of Information*, National Archives, p. 1

<sup>79</sup> AB 1/585, Quebec Agreement 1943, Lord President Negotiations, *Tube Alloys Provisional Memorandum on Interchange of Information*, National Archives, p. 1

<sup>80</sup> AB 1/585, Quebec Agreement 1943, Lord President Negotiations, *Tube Alloys Provisional Memorandum on Interchange of Information*, National Archives, p. 2

information flowing at the top levels of government in the two countries. The British pushed for a Canadian representative on the Committee, even though Canada would not be directly involved in the work on the bomb. Britain relied on Canada for resources on the heavy water experiments in Montreal. If Canada also had an interest in the Committee, this would hopefully mean the heavy water project would not be delayed ‘through any lack of interest or energy on the part of the Canadian Government.’<sup>81</sup>

James Conant’s reaction on hearing of the renewed collaboration was described as ‘interesting’.<sup>82</sup> He appeared to hold the view that ‘there should be no discussion between technicians before the decisions of the Combined Policy Committee were arrived at’<sup>83</sup> and said he himself ‘was quite capable of providing’<sup>84</sup> any information they might need. Conant also queried the value of Wallace Akers in the discussions which was not surprising given his dislike and mistrust of Akers and I.C.I. The record of that discussion showed the stubbornness and arrogance of the man. Conant appeared to be trying to water down the power of the Combined Policy Committee which he obviously saw as a threat to his own prestige and ‘to retain the policy control in his own hands.’<sup>85</sup> John Anderson seemed to get the most out of James Conant. Using his negotiating skills, Anderson pointed out Britain should be included in the project due to its exposed position, vulnerability to atomic attack and the use of plutonium as a poison spray. Conant conceded these reasons were sufficient ‘for our having the fullest

---

<sup>81</sup> AB 1/585, Quebec Agreement 1943, Lord President Negotiations, *Tube Alloys, 10/8/43*, National Archives, p. 1

<sup>82</sup> AB 1/585, Quebec Agreement 1943, Lord President Negotiations, *Notes on the negotiations in Washington Regarding Tube Alloys, 2<sup>nd</sup> to 7<sup>th</sup> August 1943*, National Archives, p. 4

<sup>83</sup> AB 1/585, Quebec Agreement 1943, Lord President Negotiations, *Notes on the negotiations in Washington Regarding Tube Alloys, 2<sup>nd</sup> to 7<sup>th</sup> August 1943*, National Archives, p. 4

<sup>84</sup> Ibid.

<sup>85</sup> AB 1/585, Quebec Agreement 1943, Lord President Negotiations, *Notes on the negotiations in Washington Regarding Tube Alloys, 2<sup>nd</sup> to 7<sup>th</sup> August 1943*, National Archives, p. 5

information and for treating the whole thing as a joint enterprise.<sup>86</sup> John Anderson deserved great credit for the way he handled Conant, who had been especially tough to deal with, due to his resentment of British involvement in the Manhattan Project.

What Britain and the U.S didn't know was that the German programme was floundering. The Allies were still concerned about the possibility that there could be a radioactive attack over Allied territory by the German air force. There was the fear 'that the Germans might use radio active fission products as a spray to be employed from aircraft operating over the United Kingdom.'<sup>87</sup> James Conant described the difficulties for the Germans in handling these fission products as 'very considerable'<sup>88</sup> but 'one cannot rule out the possibility that these difficulties could be overcome'<sup>89</sup> and that any such radioactive attack over Allied territory would be potentially very damaging. The Council had received information that the Germans were 'surveying the productive capacity throughout Europe for heavy water.'<sup>90</sup> This gave rise to the fear the Germans knew how to use plutonium.

Unknown to the Allies, the German Ministry of Education and Science was not seriously considering nuclear research in April 1942. Albert Speer, Minister for Armaments, asked Hitler to make Hermann Goering the head of the Reich Research Council to emphasise the importance of scientific research. Goering got this post on 9 June 1942. Speer did not receive

---

<sup>86</sup> AB 1/585, Quebec Agreement 1943, Lord President Negotiations, *Note of a conversation between President Conant and Sir John Anderson, 6<sup>th</sup> August 1943*, National Archives, p. 1

<sup>87</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, *Possible Use of Radioactive Material in Warfare*, Note by the Lord President of the Council, National Archives, p. 1

<sup>88</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, *Possible Use of Radioactive Material in Warfare*, Note by the Lord President of the Council, Annex A, National Archives, p. 1

<sup>89</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, *Possibility of the use of Radioactive Material in Warfare*, Note by the Lord President of the Council, Annex A, p. 1

<sup>90</sup> CAB 98/47, War Cabinet, Tube Alloys Consultative Council, *Minutes of a Meeting held on Friday 16<sup>th</sup> January 1942 at 4.30pm*, National Archives, p. 2

encouraging news from German physicists who predicted a bomb might take three or four years to produce. For example Werner Heisenberg had calculated a critical mass in the region of several tons. Heisenberg knew enriched uranium was needed for an explosion but had not accurately investigated using pure uranium 235 for a bomb. If Germany was to make an atom bomb by 1945 'it would have meant mobilising all our technical and financial resources to that end, as well as our scientific talent. It would have meant giving up all other projects, such as the development of the rocket weapons.'<sup>91</sup> An idea of a crash program to match that of the United States was never considered.

In any case, Hitler had many preconceptions about wonder weapons but could not envisage a weapon so totally different from his First World War experiences. The concept of the atomic bomb or the jet fighter was completely alien to him. Albert Speer had seen the potential the atomic bomb could have in winning the war but did not receive enough enthusiasm about nuclear research from Hitler to start a serious programme. The other difficulty that Speer had in 1942 was the stretching of resources. Germany had committed itself to the campaign against the Soviet Union and was not able to spend resources on isotope separation. German physicists told Speer that there were no guarantees a bomb would be ready for maybe another three or even four years. Speer decided not to actively pursue the programme during the autumn of 1942. Germany had some of the scientific knowledge of how to make the bomb but not the resources to produce one. This became more apparent after the Soviets launched the counter offensive at Stalingrad. With Russia turning the tide, the Germans used all their industrial productivity and economic resources to produce shells.

---

<sup>91</sup> Speer, *A Inside the Third Reich*, Phoenix, London, 1969, p.318

Many important German scientists had also been sent to the armed forces. Heisenberg and Otto Hahn complained to Albert Speer about the lack of available resources and manpower. Speer was convinced by Heisenberg that Germany would have been incapable of building a bomb in time to influence the outcome of the war. There was also an important miscalculation. Germany had been too reliant on the use of heavy water as a moderator for isotope separation and hadn't considered using graphite, which was much easier to get hold of. Due to the lack of organisation and political interest, the German program didn't take off. There was a lack of unity. German scientists did not work as a group like the British in the MAUD Committee.

The most obvious obstacle to the German programme was Hitler's resistance to nuclear research. Speer had tried to talk to Hitler about the political and defensive advantages of possessing the bomb but Hitler had refused to admit such a weapon was possible. He had a limited grasp of nuclear physics. As Speer argues: 'Hitler had sometimes spoken to me about the possibility of an atom bomb, but the idea quite obviously strained his intellectual capacity.'<sup>92</sup> Speer appears to be saying Germany would never have been a threat in the field of atomic weapons as the idea of an atomic bomb received little attention in political circles. However, this could be Speer's own attempt to put Germany in a kinder light after all the negative press from the war and the Nuremberg war crimes trials. It might not be an accurate presentation of the way the German politicians actually felt. After all, Hitler had often talked about secret weapons that would turn the war in favour of Germany.

---

<sup>92</sup> Speer, *A Inside the Third Reich*, Phoenix, London, 1969, p 317

According to the account of R. V Jones, the British were carefully watching the Germans. ‘We had the impression that they had originally been thinking of a bomb, but had decided that it would not be practicable inside the timespan of the present war, since in 1942 they allowed a number of relevant papers to be published on nuclear work done in the previous two years’<sup>93</sup> which seemed to have been kept a secret while the Germans made up their minds. This impression the Germans had given up was no definite answer and Jones recollects that ‘we could only speculate on the state and direction of their work.’<sup>94</sup> Heisenberg knew a nuclear reactor would be a way to the bomb but had not been able to build a critical reactor during the war. This was due mainly ‘to his ready acceptance of a wrong measurement of the properties of graphite as a moderator.’<sup>95</sup> This made the Germans reliant on the heavy water produced by Norsk Hydro. Even when Heisenberg was informed of the correct measurement for graphite, he still insisted on using heavy water as a moderator. When the Germans took over the Norsk Hydro plant in 1940, they had ordered production to be increased to 1500kgs of heavy water a year.<sup>96</sup> In 1942 they ordered a further increase because this resource was considered so vital. The British noticed this weakness and took full advantage of the vulnerability of the German atomic programme.

---

<sup>93</sup> Jones, R.V *Most Secret War*, London, Hamish Hamilton, 1978, p. 472

<sup>94</sup> Jones, R.V *Most Secret War*, London, Hamish Hamilton, 1978, p. 473

<sup>95</sup> Rose, P.L *Heisenberg and the Nazi Atomic Bomb Project*, London, University of California Press, 1998, p. 134

<sup>96</sup> CAB 126/171, Heavy Water (Deuterium oxide): General File, *S.O.E and Heavy Water*, National Archives, p. 1