

# The History and Science of the Manhattan Project

## Index

*Note: For some entries (such as “uranium” or “atomic number”), only the most important or initial defining passages are indexed. Roman numerals and whole numbers indicate individual pages; decimal numbers indicate chapter sections; “n” indicates a footnote. No citations are made to end-of-chapter reference lists. Suggestions for additional entries and corrections are welcomed.*

*Last update January 5, 2014*

ABCC (Atomic Bomb Casualty Commission), 408  
Abelson, Philip, 83, 110, 130, 137-138, 206, 212-219  
Anti-Ballistic Missile (ABM) Treaty, 434-435  
Accelerator, linear (*see also* cyclotron), 47-48  
Acheson, Dean, 420-422, 438  
Acheson-Lilienthal report, 421-422  
Acocella, Giovanni, 58  
actinium, 23, 76, 79, 111  
Adamson, Col. Keith, 124, 129  
Adler, Edward, 207-208  
Administrative Board (Los Alamos), 306  
AEC (*see* Atomic Energy Commission)  
Agnew, Harold, 82, 391  
Ahern, Joseph-James, xi, 213  
Aioi bridge (Hiroshima), 389-390  
Air Force, United States Army, vii, 13, 155, 293-294, 297, 328, 361-364, 366-368  
Akers, Wallace, 168, 273  
Alamogordo Army Air Field, 320, 338  
Alamogordo, town of, 320  
Alberta, Project, 293, 7.14, 363, 396, 449  
Albury, Don, 387, 398, 401  
Allison, Samuel, 82, 135, 137, 142, 147, 157, 178, 249, 307, 324, 330-331  
Allis-Chalmers Manufacturing Co., 170, 197, 199, 208  
alpha particles (and alpha decay),  
    as helium nuclei, 32-33  
    Coulomb barrier, 45-46  
    emission from element 93 as clue to presence of plutonium, 110-112  
    general decay scheme, 39  
    scattering of, 33-34  
    named by Rutherford, 21  
    role in ( $\alpha$ ,  $n$ ) predetonation reactions, 158, 285-287  
    role in inducing artificial radioactivity, 56  
    role in discovery of neutron, 50-54

- role in Fermi neutron sources, 59-60
- role in Rutherford artificial-transmutation discovery, 43-44
- use in “urchin” initiators, 287

Alpha “racetrack”, 193, 197

aluminum,

- as jacketing material in reactor fuel slugs, 186, 188, 234, 244
- as light-element target in neutron-producing bombardment reactions, 50
- as light element impurity in fissile material, 285, 288
- as target element in discovery of artificially-induced radioactivity, 56
- Fermi bombardment of with neutrons, 59-60
- foils in Rutherford experiments, 21
- foils in plutonium-discovery uranium-bombardment experiments, 109
- process tubes in Hanford reactors, 238-239, 242, 249
- radiative-capture cross-section graph, 64
- tamper sphere in implosion bomb, 310-311

Aluminum Company of America (ALCOA), 188, 242, 244

Alvarez, Luis, 83, 261, 262, 316, 388

Amaldi, Eduardo, 58, 75

American Physical Society, 49, 101, 128

Anacostia Naval Station (Washington), 215-218,

Anchor Ranch Proving Ground (Los Alamos), 300

Anderson, Herbert, 81-82, 84-85, 130, 179-183

Anderson, Sir John, 272-274

*Annual Report on the Progress of Chemistry*, 103

Appleton, Edward, 106

“Archies”, 302, 388

Argonne site (Argonne Forest Preserve), 158, 160-162, 166, 170, 179, 185, 223

Army, United States,

- Air Forces (AAF), 155
- Corps of Engineers, 6, 156
- Ground Forces (AGF), 155
- organization of, 155-156
- Services of Supply, 155

Arnold, General Henry, 361-362, 365, 368, 404

Arnold, William, 80

artificial radioactivity, 2, 56-57

artificial transmutation, 42-46

Ashworth, Cdr. Frederick, 296-298, 368, 387, 398-400

Association of Los Alamos Scientists (ALAS), 418, 441

Association of Oak Ridge Scientists, 418

Aston, Francis, 20, 28-30, 48, 65

Atomic Bomb Casualty Commission (ABCC), 408

Atomic Energy Commission, viii, 147, 223-224, 278, 417, 419, 423-424, 438, 441, 447

*Atomic Energy for Military Purposes* (Smyth Report), viii, 409-410

Atomic Scientists of Chicago, 418

atomic weight (molecular weight; A), 22, 26-28, 33, 35, 77, 205, 276, 284-286, 441

Avogadro's number ( $N_A$ ), 22, 276, 284

B-29 bomber (*see also* Enola Gay and Bockscar), vii, 11, 293-297, 300, 339, 349, 361, 363-364, 371, 395, 404, 423, 442, 444

B-pile, 6.2-6.6, 442

Badger and Sons, E. B., 158, 161

Babcock and Wilcox Company, 222, 325

Babcock, Dale, 248-249

Bacher, Robert, 262-264, 305-307, 315, 324

Bainbridge, Kenneth, 137, 263-264, 319-320, 324-325, 327, 329-330, 333, 337

balloons, Japanese, 246

Baratol, 309, 310, 313, 319

Bard, Ralph, 375, 379-380

barn (unit of cross-section), defined, 64, 441, 443

Barnard, Chester, 420

Barnes, Philip, 387, 398

Bart Laboratories, 211

Bartky, Walter, 381

Baruch, Bernard, 422

Baruch Plan, 422, 441

Base Camp (*Trinity* test), 321-323, 327, 330-331, 333

Beahan, Kermit, 387, 398, 400

Beams, Jesse, 125, 129, 137-138, 142, 146, 153, 157

Becker, Herbert, 50-52, 59, 158

Becquerel, Henri, 17-21, 40

    Becquerel as unit of radioactivity, 23, 442, 443

Bell, Daniel, 198

Berkeley, University of California at, 48, 83, 109-110, 126, 135, 138, 148-149, 157, 161, 169, 195, 197, 212, 258-259, 264, 283, 303, 304

Bernstein, Jeremy, 104

Bethel Valley, 160, 186

Beria, Lavrenti, 339

beryllium (including beryllium radiation, beryllium-based neutron sources, light-element predetonation, and use of beryllium in chain-reactions, criticality experiments, and initiators), 51-54, 59, 63, 72, 111, 132, 134, 147-148, 179, 285-288, 301-302 (Fig. 7.18), 310 (Fig. 7.21), 317

beta decay (and beta-rays), 18, 21, 36-42

    named by Rutherford, 21

beta tracks (calutrons), 193, 195-197, 201-203, 209, 212, 222

betatron, 315

Beser, Jacob, 362, 387

Bethe, Hans, 157, 158, 263-264, 268, 274, 287, 307, 323-324, 328, 330, 333, 336

Biddle, Francis, 233

Bikini Atoll, 319, 422

binding energy, 30-31, 65-67 (Fig. 2.29), 88, 91, 93, 109, 442, 444

bird, suicidal, 201

Birch, Cdr. Albert Francis, 299  
Birmingham, University of, 99, 102-103, 107, 274, 445  
bismuth, 31, 43, 135-136, 234, 250, 287, 288  
bismuth phosphate, 234  
Black Oak Ridge, 177  
Bock, Capt. Frederick C., 397  
*Bockscar*, 297, 387, 397-402, 442  
Bohemian Grove (California), 124, 162-163, 170, 190, 194, 203, 258  
Bohr, Erik, 80  
Bohr, Niels (and Bohr-Wheeler fission theory), ix, 3, 5, 14, 35, 77-83, 85-87, 90-91, 93, 96, 97, 100, 106, 107, 233  
bombing missions, 8.5  
    effects of, 8.6  
    public response to, 8.7  
Bonneville Power Authority, 231  
“boosting” (fusion weapons), 425  
Booth, Eugene, 82, 101, 206  
Born, Max, 57  
Bothe, Walther, 50-52, 59, 158  
Bowen, Adm. Harold, 125, 129, 216  
Bradbury, Lt. Cdr. Norris, 308, 329 (Fig. 7.31), 334, 417, 422  
Bramley, Arthur, 213  
Breit, Gregory, 124, 125, 127-131, 135, 137, 153, 157, 218, 258  
Brewer, Keith, 213  
Briggs, Lyman, 124-135, 137-138, 140, 143, 145-146, 148, 152-153, 155, 157-158, 162, 213, 215-218, 374, 450  
British Mission, 7.4, 309, 311, 365  
Buckley, Edward, 387, 398  
Buckley, Oliver, 133, 135  
Bundy, Harvey, 151, 165  
busbar, 193, 199  
Bush, Lt. Harold, 322  
Bush, President George H. W., 435  
Bush, President George W., 434  
Bush, Vannevar, 125, 128-131, 133-140, 142-155, 157, 158, 164-166, 171-172, 206, 216, 258, 260, 267, 268, 272-274, 283, 323, 371, 372, 375, 376, 418, 420, 421  
Byrnes, James, 372, 373, 375-377, 380, 381, 404, 420-422

Cahn, Albert, 380-381  
California, University of (*see also* Berkeley, University of California at), 7, 10, 48, 49, 148, 263, 264  
calorie (unit), 24, 25, 337, 343, 345  
calutron, 7, 8, 150, 169, 5.3, 209, 212, 222, 442, 443, 447  
Canada, 21, 122, 161, 171, 272, 435  
canning of reactor fuel, 188-189, 244, 252  
Carbide and Carbon Chemicals Corp., 209, 211

Carnegie Institution of Washington (CIW), 83, 124, 126, 129, 130, 212, 442

Caron, George R., 362, 387

Carpenter, Walter, 167

Cartwright, Gen. James E., 437

Casablanca Conference, 273

casualties, Hiroshima and Nagasaki, vii, 363, 405-409

*Castle Bravo*, 426

cemento, 177

centrifuge(s), 125, 134, 146, 150, 153, 154, 157-158, 162, 171, 272

CEW – *see* Clinton Engineer Works

Chadwick, James, 50-54, 57, 59, 106-107, 110, 130, 145, 158, 274, 323

channel(s), reaction, 60, 63, 64, 84, 111, 449

Chapman, Sydney, 213

charging machine, 238, 244

Charpak, Georges, 427

Cheshire, Group Capt. Leonard, 400

Chicago, University of (including some entries for Metallurgical Laboratory and pile experiments), 9, 65, 82 (Fig. 3.5), 112, 130-131, 134-135, 138, 140, 147-149, 153-154, 158, 160, 166-170, 179, 186, 218, 223, 233, 235, 252, 258, 266, 305, 369, 377, 379, 381, 444, 446, 447

Christy, Robert F. (and Christy core), 311-312, 315, 319, 334, 336, 339, 417

Chrysler Corp., 207, 211

Chubb, Lawrence, 135

Churchill, Winston, 126, 143n, 272-274, 294, 327, 338-339, 372, 392, 421 (Fig. 9.1)

CIW (*see* Carnegie Institution of Washington)

Clark, Ronald W., 106

Clayton, William, 375

Clinton Engineer Works (CEW), 6, 160, Ch. 5, 442, 446, 450, 451

Clinton Laboratories, 186, 189 (Fig. 5.9), 223

Clinton, Tennessee, 6

Clusius, Klaus, 103, 213

Cockcroft, John, 107

Cohen, Samuel, 394

Columbia river, 10, 231, 232, 235-237, 245

Cohen, Karl, 206-207

Colgate, Stirling, 259

Columbia University (including fission, pile, and diffusion-barrier research), 65, 81-83, 85, 101, 102, 106, 120, 124-126, 130, 134, 135, 146-149, 153, 168, 181, 206-208, 293

Combined Policy Committee (CPC; US-UK-Canada), 274, 327, 442

Community Council (Los Alamos), 271

Campania Hill, 323, 333-335

“Comp B” (explosive), 309, 310

Composite Group, 509<sup>th</sup>, 13, 297-299, 349-351, 362-363, 368, 382-383

compound nucleus, 91

Comprehensive Test Ban Treaty (CTBT) 4350

Compton, Arthur, 124 (Fig. 4.3), 125  
advocates and centralizes pile program; appointed as a Program Chief, 4.7-4.8  
and Franck Report, 377-379  
and Jeffries Report, 369-370  
and National Academy of Sciences Committee on Atomic Fission reports, 4.3-4.5  
and Szilard survey at Met Lab of attitudes toward bomb use, 381-382  
and xenon poisoning crisis, 249  
appointed to Interim Committee Scientific Panel, 375-376  
appointed to S-1 Executive Committee, 4.9  
approached by Fermi to locate CP-1 in Chicago, 179  
declines to witness *Trinity* test, 323  
design work on production piles and cooling systems, 6.2, 6.3  
informed that plutonium is fissile, 112  
informs Conant of successful operation of CP-1, 183-184  
investigates plutonium light-element impurity issue, 168  
learns of Pu-240 spontaneous fission crisis, 305  
planning of bomb-design laboratory, 258  
presents pile program to Groves, 166  
supports May-Johnson bill, 418

Compton, Karl, 125 (Fig. 4.4), 129-131, 375, 411

Conant, James, 124, 125 (Figs. 4.3, 4.4)  
advocates “all out” program: 152  
and appointment of Oppenheimer, 263  
and British Mission, 272-274  
and Byrnes committee, 420  
and CP-1 reactor, 179, 183-184  
and demilitarization of Los Alamos, 263  
and DuPont, 167  
and implosion, 283, 308, 318-319  
and May-Johnson bill, 418  
and Military Policy Committee, 166  
and plutonium-240 spontaneous fission crisis, 305-306  
and plutonium light-element impurities, 168, 286  
and postwar planning, 371-372  
and Navy thermal diffusion research Project, 216-220  
appointed Chair of S-1 Executive Committee, 157  
appointed to Interim Committee, 375-376  
asks Ernest Lawrence to devote himself to bomb project, 138-139  
as advisor to Groves, 172  
as member of NDRC, 129  
changes opinion of feasibility of Project, 140  
elevated to Chairmanship of NDRC under OSRD, 136  
endorses Lawrence proposal for electromagnetic separation research, 148  
establishes London office of NDRC, 137  
July 25, 1942, meeting with Army representatives, 158  
May 23, 1942, Program Chiefs meeting, 152

opinion of Glenn Seaborg and use of plutonium for a bomb, 147  
 opposes development of “super”, 423-424  
 receives MAUD report, 137, 140  
 reorganization of Project administration, November 1941, 143-145  
 reports to Vannevar Bush: February 20, 1942: 149-150; April 1, 1942: 152; May 25, 1942: 153-154, 157  
 unpublished history of Project, 130, 142, 172  
 witnesses *Trinity* test, 323, 333

Conant, Jennet, 270

Condon, Edward, 137, 157, 264-266

Coolidge, William D., 131, 135, 138

cooling system, Hanford, 6.3

Corps of Engineers, U. S. Army, 6
 

- acquisition of Hanford site, 233
- acquisition of Los Alamos site, 259
- takes on and begins to organize Project, 4.9

cosmic rays, 179, 304-305

Cosmos Club, 147

cost of Manhattan Project, 1

Coulomb Barrier, 38, 44-49, 54, 58, 443

Coulomb, Charles, 45

Cowpuncher Committee, 307, 324, 326

CP-1, 9, 82 (Fig. 3.5), 135, 148, 169, 178-185, 234, 246, 249, 252, 259, 423, 443

CP-2, 180 (Fig. 5.3), 183, 185, 223-224

CP-3, 185, 223-224

Creutz, Edward, 154

critical mass (also critical radius), 10-11, 98-100, 103-105, 137, 139-141, 266-267, 7.5-7.7, 316-317, 374, 443

criticality, first and second, 284

criticality, physics of, 7.5

cross-section, (reaction, absorption, fission, capture, scattering, etc.), 63-64, 83, 3.2-3.5, 101, 103-107, 112, 127, 132, 147, 181, 185, 234, 248-249, 253, 266, 268, 7.5, 301, 304, 307, 441, 443

*Crossroads Able*, 422

*Crossroads Baker*, 423

CTBT – *see* Comprehensive Test Ban Treaty

Curie, as unit of radioactivity, 23
 

- Pierre, 19, 22, 25
- Irène and/or Frédéric, 19 (Fig. 2.3), 51-54, 56-59, 72, 82, 85, 122, 158
- Marie, 19-20, 22, 51

cyclotron (calutron), 7, 48-50, 57, 82 (Fig. 3.6), 106, 109, 111-112, 138, 149-150, 161, 190-194, 267-268, 303, 305, 442, 443, 447

Czechoslovakia, 122

D-pile (Hanford), 237, 250, 253

Daghlian, Harry, 317

D'Agostino, Oscar, 58  
Dahlgren Naval Proving Ground, 294, 308  
Dalton, John, 27, 30, 65  
Darwin, Charles, 136  
Dayton, Ohio, 288, 294, 297  
de Broglie wavelength, 63  
decay (alpha, beta, and natural sequences),  
    named by Rutherford, 21  
    schemes, 36-42  
D-D reaction, 425-426  
Dee (cyclotron), 48  
Defense Advanced Research Projects Agency (DARPA), 438  
Dehart, Albert, 387, 398  
demonstration shot of fission bomb, 369, 371, 376, 378-382  
Dempster, Arthur, 65  
Dickel, Gerhard, 103, 213  
diffusion,  
    Aston's use of to separate isotopes, 28  
    definition, 443  
    gaseous thermal (barrier diffusion; K25), 7-8, 103, 107, 125, 129, 134, 137, 142, 146,  
    149, 150, 152-154, 157-159, 162, 168-172, 5.4, 272-274  
    liquid thermal (S50), 8, 120, 138, 166, 5.5  
    theory (bomb criticality and efficiency), 10, 98, 100, 105, 266, 7.5  
Dodson, R. W., 83  
Donne, John, 320  
Dow Chemical Corp., 162  
dragon drops, 317-318  
dry criticality, 247  
DSM (Development of Substitute Materials), 155, 161, 164  
Dudley, Maj. John, 259  
Dunning, John, 81-82, 101, 146, 206  
DuPont (E. I. du Pont de Nemours and Company),  
    accepts contract to build plutonium separation plants (fall 1942), 166  
    accepts contract to design and construct X-10 pile and separation facilities (January  
    1943), 170  
    and construction of X-10 pile, 188  
    and cooling system for Hanford reactors, 234, 237  
    and design of Hanford piles, 6.2-6.3  
    and xenon poisoning crisis, 248  
    pressured by Groves to take on plutonium production, 167-168  
    purchase orders for Hanford, 239  
    recruitment for Hanford site, 236  
    requirements for Hanford site, 231  
    "Rome wasn't built in a day, but DuPont didn't have that job", 236  
    separation chemistry research, 234  
Duzenbury, Wyatt, 362, 387



D-T reaction, 425-427, 443,  
Dyson, Freeman, 334

East Town (Oak Ridge), 176  
Eastman Kodak Co., 195, 340  
Edlefsen, Nils, 48  
efficiency, bomb, 137, 140-141, 266, 325-326, 377  
    comparison of chemical and fission bomb of equal efficiencies, 25  
    degraded by impurities in fissile material, 157  
    degraded by possible predetonation during core assembly, 7.7  
    enhanced with use of tamper, 11, 281, 311  
    of fusion weapons, 427  
    of implosion technique, 311, 319  
    of *Trinity* test, 339  
Einstein, Albert, 2, 38, 54, 121, 124-126, 129-130, 137, 380  
elastic collision (elastic scattering of neutrons), 93-94, 275, 276n, 301  
“electric method” implosion diagnostic, 314-315  
electromagnetic method of uranium enrichment/separation (calutrons), 7, 142, 146-150, 153-154,  
    157-158, 161-162, 165, 169-172, 175, 5.3, 212, 219, 222, 272-274, 420, 451  
electron, discovery of, 20  
    beta particles as, 21  
Elza Gate (Oak Ridge), 176  
*Enola Gay*, 296 (Fig. 7.15), 297, 357, 362 (Fig. 8.1), 383, 385-390, 444  
Enskog, David, 213  
Ent, Gen. Uzal, 361  
“emanation” (thorium), 21, 23, 41  
Energy Research and Development Administration, U. S., 419  
Engineering Council (Metallurgical Laboratory), 233  
enrichment, *see* diffusion, gaseous; diffusion, liquid thermal; electromagnetic method of uranium  
    enrichment/separation  
eV (electron volt), 25  
excess deaths (radiation exposure), 346-347

F-Division (Los Alamos), 307  
F-pile (Hanford), 237, 250, 253  
Farrell, Brig. Gen. Thomas, 219 (Fig. 5.28)  
    and Manhattan Project Atomic Bomb Investigating Group, 405  
    and target Committee, 366  
    cable to Groves re Hiroshima mission, 391  
    description of *Trinity* test, 330-331  
    informs Groves of *Enola Gay* takeoff and arming procedure, 385  
    signs *Fat Man*, 396  
    throws up over fear that *Fat Man* mission aborted, 400  
FAS, *see* Federation of American Scientists  
*Fat Man* (implosion bomb), vii, 12, 50, 253, 296 (Fig. 7.16), 7.11, 398 (Fig. 8.12), 402, 426, 427,  
    444

- assembly problems with Nagasaki bomb, 396-397
- delivery of components to Tinian, 348-349
- delivery program test drops, 293-295, 297
- dropped at Nagasaki, 400
- F-unit test bombs, 349-350
- Klaus Fuchs transmits design information to Soviets, 269
- origin of name, 294-295
- potentially delayed by plutonium-240 crisis, 189
- rate of plutonium production for, 250-251
- Soviet test of equivalent design, 423
- tests at Bikini, 422-423
- Trinity* test of, 7.12
- uncertain yield estimates of (spring 1945), 367
- X-unit, 298

Feather, Norman, 57

Federation of American Scientists (FAS), 265, 418, 441, 444

Fercleve Corp., 221

Ferebee, Maj. Thomas, 362, 363, 387, 389

Ferguson Co., H. K., 220, 221

Fermi, Enrico, 16, 50, 57, 2.4, 69, 71-72, 79-83, 85, 101, 109, 120, 122, 124-130, 135-137, 140, 147, 148, 160, 162, 169, 5.2, 242, 247-248, 252, 258, 285, 304, 305, 307, 315, 323, 330, 331-332, 356, 369, 375, 423, 424, 450

Fermi National Accelerator Laboratory (FNAL), 49

Fifth Washington Conference on Theoretical Physics, 83

fireball, of bomb, 12 (Fig. 1.5), 325, 326, 332 (Fig. 7.32), 335-338, 407

- thermal effects of, 344-345

firebombing, Tokyo, 363-364

Fisher, Col. William, 366

fission barrier, 90-91

fission, nuclear

- discovery of, 3.1
- energy release in, 72, 78
- Otto Hahn's disavowal of Lise Meitner role in discovery, 76-77
- products of, 84
- role of neutron energy (fast/slow) in, 3.2
- role of uranium 235 and 238 isotopes in, 3.2
- threshold (fission barrier), 90-91

fizzle yield, 291-292

Flügge, Siegfried, 98-99

Fowler, R. D., 83

Fox, Lt. Col. Mark, 220

Franck, James, 377-378

Franck report, 377-378, 444, 446

Frisch, Otto, 57, 61, 77-80, 83, 86, 99, 100, 3.7, 108, 126, 274, 317-318

*Frisch-Peierls memorandum*, 3.7, 130, 279-280, 445, 447

Fuchs, Klaus, 268-269, 274, 423

fuse, bomb, 295, 298, 301-302, 367  
fusion weapons, 9.2

G-Division (Los Alamos), 306-307, 315-316

Gallagher, Ray, 387, 398

gallium (as alloying agent with plutonium), 288

gamma-ray, 18, 44, 50-53, 64, 72, 246, 304, 315, 324, 326, 334, 342, 346, 425

Gamow, George, 78, 82 (Fig. 3.6), 83

Garwin, Richard, 427

Gary, Thomas, 168

Geiger counter, 18, 33-34, 36, 56, 59, 72, 314

Geiger, Hans, 33-35

General Advisory Committee (Atomic Energy Commission), 419, 423, 445

General Electric Corp., 131, 138, 140, 170, 197, 211, 252, 369, 420

George Washington University (GWU), 83, 126

Gherardi, Bancroft, 131

“Godiva” assemblies, 317

Goodyear Rubber Co., 180

Göteborg (Sweden), 77

Governing Board (Los Alamos), 264, 268, 306, 308

graphite, 4, 9, 63, 123-126, 132, 135, 147, 148, 154, 168, 5.2, 239-241, 250, 374, 422, 448

Grand Coulee Dam, 231

Greenewalt, Crawford, 168-169, 183, 186, 217

Greenglass, David, 269

*Greenhouse George*, 426, 445

*Greenhouse Item*, 425

Grinnell Co., 221

Graves, George, 241-242

Groueff, Stephane, viii

Groves, Gen. Leslie R.,

and Acheson-Lilienthal report, 421-422

and Atomic Energy Commission, 419-420

and beer at Hanford, 236

and bombing orders, 350-351

and British contributions to Project, 136

and choice of Hanford site, 229-231, 233

and establishment of Los Alamos, 258-259

and gaseous diffusion program (K-25), 208-212

and General Marshall, 403-404

and Hanford plutonium production speed-up, 250-251

and Interim Committee, 379

and Manhattan Project Atomic Bomb Investigating Group, 405

and Oak Ridge, 176-177

and Oppenheimer, 258, 260-262, 394

and plutonium spontaneous-fission/implosion crisis, 305, 308

and response to scientists’ petitions, 382

- and Royall-Marbury bill, 417 and secrecy, 266, 268-269, 410
- and Smyth Report, 409
- and target selection, 364-368
- and thermal diffusion program (S-50), 216-220
- and *Trinity* media day, 340-341
- and *Trinity* test, 331
- and *Trinity* weather forecast, 328-330
- and William S. Parsons, 267
- and xenon poisoning crisis, 249
- and Y-12, 194-197, 199-202
- and Y-12 silver program, 199
- background and appointment to Manhattan Project, 155-159, 161-170, 172
- briefs President Truman, 373-374
- death of, 222
- informed of Hiroshima bombing, 390-391
- informs Oppenheimer of Hiroshima bombing, 394
- reaction to use of bomb, 412
- report on *Trinity* test to Henry Stimson, 338
- sprayed with hot water, 313

Guam, 298, 350, 363

Guerra, Francesco, 58, 60

Gunn, Ross, 120, 125, 129-131, 137, 138, 166, 213, 216-218

HAER (Historic American Engineering Record), Ch. 6; esp. p. 237

Hafstad, Lawrence, 83

Hahn, Otto, 50, 73 (Fig. 3.1)

- background with Lise Meitner, 72
- disavowal of Meitner's role in discovery of fission, 76-77
- discovery of fission and exchange of letters with Meitner and Frisch, 77-79
- Nobel Prize, 77

half-life, Rutherford's discovery and mathematics of, 20-24

Hall, Theodore, 269

Handy, Gen. Thomas, 350-351, 368, 383

Hanford (Hanford Engineer Works; HEW; *see also* B-pile), 10, 12, 13, 148, 186, 189, 224, Ch. 6, 257, 305, 307, 369, 374, 442, 445, 449

- as component of Manhattan Project National Historic Park, 438
- fuel slug fission products used to seed 100-ton TNT test, 324
- piles used to breed polonium for initiators, 136, 287-288
- radioactive contamination at, 430
- Russian F-1 reactor as copy of fuel-slug testing reactor, 422

Hanford Site Patrol, 236

Hanstein, H. 85

Happy Valley (Oak Ridge), 209

*Harper's Magazine*, 102, 411

Harrington, Willis, 167

Harrison, George, 338, 368, 374-376, 378-380, 382

Health Instruments Division (Hanford), 246  
Hecker, Siegfried, 112  
helium,  
    alpha particles as nuclei of, 32-33  
    as coolant in plutonium production piles, 166-169, 186, 230-231, 233-235  
    as operating atmosphere for Hanford piles, 235, 239-240, 245, 247, 250  
    use in Geiger counter, 36  
    use in K-25 plant to detect leaks, 211  
Hempelmann, Louis, 265, 340  
Hersey, John, 411  
Hertz, Gustav, 377  
HEU (highly enriched uranium; 90% U-235), 8, 96, 223, 278, 432  
HEW (Hanford Engineer Works – *see* Hanford)  
hexafluoride, uranium (UF<sub>6</sub>), 8, 9 (Fig. 1.3), 65, 202, 205, 206, 208, 214 (Fig. 5.27), 215, 445  
Hilberry, Norman, 82 (Fig. 3.5), 182  
Hirohito, Emperor, vii, 366, 402, 404-405  
Hiroshima,  
    as bomb target, 366-369, 383  
    bombing mission, 383-395  
    casualty statistics and effects of bombing, 363, 8.6  
    location and population at time of bombing, 384  
    President Truman informed of bombing, 391-393  
    radiation exposure of survivors, 347  
Hirschfelder, Joseph, 267, 437  
Holzman, Col. Ben, 328-329  
Honshu (Japan), 364, 367 (map), 368, 384  
Hooper, Adm. Stanford, 120  
Hoover, Cdr. Gilbert C., 124, 129  
Hoover Dam, 231  
Hopkins, Capt. James, 398-400  
Hopkins, Harry, 273  
Hornig, Donald, 316, 329, 330  
Houdaille-Hershey Corp., 207, 208  
Hubbard, Jack, 327-330  
Hull, McAllister, 312-313, 395  
hydrogen,  
    as component of water, 25-26  
    as fundamental building block of all atoms, 27-28, 30  
    as moderating agent, 63, 316  
    as product of Rutherford's discovery of artificial transmutation, 37, 42-44  
    deuterium isotope of ("heavy hydrogen"), 49, 371, 425  
    football field analogy for size of, 35  
    mass of, compared to electron, 33  
hydrogen bomb, 13, 307, 423-427, 445  
  
ICBM (Inter-Continental Ballistic Missile), 431-432, 434, 436, 445

Imperial Chemical Industries, 107  
Imperial College London, 106  
India, nuclear arsenal, 9.2, 9.3  
*Indianapolis, U. S. S.*, 348, 350  
inelastic scattering of neutrons, 93-96, 137, 276  
initiator (“Urchin”), 11, 277, 287-288, 294, 302 (Fig. 7.18), 310 (Fig. 7.21), 311, 324, 328, 348, 445  
Institute for Advanced Study (New Jersey), 80, 308  
Institute of Theoretical Physics (Copenhagen), 77, 90  
Interim Committee, 375-379, 394, 411, 417, 445  
Iowa State College, 178  
isotope(s), definition, 3, 3n  
    discovery of, 2.1.4  
    discovery of uranium-235, 65  
    in radioactive decays, 2.1.6.1 – 2.1.6.3  
    in Fermi bombardment experiments, 59-62  
    of uranium, 3-4  
    role of in discovery and interpretation of fission and fast and slow chain reactions, 3.1-3.4  
    role in Los Alamos spontaneous-fission crisis, 289-291  
    role of in xenon poisoning at Hanford, 248-249  
Iwo Jima, 349, 364, 383, 388  
*Ivy Mike*, 426, 446

J. A. Jones Construction Co., 209  
JANCFU, 396  
Jeffries report, 369-373, 377, 446  
Jeffries, Zay, 369  
Jemez Springs, 259  
Jenkin, John, 55  
Jeppson, Morris, 362 (Fig. 8.1), 386-388  
Jewett, Frank, 129, 131-133, 135, 138, 140, 141  
Johns Hopkins University, 83, 130  
Johnson, Clarence, 208-209  
Johnson, Edwin, 418  
Johnston, Lawrence, 388  
Joliot-Curie, Frédéric and/or Irène, 19, 51-54, 56-57, 59, 72, 82, 85, 122, 158  
Jornada del Muerto, 320  
Jumbo, 324-325, 342, 446

K-25 (gaseous diffusion; barrier diffusion), 6-8, 107, 160 (Fig. 4.14), 175, 202, 203-212, 446  
    powerhouse, 220  
    receives S-50 product, 221  
    shutdown and demolition of, 223  
Keith, Percival C. 146, 207  
Kellex Corp., 207-210, 212  
Kellogg Co., M. W. (*see also* Kellex Corp.), 159, 206-207

Kennedy, Joseph, 111, 264  
Kerst, Donald, 315  
kiloton (defined), 78, 446  
kilowatt (*see* also megawatt), 25, 159, 185  
kilowatt-hour (kWh), 24, 25, 446  
Kingman (site K; W-47), 296  
Kistiakowsky, George, 140-141, 264, 307-309, 312, 314, 324, 325, 328, 330, 331, 334, 335  
Knoxville (Tennessee), 6, 159-161, 170, 171, 393  
kWh (kiloWatt-hour), 24, 25, 446  
Kobe, 364  
Kokura (also Kokura Arsenal), 351, 367 (Fig. 8.3), 368, 383, 397, 399, 400  
Kowarski, Lew, 85  
krypton (as fission product), 71, 83-84  
Kuharek, John, 387, 397, 398 (Fig. 8.13)  
Kungälv (Sweden), 77  
KWI (Kaiser Wilhelm Institute), 72, 122-123  
Kyoto, 352, 367, 368  
Kyushu, 350, 364-366, 397, 398

“lags” (spent reactor fuel), 252  
lanthanum, 60, 76, 79, 189, 315  
Lansdale, Col. John, 165, 361  
Laurence, William, viii, 102, 334-335, 375, 388  
Lauritsen, Charles, 137  
Lawrence Berkeley National Laboratory (LBNL), 49  
Lawrence, Ernest O.,  
    and consideration of bomb-design laboratory, 258-260  
    and electromagnetic isotope separation research, 146, 148-150, 158, 161-162  
    and Interim Committee Scientific Panel, 375-376

    and plutonium purity requirements, 168  
    and Y-12 electromagnetic plant, 5.3  
    appointed to S-1 Executive Committee, 157-158  
    as loose cannon, 133  
    as member of Compton NAS uranium fission Committee, 131  
    cyclotron invention, 7, 48-50  
    cyclotrons used in discovery of plutonium, 111-112  
    cyclotron operators miss discovering artificially-induced radioactivity, 57  
    “If you tell me this is my job, I’ll do it”, 139  
    informs Arthur Compton of fissility of element 112, 135  
    meets with Marcus Oliphant (fall 1941), 138  
    suggested as deputy to Lyman Briggs, 131  
    suggested by Compton as “key man”, 142  
    witnesses *Trinity* test, 323  
LeMay, Gen. Curtis, 363, 364, 383  
Leone, Matteo, 58

Lewis Committee(s), 446  
     Naval Research Laboratory liquid thermal diffusion project review, 216-2201  
     November/December 1942 program review, 168-169, 182, 190, 206, 230  
     Los Alamos project review, 266, 268  
 Lewis, Robert, 297, 362 (Fig. 8.1), 363, 387-389  
 Lewis, Warren K.,  
     and Compton NAS committee, 140  
     and Naval Research Laboratory liquid thermal diffusion project review, 216-220  
     and November/December 1942 program review, 168-169, 182, 190, 206, 230  
     Los Alamos project review, 266, 268  
     on Planning Board, 145-146  
     and Tolman postwar planning committee, 370  
 Leyte island, 350, 364  
 Libby, Leona (Leona Woods), 82 (Fig. 3.5), 252  
 Lifton, Robert Jay, 408  
 Lilienthal, David E., 420-422  
 Limited Test-Ban Treaty (LTBT), 433, 446  
 liquid-drop model of nuclei (Gamow-Bohr), 78, 86  
 liquid thermal diffusion (LTD; *see also* diffusion, liquid thermal, and S-50), 8, 120, 166, 175, 5.5  
 Littell, Norman, 233  
*Little Boy* (gun bomb), vii, 7, 12, 50, 169, 175, 203, 221, 251, 278 (Fig. 7.6), 280, 281, 290, 298, 299-303, 339, 368  
     delivery of uranium and components to Tinian, 348  
     detonation heights, 366-367, 387  
     drop test program, 294-297  
     dropped at Hiroshima, 389  
     effects of, 405-409  
     final assembly and loading at Tinian, 384-386  
     L-type test units, 349  
     origin of name, 294-295  
 Liverpool, University of, 106, 107  
 Livingston, M. Stanley, 49, 50 (Fig. 2.20)  
*London Times*, 55  
 Lorentz Force Law, 29, 48  
 Los Alamos, 6, 10-13, 172, 175, 185, 201, 202, 217-219, 224  
     accelerators and cyclotrons at, 267-268  
     British physicists at, 274  
     delivery of Hanford plutonium to, 250, 252  
     delivery program, 292-299  
     discovery of plutonium allotropic forms, 112-113  
     dual civilian/military nature, 263-264  
     gun and implosion assembly methods considered, 281-283  
     gun bomb (*Little Boy*), 299-303  
     Health Group, 265  
     housing and lifestyles at, 270-271  
     implosion bomb, 307-319



initial organizational structure, 264  
 initiator research and fabrication, 287-288  
 introductory lectures (Serber's *Los Alamos Primer*), 265-266  
 Lewis committee reviews research program, 266  
 metallurgical research, 288-289  
 ordnance research, 266  
 Planning Board, 264-265, 283  
 population growth, 269  
 preparations for and weather concerns involving *Trinity* test, 321-328  
 selection of Oppenheimer as Director, 260-262  
 site selection and land acquisition, 259-260  
 Special Engineer Detachment (SED), 270-271  
 spontaneous fission crisis, 289-292, 303-307  
 support services (machine shop, library, etc.), 264-265  
 technical colloquium proposed by Hans Bethe, 268  
*Trinity* site characteristics, 319-322  
*Trinity* test, 319-343  
*Los Alamos Primer* (Serber), 104-105, 141, 265-266, 276n, 281-284, 301, 303  
 Los Alamos Ranch School, 259, 267, 270  
 Lotz, John R., 159  
*Lucky Dragon 5*, 426

magnetic method (implosion diagnostic), 314, 328  
 Mallinckrodt Chemical Co., 161, 179, 194  
 Manchester Literary and Philosophical Society, 35  
 Manhattan Engineer District (MED), 1, 119, 154, 178, 258, 405, 447  
     established, 156, 161  
 Manhattan Project National Historic Park, 223, 438  
 Manhattan Project, origin of name, 1  
 Manley, John, 261 (Fig. 7.3), 264, 266, 267, 269, 305, 323  
 Marbury, William, 417-418  
 Marks, Herbert, 438  
 Marsden, Ernest, 33-34, 42-44  
 Marshak, Ruth & Robert, 270  
 Marshall, Col. James C., 155-164  
 Marshall, Gen. George C., 139, 150-151, 154, 155, 163, 166-167, 258  
     and Interim Committee, 375-376  
     directs Groves to see to targeting, 364, 368  
     informed of Hiroshima bombing, 390-391  
     informs Groves that Truman orders halt to further atomic bombings, 403-404  
     preparation of bombing orders, 350-351  
     receives report of *Trinity* test, 338  
 Marshall, Leona (Leona Woods; Leona Libby), 82 (Fig. 3.5), 252  
 mass defect, 30-31, 38-39, 65-67, 86, 90, 442, 447  
 mass spectroscopy, 7, 27-30, 38, 101, 134, 190, 447  
 mass unit, atomic, 30, 38, 54, 65-67, 441

Matthias, Col. Franklin, 230-231, 236, 250  
MAUD committee and report, 107-108, 130, 136-137, 140, 143, 206, 447  
Maud Ray Kent, 107  
May, Andrew, 418  
McCloy, John J., 420  
McCullough, David, 339, 372  
McDonald ranch house, 320, 322 (Fig. 7.28), 342, 358  
McGill University, 21, 41  
McKellar, Sen. Kenneth, 160  
McKibben, Joseph, 330  
McKibbin, Dorothy, 270  
McMahon, Sen. Brien, 418-419, 447  
McMillan, Edwin, 109-110, 130, 168, 212, 258-260, 262, 264, 271, 300, 308  
McMillan, Elsie, 271  
McVay, Capt. Charles, 350  
MDH (Manhattan District History), x  
mean free path (MFP), 205, 275-279, 447  
MED, *see* Manhattan Engineer District  
megawatt (MW), 9, 107, 135, 186, 229, 448  
Mehring and Hanson Co., 221  
Meitner, Lise, 50, 85-86, 107, 109  
    background, 72  
    flees to Holland, 76  
    interpretation of fission with Otto Frisch, 77-80, 83  
    letters exchanged with Hahn, 77-79  
    role in discovery of fission disavowed by Hahn, 76-77  
    uranium neutron bombardment and transuranic element research, 73-75, 84  
meitnerium, 77  
“Memorandum on the Properties of a Radioactive Super-bomb”, 102-106  
Metal Hydrides Co., 161, 178  
Metallurgical Laboratory (University of Chicago), 159-160, 166, 178, 218, 233, 258, 266, 369, 377, 447  
MeV (million electron volts) defined, 25  
    equivalence of atomic mass unit, 30, 66  
*Mike* (*Ivy Mike* weapon test), 253, 426, 446  
Millikan, Robert, 132-133  
Military Liaison Committee (Atomic Energy Commission), 419  
Military Policy Committee (MPC),  
    and diffusion barrier issue, 208  
    and Committee on Postwar Policy (Tolman), 370  
    and Hanford land acquisition, 232  
    and implosion program, 308  
    and ordnance position at Los Alamos, 267  
    and technical colloquium at Los Alamos, 268  
    December 10, 1942, meeting, 170, 190, 206, 230, 234  
    origin of, 166, 447

in charge of Manhattan Project, 172  
Mills, Rear Adm. Earle, 370  
Minnesota, University of, 101, 130, 134  
MIRV (Multiple Independently targetable Re-entry Vehicle), 435  
moderator, 4, 63, 105, 126, 132, 135, 168, 234, 239-241, 246, 445, 448  
Mohler, Fred, 124  
Møller, Christian, 79  
Monsanto Chemical Corp., 162, 170, 288, 420  
Montreal (Canada), 21, 171, 274  
Moore, Thomas V., 233-234  
Morgenthau, Henry, 199  
Morrison, Philip, 87, 405  
mouse, trapped (Y-12), 201  
Müller, Walther, 36  
Mulliken, Robert, 140, 141, 208, 215, 369  
Murphree, Eger V., 124 (Fig. 4.3), 144-147, 152-154, 157, 158, 162, 168, 217-219, 450  
Muroc Field, 295

*N* (neutron number), 26  
(n, gamma) radiation, 304  
Nagasaki,  
    bombing of, 387, 396-402  
    casualties, 363  
    considered as target, 366, 368, 383  
    effects of bomb, 337, 363, 406-408  
    radiation exposure of survivors, 347, 407  
Nagoya, 364, 367 (Fig. 8.3)  
National Academy of Sciences (NAS, including Compton committee reports), 112, 129, 136-138, 140, 142, 168, 208, 347, 408, 448  
National Advisory Council on Aeronautics (NACA), 129  
National Archives and Records Administration (NARA), x-xi  
National Bureau of Standards (NBS), 124, 126, 130, 134, 178-179, 215, 283, 448  
National Carbon Co., 178  
National Defense Research Committee (NDRC),  
    absorbs Briggs Uranium Committee, 129, 138, 448  
    and Naval Research laboratory liquid thermal diffusion research, 216  
    Compton proposes to take more active role in Project, 131  
    establishment of 42, 128-129  
    Explosives Division, 308  
    initial funding of Project, 129-130, 134  
    London office, 137  
    sidelining of Lyman Briggs, 143-145  
    succeeded by OSRD, 129, 136  
National Nuclear Security Administration (NNSA), 435  
National Park Service, 253, 342  
National Register of Historic Places, 253

National Research Council (NRC), 127, 128, 448  
National Research Council of Canada, 171  
National Science Foundation (NSF), 438  
*Nature*, 54, 57, 60, 80, 85  
*Naturwissenschaften*, 77, 79, 98  
Naval Boiler and Turbine Laboratory, 218  
Naval Research Laboratory (NRL), 120, 125  
    liquid thermal diffusion research, 120, 138, 212-222  
Neddermeyer, Seth, 282 (Fig. 7.9), 283, 307-308, 311, 315  
Nelson, Donald, 165  
Nelson, Richard, 362 (Fig. 8.1), 387  
neptunium, 61, 110-111, 212  
New START Treaty, 436  
*New York Times* (see also Laurence, William)  
    announces discovery of fission, 83  
    description of Indianapolis disaster, 350  
    description of *Trinity* test, 335  
    quotes Chadwick on uselessness of neutrons, 54  
    report on General Cartwright and nuclear deterrence, 437  
    report on Nier/Columbia isotope and fast/slow neutron work, 102  
neutron(s),  
    as links in chain reaction, 2  
    cross-section graphs for uranium and plutonium bombardment, 94-95  
    cross-sections for fast and slow uranium bombardment, 96-97  
    energy release in odd/even isotope capture of, 85-89  
    discovery of, 50-56  
    excess, 32  
    fast and slow (thermal), 63  
    mass of, 66  
    party animal analogy in isotope parity, 88  
    reaction channels in Fermi bombardment experiments, 60  
New War Building, 164  
*Newseum*, vii  
Nichols, Col. Kenneth D., 124 (Fig. 4.3), 155 (Fig. 4.12)  
    and acquisition of Oak Ridge silver, 198  
    and Manhattan Project Atomic Bomb Investigating Group, 405  
    asks Compton to poll attitudes on use of bomb, 381-382  
    early involvement with project and as Manhattan District Engineer, 155-167, 175, 220, 222, 230, 305  
    opinion of Groves, 165  
    reports to Groves on K-25 progress, 211-212  
Nicholson, John, 35  
Nier, Alfred Otto Carl, 100 (Fig. 3.16)  
    discovery of U-234 and separation of uranium isotopes for investigation of fast/slow neutron fissility, 101-102  
    mass spectrometers for K-25 program, 211

Niigata, 351, 367-368, 383  
Nimitz, Adm. Chester, 298, 351  
Nix, Foster, 207-208  
NPT (Treaty on the Non-Proliferation of Nuclear Weapons), 433-434, 448  
Noddack, Ida, 61-62  
Non-Nuclear Weapons States (NNWS), 434  
Norris, Edward, 207-208  
Norstad, Gen. Lauris, 364, 366  
nuclear parity (proton and neutron numbers), 85-92, 102, 109, 449  
Nuclear Posture Review, 222  
Nuclear Regulatory Commission, 347, 419, 441, 448  
Nuclear Weapons States (NWS), 433  
nucleon(s), 26  
    conservation of number of, 37  
nucleus, compound, 91  
    discovery of (Rutherford, Geiger, Marsden), 32-35  
nuclide (isotope), 26, 448

Oak Ridge, 136, 148, 156, 160 (Fig. 4.14), 177 (Fig. 5.1)  
    growth of population and housing, 176-177  
    operation of, 177-178  
    transition to municipal operation, 223-224  
Oak Ridge National Laboratory, 223  
Office of Naval Research, 438  
Office of Scientific Research and Development (OSRD), 129, 130, 136-137, 140, 143, 146, 154, 157-158, 161-162, 171-172, 216, 258, 265, 448, 449, 450, 451  
Office of War Mobilization, 372  
O’Keefe, Bernard, 396-397  
Okinawa, 364, 387, 400-401  
O’Leary, Jean, 338  
Olivi, Fred, 387, 398 (Fig. 8.13), 401  
“*On the construction of a super bomb ...*” (Frisch-Peierls memorandum), 104  
O’Neill, John, 102  
Oppenheimer, Frank, 195 (Fig. 5.16), 323, 334  
Oppenheimer, Katherine, 269  
Oppenheimer, J. Robert, viii, 10, 14, 50 (Fig. 2.19), 87, 124 (Fig. 4.3), 155 (Fig. 4.12), 250, 257, 341 (Fig. 7.36)  
    advocates full-scale test of implosion bomb, 319-320  
    advocates weekly technical colloquium at Los Alamos, 268  
    and Acheson-Lilienthal report, 420-422  
    and “Christy core”, 319  
    and Compton National Academy of Sciences Committee, 140, 148  
    and “incompressibility of water”, 313  
    and laboratory reorganization resulting from spontaneous fission crisis, 305-306  
    and liquid thermal diffusion program, 219-220  
    and plutonium light-element impurity issue, 168, 286

- and polonium production for neutron initiators, 287
- and Serber introductory lectures at Los Alamos, 265-266
- and Target Committee meeting of May 10-11, 1945, 366
- appointed Director of Los Alamos, 257-258, 260-262, 264
- appointed to Interim Committee Scientific Panel, 375-376
- appoints Cowpuncher Committee, 324
- as first Chair of General Advisory Committee of AEC, 419
- assigns Seth Neddermeyer to implosion research, 283, 308
- Berkeley conference (summer 1942) 157
- heads fast-neutron research, 153
- informed of Hiroshima bombing by Groves, 394
- invites Segrè to Los Alamos, 304
- opposes hydrogen bomb, 423-424
- personality and managerial style, 262
- predicts work of few men needed to solve theoretical problems of bomb, 157
- proposes use of composite cores, 339
- reaction to Hiroshima bombing, 394-395
- reaction to *Trinity* test (“the physicists have known sin”), 334
- recruitment of scientists to Los Alamos, 262-263
- recruits George Kistiakowsky, 308
- replaces Teller in theoretical Division, 307
- resignation from Los Alamos, 412, 417
- selection of *Trinity* name and site, 320
- supports May-Johnson bill, 418
- witnesses *Trinity* test, 323, 329-334

Operation Olympic, 364

Ordnance and Engineering Division (Los Alamos), 219, 263-267, 283, 293, 299, 301, 306-308

Osaka, 364

Ota River (Hiroshima), 383, 384

Oxford, University of, 104, 107, 206

overpressure, 344, 449

P5 countries, 427-434

Pacific District Real Estate Branch (Corps of Engineers), 233

Pajarito Canyon, 304

Pakistan, 427, 429-432, 434, 435

paraffin,

- as neutron moderator in discovery of plutonium, 111-112
- effect on fission rate in neutron-bombarded uranium, 83
- increases neutron activation in Fermi’s bombardment experiments, 62-63
- role in neutron discovery, 51-54

parity, nuclear, 3.2, 3.3, 109, 449

Parsons, Cdr. William S., 219, 264, 267, 293-295, 297, 307-308, 324, 362, 368, 383, 385-388, 390-391, 396

Pasco (Washington state), 167, 236, 393

Patterson, Robert, 231

Patton, Gen. George, 320  
Pegram, George, 120, 124, 125, 127, 129-131, 135, 137  
Peierls, Rudolf (*see also* Frisch-Peierls Memorandum), 99-100, 102-108, 126, 130, 137, 208, 274, 279-280, 307, 382, 445  
periodic table, 26-27, 30, 35, 39-40, 61, 71, 73, 74 (Fig. 3.2), 76-77, 91, 93  
Perrin, Francis, 98, 100, 105  
Phelps Dodge Copper Products Co., 199  
Philadelphia Naval Yard, 218-219  
*Physical Review*, 83, 85, 90, 101, 108-110, 303  
pile program (*see also* CP-1, Hanford, and X-10), 4, 9, 154, 158, 162  
    and spontaneous fission crisis discovery, 304-305  
    Compton's proposal to Groves (October 1942), 166  
    development and operation assigned to DuPont, 167-168  
    plutonium production rate, 229  
    polonium production rate, 287  
    program rescued and centralized under Arthur Compton, 146-150  
    radioactivity produced by Hanford reactors, 229  
    recommendations by Military Policy Committee, 170  
    research at Columbia, 147  
    studied by Lewis review committee, 169  
pitchblende, 19-20  
Placzek, George, 80  
Planning Board (Los Alamos), 264-265, 283, 449  
Planning Board (OSRD, fall 1941), 144, 146, 151-152, 154, 157, 172  
plutonium (*see also* Hanford and X-10), viii, 5-6, 9-10, 27  
    alpha-decay rate, 23  
    breeding of from uranium-238, 61, 94, 111  
    bomb design differs from uranium bomb, 11-12  
    critical mass of, 278  
    discovery and fissility of, 108-112  
    fission barrier and  $Q$ -value of, 91-95  
    mass of in *Trinity* and *Fat Man* bombs, 290, 338  
    production at Hanford, 251  
    produced by X-10 pile, 189 (Fig. 5.9)  
    properties of, 112-113  
    spontaneous fission of 240 isotope, 289-292  
    United States production of to 1994, 253  
polonium,  
    as source of alpha particles in discovery of neutron, 51-52  
    as source of alpha particles in discovery of artificial radioactivity, 56  
    breeding via bismuth bombardment, 135-136, 250  
    discovery of, 19-20  
    neutron yield when mixed with beryllium, 285  
    use in bomb initiators, 287-288, 302 (Fi. 7.18), 310 (Fig. 7.21)  
polytetrafluorethane (PTFE; teflon), 208  
positron( $\beta^+$  particle), 37, 40, 56, 76, 442, 449

Potsdam (including Potsdam Conference and Declaration), 327, 338, 348, 350-352, 368, 380, 393, 402, 403, 404, 409

power (unit), 24-25

    Rutherford's "moonshine" opinion on nuclear energy as source of, 55-56

predetonation,

    caused by light-element impurity ( $\alpha, n$ ) reactions, 168, 285-289

    caused by spontaneous fissions, 289-292, 304

    reorganization of Los Alamos in response to, 303-307

Princeton University, 80-82, 89, 90, 108, 120, 126, 130, 137, 148, 149, 153, 208, 307, 370, 409-410

*Proceedings of the Royal Society of London*, 54

Program Chiefs (November 1941), 146, 152-153, 157, 206

*Proposed Program for Japan* (Stimson), 380

*Prospectus on Nucleonics* (Jeffries Report), 369-370

protactinium, 72-73

proton(s), 3n, 15

    in nuclei of atoms (Rutherford scattering), 32-35

    mass of, 66

    name coined by Rutherford, 35

    number of as atomic number  $Z$ , 26

    protyle terminology, 27

Prout, William, 27, 30

PTFE (teflon), 208

Purnell, Rear Adm. William (Military Policy Committee), 166, 216-217, 219 (Fig. 5.28), 396

Q-value (definition), 38

Quebec Agreement, 273-274, 372

Queen Marys, 237, 251, 449

R (Research) Division (Los Alamos), 307

Rabi, I. I., 262-264, 330, 333, 424

radiation compression (fusion bomb), 425

Radiation Effects Research Foundation, 408

Radiation Laboratory (University of California; "Rad Lab"), 49, 83, 109, 196, 258

radioactivity,

    artificial, 2, 56-57

    alpha and beta decay schemes, 39-41

    half-life, 22-23

    natural decay discovered to be associated with, 21

    discovery of, 17-18

    neutron-induced, 57-65

    term coined by Curies, 20

radiolanthanum (RaLa), 315, 449

radium,

    as standard of decay rate, 22-23

    -C (bismuth-214 in Rutherford transmutation experiment), 43-45



- decay of and use in neutron-generating sources, 39, 59, 179, 285
- discovery of, 19-20
- energy released in decay of, 25-26
- suspected as product of uranium bombardment, 77

radon, 23, 32, 33, 41, 42, 59, 63, 72

Ramsey, Norman, 293-295, 362, 368, 385, 396

range, alpha-particle, 285-286

Rasetti, Franco, 58

RDS-1 (Joe 1), 423

reactor – *see* pile

reproduction factor ( $k$ ), 147, 179, 180, 184-186, 235, 249, 450

rem (unit of radiation exposure), 184, 345-347

resonance capture lines, 64, 85-86, 93-95

Reybold, Lt. Gen. Eugene, 156

Rhodes, Richard, viii, ix, 219, 425

Richland (Washington), 231, 235, 236, 393

Roane-Anderson Co., 177-178

Roberts, Richard, 83, 124

Robins, Maj. Gen. Thomas, 156, 161

Robotti, Nadia, 58, 60

Rodden, Clement, 178

Rome, University of, 57

Röntgen, Wilhelm Conrad, 17, 21

Roosevelt, Franklin,

- cited in Truman statement on bomb, 392
- death of, 372
- Einstein letters to, 121-123, 126
- establishes Advisory Committee on Uranium (Briggs Committee), 124, 129
- establishes National Defense Research Committee (NDRC), 128-129
- establishes Office of Scientific Research and Development (OSRD), 136
- establishes Top Policy Group, 139
- excludes Navy from project, 216
- hides Manhattan Project budget, 160
- letter to Oppenheimer re secrecy, 268
- relations with British and Quebec Agreement, 272-274
- reports of Briggs committee, 125-126
- Vannevar Bush's reports to: November 1941: 142-144; March 1942: 150, 151; June 1942: 155, 206; December 1942: 170-172

Rosenfeld, Léon, 80, 82, 83

Royall, Kenneth, 417-418

Royds, Thomas, 32-33

Russ, Harlow, 386

Rutherford, Ernest,

- and development of Geiger counter, 36
- arrival at Cambridge (1895), 20
- coins "proton," 35

- death of, 44, 76
- discovery of alpha and beta rays, 21
- discovery of artificial transmutation, 42-44
- discovery of half-life, 21
- energy of radioactive decay, 25-26
- identification of alpha particles as helium nuclei, 33
- move to Manchester University (1907), 32
- move to McGill University (1898), 21
- return to Cambridge University (1919), 44
- scattering of alpha particles and discovery of nuclei, 33-35
- speculation on atomic energy as “moonshine” (1933), 55
- thorium emanation, 21, 23, 41

rutherfordium, 76

S-1 Executive Committee, 157, 162, 172, 179, 206, 216, 217, 450

S-1 Section and Committee (of OSRD), 137, 138, 140, 145, 146, 149, 151, 153, 157, 158, 216, 218, 450

S-50 (*see also* diffusion, liquid thermal), 6, 8-9, 160 (Fig. 4.14), 175, 202, 207, 212, 212-222  
demolition of, 223

S-10,000 shelter (*Trinity* test), 329, 330

Sachs, Alexander, 121, 123-127, 129, 130, 137

“Salient Points Concerning Future International Handling of Atomic Bombs” (Bush & Conant), 371

Special Alloy Materials (SAM) Laboratory, 206

Savitch, Paul, 75-77

Schmidt, Gerhard, 19

Scientific Panel,

- Acheson Committee, 420-421, 450
- Interim Committee, 375-379, 382, 411, 450

Seaborg, Glenn T., 50 (Fig. 2.19), 110, 140, 213, 264  
and Franck Report, 377  
concern with light-element impurities in plutonium, 168  
concern with Pu-240 spontaneous fission, 304  
Crossroads Baker as “world’s first nuclear disaster”, 423  
discovery of neptunium and plutonium, 110-113, 132  
expects to have plutonium ready for a bomb in six months, 147

Segrè, Emilio, 57, 58  
and discovery of plutonium, 109-110, 132  
and spontaneous fission research at Los Alamos, 303-305  
reaction to *Trinity* test, 334-334

Sengier, Edgar, 165

Serber, Charlotte, 265

Serber, Robert, 104, 105, 141, 157, 158 (Fig. 4.13), 264-266, 268, 281- 284, 294, 301, 303, 304, 315, 323, 368, 399-400, 405, 407

Shasta Dam, 231

Sherwin, Martin, 260, 369

shim rods, 187, 245  
Shumard, Robert, 362 (Fig. 8.1), 387  
*Silverplate*, 294, 297, 298  
Sime, Ruth, 71  
Simon, Walter (“Rome wasn’t built in a day, but DuPont didn’t have that job.”), 236  
Simon, Franz, 107, 206, 208  
Skidmore, Owings, and Merrill, 176, 177  
Sklodowski, Marie – *see* Curie, Marie  
Slater, John, 131  
Sloan, David, 48  
Slotin, Louis, 317  
slugs, reactor fuel,

- dimensions and numbers of Hanford slugs, 242-243
- dimensions of CP-1 slugs, 181
- dimensions of X-10 slugs, 186
- production of at Hanford, 244

Smith, Cyril, 288-289, 324, 395  
Smyth, Henry D. (and Smyth Report), viii, 137, 145-147, 157, 205, 207, 258, 370, 409, 410, 450  
Socorro (New Mexico), 320, 325, 342  
Soddy, Francis,

- and energy of radioactive decay, 25-26
- and isotopes, 27
- and thorium emanation, 23

Somervell, Lt. Gen. Brehon, 151, 155, 156, 163-164, 166  
Spatz, Gen. Carl, 350, 351, 383, 390, 391  
Special Engineer Detachment (SED), 269, 270-271, 450  
Spedding, Frank, 178  
Speer Carbon Co., 178  
Spitzer, Abe, 387, 398, (Fig. 8.13), 400-401  
spontaneous fission, 303-307  
Stalin, Joseph, 327, 338, 339, 352  
Standard Oil Co., 134, 217  
Standard Oil Development Company (SODC), 130, 144, 450  
Standards, National Bureau of (NBS), 124, 126, 130, 134, 178-179, 215, 283, 448  
Stanford Linear Accelerator, 48  
*Starfish Prime*, 429  
Stiborik, Joseph, 362 (Fig. 8.1), 387  
Stine, Charles, 167  
Stone and Webster Construction Co., 158, 159, 161, 162, 165-167, 176, 194, 199  
Strassmann, Fritz, 50, 72, 73 (Fig. 3.1), 75-77, 79, 80, 82-86, 109, 437  
Strategic Arms Reduction Treaty (START I, II), 434-435; *see also* New START  
Strategic Offensive Reduction Treaty (SORT), 435  
Styer, Gen. Wilhelm D., 151, 152, 154-158, 163-166  
Submarine Launched Ballistic Missile (SLBM), 431 (Tab. 9.2), 432, 434, 436, 450  
supercriticality, 277, 290-292, 316  
Suzuki, Prime Minister Kantaro, 348

Sweeney, Charles, 387, 397-402

Szilard, Leo, 82 (Fig. 3.5)

- and advisory group to Uranium Committee, 130
- and Einstein letter, 121
- and Franck Report, 377
- and Uranium Committee initial meeting, 124
- calculations regarding chain-reacting pile, 125, 126
- conceives chain reaction, 55-56
- frustration with bureaucratic foot-dragging, 125, 154
- letter to President Roosevelt (March 1945), 380
- measurement of neutrons liberated in fission (Szilard & Zinn), 85
- meeting with James Byrnes, 381
- neutron/graphite diffusion experiments (Columbia), 147
- petition to President Truman, 381-382

tamper, 11, 98, 105, 141, 266, 277-278, 281-283, 294, 300, 306, 410, 451

- in criticality experiments, 317
- materials considered for, 301
  - Fat Man*, 310-311, 354 (Prob. 7.6)
  - Little Boy*, 301
  - Trinity*, 326

Target Committee, 366-368, 375, 381, 451

Taylor, Geoffrey, 311

Taylor, Hugh, 208

Technical and Scheduling Conference (TSC, Los Alamos), 307, 319

Technical Area (Los Alamos), 260, 261 (Fig. 7.2)

Technical Board (Los Alamos), 264, 306

Technical Council (Metallurgical Laboratory), 233

teflon, 208

Teller, Edward, 83, 121, 124, 157, 158 (Fig. 4.13), 307, 323, 330, 423, 426-427

tellurium, 83, 248

Tennessee Eastman Corp., 162, 194-195, 199

Tennessee Valley Authority (TVA), 159, 161, 164, 209, 420, 451

terminal observations, 314

tetrachloride, uranium, 194, 201, 202

Thayer, Harry, 241

Thomas, Charles, 288, 305, 420

Thompson, William I., 217

Thomson, George P. (*see also* MAUD committee and report), 106, 107, 137

Thomson, J. J., 20-21, 27-28, 33-34, 40, 44

thorium, 3, 31, 73, 92, 111, 421

- as possible product neutron bombardment of uranium (Curie & Savitch), 75-76
- as starting point in natural decay schemes, 41
- discovered to be radioactive, 19
- emanation (Rutherford and Soddy), 21, 23
- fission characteristics, 80, 83, 85-86

Tibbets, Col. Paul, 296 (Fig. 7.15), 297, 361-363, 368, 383, 385-390

Tinian island, 219 (Fig. 5.28), 297, 299, 350

- 509<sup>th</sup> Composite Group crews begin arriving, 363, 368
- Bockscar* takeoff from, 397
- bomb component and test bomb deliveries to, 348-350, 368
- chosen for 509<sup>th</sup> Composite Group base, 2989
- distance to Tokyo, 300, 399 (Fig. 8.14)
- Enola Gay* takeoff from, 386
- return of *Bockscar* to, 402
- return of *Enola Gay* to, 390
- time difference from Tokyo, Potsdam, and Washington, 348, 385-387

Titterton, Ernest, 274

Tizard, Sir Henry, 106, 108, 136

TNX Division (DuPont), 168, 242

Tolman, Richard, 129, 172, 219, 220, 266, 283, 370, 372, 409

Top Policy Group (October, 1941), 139, 142, 150, 170, 451

transuranic elements,

- as possible bomb material, 135
- discovery of neptunium and plutonium, 109-112
- Fermi suspects that he is producing (Summer-Fall 1934), 60-61, 72
- Glenn Seaborg and, 147
- Hahn, Meitner, and Strassmann research, 72-76, 79
- Louis Turner speculation on, 108-109

transmutation, artificial,

- Rutherford's discovery of, 42-44

Treaty on the Non-Proliferation of Nuclear Weapons (NPT), 433-434, 448

Treasury, United States, 197-199, 222

troy ounce, 198

*Trinity* test, 10, 12, 50, 137, 253, 264, 265, 270, 288, 301, 307

- 100-ton TNT test, 324
- arming party, 329
- Base camp, 322 (Fig. 7.28), 323, 330-333
- binary explosive implosion design, 309-310
- brightness of, 337
- Christy core, 311, 319, 339
- countdown, 330
- estimated number of witnesses, 323
- estimated radioactivity generated by, 336
- estimated yield, 337, 339
- eyewitness descriptions of, 331-335
- fallout from, 340-341
- final assembly, 328
- fireball, 335-336
- Jumbo program, 324-325
- monitoring instruments, 325-326
- plutonium used in, 290, 338

- schedule for preparation of bomb components, 326
- shelters, 323
- site selection and preparation, 320-323
- Trinitite*, 338
- weather considerations, 327-330

tritium, 252-253, 425-426

Truman, Harry S.,

- announces Russian bomb test (1949), 423
- and deletion of Kyoto from target list, 368
- and Japanese surrender negotiations, 403-405
- and postwar international control of nuclear energy (Acheson-Lilienthal report), 420, 422
- and Royall-Marbury bill, 418
- announces Russian declaration of war against Japan, 395
- approves Groves/Handy orders, 350, 383
- approves Stimson press releases, 352
- at Potsdam conference, 327, 338-339
- authorizes hydrogen bomb research, 424
- authorizes Smyth Report release, 409
- becomes President, 372
- briefed by Stimson and Groves on project, 373-374, 411
- briefed on Interim Committee deliberations, 377
- “decision” to use bomb, 339, 350-352, 383, 395
- establishes Atomic Bomb Casualty Commission, 408
- informed by Stimson and Byrnes of bomb project, 372
- informed of Hiroshima bombing, 393-394
- informed of *Trinity* test, 338, 351-352
- signs McMahon bill, 419
- statement on Hiroshima bombing, 391-394

*Tsar Bomba*, 426

Tsuchizaki (Japan), 404

tubealloy, 145

Tuck, James, 309

Turner Construction Co., 177

Turner, Louis, 89, 108-119, 130

Tuve, Merle, 124, 129-131, 137, 138, 212, 214, 215

Twenty-First Bomber Command, 363, 366, 383

Twining, Lt. Gen. Nathan, 383, 391

  

UF<sub>6</sub> (uranium hexafluoride, “hex”), 8, 9 (Fig. 1.3), 65, 202 205-207, 211, 214 (Fig. 5.27), 215, 218, 445

underwater canning, 244

Union Carbide and Carbon Co., 159, 209

United Nations Atomic Energy Commission (UNAEC), 420, 422

United States Metals Refining Co., 199

United States Strategic Bombing Survey (USSBS), vii, 385 (Fig. 8.6), 405, 451

Union-Minière du Haut-Katanga, 123, 165

uranium,

- alpha decay of, 39, 41
  - Bohr and Bohr-Wheeler analysis of fission process, 81, 85-95
  - concept of chain reaction with, 4-5
  - Coulomb barrier of, 46
  - critical mass of 235 isotope, 278
  - discovery of 234 isotope, 101
  - discovery of 235 isotope, 65
  - discovery and verification of neutron-induced fission, 2, 71-85
  - discovery of radioactivity, 17-18
  - energy release in fission, 72, 78
  - fast and slow neutron cross-sections, 96-97
  - Fermi neutron bombardment experiments, 60-63
  - fission products of, 72, 84
  - hexafluoride ( $\text{UF}_6$ ), 8, 9 (Fig. 1.3), 65, 202 205-207, 211, 214 (Fig. 5.27), 215, 218, 445
  - isotopes of, 3, 27, 65, 101
  - neutron-bombardment cross-section graphs, 94-95
  - secondary neutrons emitted in fission of, 84-85
  - world stockpiles of highly-enriched, 432
- Uranium Committee (Advisory Committee on Uranium; *see also* National Defense Research Committee and Office of Scientific Research and Development),
- absorbed into NDRC, 128-129
  - April, 27, 1940 meeting, 126
  - described as like “swimming in syrup” (Wigner), 131
  - established, 124
  - November 1, 1939, report to President Roosevelt, 125
  - October 21, 1939 meeting, 124
- Urchin, 287-288
- Urey, Harold,
- and Compton committee, 131, 140
  - and James Byrnes, 381
  - and liquid thermal diffusion research, 213, 216-218
  - as Program Chief for isotope separation by diffusion and centrifugation, 146, 148
  - appointed to Uranium Committee Science Advisory Sub-Committee, 124-125
  - appointed to NDRC Committee on Uranium, 129-130, 137
  - appointed to S-1 Executive Committee, 157-158
  - frustrated with pace of project, 131, 145
  - gaseous diffusion research, 168, 206
- van Keuren, Adm. Alexander, 216-218
- van Kirk, Theodore, 362-363, 387, 389
- van Pelt, James, 387, 398 (Fig. 8.13)
- van Vleck, John, 131, 266
- vertical safety rods (VSRs, Hanford), 246
- Villard, Paul, 18
- Vogel, Peter, 213

von Grosse, Aristide, 101  
von Halban, Hans, 85, 106  
von Neumann, John, 308, 309, 365  
von Weizäcker (Carl Friedrich), 122

W-47, 296  
Wahl, Arthur, 111-112  
Wallace, Henry, 139, 148, 150, 154, 258, 404  
War Production Board, 165  
Warren, Stafford, 265, 407  
Washington Navy Yard, 300  
Washington, University of, 245  
Watson, Gen. Edwin M., 123, 125-127  
Wattenberg, Albert, 82 (Fig. 3.5), 180  
Weil, George, 182  
Weisskopf, Victor,  
    opinion of Oppenheimer, 262  
Wendover Army Air Field, 293 (Fig. 7.14), 295-297, 363, 368  
West Point Bullion Depository, 199  
Westinghouse Electric Corp., 135, 137, 162, 170, 178, 197, 264  
wet criticality, 247  
Wheeler, John,  
    and extra fuel channels in Hanford piles, 242  
    and Hanford xenon poisoning crisis, 248-249  
    Bohr-Wheeler fission theory, 90-93, 106  
    pile design work, 233-234  
White Bluffs (Washington), 231  
White Sands Missile Range, 341-342  
Wickward, Claude, 259  
Wideröe, Rolf, 47-49  
Wigner disease, 250  
Wigner, Eugene,  
    and CP-1 startup, 183, 184  
    and Einstein/Roosevelt letter, 120-121  
    and production-pile research, 234-235, 241-242, 249-250  
    and Uranium Committee, 124, 130, 140  
    view of Briggs Committee as “like swimming in syrup”, 131  
Williams, Roger, 168, 251  
Wilson, E. Bright, 266  
Wilson, Robert, 264, 271, 307, 323, 365  
Winne, Harry, 420  
Women’s Army Corps, 269

X-10 pile, 9, 136, 148, 158, 160 (Fig. 4.14), 175, 451  
    control rods, 187  
    construction and first criticality, 188



- DuPont contracts to design and construct, 170
- operating power increases, 188-189
- plutonium delivered to Los Alamos, 305
- plutonium production, 189 (Fig. 5.9)
- polonium production, 287
- postwar use, 222-223
- radiolanthanum production, 189, 315
- specifications, 186-187
- X-Division (Los Alamos) 306-307, 312
- X-unit, 298
- XAX, 197
- XBX, 197
- X-rays, 212, 239, 244
  - discovery of, 17, 21
  - in boosted and fusion weapons, 425
  - in implosion diagnostics, 314
  - released in bomb detonation, 335
- xenon poisoning, 242, 247-250, 451
  
- Y, Project (Los Alamos), 258
- Y-12 (electromagnetic project), 6-8, 160 (Fig. 4.14), 175, 190-203
  - Alpha and Beta calutrons, 193-197
  - cost, 190
  - electricity use, 203
  - number of employees, 190
  - partial layout diagram, 191
  - postwar evolution of, 222-223
  - silver bullion used at, 197-199
  - startup difficulties, 201
  - uranium production, 201-203
- Yakushima (Japan), 398
- Yamaguchi, Tsutomu, 402
- Yawata (Japan), 366, 400
- yield,
  - bomb, 141, 154, 169, 280, 311, 319, 343-347, 374, 377
    - and detonation height, 366-367
    - effect of predetonation on, 290-292
    - Frisch-Peierls formula, 105, 280
  - Fat Man*, 387 (Tab. 8.3), 408
  - Little Boy*, 348, 387 (Tab. 8.3), 408
  - Trinity* test, 324, 330, 339
  - enhanced by tamper, 98
  - (n, gamma) of <sup>239</sup>94 (Seaborg), 304
  - of Chadwick and Fermi neutron sources, 57, 59-60
  - of chemical bombs compared to nuclear, 97
  - of current United States weapons, 432

of fusion bombs, 253, 425-428  
of nuclear reactions ( $\gamma$ ), 285-286  
of polonium-beryllium neutron initiators, 287  
uranium thermal-neutron products, 84  
Yokohama (Japan), 366-368  
yttrium, 76

Z (atomic number), 3n, 26  
Zinn, Walter, 82 (Fig. 3.5), 85, 180, 183, 234  
zip rods (CP-1), 182-183