AUSTRALIAN NUCLEAR FORUM
INFORMATION PAPER No. 8

Chronology of the Bomb (Approved 10/12/03)

The Australian Nuclear forum promotes the peaceful applications of nuclear technology in Australia. However, it should be understood that the efforts to utilise nuclear technology during World War II to construct fission (and later fusion) weapons significantly accelerated the wider knowledge of this important aspect of science, thereby providing the basis for most of its current peaceful applications. As such it is important to have some acquaintance with the sequence of events that occurred during this time.

24 September 1789: Martin Heinrich Kalproth announces discover of uranium (Ep9)

1828: Berzelius isolates thorium (p283)

7 November 1867: Marie Curie born Warsaw (p214)

1871: Rutherford born (p36)

14 March 1879: Einstein born in Ulm (p170)

1882: Hans Geiger born (Dp98)

7 October 1885: Niels Bhor born (p225)

1891: Chadwick born (p155)

8 November 1895: Wilhelm roentgen discovers X-rays (p38)

1 March 1896: Henri Becquerel discovers radiation from matter (p42)

Spring 1897: J.J. Thompson identifies the electron (p40)

11 February 1898: Leo Szilard born in Budapest (p13)

1898: Curies discover polonium and radium (Bp2)

1901: Heisenberg born Wurtzburg (Cv9p159)

29 September 1901: Enrico Fermi born Rome (p207)

1902: Rutherford & Soddy show spontaneous transmutation (Bp7)

22 April 1904: Robert Oppenheimer born, New York (p119)

2 July 1906: Hans Bethe born Strasbourg (p188)

1907: Rutherford group Alpha Scattering experiment (p49)

1908: Geiger & rutherford devise counter (p158)

1908: Geiger & rutherford determine that ZnS screen scintillations are from individual (alpha) particles (Dp212)

1910: Idea of isotopes propounded by Soddy (Bp7)

7 March 1911: Rutherford announces the nuclear atom (p50)

1912: Austrian Victor Hess aloft in a balloon with an electroscope finds radiation increases with altitude (i.e cosmic rays)(Cv4p857)

6 March 1913: Part I of Bohr's paper finished (p69)

1919: Francis Aston develops mass spectrograph (p141)

1919: Rutherford's transmutation of N using alpha particles (p135)

1928: George Gamow suggests Liquid Drop model of nucleus (p228)

2 January 1931: E.O. Lawrence operates his cyclotron for the first time.

1932: Cockroft and Walton achieve artificial transmutation with accelerator (Bp15)

1932: H.C. Urey announces the existence of deuterium (Bp16)

27 February 1932: Chadwick letter to Nature announcing possible existence of the neutron (p23)

June 1932: Chadwick confirms neutron in paper in Proceedings of the Royal Society (p23)

2 August 1931: Carl Anderson discovers positron (p199)

12 September 1933: Szilard conceives chain reaction (p13)

1934: Joliot Curies discover artificial radioactivity (bombarded Al with alphas to produce P30) (Bp22)

12 March 1934: Szilard patents idea of chain reaction (Bp32)

25 March 1934: Fermi detects induced radioactivity in neutron irradiated Al (p211)

May 1934: Fermi paper on activation of some 40 elements published (Bp19)

28 June & 4 July 1934: Patent amendments by Szilard re nuclear power production (p214)

4 July 1934: Marie Curie dies (p214)

September 1934: Ida Noddack suggests the generation of light elements on the bombardment of U with neutrons (p230)

22 October 1934: Fermi discovers the effect of slow neutron irradiation of silver (p281)

1935: A.J. Dempster of the U Chicago detects U235 by mass spectrograph (p285)

9 April 1935: Szilard patent application indicated uranium might produce more than one neutron per fission (p221)

27 January 1936: Niels Bohr lecture to Danish Academy on liquid drop model of nucleus (p227)

October 1937: Rutherford dies (p228)

Sept-Nov 1938: Hahn & Strassman analyze the neutron bombardment products of uranium (p248)

19 December 1938: Letter from Hahn to Meitner suggesting production of barium (p253)

24 December 1938: Meitner & Frisch interpret Hahn & Strassman data to mean nuclear fission had occurred (p260)

6 January 1939: Hahn & Strassman publish results (p262)

13 January 1939: Frisch detects U fission energy directly (p263). Also detects fission in Th (p283)

28 January 1939: Demonstration of U fission at Columbia University (p273)

29 or 30 January 1939: Abelson at Berkley discovers the Te/Zr fission product pair (p274)

7 February 1939: Bohr at Princeton suggests forms of U238, Th232 and U235 cross sections for absorption and fission as a function of energy – particularly indicating slow neutron fission in U comes from U235 (p284). Phys Rev article (p287)

Mid-February 1939: Discovery of delayed neutrons by R. Roberts and R.C. Meyer – letter to Phys Rev (p290)

16? March 1939: Fermi briefs Navy on U chain reaction (p295)

Early March 1939: Szilard & Zinn experiment to measure neutron yield from fission (about 2) (p291)

18 March 1939: Joliot/von Halban/Kowarski paper published in Nature describing experiment with U in H2O + source (excess neutrons generated) (p290)

Mid-April 1939: Fermi/Szilard/Anderson experiment to measure neutron multiplication in H2O with source and UO2 in 52 cans (p300)

22 April 1939: Joliot et al paper saying 3.5 neutrons released per fission (p296)

29 April 1939: Meeting in Berlin launches research program and restricts U exports from Czechoslovakia (p296)

29 April 1939: New York Times article reporting on American Physical Soc Meeting says Bohr suggests explosions from U235 and L. Onsager describes gaseous diffusion process that could be used for separation of U235 (p297)

May 1939: F. Perrin paper on critical mass calculations published (p321)

May-June 1939: R. Peierls publishes criticality estimates for U238 with fast neutrons (p321)

Early July 1939: Fermi & Szilard conceive of segregating the U and the moderator to improve multiplication (p302)

2 July 1939: Szilard letter to Strauss mentioning Graphite or D2O a alternative moderators to H2O (p301)

August 1939: Letter from Einstein to Roosevelt (p307), received 11 October 1939 (Bp43)

September 1939: Phys Rev article by Bohr & Wheeler on The Mechanism of Nuclear Fission (p311)

3 September 1939: Britain and France declare war on Germany

16 September 1939: German physicists learn of German intelligence on uranium research abroad (p311)

26 September 1939: Heisenberg discussed U burner and U separation for bomb, Harteck proposes U segregation and D2O moderator. Organisation set out for German effort (p311)

21 October 1939: First meeting of Advisory Committee on U attended by Tuve, Briggs, Sachs, Szilard, Wigner, Teller, Roberts, Adamson & Hoover. Teller says they need $6000 (p315)

1 November 1939: Advisory Comm on U report to President mentions use as power source for submarines (p317)

January 1940: First ton of pure U oxide delivered to German War Office (p326)

Early February 1940: Fermi gets $6000 for graphite (p331)

28 February 1940: First separation of U235 by Nier at University of Minnesota (p332)

16 March 1940: Norsk Hydro Stocks of D2O flown o England and then to Paris (p327)

March 1940: Frisch & Peieris write memorandum for Oliphant concerning U235 bomb estimate 5 Kg giving several thousand tons of dynamite (p324)

10 April 1940: First meeting of Thompson Committee including Oliphant, Tizard, C.P. Thompson, Chadwick, Cockroft (p330)

24 April 1940: Second meeting of Thompson Comm – Frisch estimates U bomb feasible – Chadwick to study U separation (p330)

May 1940: Fermi measures cross-section of graphite (p334)

3 May 1940: Norsk Hydro D2O plant captured by Germans (p329)

27 May 1940: McMillan and Abelson announce the discovery of Neptunium, Phys Rev paper (p350)

June 1940: Russians publish in Phys Rev observations of spontaneous fission in U (p327)

June 1940: Germans order 60 tons of U Oxide (p343)

June 1940: P Harteck in Germany attempts to measure neutron multiplication using U oxide & dry ice as moderator (p343)

Late June 1940: Meitner “Maud Ray Kent” cable (p340)

1 July 1940: Briggs ends Adv Comm on U work with recommendation to expend $140,000 (p338)

October 1940: Heisenberg’s building to house first U burner (i.e. reactor) finished (p344)

October 1940: Suzuki in Japan reports Ysuda re availability of U (p346)

Fall 1940: Fermi measures graphite cross-section [see May 1940?] (p345)

December 1940: First German experiment using H2O shows no multiplication (p344)

December 1940: F. Simon report to Maud Comm on U separation plant – about 5 million pounds (p343)

16 December 1940: Halban and Kowaski conduct D2O moderated experiment in England estimate Kinf = 1.06 (Bp55)

January 1941: W. Bothe at Heidelberg measures graphite cross section and finds it too high (p344)

23 February 1941: Seaborg's team discovers plutonium (p253)

28 March 1941: Seaborg team demonstrates fissionability of plutonium (p355)

March 1941: Tuve sends U235 cross-section data to England where the critical size estimate of 18 pounds untamped is made (p355)

April 1941: Japanese Air Force authorises research on A-bomb (p346)

18 May 1941: Plutonium cross-sections measured (p366)

May 1941: Hagiwara in Japan speculates on fusion bomb (p375)

15 July 1941: MAUD Committee Report accepted and Committee disbanded (p368)

August 1941: F. Houtermans issues report on chain reactions but keeps it from German War Office (p371)

27 August 1941: Churchill accepts Cherwell recommendation to keep separation work in Britain (p372)

Late August 1941: Oliphant flies to US to press for bomb program including talks with Lawrence, Fermi and Conant (p372)

September 1941: Fermi speculates to Teller re if A-bomb could ignite fusion in deuterium (p374)

September 1941: Heisenberg receives first 40 gallons of D2O from Norsk Hydro and obtains experimental evidence that a critical mass could be achieved, Pu could be produced and could make a bomb (p383)

September 1941: Fermi Conducts first graphite moderated lattice exponential experiment, Kinf=0.87 (p397)

October 1941: Official transmittal of MAUD Report to US (p377)

9 October 1041: Bush gives MAUD report to Roosevelt – Top Policy Group appointed (p378)

1 November 1941: Third Report from US National Academy of Sciences on fission explosive (p386)

2 December 1941: Lawrence develops Calutron concept (Bp64)

6 December 1941: Bush appoints Compton t set up program at Chicago (p389)

8 December 1941: US declares war on Japan

11 December 1941: US declares war on Germany and Italy

19 January 1942: Roosevelt OKs A-bomb program (p388)

24 January 1942: Compton opts for Chicago for first reactor (p399)

26 February 1942: German Ministry of Education allocates funding for A-bomb program (p403)

April 1942: Fermi builds exponential with Kinf=0.918, Allison builds on (7 foot) with Kinf=0.94 (p401)

May 1942: Doepel and Heisenberg in Liepsig measure Kinf=1.01, assembly of 572 KgU and 140 Kg D2O subsequently destroyed in chemical explosion and fire (i.e. world's first reactor accident) (Bp106)

23 May 1942: Conant decides to pursue all routes to bomb in parallel (p406)

May 1942: Fermi exponential reaches Kinf=0.995 (p428)

17 June 1942: US Army Corps of Engineers included in project (p412)

June 1942: Heisenberg et al report to Speer on bomb & reactors – 23 June Speer reports to Hitler who's lukewarm – scientists tell Speer 3-4 years for bomb – program dropped (p405)

July 1942: Fermi Measures Kinf= 1.007 (Bp80)

July 1942: Oppenheimer convenes Luminaries Group (Bethe, Teller, Van Vleck, Bloch, Konopinski) at Berkley (p415)

20 August 1942: Seaborg team isolates plutonium (p414)

Late August 1942: Luminaries Group conclusions given to Conant (i.e. 30 Kg U235, 100 Kt, Super 10 Mt) (p421)

29 August 1942: Bush reports to Secretary of War (p421)

17 September 1942: General G.R. Groves appointed to head project by Secretary of War (p425)

19 September 1942: Groves signs for acquisition of 52,000 acres at Clinch River (p427)

About September 1942: German A-bomb project halted, Hitler not interested, too late to use in war (p405)

19 October 1942: Oppenheimer confirmed to head bomb design (p448)

November 1942: DuPont takes over construction of plutonium piles (p431)

16 November 1942: Los Alamos site chosen (p450)

2 December 1942: CP-1 goes critical with Keff=1.0006 (p440)

4 January 1943: P.M. Abelson submits report on US Navy program to enrich U with liquid thermal diffusion (p551)

21 January 1943: Groves chooses Hanford site for plutonium production reactors(p497)

27 February 1943: Norsk Hydro D2O plant knocked out (p456)

6 March 1943: Japanese Navy withdraws support for bomb project as too long term for any country for WWII purposes (p458)

15 March 1943: Staff start to arrive at Los Alamos (p459)

10 May 1943: Recommendation to H-bomb as second priority (p476)

7 June 1943: Construction of B Reactor started (Dp529)

August 1943: Roosevelt & Churchill meet in Quebec (p500)

6 October 1943: Bohr flies to Britain from Sweden (p484)

October 1943: Teller and von Neumann realise that implosion compressions (on the order of 1 million atm) could significantly increase the density of a solid Pu core to achieve criticality without the need for a hollow shell configuration (p480)

4 November 1943: X-10 goes critical at Oak Ridge (p547)

December 1943: Segre at Los Alamos measures spontaneous fission rates in U & Pu enabling adoption of Little Boy design for U bomb (p540)

3 December 1943: Klaus Fuchs arrives in US as part of the British team (Gp100).

January 1944: Staff on USSR bomb project numbered about 50, investigating graphite as a reactor moderator (p502)

February 1944: Installation of B Reactor begins (p500)

April 1944: British team begins to arrive at Los Alamos (p544)

12 June 1944: Groves authorizes thermal liquid diffusion plant (S-50) at Oak Ridge (p553)

11 July 1944: High spontaneous fission rate measured for Pu240 dictates switch to implosion device (p548)

13 September 1944: Start of B Reactor loading (Bp87)

26 September 1944: B Reactor goes dry critical (p557)

27 September 1944: B Reactor poisons out and shuts down (Bp87)

28 September 1944: J.A. Wheeler identifies Xe135 as probable cause of poison out (p559)

17 December 1944: D Reactor critical (p560)

1945: Hans Geiger dies (Dp98)

6 January 1945: Conant notes from this day that a uranium gun-bomb requires about 42 Kg (p601)

20 January 1945: First feed of UF6 to K25 (Bp76)

12 March 1945: 1.1% enrichment (Bp77)

13 April 1945: Nishina's (Japan) thermal gaseous diffusion plant destroyed in air raid (p612)

23 April 1945: US Army unit captures Hahn and Heisenberg and German ½ critical size D2O reactor, plus 1100 tonnes U ore (p610)

April 1945: Enough enriched U235 on hand for one critical mass (p612)

7 May 1945: Germany surrenders.

31 May 1945: Enough Pu available for critical mass tests. Solid ball Pu core with tamper mass set at 5 Kg (previous shell design discarded as too difficult). Expected Compression by implosion to increase Pu density by at least a factor of 2 (p655)

10 June 1945: K25 reaches 7% enrichment (Bp77)

4 July 1945: British officially give their approval to use atomic bombs on Japan, as per Quebec agreement (p655)

16 July 1945: Trinity test of Fat Man bomb 19 Kt (Cv1p843)

6 August 1945: Enola Gay drops Little Boy on Hiroshima (p705) 13 Kt (Cv1p845) 140,000 deaths by end of 1945, 200,000 by 1950 (p734)

9 August 1945: Bock's Car drops Fat Man on Nagasaki 70,000 deaths by end of 1945, 140,000 by 1950 (p739)

14 August 1945: Japan Surrenders (p745)

14 June 1945: Klaus Fuchs Leaves Los Alamos for Britain (Gp259)

July 1946: Two 20 Kt weapons tested at Bikini (Cv1p846)

25 December 1946: USSR first reactor goes critical (Bp123)

29 August 1949: USSR conducts first fission device test (Bp123)

3 October 1952: Britain tests first fission device (Cv1p846,F)

1 November 1952: Mike H-bomb shot at Enewetok (p777), 10.4 Mt (Cv1p846)

31 May 1953: First PWR operates – a prototype of the power plant for the USS Nautilus which began sea trials in 1955 (Dp585)

August 1953: USSR explodes small H-bomb component device (p778)

1954: Fermi dies (Cv7p77)

18 April 1955: Einstein dies (Cv6p102)

16 May 1956: Britain tests first fusion device (F)

1 December 1956: EBWR goes critical (Dp586)

2 December 1957: Shippingport goes critical (Dp586)

1960: Dresden I goes critical (Dp588)

13 February 1960: France tests first fission device (Cv1p846,F)

1962: Niels Bohr dies (Dp109)

1962: NPD2 completed (Dp590)

16 October 1964: China tests first fission device (Cv1p846,F)

17 June 1967: China tests first fusion device (Cv1p846,F)

1967: Oppenheimer dies (Cv14p612)

24 August 1968: France tests first fusion device (Cv1p846,F)

1974: India tests first fission device (Cv1p846)

1976: Heisenberg dies (Cv9p159)

22 September 1979: Suspected joint South African/Israeli fission device test in Indian Ocean (F)

28 May 1998: Pakistan tests five fission devices simultaneously (F)

Note: There were 520 atmospheric bomb tests up to 1962, by USA, USSR and Britain. Between 1962 and 1990 there were another 23 atmospheric tests and an estimated 1400 underground tests. The radiation dose to the average person from the fallout is about 0.005 milliSv/year, whereas the world average annual dose from natural sources is 2.4 milliSv/year (with about 0.4 milliSv/year of this from the naturally occurring potassium-40 and carbon-14 in our bodies)(H).

REFERENCES:

Plain page references are the “The Making of the Atomic Bomb,” by R. Rhodes, Pub Simon & Schuster (1986)

Reference B: “The Making of the Atomic Age,” A. McKay, Pub. Oxford U Press (1984)

Reference C: Worldbook Encyclopedia (1980)

Reference D: “Sourcebook on Atomic Energy,” S. Glasstone, Van Nostrand Reinhold (1967)

Reference E: Nuclear Europe, p 9, ½ January/February 1989

Reference F: http://nuketesting.enviroweb.org

Reference G: “Dark Sun, The Making of the Hydrogen Bomb,” by R. Rhodes, Pub Simon & Schuster (1996)

Reference H: “United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), Year 2000 Report.”