HW-66666 (Rev. 2)

REVIEW OF POWER AND HEAT REACTOR DESIGNS

Domestic and Foreign

By
E. R. Appleby

October 1963

Hanford Atomic Products Operation
General Electric Company
Richland, Washington

UNITED STATES ATOMIC ENERGY COMMISSION • DIVISION OF TECHNICAL INFORMATION

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REVIEW
OF
POWER AND HEAT REACTOR DESIGNS

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Compiled by

E. R. Appleby

Technical Information
Finance and Administration Operation

Hanford Laboratories

October 1963

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

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Atomic Energy Commission and General Electric Company

NOTE: THIS DOCUMENT IS THREE-HOLE PUNCHED SO THAT IT MAY BE PLACED IN A RING BINDER.

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INTRODUCTION

The Review of Power and Heat Reactor Designs (Revision 2) is a bibliography of unclassified information taken from foreign and domestic literature for the period January 1952 through September 1963. Chemo-nuclear and test reactors having characteristics similar to power reactors are included. Reactor design characteristics and current information taken from news releases on the status of the individual designs are given. The volume is divided into sections according to reactor type. Within each section the designs appear alphabetically by designer (domestic) or by country of origin (foreign). A glossary and address list for designers and/or operators and a subject index are provided.

GLOSSARY AND ADDRESSES

Abbreviations given in the glossary are used throughout the text to identify the designer and/or the country.

GLOSSARY AND ADDRESSES

DOMESTIC

AC	Allis-Chalmers Manufacturing Co. Atomic Energy Division Milwaukee 1, Wisconsin
ACF	ACF Industries Nuclear Products - Erco Division 508 Kennedy St. NW Washington 11, D.C. Division was acquired by Allis-Chalmers in 1959
AEC	U.S. Atomic Energy Commission Washington 25, D.C.
AGN	Aerojet-General Nucleonics Subsidiary of Aerojet-General Corporation P.O. Box 78 San Ramon, Calif.
AI	Atomics International Div. North American Aviation Inc. 8900 De Soto Ave. Canoga Park, Calif. Affiliated with Interatom, Danatom
AIRESEARCH	AiResearch Manufacturing Co. Div. Garrett Corp. 402 S. 36th St. Phoenix, Arizona
ALCO	Alco Products Inc. Nuclear Projects Dept. 220 Schenectady, N.Y.

AMES	Ames Institute for Atomic Research Iowa State University Ames, Iowa
AMF	AMF Atomics Div. American Machine & Foundry Co. 140 Greenwich Ave. Greenwich, Conn.
AMSTAN	American Standard Corp. Div. American Radiator and Standard Sanitary Corp. 1682 Broadway Redwood City, Calif. Advanced Technology Laboratories 369 Whisman Road Mountain View, Calif.
ANL	Argonne National Laboratory 9700 South Cass Ave. Argonne, Illinois
APDA	Atomic Power Development Associates, Inc. 1911 First Street Detroit 26, Michigan Utilities Group
ARDA	Advanced Reactor Development Associates Utilities Group Public Service Company of Colorado Denver, Colorado
ARMOUR	Armour Research Foundation Illinois Institute of Technology 10 W. 35th Street Chicago 6, Illinois
BAR	Burns and Row, Inc. 160 West Broadway New York 13, N.Y.
BAW	Babcock and Wilcox Atomic Energy Division P.O. Box 1260 Lynchburg, Virginia

BNL	Brookhaven National Laboratory Upton, Long Island, N.Y.
CALRD	California Research and Development Co. Livermore Research Laboratory Livermore, Calif.
CE	Combustion Engineering, Inc. Prospect Hill Road Windsor, Conn. Acquired General Nuclear Engineering
COM/ED	Commonwealth Edison Company Chicago, Ill.
CON/ED	Consolidated Edison Company of New York, Inc. New York, N.Y.
DANIELS	(Farrington Daniels)
DETROIT/ED	Detroit Edison Co. Detroit, Michigan
DOW	Dow Chemical Co. Midland, Michigan
DUPONT	E. I. duPont de Nemours and Co., Inc. Wilmington 98, Del.
ECFWCNG	East Central Florida West Coast Nuclear Group Florida West Coast Group 101 South 5th Street St. Petersburg, Florida
FAIRCHILD	Fairchild Engine and Airplane Corp. NEPA Division Oak Ridge, Tennessee

FICO	Ford Instrument Company Division Sperry Rand Corp. 31-10 Thomson Ave. Long Island City 1, N.Y.
FLUOR	Fluor Corporation Ltd. 1200 E. Washington Blvd. Whittier, Calif.
FW	Foster Wheeler Corp. 666 Fifth Ave. New York 19, N.Y.
GD	General Dynamics Corporation General Atomics Division San Diego, Calif.
GE	GENERAL ELECTRIC COMPANY Atomic Power Equipment Dept. 2151 First St. San Jose 12, Calif. Hanford Atomic Products Operation Richland, Washington Flight Propulsion Laboratory Dept. Nuclear Materials and Propulsion Operation Cincinnati, Ohio Knolls Atomic Power Laboratory P.O. Box 1072 Schenectady, N.Y. Special Purpose Nuclear Systems Operation Palo Alto, Calif.

GIC	General Instrument Corporation 65 Governeur Street Newark, N.J.
GILBERT	Gilbert Associates Inc. 525 Lancaster Ave. Reading, Penna.
GM	General Motors Corporation Allison Division Indianapolis 6, Indiana
GNEC	General Nuclear Engineering Corporation P.O. Box 245 Dunedin, Florida Now a division of Combustion Engineering
HERC	Hercules Powder Co. Delaware Trust Building Wilmington 99, Delaware
INTERNUC	Internuclear Co. 7 North Brentwood Blvd. Clayton 5, Missouri
KE	Kaiser Engineers Division Henry J. Kaiser Co. Kaiser Bldg. Oakland 12, Calif.
KIDDE	Walter Kidde Nuclear Laboratories Garden City, N.Y.
LADWP	Los Angeles Department of Water and Power Los Angeles, Calif.

LASL	Los Alamos Scientific Laboratory P. O. Box 1663 Los Alamos, N.M. Project Rover Los Alamos Scientific Laboratory 4375 Las Vegas Blvd. South Las Vegas, Nevada
LOCKHEED	Lockheed Missiles and Space Company Division of Lockheed Aircraft Corporation Sunnyvale, Calif.
MARQ	Marquardt Corporation Nuclear Systems Division 16555 Saticoy Street Van Nuys, California
MARTIN	Martin-Marietta Corporation Nuclear Division Baltimore, Maryland
MONSANTO	Monsanto Chemical Company 800 N. Lindbergh Blvd. St. Louis 66, Missouri
NASA	National Aeronautics and Space Administration 400 Maryland Ave. SW Washington, D.C.
NDA	Nuclear Development Corporation of America Eastview, Westchester County, N.Y. Member of United Nuclear Corporation White Plains, N.Y.
NPG	Nuclear Power Group Chicago, Illinois

NUTMEG*	Nutmeg Electric Companies Atomic Project Connecticut Utilities study group Hartford Electric Light United Illuminating Connecticut Light and Power
ORNL	Oak Ridge National Laboratory Oak Ridge, Tennessee
ORSORT	Oak Ridge School of Reactor Technology Oak Ridge, Tennessee
PGE	Pacific Gas & Electric Company San Francisco, Calif.
PHILLIPS	Phillips Petroleum Company Bartlesville, Oklahoma
PNPG	Pacific Northwest Power Group Richland, Washington
PRDC	Power Reactor Development Company 1911 First Street Detroit 26, Michigan Utilities Group
PWAC	Pratt and Whitney Aircraft Division of United Aircraft East Hartford, Connecticut
RRC	Royal Research Corporation Hayward, Calif.

* Plant proposed by the Nutmeg Electric Companies has been replaced by the CONNECTICUT YANKEE Project, sponsored by the 12-utility group Connecticut Yankee Atomic Power Company.

SAL	Sargent & Lundy 140 S. Dearborn Street Chicago 3, Illinois
SAP	Sanderson & Porter 72 Wall Street New York 5, N.Y.
STUD	Studebaker-Packard Corporation 635 S. Main Street South Bend 27, Indiana
TRG	Technical Research Group 17 Union Square West New York 3, N.Y.
THIOKOL	Thiokol Chemical Corporation Bristol, Penna.
USAF	United States Air Force Washington 25, D.C.
USBM	United States Bureau of Mines Washington 25, D.C.
WEST	Westinghouse Electric Corporation Bettis Atomic Power Laboratory P.O. Box 1468 Pittsburgh 30, Penna.
YAEC	Yankee Atomic Electric Company P.O. Box 346 Boston 16, Massachusetts

GLOSSARY AND ADDRESSES

FOREIGN

AUSTRALIA

AAEC	Australian Atomic Energy Commission 45 Beach Street Coogee New South Wales, Australia

AUSTRIA

	Osterreichische Beratende Regierungskommission fur Fragen der Atomenergie 3 Hohenstaufengasse Vienna 1, Austria

BELGIUM

ACEC	Ateliers de Constructions Electriques de Charleroi S.A. Atomic Energy Division Avenue E. Rousseau Charleroi, Belgium Associated companies: Westinghouse (U.S.) Framatome (France)
BELGONUC	Societé Belge pour l'Industrie Nucleaire S.A. (Belgonucleaire) 35 Rue des Colonies Brussels, Belgium
CEA	Commissariat a l'Energie Atomique 8 Rue de la Loi Brussels, Belgium
CEN	Centre d'Etude de l'Energie Nucleaire Brussels, Belgium

BRAZIL

CNEN	Comissao Nacional de Energia Nuclear Avenida Marechal Camara 360-6^{o} andar Rio de Janeiro, Brazil

CANADA

AECL	Atomic Energy of Canada, Ltd. P.O. Box 711 Ottawa, Ontario, Canada
GEC	Canadian General Electric Company, Ltd. 107 Park Street Peterborough, Ontario, Canada
WEST	Canadian Westinghouse International Company, Ltd. Box 510 Hamilton, Ontario, Canada

CZECHOSLOVAKIA

	Ministry of Power Nuclear Energy Administration Jungmannova 29 Prague 2, Czechoslovakia

DENMARK

DAEC	Danish Atomic Energy Commission Christiansborg Ridebane 10 Copenhagen K, Denmark
DANATOM	Danish Association for Industrial Development of Atomic Energy Strandvejen 102 Hellerup (near Copenhagen), Denmark

EAST GERMANY

	GERMAN DEMOCRATIC REPUBLIC (East Germany) AMT fur Kernforschun und Kerntechnik Schnellerstrasse 1-5 Berlin-Niederschonewiede German Democratic Republic

ENEA	EUROPEAN NUCLEAR ENERGY AGENCY
	O.E.E.C. 38 Boulevard Suchet Paris 16, France
EURATOM	EUROPEAN ATOMIC ENERGY COMMUNITY
	51-53 Rue Belliard Brussels, Belgium
FORMOSA	(Republic of China)
AEC	Atomic Energy Council 11 South Chung Shan Road Taipei, Formosa
FRANCE	
ATEN	Association Technique pour la Production et l'Utilization de l'Energie Nucleaire 4 Rue de Teheran Paris 8, France
BREVATOME	Brevatome 25 Rue de Ponthieu Paris 8, France
CEA	Commissariat à l'Energie Atomique 69 Rue de Varenne Paris 7, France
EDF	Electricité de France 2-4 Avenue de la Liberation B.P. 47 Clamart (Seine), France
FR-ATOM	France-Atome 6 et 8 Boulevard Haussman Paris 9, France

FRANCE (contd)

GAAA	Groupement Atomique Alsacienne Atlantique 100 Avenue Edouard Herriot Le Plessis Robinson (Seine), France
INDATOM	Indatom 48 Rue la Boetie Paris 8, France
SNECMA	Société Nationale d'Étude et de Construction de Moteurs d'Aviation Division Atomique 22 Quai Gallieni à Suresnes Paris 8, France Associate company: INDATOM

ISRAEL

IAEC	Israel Atomic Energy Commission P.O. Box 7056 Hayirya Tel-Aviv, Israel
ISRATOM	Israel Nuclear Engineering Co., Ltd. 6 Ahuzat Bayit St. Tel-Aviv, Israel

ITALY

AGIP	Agip Nucleare S.p.A Casella Postale 4179 Milan, Italy
CISE	Centro Informazioni Studi Experienze Via Redecesio 12 Segrate Milan, Italy
CNEN	National Committee for Nuclear Energy (Comitato Nazionale per l'Energia Nuclear) Via Belisario 15 Rome, Italy

ITALY (contd)

FIAT	Fiat S.p.A Sezione Energia Nucleare Corso Marconi 10/20 Turin, Italy
MONTECATINI	Montecatini Energy Dept. Nuclear Division Largo Guido - Donegani 1-2 Milan, Italy
SELNI	Societa Elettronucleare Italiana Foro Buonaparte 31 Milan, Italy
SENN	Societa Elettronucleare Nazionale Via Torino 6 Rome, Italy
SIMEA	Societa Italiana Meridionale Energia Atomica Via S Teresa 35 Rome Italy
SORIN	Societa Ricerche Impianti Nucleari Via Fatebenefratelli 19 Milan, Italy

JAPAN

AEC	Atomic Energy Commission of Japan 2-2 Kasumigaseki Chiyoda-ku Tokyo, Japan
FAPIG	First Atomic Power Industry Group Tokyo Boeki Kaikan Bldg. 2, 1-chome Ohtemachi Chiuoda-ku Tokyo, Japan

JAPAN (contd)

HITACHI	Hitachi Ltd. Atomic Energy Dept. 4, 1-chome Marunouchi Chiyoda-ku Tokyo, Japan
JAERI	Japan Atomic Energy Research Institute 1-1 Shiba Tamuracho Minato-ku Tokyo, Japan
JAORG	Japan Atomic Powered Ore Carrier Research Group Tokyo, Japan
MITSU	Mitsubishi Atomic Power Industries, Inc. Otemachi Bldg. Chiyoda-ku Tokyo, Japan
NAIG	Nippon Atomic Industry Group Co., Ltd. No. 4 Yurakucho 2-chome Chiyoda-ku Tokyo, Japan
SUMIMOTO	Sumimoto Atomic Energy Industries, Ltd. 5-22 Kitahama Higashi-ku Osaka, Japan

KOREA

OAE	Office of Atomic Energy Atomic Energy Commission 77 Sechong-ro Chongro-ku Seoul, Korea

NETHERLANDS

CAE	Nuclear Energy Commission (Commissie voor Atoom Energie) le van de Boschstraat The Hague, Netherlands
KEMA	Company for Testing Electrotech. Mat'ls Arnhem, Netherlands
NERATOOM	NERATOOM N.V. Noordeine 38 The Hague, Netherlands
RCN	Reactor Centrum Nederland Schevevingseweg 112 The Hague, Netherlands
SEP	Samenwerkende Electriciteits Productiebedrijven Utrechtseweg 310 Arnhem, Netherlands
SKK	Stichting Kernvoortstuwing Koopvaardijschepen (Foundation for Nuclear Propulsion of Merchant Ships) Nassaulaan 13 The Hague, Netherlands

NORWAY

	National Atomic Energy Council P.O. Box 175 Lillestrom, Norway
IFA	See KRE
JENER	Joint Establishment for Nuclear Energy Research P.O. Box 175 Lillestrom, Norway IFA (Institut for Atomenergi) and RCN (Reactor Centrum Nederland)

NORWAY (contd)

KRE	Kjeller Research Establishment (Institut for Atomenergi) IFE Kjeller (near Lillestrom), Norway
NORATOM	Noratom A/S Holmenveien 20 Vinderen Oslo, Norway
REDERIATOM	Rederiatom (Nuclear Research Group of Norwegian Shipowners) P.O. Box 175 Lillestrom, Norway

PERU

JCEA	Junta de Control de Energia Atomica Avenida Nicolas de Pierola 611 Apt. 914 Lima, Peru

POLAND

	Office of Government High Commissioner for Atomic Energy Palace of Culture and Science, 18th Floor Warsaw, Poland

SPAIN

JEN	Ministerio de Industria JUNTA DE ENERGIA NUCLEAR Serrano 121 Madrid, Spain
TECNATOM	Tecnatom S. A. Vallehermoso 30 Madrid, Spain

SPAIN (contd)

UEM	Union Electrica Madrilena S.A. Av. José Antonio 4 Madrid, Spain

SWEDEN

	Swedish Atomic Research Council Dobelnsgatan 64 Stockholm Va, Sweden
AB-ATOM	A. B. Atomenergi Lovholmsvagen 7 Stockholm 9, Sweden
ASEA	Allmanna Svenska Electriska A.B. Nuclear Power Department Vasteras, Sweden
KVS	Swedish State Power Board Nuclear Power Department Karduansmakargatan 8 Fack Stockholm 1, Sweden
GOTAVERK	Gotaverken AG Goteborg 8, Sweden (Swedish Shipbuilding Research Foundation)

SWITZERLAND

	Federal Commission for Atomic Energy Effingerstrasse 55 Bern, Switzerland
ATOMKRAFT	Atomelektra A.G. Force Atomique S.A. Privatbank & Verwaltungsgesellschaft Barengasse 29 Zurich 1, Switzerland

SWITZERLAND (contd)

BBC	Brown, Boveri, and Co. Ltd. Atomic Power Department Baden, Switzerland
ENUSA	Energie Nucleaire S. A. 10 Avenue de la Gare Lausanne, Switzerland
RAG	Reactor A. G. Wurenlingen/A. G. Switzerland
SNA	Societé Nationale pour l'Encouragement de la Technique Atomique Industrielle Members are ENUSA, THERMATON, and SUISATOM.
SUISATOM	Suisatom, S. A. Bahnhofplatz 3 Zurich 1, Switzerland
SULZER	Sulzer Brothers, Ltd. Winterthur Zurich, Switzerland
THERMATOM	Thermatom, S. A. Zurcher Strasse 9 Winterthur Zurich, Switzerland

UNITED KINGDOM

AEA	United Kingdom Atomic Energy Authority 11 Charles II Street London S. W. 1 England
AERE	Atomic Energy Research Establishment Harwell Didcot, Berkshire England

UNITED KINGDOM (contd)

AEI (See also NPG)	A.E.I. - John Thompson Nuclear Energy Co. Ltd. Radbroke Hall Knutsford, Cheshire England
APC	Atomic Power Construction, Ltd. 29 Theobald's Road London W.C. 1 England
BAW	Babcock and Wilcox Ltd Atomic Energy Department 209 Euston Road London N.W. 1 England
CEGB	Central Electricity Generating Board Bankside House Sumner Street London S.E. 1 England
DEHAV	De Havilland Engine Co. Ltd. Nuclear Power Group Leavesden, Herfordshire England
DER	Dounreay Experimental Reactor Establishment Dounreay Thurso, Caithness Scotland
EE	English Electric Co. Ltd. Atomic Power Division Cambridge Road Whetstone, near Leicester England

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UNITED KINGDOM (contd)

EE-BW-TW	English Electric, Babcock and Wilcox, and Taylor Woodrow Atomic Power Constructions Ltd. Cambridge Road Whetstone, near Leicester England
FAIREY	Fairey Engineering Ltd. Heston, Middlesex England
FW	Foster Wheeler Ltd. Foster Wheeler House 3 Ixworth Place London S.W. 3 England
GEC	General Electric Co. Ltd. of England Erith, Kent England
GEC-SC	G.E.C. and Simon-Carves Atomic Energy Co. General Electric Co. Ltd. of England (GEC) Atomic Energy Division Erith, Kent England Simon-Carves Ltd. (SC) Nuclear Power Division Cheadle Heath Stockport, Cheshire England
HAG	Humphreys and Glasgow Ltd. Power Division 22 Carlisle Place London S.W. 1 England

UNITED KINGDOM (contd)

HS	Hawker Siddeley Nuclear Power Co. Ltd. Sutton Lane Langley, near Slough Buckinghamshire England
MITCHELL	Mitchell Engineering Ltd. Nuclear Power Division 1 Bedford Square London W.C. 1 England
NPG	Nuclear Power Group Radbroke Hall Knutsford, Cheshire England
RR	Rolls-Royce and Associates Ltd. P.O. Box 31 Derby England
SC	Simon Carves Ltd (See GEC-SC)
UKAEA	United Kingdom Atomic Energy Authority 11 Charles II Street London S.W. 1 England
UPC	United Power Co. Magnet House Kingsway London W.C. 2 England
VICK	Vickers Nuclear Engineering Ltd. Vickers House Westminster London S.W. 1 England

UNION OF SOVIET SOCIALIST REPUBLICS

USSR	Soviet Atomic Energy Committee (State Atomic Energy Committee of the USSR Council of Ministers) Staromonetny Pereulok 26 Moscow, U.S.S.R.

WEST GERMANY

	GERMAN FEDERAL REPUBLIC (West Germany) Federal Ministry for Nuclear Energy and Water Economy Luisenstrasse 46 Bad Godesberg, Germany
AEG	Allgemeine Electrizitats Gesellschaft Frankfurt-am-Main-Sud 10 Germany
AKS	Arbeitsgemeinschaft Kernkraftwerke Stuttgart Stuttgart, Germany
ATOMFORUM	Deutsches Gesellschaft fur Atomenergie e.V. Wenzelgasse 2 II Bonn, Germany
ATOMKRAFT-BAYERN	Gesellschaft fur die Entwicklung der Atomkraft in Bayern m.b.H. Blutenburgstrasse 6 Munich 2, Germany
AVR	Arbeitsgemeinschaft Deutscher Energieversorgungs-unternehmen zur Vorbereitung der Errichtung eines Leistungsversuchs-Reaktors e.V. Luissenstrasse 105 Dusseldorf, Germany
BBC-KRUPP	Consortium BBC-Krupp Arbeitsgemeinschaft Carl-Reiss-Platz 1-5 Mannheim, Germany

WEST GERMANY (contd)

BEWAG	Berliner Kraft und Licht Berlin, Germany
DEUTSCH ATOMFORUM	See ATOMFORUM
DEUTSCH BAW	Deutsch Babcock und Wilcox-Dampfkesselwerke A.G. Atomabteilung Duisburgerstrasse 375 Oberhausen, Germany
DEUTSCH WERFT	Deutsch Werft A.G. Hamburg 1, Germany (Member of GKSS)
GEA	See ATOMKRAFT-BAYERN
GKSS	Gessellschaft fur Kernenergievertung im Schiffbau und Schiffahrt m.b.H. (Company for the Utilization of Nuclear Energy in Shipbuilding and Navigation) Normannenweg 10 Hamburg 6, Germany
INTERATOM	Internationale Atomreaktorbau G.M.b.H. 506 Bensberg/Koln Postfach, Germany
KPWP	Kernkraftwerk Baden-Wurttemberg Planningsgesellschaft m.b.H. Stuttgart-0, Neckarstr. 121 Germany
KRB	Kernreactor Bau- und Betriebs- Gesellschaft m.g.H. Karlsruhe, Germany

WEST GERMANY (contd)

MAN	Maschinenfabrik Augsburg-Nurnberg A.G. Nurnberg, Katzwangerstr. 101 Germany
RWE	Rheinisch Westfalisches Electrizitatswerke Essen, Germany
SIEMENS	Siemens-Schuckertwerke A.G. Abteilung Reaktorentwicklung Werner-von-Siemens-Strasse 50 Erlangen, Germany
SKW	Studiengesellschaft fur Kernkraftwerke G.m.b.H. Pepenstieg 10-12 Hanover, Germany

SECTION A

AQUEOUS HOMOGENEOUS SUSPENSION AND MOLTEN SALT HOMOGENEOUS REACTORS:

DOMESTIC

AQUEOUS HOMOGENEOUS SUSPENSION AND MOLTEN SALT HOMOGENEOUS REACTORS — LAPRE (LASL)

DESIGNER	LASL
TYPE	Aqueous homogeneous, single region, circulating fuel
POWER	Mw(e) - - Mw(t) (LAPRE I: 20 kwt; LAPRE II: 800 kwt)
COOLANT	H_2O
MODERATOR	Fuel solution
FUEL	93.4% enriched UO_2 in H_3PO_4 aqueous solution
CLADDING	- - - -
NAME/OWNER	LAPRE (Los Alamos Power Reactor Experiment)/AEC
OPERATOR	LASL
LOCATION	Los Alamos, N. M.
PURPOSE	Power experiment
REMARKS	LAPRE-I was in operation in 1956, dismantled in 1957. LAPRE-II, in operation in 1958, is to be dismantled. Two versions have been studied, both using phosphoric acid solutions of enriched U as fuel. In both systems the heat exchanger for power removal is in the same pressure vessel as the reacting fluid. Fuel solution circulation is by convection in one version and by forced circulation in the other; in the convection flow plant the acid is about 95% strength, while in the forced circulation system it is 50% by weight. Purpose of the experiments was to develop high pressure superheated steam for good turbine utilization.
REFERENCES	The Los Alamos Power Reactor Experiment D. Froman, others Proc. Int'l. Conf. on the Peaceful Uses of Atomic Energy 3: 283-6 (1955) The fuel system UO_2-H_3PO_4-H_2O and Los Alamos Power Reactor Experiment II B. J. Thamer Second U. N. Int'l. Conf. on the Peaceful Uses of Atomic Energy 7: 54-6 (1958)

AQUEOUS HOMOGENEOUS SUSPENSION
AND MOLTEN SALT HOMOGENEOUS REACTORS — HRE (ORNL)

DESIGNER	ORNL
TYPE	Aqueous homogeneous, circulating fuel
POWER	Mw(e) (HRE-II: 5) Mw(t): (HRE-I: 1; HRE-II: 5-10)
COOLANT	HRE-I: H_2O HRE-II: D_2O fuel solvent
MODERATOR	HRE-I: H_2O fuel solvent HRE-II: D_2O fuel solvent
FUEL	HRE-I: 93% enriched UO_2SO_4 in H_2O HRE-II: 93% enriched UO_2SO_4 in D_2O
CLADDING	- - - -
NAME/OWNER	HRE (Homogeneous Reactor Experiment)/AEC
OPERATOR	ORNL
LOCATION	Oak Ridge, Tennessee
PURPOSE	Power experiment
REMARKS	Preliminary studies of boiling homogeneous systems were based on UO_3-D_2O or uranyl sulfate slurries as fuel, with D_2O as coolant and moderator. Single and two-region designs were studied. The HRE reactor series at Oak Ridge operated on uranyl sulfate-water and uranyl sulfate-D_2O solutions. HRE-I was in operation in 1953, dismantled in 1954. HRE-II was operated in 1958, and closed out in 1961 in favor of expanded development of the molten salt concept (see MSRE). HRE-III, proposed for investigating the Th-U^{233} cycle, has been canceled.
REFERENCES	A preliminary design and feasibility study of a large-scale boiling slurry plutonium-power producer. L. C. Widdoes, others CF-51-8-84 (1951) Boiling homogeneous reactor for producing power and plutonium. H. F. Karmack, others CF-54-8-238 (1954)

(contd)

REFERENCES (contd)

The Homogeneous Reactor Experiment. A chemical engineering pilot plant.
S. E. Beall, C. E. Winters
Chem. Eng. Prog. 50: 256-63 (May 1954)

Ultimate homogeneous reactor . Reactor and feasibility problem.
R. A. Thomas, others
CF-54-8-239 (1954)

The Homogeneous Reactor Test.
S. E. Beall, J. A. Swartout
Proc. Int'l. Conf. on the Peaceful Uses of Atomic Energy 3: 263-82 (1955)

Civilian Power Reactor Program. Part III. Status report on aqueous homogeneous reactors. 1960.
TID-8518 (Book 3)

HRE-3 preliminary design summary and reference report.
R. H. Chapman
CF-59-11-112 (1958)

Proposed modifications to the HRE core
C. G. Lawson
CF-60-1-20 (January 1960)

AQUEOUS HOMOGENEOUS SUSPENSION
AND MOLTEN SALT HOMOGENEOUS REACTORS MSRE (ORNL)

DESIGNER	ORNL
TYPE	Molten salt fuel. Single region, compact. High power density
POWER	Mw(e) - - Mw(t) 10
COOLANT	Li and Be fluorides (Simple fuel mix)
MODERATOR	Graphite (Cylindrical core)
FUEL	Li-Be-U-Th-Zr fluorides
CLADDING	- - - -
NAME/OWNER	MSRE (Molten Salt Reactor Experiment)/AEC
OPERATOR	
LOCATION	Oak Ridge, Tennessee
PURPOSE	Power experiment
REMARKS	Final design, construction. Internally-cooled, graphite core shell, and unit fuel tube designs were studied, the latter concept being selected for design development. Fuel salt passes through the core through tubes of impervious graphite. In the final design, to which aircraft reactor R&D will be applied, the core is a graphite matrix penetrated by parallel channels, which may be clad with INOR-8. The whole system operates at a single pressure. A 10 Mw(t) power experiment is under construction. A preliminary design study for a 10 Mw(e), 30 Mw(t) plant with a $LiF-BeF_2$ moderator has also been completed.
REFERENCES	Molten salt breeder reactor. H. G. MacPherson CF-59-12-64 (Rev.) (1960) Experimental molten salt fueled 30 MW power reactor. L. C. Alexander, others ORNL-2796 (March 1960)

(contd)

REFERENCES (contd)

A 10 MW(thermal) molten-salt reactor experiment.
A. L. Boch, others
Trans. American Nuclear Soc. 4: 331-2 (November 1961)

The Molten Salt Reactor Experiment.
A. L. Bloch, others
Power Reactor Experiments, Vol. 1, p. 247-92
International Atomic Energy Agency, Vienna (1962)

DESIGNER	WESTINGHOUSE
TYPE	(a) Aqueous homogeneous. Single region (b) Aqueous homogeneous slurry fuel. Single region
POWER	(a) Mw(e) 80 Mw(t) (b) Mw(e) 150 Mw(t) 550
COOLANT	(a) Fuel solution (b) Fuel slurry
MODERATOR	(a) Fuel solution (b) Fuel slurry
FUEL	(a) Fully enriched UO_2SO_4-D_2O solution (dilute) (b) UO_2 and ThO_2 suspended in D_2O
CLADDING	- - - -
NAME/OWNER	PAR (Pennsylvania Advanced Reactor)/WEST
OPERATOR	
LOCATION	
PURPOSE	Power demonstration proposal
REMARKS	System is a pressurized single region concept. The PAR third round proposal by Pennsylvania Power and Light and Baltimore Gas and Electric was dropped in 1958. An extended R&D effort was granted by AEC for justification of the system, with possible construction of a demonstration plant by 1963. PAR experimental and design studies were for an aqueous homogeneous system based on the Th-U cycle, the primary system generating 550 Mw(t) in a single region spherical vessel through which a suspension of Th and U oxides in heavy water flows. Electrical output of this system is 150 Mw.
REFERENCES	Preliminary system analysis for the Pennsylvania Advanced Reactor T. Gogniat, others WCAP-433 (1956)

(contd)

REFERENCES (contd)

The PAR homogeneous reactor project.
W. E. Johnson, others
ASME Preprint 56-A-170 (1956)

The PAR homogeneous reactor project-plant design and operating problems.
W. E. Johnson, others
Proc. American Power Conf. 19: 640-50 (1957)

Proposed 80,000 kilowatt homogeneous reactor plant. Process and plant description.
D. H. Fox, ed.
WIAP-9 (1955. Declassified February 1957)

PAR homogeneous unit.
J. E. Kenton
Nucleonics 15: 166 (September 1957)

Design consideration for the PAR slurry homogeneous plant.
W. E. Johnson, others
Second U. N. Int'l. Conf. on the Peaceful Uses of Atomic Energy 9: 202-10 (1958)

SECTION A

AQUEOUS HOMOGENEOUS SUSPENSION AND MOLTEN SALT HOMOGENEOUS REACTORS:

FOREIGN

AQUEOUS HOMOGENEOUS SUSPENSION
AND MOLTEN SALT HOMOGENEOUS REACTORS PHOEBUS (FRANCE)

DESIGNER	CEA
TYPE	Aqueous homogeneous, circulating fuel
POWER	Mw(e) - - Mw(t) ~1
COOLANT	Fuel slurry (H_2O)
MODERATOR	Fuel slurry (H_2O)
FUEL	UO_2 in H_2O: slurry of glass marbles with UO_2
CLADDING	- - - -
NAME/OWNER	PHOEBUS/CEA
OPERATOR	CEA
LOCATION	Grenoble, France
PURPOSE	Power experiment
REMARKS	Research and development project; prototype under construction. Boiling slurry concept. Second phase of the research program is to be the study of a boiling cyclone-reactor. Phoebus is moderated with H_2O, and has a cylindrical core. Liquid fuel is injected tangentially at the periphery of the core, and a vortex flow maintained.
REFERENCES	Ideas on a project for a homogeneous reactor. J. Beneviste, others Second U. N. Int'l Conf. on the Peaceful Uses of Atomic Energy 9: 415-20 (1958)

AQUEOUS HOMOGENEOUS SUSPENSION AND MOLTEN SALT HOMOGENEOUS REACTORS | SUS-POP (THE NETHERLANDS)

DESIGNER	KEMA
TYPE	Aqueous homogeneous, suspension fuel
POWER	Mw(e) 250 kw Mw(t) - -
COOLANT	H_2O fuel slurry
MODERATOR	H_2O fuel slurry
FUEL	20% enriched UO_2 in H_2O suspension
CLADDING	- - - -
NAME/OWNER	SUS-POP (Suspension Power Only Pile)/KEMA
OPERATOR	KEMA
LOCATION	Arnheim, The Netherlands (KEMA Labs.)
PURPOSE	Power experiment
REMARKS	A subcritical system has been in operation. Three-phase program for a D_2O system, entailing preliminary study, Dutch industry study, and construction, has been instituted by SEP with assistance from KEMA, RCN and U.S. industry, replacing the primary project. A circulating system using a circulating fuel of ThO_2 and UO_2 suspended in D_2O was studied, and is currently under development. See KEMA Homogeneous Suspension Reactor.
REFERENCES	The design of a small-scale prototype of a homogeneous reactor fueled with uranium oxide suspension. H. de Bruyn, others Int'l. Conf. on the Peaceful Uses of Atomic Energy 3: 116-20 (1955) Nucleonics Week, October 27, 1960, p. 5. News Release

AQUEOUS HOMOGENEOUS SUSPENSION AND MOLTEN SALT HOMOGENEOUS REACTORS — KEMA (THE NETHERLANDS)

DESIGNER	KEMA, SEP, RCN
TYPE	Aqueous homogeneous, suspension fuel
POWER	Mw(e) - - Mw(t) - -
COOLANT	D_2O
MODERATOR	D_2O fuel slurry
FUEL	ThO_2 and UO_2 suspended in D_2O
CLADDING	- - - -
NAME/OWNER	KEMA HOMOGENEOUS SUSPENSION REACTOR/ RCN-KEMA
OPERATOR	RCN
LOCATION	Arnheim, The Netherlands
PURPOSE	Power experiment
REMARKS	Subcritical reactor in operation, second step (process) reactor under construction. Part of SEP's 3-phase program (see SUS-POP). The SEP program, with assistance from KEMA, RCN, and US industry, will largely replace KEMA's AHR development program.
REFERENCES	Development of a 250 kw aqueous homogeneous single region suspension reactor. P. J. Kreyger, others Second U. N. Int'l. Conf. on the Peaceful Uses of Atomic Energy 9: 427-30 (1958) Nucleonics Week, June 22, 1961, p. 1. News Release

SECTION B

BOILING LIGHT WATER REACTORS

DOMESTIC

DESIGNER	AC
TYPE	BWR, controlled recirculation, nuclear superheat
POWER	Mw(e) 62 Mw(t) 164
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Boiling: 1.7% enriched UO_2 Superheat: 20% enriched UO_2
CLADDING	Boiling: Al-Ni alloy Superheat: Stainless steel
NAME/OWNER	PATHFINDER ATOMIC POWER PLANT/AEC, NSP
OPERATOR	NSP
LOCATION	Sioux Falls, South Dakota
PURPOSE	Power demonstration, third round
REMARKS	Construction; criticality target, 1963; power operation, summer 1964. Fuel elements in central superheat region contain highly enriched UO_2 in stainless steel cermet, clad with stainless steel; boiler elements are of slightly enriched UO_2 clad with Zircaloy-2. Coolant is circulated by pumps located externally to the reactor vessel. Steam generated in the boiling region will pass through the superheat region for ultimate use in a condensing steam turbine.
REFERENCES	A controlled recirculation boiling water reactor with nuclear superheater. C. B. Graham, others Second U. N. Int'l. Conf. on the Peaceful Uses of Atomic Energy 9: 74-8 (1958) Interim feasibility report, nuclear superheater for a controlled recirculation boiling reactor. Allis-Chalmers AECU-3704 (May 1958)

(contd)

REFERENCES (contd)

A controlled recirculation boiling water reactor with nuclear superheater. Pathfinder Atomic Power Plant feasibility report.
Allis-Chalmers
ACNP-5917 (August 1959)

Pathfinder Atomic Power Plant safeguards report. Part II. License application.
Northern States Power Co.
ACNP-5905 (January 15, 1962)

DESIGNER	AC
TYPE	BWR, direct cycle, forced circulation
POWER	Mw(e) 50 Mw(t) 165
COOLANT	H_2O
MODERATOR	H_2O
FUEL	3.4% enriched UO_2 pellets (rods)
CLADDING	Stainless steel
NAME/OWNER	LA CROSSE BWR/AEC, DAIRYLAND POWER
OPERATOR	Dairyland Power
LOCATION	Genoa, Wisconsin
PURPOSE	Power demonstration
REMARKS	AEC contracts awarded to AC and Dairyland Power in June 1962. Target 1965, on-line 1966. Fuel elements consist of 25 stainless steel-clad UO_2 rods in a 5 x 5 array. Core has 288 elements divided into 72 groups of four, each group of four enclosed in a movable section of the Zircaloy-2 shroud. (The first core will use stainless steel shroud cans.)
REFERENCES	Hazards summary report for construction authorization of the La Crosse Boiling Water Reactor. Allis-Chalmers Manufacturing Co. ACNP-62574 (October 1962)

BOILING LIGHT WATER REACTORS ELK RIVER REACTOR (ACF/AC)

DESIGNER	ACF/AC Allis-Chalmers has acquired the Nuclear Products-Enco Division of ACF, including responsibility for the Elk River Plant.
TYPE	BWR, indirect cycle, natural circulation, separate superheat
POWER	Mw(e) 22 Mw(t) 64
COOLANT	H_2O
MODERATOR	H_2O
FUEL	4.3% enriched UO_2-ThO_2 cylindrical pellets
CLADDING	Stainless steel tubing
NAME/OWNER	ELK RIVER REACTOR/AEC, RCPA
OPERATOR	AC
LOCATION	Elk River, Minnesota
PURPOSE	Power demonstration, second round
REMARKS	Fuel loading November 1962; critical November 19, 1962. Fuel assembly consists of 25 fuel rods in a 5 x 5 array. One hundred forty-eight assemblies make up the core. Spiked assemblies, 5.23% enriched, may be used later in core life.
REFERENCES	A proposal for a nuclear steam generating plant for the Rural Cooperative Power Association, Elk River, Minnesota. ACF Ind. Inc. NP-7331 (1958) Elk River Reactor quarterly progress report for June, July, August 1959. Allis-Chalmers ACNP-ERR-5 (1959)

(contd)

REFERENCES (contd)

Final hazards report for the RCPA Elk River reactor at Elk River, Minnesota, and additions and corrections to final hazards report for the Elk River reactor at Elk River, Minnesota.
W. S. Farmer, D. G. Strawson
TID-11734 (July 1960)

Design practice. The Elk River Reactor.
Power Reactor Technology 5: 33-47 (March 1962)

Nucleonics Reactor File No. 18
ERR. Elk River Reactor
Nucleonics 21 (7):(July 1963) (Foldout)

BOILING LIGHT WATER REACTORS STUDY (AMF)

DESIGNER	AMF-MITCHELL
TYPE	BWR
POWER	Mw(e) 25-100 Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Slightly enriched U rods
CLADDING	Stainless steel
NAME/OWNER	(Study)/AMF-MITCHELL
OPERATOR	
LOCATION	
PURPOSE	Study
REMARKS	A study submitted to Italy's Larderello Co. on the feasibility of integrating a BWR into the Larderello geothermal steam generating system. Completion of study in 1962. AMF has designed a dual purpose reactor for power and water desalination based on this study.
REFERENCES	Forum Memo, December 1961, p. 12. News Release Nucleonics 21: 27 (April 1963). News Release

BOILING LIGHT WATER REACTORS STUDY (AMF-3)

DESIGNER	AMF
TYPE	BWR-PWR
POWER	Mw(e) 110 Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Slightly enriched uranium rods
CLADDING	Stainless steel tubes
NAME/OWNER	(Study)/AMF Atomics
OPERATOR	
LOCATION	
PURPOSE	Dual purpose, power and water desalination
REMARKS	AMF design for a reactor incorporating features of both the BWR and PWR concepts has a slightly enriched uranium core with 88 elements, each having 64 fuel rods contained in stainless steel tubes. The reactor would be used with a multistage flash unit supplied by AMF's Maxim Division. The plant would desalinize 10 million gallons per day and would supply about 158,000 kwh/day and would supply about 158,000 kwh/day of electricity. The dual purpose design is an outgrowth of an AMF-Mitchell (UK) study of a boiling-superheat reactor for Italy's Larderello Company.
REFERENCES	Nucleonics Week, March 7, 1963, p. 3. News Release

BOILING LIGHT WATER REACTORS WOLVERINE STATION (AMSTAN)

DESIGNER	AMSTAN
TYPE	BWR, variable moderator concept, nuclear superheat
POWER	Mw(e) 5-50 Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	2.2% enriched UO_2
CLADDING	Zirconium
NAME/OWNER	WOLVERINE ELECTRIC COOPERATIVE STATION/ WOLVERINE
OPERATOR	Wolverine
LOCATION	Big Rapids, Michigan
PURPOSE	Power prototype
REMARKS	Proposal has been made for a power prototype based on American-Standard's design study of Variable Moderator Reactor. A VMR is under study at Battelle Memorial Institute. AMSTAN has completed a reference design for a 20 Mw(e) plant. Reactor concept proposes an arrangement of fuel rods in clusters which are separated from one another by relatively wide moderator channels. The coolant water in the channels is separated from the moderator water outside the clusters by a calandria design of the core structure. Level of the moderator can be adjusted to regulate and control reactivity. Fuel rods are 2.2% enriched UO_2 in zirconium tubes, a hexagonal fuel assembly containing 37 such rods. Core structure is like a shell-and-tube heat exchanger.
REFERENCES	Variable moderator reactor development program. Quarterly progress report No. 1, August 31, 1959. ATL-A-100 (1959) Hazards summary report for the VMR critical assembly experiments. R. A. Egen, others BMI-1445 (June 10, 1960)

(contd)

REFERENCES (contd)

Technical feasibility and economic potential of the Variable Moderator Reactor. Final Report. American-Standard, Adv. Technology Labs. ATL-A-109 (Rev. 1) (December 1960)

DESIGNER	ANL
TYPE	BWR, direct cycle
POWER	Mw(e) 2 Mw(t) 15
COOLANT	H_2O
MODERATOR	H_2O
FUEL	BORAX-III: 90% enriched U-Al alloy plate elements BORAX-IV: 7% enriched UO_2-ThO_2 pellets
CLADDING	BORAX-III: Aluminum BORAX-IV: Al-Ni alloy
NAME/OWNER	BORAX (Boiling Reactor Experiment)/AEC
OPERATOR	ANL
LOCATION	NRTS, Idaho
PURPOSE	Power experiment
REMARKS	The early BORAX experiments used metallic fuel to investigate BWR stability. The fuel element for BORAX-IV was a box of six plates of extruded Al. The plates contained tubular cavities in which the ThO_2-UO_2 pellets were thermally bonded to the cladding with lead. BORAX-III operated in 1957-1958, when it was shut down for core III revision.
REFERENCES	Design and operating experience of a prototype boiling water power reactor. J. R. Dietrich, others Proc. Int'l. Conf. on the Peaceful Uses of Atomic Energy 3: 56-60 (1958) Operational experience with BORAX power plant. W. H. Zinn, others Nuclear Sci. and Eng. 1: 420-37 (October 1956)

(contd)

REFERENCES (contd)

Performance evaluation of direct cycle boiling water nuclear power plants based on recent EBWR and BORAX data.
J. M. Harrer, others
Second U. N. Int'l. Conf. on the Peaceful Uses of Atomic Energy 9: 264-85 (1958)

Civilian Power Reactor Program. Part III. Status report on the boiling water reactor technology as of 1959.
TID-8518 (5) Book 5.

DESIGNER	ANL
TYPE	BWR, direct cycle, forced or natural circulation, nuclear superheat
POWER	Mw(e) 2 Mw(t) 20
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Boiling: 5% and 10% enriched UO_2 Superheat: 93% enriched UO_2-SS cermet plates
CLADDING	Stainless steel
NAME/OWNER	BORAX-V (Boiling Reactor Experiment-5)/AEC
OPERATOR	ANL
LOCATION	NRTS, Idaho
PURPOSE	Power experiment, nuclear superheat demonstration
REMARKS	Limited operation in 1961. Design power of 40 Mw(t) with full boiler-superheater core is expected in 1963. Three separate core configurations are possible: pure boiler core, no superheater; boiler-superheater core with superheat section at the center; and boiler-superheater core with superheater at the periphery. Natural and forced circulation operation will be possible. Fuel assemblies are square in cross section. Boiler assemblies are composed of rods of slightly enriched UO_2 in steel jackets. Superheat assemblies are thin UO_2-stainless steel cermet plates, each assembly containing 20 fuel plates grouped into five subassemblies separated by a water-filled moderator channel. Steam is superheated in two passes through the superheater assemblies. BORAX-V was critical February 1962. Superheat elements will be installed after testing.
REFERENCES	Preliminary design and hazards report. Boiling Reactor Experiment V (BORAX-V). Argonne National Laboratory ANL-6120 (February 1960)

(contd)

REFERENCES (contd)

A nuclear superheating reactor - BORAX-V.
N. Novick, others
Small and Medium Power Reactors, Vol. 1, pp. 111-25
International Atomic Energy Agency, Vienna, 1962

Design and hazards summary report, Boiling Reactor Experiment V (BORAX-V).
Argonne National Laboratory
ANL-6302 (May 1961)

BORAX-V integral nuclear superheat reactor experiments.
W. R. Wallin, others
Power Reactor Experiments, Vol. 2 pp. 9-26
International Atomic Energy Agency, Vienna, 1962

DESIGNER	ANL
TYPE	BWR, direct cycle, natural circulation
POWER	Mw(e) 250 kw + 400 kw space heat Mw(t) 3
COOLANT	H_2O
MODERATOR	H_2O
FUEL	91% enriched U-Al-Ni alloy plates
CLADDING	Al-Ni alloy
NAME/OWNER	ALPR (Argonne Low Power Reactor)/AEC-Army
OPERATOR	CE
LOCATION	NRTS, Idaho
PURPOSE	Prototype package power, military installations
REMARKS	Operation1958. Explosion on January 3, 1961 destroyed core, resulting in three fatalities. Investigations, still in progress, indicate nuclear incident. Reactor is being dismantled. The core was composed of 531 Al-U metallic fuel plates arranged in 59 assemblies, contained in a steel pressure vessel. Control was by the vertical motion of five cruciform rods and four T-shaped rods.
REFERENCES	Design study of a nuclear power plant for 100 kw electric and 400 kw heat capacity. M. Treshow, others ANL-5452 (1957) Argonne Low Power Reactor: a prototype direct cycle boiling water reactor package plant for electric power production and space heating. C. R. Braun Second U. N. Int'l. Conf. on the Peaceful Uses of Atomic Energy 9: 244-54 (1958)

(contd)

REFERENCES (contd)

ABWR PL-1 reference design report.
F. J. Staron, L. M. Johnson
CEND-70 (January 1960)

Design of the Argonne Low Power Reactor (ALPR)
N. R. Grant, others
ANL-6076 (May 1961)

DESIGNER	ANL
TYPE	BWR, direct cycle, natural circulation
POWER	Mw(e) 5 Mw(t) 20
COOLANT	H_2O
MODERATOR	H_2O
FUEL	1.44% enriched U-Nb-Zr alloy plates
CLADDING	Zircaloy-2
NAME/OWNER	EBWR-I (Experimental Boiling Water Reactor 1)/AEC
OPERATOR	ANL
LOCATION	Lemont, Illinois
PURPOSE	Power experiment
REMARKS	Operation 1956. Modification for 100 Mw(t) operation in 1960, full power resumed in 1962. First fuel assemblies were composed of six fuel plates with an active length of 4 feet. New elements added to the core for 100 Mw(t) operation are of the rod-type, the 5-foot-long fueled rod being a dispersion of highly enriched U_3O_8 in an aluminum matrix, contained in a Zircaloy-2 tube. Forty-nine rods make up a fuel element assembly. Core loading for 100 Mw(t) operation employed the highly enriched elements as spikes, the spike elements located in a square surrounding 36 of the shorter fuel elements. On November 15, 1962, the EBWR reached 100 Mw(t). Modifications included adding 32 highly enriched elements to the core, addition of control rods, appropriate piping and valves. EBWR has been shut down again for further modification leading to fueling with PuO_2/UO_2. The mixed oxide fuel will be in the center of the core, with enriched UO_2 assemblies surrounding it. EBWR with the new fuel is expected to be ready for the experimental program by early 1964; it will become part of the plutonium recycle program, in conjunction with Hanford.
REFERENCES	The Experimental Boiling Water Reactor (EBWR) ANL-5607 (May 1957) Reactors on-the-line. Experimental Boiling Water Reactor. Nucleonics 15: 52a-53a (July 1957) (contd)

REFERENCES (contd)

Hazards evaluation report associated with the operation of EBWR at 100 Mw.
E. A. Wimunc, J. M. Harrer
ANL-5781 (Add) (Rev 1) (October, 1960)

Modification of the Experimental Boiling Water Reactor (EBWR) for high-power operation.
J. F. Matousek, comp.
ANL-6552 (April 1962)

Nuclear News 5: 27 (December 1962) News Release

BOILING LIGHT WATER REACTORS PL (CE)

DESIGNER	CE
TYPE	BWR, direct cycle natural circulation
POWER	Mw(e) 1 Mw(t) 8.5
COOLANT	H_2O
MODERATOR	H_2O
FUEL	4.8% enriched UO_2 pellets
CLADDING	Stainless steel tubes
NAME/OWNER	PL (Portable Low-power)/(Army Boiling Reactor Program)
OPERATOR	
LOCATION	Design for Byrd Station, Antarctica
PURPOSE	Power and heat
REMARKS	PL is one of several reactors in the Army's BWR program intended for installation in a snow tunnel at Byrd Station, Antarctica. The core contains 24 fuel assemblies, each composed of 59 fuel elements and three poison elements.
REFERENCES	PL final design report. Vol. IV. Reactor design. Combustion Engineering Inc. CEND-135 (Vol. 4) (1961) Volumes 1-5 are dated June 30, 1961.

DESIGNER	GE
TYPE	BWR, dual cycle, natural circulation
POWER	Mw(e) 5 Mw(t) 20
COOLANT	H_2O
MODERATOR	H_2O
FUEL	90% enriched UO_2-SS plate elements
CLADDING	Stainless steel
NAME/OWNER	VBWR (Vallecitos Boiling Water Reactor)/GE
OPERATOR	Pacific G&E
LOCATION	Pleasanton, California
PURPOSE	Power prototype
REMARKS	Operation 1957. Modifications in 1960. Test facility for the Dresden reactor, demonstration plant. Core is composed of assemblies of stainless steel-clad plates. There are from six to nine parallel plates per assembly. Superheating is being investigated in the VBWR system. See VESR. See also SADE.
REFERENCES	Reactors on-the-line. VBWR. Nucleonics 16: insert. (February 1958) General Electric Vallecitos Boiling Water Reactor. Final hazards summary report. J. L. Murray, ed. SG-VAL-2 (3rd ed) (November 30, 1959)

BOILING LIGHT WATER REACTORS DRESDEN STATION (GE)

DESIGNER	GE
TYPE	BWR, direct cycle, forced circulation
POWER	Mw(e) 180 Mw(t) 626
COOLANT	H_2O
MODERATOR	H_2O
FUEL	1.5% UO_2 solid sintered pellets
CLADDING	Zircaloy-2
NAME/OWNER	DRESDEN NUCLEAR POWER STATION/COMMONWEALTH EDISON
OPERATOR	Commonwealth Edison
LOCATION	Morris, Illinois
PURPOSE	Power
REMARKS	Operation 1960. Closed down in November for control rod drive and blade revision, back on-line in June 1961. Base loaded at 194 Mw(e) gross. Requests made for power increase to 630-700 Mw(t), 210 Mw(e). Reactor shut down November 1962 for replacement of about 2/5 of its fuel. Refueling and testing will take about 12 weeks. Fuel rods are composed of four fuel segments joined end-to-end to form a rod approximately 117 inches long. Each segment is composed of sintered cylindrical pellets of 1.5% enriched UO2. Spacer plates are inserted between the segments. Tubular jacket is Zircaloy-2. Thirty-six rods in a 6 x 6 array make up an assembly or bundle, which is encased in a Zircaloy-2 sheath. There are 488 assemblies in the core. Subcooled water enters at the bottom of the reactor vessel and flows upward through the assemblies, where it boils. The steam-water mixture flows out at the top of the fuel assemblies and is directed to the reactor vessel outlet nozzles. External loops handle recirculation flow, there being no recirculation of the core coolant within the reactor vessel.
REFERENCES	Preliminary hazards summary report for the Dresden nuclear power station. G. Sege GEAP-1044 (May 1, 1957

(contd)

REFERENCES (contd)

Preliminary hazards summary report for the Dresden nuclear power station.
Amendment No. 1
GEAP-3009 (May 1, 1958)
Amendment No. 2 (D. P. Ebright)
GEAP-3053 (August 22, 1958)
Amendment No. 3 (J. L. Murray, D. P. Ebright)
GEAP-3076 (December 23, 1958)
Amendment No. 4, Part I (D. P. Ebright)
GEAP-3106 (February e, 1959)
Amendment No. 6 (D. P. Ebright)
GEAP-3186 (June 12, 1959)

Dresden on-the-line.
Nucleonics 17: insert. (December 1959)

Performance and operating experience of the Dresden nuclear power station.
I. L. Wade
ASME Preprint 61-WA-268 (1961)

The Dresden Nuclear Power Station.
Power Reactor Technology 4(4); 56-68 (September 1961)

BOILING LIGHT WATER REACTORS — FITCHBURG GAS & ELECTRIC PLANT (GE)

DESIGNER	GE
TYPE	BWR, natural circulation, pressure-suppression
POWER	Mw(e) 28 Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	
CLADDING	
NAME/OWNER	FITCHBURG GAS & ELECTRIC PLANT/FITCHBURG G&E, FITCHBURG PAPER
OPERATOR	
LOCATION	Massachusetts
PURPOSE	Power and process heat
REMARKS	Proposal by Fitchburg Gas & Electric to the AEC for a dual purpose plant. Maximum electrical power of the GE supplied BWR will be 28.5 Mw(e) and will supply an average of 140,000 pounds of steam a day for the paper company. Contract terms are being negotiated.
REFERENCES	Nucleonics Week, January 24, 1963, p. 5. News Release. Forum Memo, September 1963, p. 16. News Release.

DESIGNER	GE	
TYPE	BWR	
POWER	Mw(e) 22	Mw(t)
COOLANT	H_2O	
MODERATOR	H_2O	
FUEL		
CLADDING		
NAME/OWNER	GOLDEN VALLEY REACTOR/Golden Valley Electric Association	
OPERATOR	Golden Valley Electric Association of Fairbanks	
LOCATION	Alaska	
PURPOSE	Power	
REMARKS	Golden Valley has proposed the construction of a 22 Mw(e) nuclear station on its system	
REFERENCES	Forum Memo, September 1962, p. 16. News Release	

BOILING LIGHT WATER REACTORS BIG ROCK POINT STATION (GE)

DESIGNER	GE
TYPE	BWR, direct cycle, forced circulation, high power density
POWER	Mw(e) 50 Mw(t) 156
COOLANT	H_2O
MODERATOR	H_2O
FUEL	3.2% enriched UO_2 pellets
CLADDING	Stainless steel
NAME/OWNER	BIG ROCK POINT STATION/CONSUMERS POWER COMPANY
OPERATOR	Consumers Power
LOCATION	Big Rock Point, Michigan
PURPOSE	Power
REMARKS	An Operation Sunrise Step 2 design. Ultimate power design is for 75 Mw(e), 240 Mw(t). Critical September 1962. Power production in November 1962. The fuel bundle consists of a 12 x 12 array of 144 fuel rods, which are stainless steel tubes containing stacks of cylindrical UO_2 pellets. Corner rods in each assembly are of reduced size. The core contains 56 bundles. Fuel channels are stainless steel, initial enrichment is 3.2%. Coolant flow is from inlet diffusers, through openings in the guide tube support, upward through the guide tube and through the fuel channels. A conceptual design for a high power density, 300 Mw(e) reactor is in progress.

REFERENCES

New boiling water nuclear plant (Big Rock Point, Michigan).
Mech. Eng. 81: 80 (October 1959)

Final hazards summary report for Big Rock Point plant. Volume I. Plant technical description and safeguard evaluation.
Consumers Power Co.
NP-11153 (Vol. I) (November 1961)

High power density development project. Interim report, 300 Mw(e) HPD conceptual design study.
GEAP-3967 (June 22, 1962)

BOILING LIGHT WATER REACTORS HUMBOLDT BAY PLANT (GE)

DESIGNER	GE
TYPE	BWR, single cycle, natural circulation
POWER	Mw(e) 48.5 (third core: 67.5) Mw(t) 165
COOLANT	H_2O
MODERATOR	H_2O
FUEL	2% enriched UO_2 pellets
CLADDING	Stainless steel
NAME/OWNER	HUMBOLDT BAY PLANT/PACIFIC G&E
OPERATOR	Pacific G&E
LOCATION	Humboldt Bay, California
PURPOSE	Power
REMARKS	Operation Sunrise design with pressure-suppression containment. Fuel loading November, 1962. Critical February 16, 1963. Full power target April-May 1963. Reactor core consists of 8428 stainless steel clad tubes packed with UO_2 pellets. Cooling water enters at the bottom of the core. Initial steam separation occurs when the steam-water mixture leaves a chimney above the core, the separated water returning down the annulus outside the core assembly and the wet steam flowing through a steam dryer to the turbine.
REFERENCES	Humboldt Bay power plant. Preliminary hazards summary report. NP-7512 (April 1959)

BOILING LIGHT WATER REACTORS

BODEGA BAY ATOMIC PLANT (GE)

DESIGNER	GE
TYPE	BWR, direct cycle, forced circulation, pressure-suppression containment
POWER	Mw(e) 325 Mw(t) 1000
COOLANT	H_2O
MODERATOR	H_2O
FUEL	2.7% enriched UO_2 pellets
CLADDING	Stainless steel
NAME/OWNER	BODEGA BAY ATOMIC PLANT/PACIFIC G&E
OPERATOR	Pacific G&E
LOCATION	Bodega Bay, California
PURPOSE	Power
REMARKS	Construction. Target 1965. Enlarged version of Humboldt. Fuel assemblies are composed of 49 fuel rods in a 7 x 7 (square) array; the core has 529 fuel assemblies. Slightly subcooled water enters at the bottom of the core. Boiling produces a steam-water mixture increasing in steam quality and velocity as it flows upward. Axial flow steam separators are located above the core. Water is driven to the outside walls of the separators by centrifugal force, drains to the downcomer annulus, passes to four recirculation loops and is pumped back to the plenum below the core. A steam dryer and dry box assembly near the top head of the vessel provides final separation of steam and water and channels dry steam to the outlet nozzles. GE has received a feasibility study contract from the AEC for a 1000 Mw(e) BWR.
REFERENCES	Nuclear reactors built, being built, or planned as of June 30, 1962. U.S. Atomic Energy Commission TID-8200 (6th revision) (1962)

(contd)

REFERENCES (contd)

Bodega Bay Atomic Park. Unit Number 1. Exhibit C.
Preliminary hazards summary report, December 28, 1962.
Pacific Gas and Electric Co.
NP-12476 (nd)

DESIGNER	GNEC
TYPE	BWR, forced circulation, nuclear superheat
POWER	Mw(e) 16.3 Mw(t) 50
COOLANT	H_2O and steam
MODERATOR	H_2O
FUEL	Boiling: 2.4% enriched UO_2 pellets Superheat: 3.5% enriched UO_2
CLADDING	Boiling: Zircaloy-2 Superheat: Stainless steel (Stainless steel pressure tubes)
NAME/OWNER	BONUS (Boiling Nuclear Superheat)/AEC, PRWRA
OPERATOR	PRWRA
LOCATION	Puerto Rico (Punta Higuera)
PURPOSE	Power demonstration
REMARKS	Construction, target 1963. Core consists of two zones: a central forced-circulation boiler region producing saturated steam, and a peripheral four-pass steam-cooled region which superheats the steam. The boiler region consists of 64 fuel assemblies, each assembly made up of 32 Zircaloy-2 tubes containing UO_2 pellets. The superheat zone consists of 32 fuel assemblies, arranged in four groups around the square boiler zone; each superheater assembly contains 32 fuel elements. The fuel element is a stainless steel clad UO_2 pellet, rod-type element. The fuel rod is surrounded by a stainless steel tube to form the steam coolant annulus, and this is surrounded by a stainless steel pressure tube to provide a thermal insulating gap between the coolant tube and the water moderator. Containment will be a very large dome with maximum design pressure of 4.5 psia. Design has been extrapolated to a large central station integral nuclear superheat steam plant.
REFERENCES	Boiling Nuclear Superheater (BONUS) power station. Preliminary design study and hazards summary report. Vol. II. Reference design. Vol. III. Alternate design studies. Vol. IV. Preliminary hazards summary report. PRWRA, General Nuclear Eng. TID-8524 (June 1960)

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REFERENCES (contd)

Nuclear superheat: the BONUS reactor.
Power Reactor Technology 3: 68-74 (September 1960)

Boiling nuclear superheater (BONUS) power station technical specifications.
F. Bevilacqua
GNEC-214 (October 26, 1962)

Boiling Nuclear Superheater (BONUS) power station. Supplementary study. Extrapolation to large central station integral nuclear superheat plant.
General Nuclear Eng.
PRWRA-GNEC-4 (nd)

SECTION B

BOILING LIGHT WATER REACTORS

FOREIGN

BOILING LIGHT WATER REACTORS IBR (UK)

DESIGNER	UKAEA
TYPE	BWR, direct or indirect cycle
POWER	Mw(e) Mw(t) 60
COOLANT	H_2O
MODERATOR	H_2O
FUEL	5% enriched UO_2 pins
CLADDING	Stainless steel or zirconium
NAME/OWNER	IBR (Integral Boiling Reactor)/UKAEA
OPERATOR	
LOCATION	
PURPOSE	Ship propulsion study
REMARKS	The AEA will study this concept, and the Belgium concept Vulcain, in their ship propulsion program, all other designs having been dropped. Two versions of the IBR are being investigated. Indirect cycle, in which the tubes containing the fuel elements are closed and interconnected to form a circuit through which high pressure water is pumped as an intermediate heat transfer fluid. Boiling takes place only in the main coolant. Direct cycle, in which the tubes containing the fuel are open at the ends, and the coolant flows directly over the fuel. Boiling takes place in the core. Fuel tubes are zirconium alloy; in the present design UO_2 fuel pins are clad in stainless steel. Fuel pins are clustered around a central burnable poison pin and mounted within a Zr-Nb alloy shroud. The primary coolant pump, steam separators and pressurizer are all within the reactor vessel.
REFERENCES	The U. K. Atomic Energy Authority's nuclear ship concepts. Nuclear Eng. 8: 88-9 (March 1963)

BOILING LIGHT WATER REACTORS — GAMMA (DENMARK)

DESIGNER	DANATOM
TYPE	BWR, Dual cycle and single cycle designs
POWER	Mw(e) 200 Mw(t) 667
COOLANT	H_2O
MODERATOR	H_2O
FUEL	1.9% enriched UO_2 rods
CLADDING	Zircaloy-2
NAME/OWNER	GAMMA PROJECT/DANATOM
OPERATOR	
LOCATION	Karlby Klint, Djursland, Jutland
PURPOSE	Power
REMARKS	Design - to be constructed. GAMMA-I design specified a dual cycle plant. Fuel segments composed of slightly enriched UO_2 pellets were joined to form a fuel rod. Each segment was clad in Zircaloy-2. A fuel element consisted of 223 fuel rods in a 15 x 15 array, with some rods omitted. Eighty-nine elements make up the core. Studies which incorporate spectral shift control have been proposed. Revised design (GAMMA II) includes a single cycle system, internal steam separation and pressure-suppression containment.
REFERENCES	Gamma. A 200 Mw boiling water reactor power station. DANATOM Danatom-04-61 (August 1961) GAMMA II - A 200 Mw boiling water reactor power station. A revision. DANATOM Danatom-03-62 (June 1962)

DESIGNER	GE
TYPE	BWR, dual cycle, internal steam separation, pressure-suppression containment
POWER	Mw(e) 380 (2-reactor station) Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Slightly enriched uranium
CLADDING	
NAME/OWNER	TARAPUR PLANT/INDIA
OPERATOR	
LOCATION	Tarapur, India
PURPOSE	Power; states of Gujarat and Maharashtra.
REMARKS	International GE has been selected as prime nuclear contractor (September 1962) for the design and construction of two 190 Mw(e) dual cycle BWR plants. Target 1966. First fuel loading will be enriched uranium; the possibility is being considered of operating the plant, subsequent to first loading, on plutonium-enriched natural uranium fuel. A small-scale prototype version (20 Mw(e)) of the Tarapur BWR is currently being designed by Indian scientists and will be built at the Trombay atomic energy establishment. Intended primarily for R&D, the 20 Mw(e) capacity would, however, be fed to the Bombay power grid.
REFERENCES	Forum Memo, October 1962, p. 5-9. News Release.

BOILING LIGHT WATER REACTORS SENN (ITALY)

DESIGNER	GE
TYPE	BWR, dual cycle, forced circulation
POWER	Mw(e) 150 (To be increased to 230 Mw(e)) Mw(t) 507
COOLANT	H_2O
MODERATOR	H_2O
FUEL	2.1% enriched UO_2, sintered cylindrical rods
CLADDING	Stainless steel
NAME/OWNER	SENN NUCLEAR POWER STATION/SENN
OPERATOR	SENN
LOCATION	Punta Fiume, Italy (Garigliano)
PURPOSE	Power (U.S.-Euratom program)
REMARKS	Critical June 1963. Trial operations were discontinued in September because of a mechanical breakdown. Full power operation is not expected this year. Fuel assembly consists of 81 rods. Fuel material is 2.7% enriched UO_2 sintered pellets. Cladding is stainless steel, and channels are Zircaloy-2. SENN plans to construct a second reactor at this site.
REFERENCES	The Garigliano nuclear power station. M. Covino Nuclear Power 7: 65-7 (February 1962) Final hazard summary report for the Garigliano Nuclear Power Station. Societa Elettronucleare Nazionale (SENN), Italy APED-4022 (1962)

BOILING LIGHT WATER REACTORS JAERI (JAPAN)

DESIGNER	GE
TYPE	BWR, direct cycle, natural circulation
POWER	Mw(e) 12.5 Mw(t) 45
COOLANT	H_2O
MODERATOR	H_2O
FUEL	2.6% enriched UO_2 hollow tubes
CLADDING	Zircaloy-2
NAME/OWNER	JAERI STATION/JAERI
OPERATOR	JAERI
LOCATION	Tokai Mura, Japan
PURPOSE	Power demonstration (electricity production and ship propulsion)
REMARKS	Critical August 1963; full power operation target October 1963.
REFERENCES	Nuclear powered tanker design and economic analysis; direct cycle boiling water reactor. GEAP-3294 (December 1959)

BOILING LIGHT WATER REACTORS SEP (THE NETHERLANDS)

DESIGNER	GE-SEP
TYPE	BWR, Up-dated Humboldt design
POWER	Mw(e) 50 Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	
CLADDING	
NAME/OWNER	SEP BWR/SEP
OPERATOR	SEP
LOCATION	Dodewaard, Holland
PURPOSE	Power
REMARKS	SEP engineers working with GE (SanJose) will do preliminary design, scoping and economic studies. Euratom has earmarked funds toward construction of a 50 Mw(e) station, probably a natural circulation BWR, for construction in 1964 and operation in 1967. SEP will design and build the station. Probable site is Dodewaard, in central Holland.
REFERENCES	Applied Atomics, March 1963, p. 6. News Release

BOILING LIGHT WATER REACTORS SIMPVARP (SWEDEN)

DESIGNER	AC-KOCKUMS
TYPE	BWR, direct cycle, natural circulation
POWER	Mw(e) 56 Mw(t) 173
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Slightly enriched UO_2 ceramic pellets
CLADDING	Zircaloy or stainless steel
NAME/OWNER	SIMPVARP REACTOR/AB-ATOMKRAFTWERK (AKK)
OPERATOR	AB-ATOMKRAFTWERK
LOCATION	Simpvarp, Smaaland Province, Sweden
PURPOSE	Power
REMARKS	Contract has been awarded to AC and Kockums. Construction will be by Swedish firms, probably with cooperation of U.S. manufacturer
REFERENCES	Forum Memo, August 1961, p. 12. News Release.

BOILING LIGHT WATER REACTORS ULYANOVSK (USSR)

DESIGNER	USSR
TYPE	BWR, direct cycle
POWER	Mw(e) 50 Mw(t) 250
COOLANT	H_2O
MODERATOR	H_2O
FUEL	1.5% enriched UO_2 pellets
CLADDING	Nb-Zr
NAME/OWNER	ULYANOVSK ATOMIC POWER STATION/USSR
OPERATOR	USSR
LOCATION	Ulyanovsk region, USSR (Melekess)
PURPOSE	Power
REMARKS	Construction. Target 1962-64. Fuel elements are rods of sintered UO_2 pellets canned in a Nb-Zr alloy. Enrichment is 1.5%. Fuel assemblies are tubular, containing the fuel rods; walls of the assemblies are also a Nb-Zr alloy. Coolant water flows into an annulus between the steel pressure vessel wall and the core, flows downward, passes over the fuel elements in the core from the bottom to the top, leaves the reactor and goes to the steam generators. The reactor core is about 3 m in diameter and 2.5 m in height.
REFERENCES	Double water circuit power reactors in the USSR. S. A. Skortsov Soviet J. Atomic Energy 5: 1107-19 (September 1958)

DESIGNER	USSR
TYPE	BWR, pressure tube, nuclear superheat
POWER	Mw(e) 100 Mw(t) 285 (per reactor; four-reactor station)
COOLANT	H_2O Superheat channel: steam
MODERATOR	GRAPHITE
FUEL	1.3% U-Mg alloy annular elements
CLADDING	Stainless steel inside and outside
NAME/OWNER	PROJECT I (Kurchatov Station)/USSR
OPERATOR	USSR
LOCATION	Beloyarsk Urals, USSR
PURPOSE	Power
REMARKS	Construction. Completion 1962-3. Recent reports indicate two or more of the reactors may have been canceled. The cylindrical graphite stack of the reactor is composed of separate blocks with gaps of definite dimensions between them. Central part of the stack is pierced with fuel assemblies, which are long graphite cylinders containing thin-walled steel tubes with the fuel elements inside. The reactor has 998 fuel assemblies, each assembly containing six elements. Some of the assemblies are cooled with boiling water, and the rest (268) are steam superheated. The coolant enters a boiling assembly at its upper end, flows down the central tube, then rises along the fuel element tubes to the upper head where it is collected and removed from the reactor. Secondary steam produced in the steam generator is sent to the steam-superheating assemblies of the reactor. The second reactor will be single cycle, with one set of fuel elements which will both boil and superheat the steam. Capacity will be 200 Mw(e).
REFERENCES	Uranium-graphite reactors with superheated steam for electric power stations. N. A. Dollezhal Sov. J. Atomic Energy 5: 1085-1106 (September 1958)

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REFERENCES (contd)

Steam cooled power reactor evaluation - Beloyarsk (Ural) reactor.
General Electric Company, Hanford
HW-67473 (April 1961)

Experimental uniflow steam superheating reactor installation of the First Atomic Power Plant.
V. V. Kologov, others
FTD-TT-61-340 (1962) (Translation)

Uranium graphite power reactor with direct feeding of steam steam to turbines.
N. A. Dollezhal, others
FTD-TT-61-342 (1962) (Translation)

Atomic Energy in the Soviet Union.
Trip report of the U.S. Atomic Energy Delegation
May 1963

BOILING LIGHT WATER REACTORS — RWE (W. GERMANY)

DESIGNER	GE-AEG
TYPE	BWR, natural circulation
POWER	Mw(e) 15 Mw(t) 60
COOLANT	H_2O
MODERATOR	H_2O
FUEL	2.3% enriched UO_2 pellets
CLADDING	Zircaloy-2
NAME/OWNER	RWE-1 (Kahl Experimental High Temperature Reactor) /RWE
OPERATOR	Atomkraft Kahl
LOCATION	Kahl-am-Main, W. Germany
PURPOSE	Power experiment
REMARKS	Critical November 1960, full power December 1961. Core consists of 88 fuel elements, each element being an assembly of 36 fuel rods in a square array. Each fuel rod is made up of two segments composed of UO_2 pellets. Cladding is Zircaloy-2. Superheater will be added. A provision has been made for doubling the design power. Second turboset may be operated in direct cycle. AEG will develop the concept in a study of a superheat steam plant (see RWE-BAYERNWERK AG STATION).
REFERENCES	The Kahl nuclear power station. H. J. Bruchner Nuclear Power 6: 67-70 (March 1961) Commissioning Kahl's 15 MW BWR. R. Kuhnel, R. Misenta Nuclear Engineering 7: 407-14 (October 1962)

BOILING LIGHT WATER REACTORS — RWE-BAYERNWERK (W. GERMANY)

DESIGNER	GE-AEG
TYPE	BWR, natural circulation, high power density, nuclear superheat
POWER	Mw(e) 237 Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	UO_2
CLADDING	
NAME/OWNER	RWE-BAYERNWERK AG STATION/RWE
OPERATOR	RWE
LOCATION	Gundremingen, Bavaria (on Danube), W. Germany
PURPOSE	Power. U.S.-Euratom project. Development of U.S. GE designed RWE-1. Site preparation is under way. Target 1965, on-load 1966. Two approaches to the improved superheat reactor have been taken by AEG. In the first, coolant passes through the core at normal temperatures and then recirculates into a superheated reactor core contained in the same pressure vessel. Alternatively, the combination of separate boiling and superheating zones in one zone with the use of uniform tubular fuel elements is being investigated. In the second approach, preheated feedwater is superheated to the desired temperature in a single pass.
REFERENCES	The General Electric Company 100 megawatt natural circulation boiling water reactor power plant. General Electric Co., APED TID-15057 (1960) The 150 MWe atomic power station with an evaporating reactor, designed by AEG. E. Moldovanyi Energia es Atomtech. (Hungary) 15: 139-43 (March 1962)

BOILING LIGHT WATER REACTORS STUDY (W. GERMANY)

DESIGNER	AEG DEUTSCHE WERFT AG
TYPE	BWR, ship propulsion
POWER	Mw(e) Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	
CLADDING	
NAME/OWNER	(Study)/DEUTSCHE WERFT AG
OPERATOR	
LOCATION	
PURPOSE	Ship propulsion
REMARKS	Deutsche Werft AG has announced plans to build a freighter of at least 45,000 tons to be powered by a BWR. Study and development of the plans was done in cooperation with AEG.
REFERENCES	Energie Nucleaire, July-August 1962, p. 296. News Release

SECTION C

CAVITY REACTORS (GASEOUS CORE)

DOMESTIC

CAVITY REACTOR (GASEOUS CORE) STUDY (BAR)

DESIGNER	BAR	
TYPE	Gaseous fuel	
POWER	Mw(e)	Mw(t) 30
COOLANT	Helium	
MODERATOR		
FUEL	UF_6 gaseous fuel (BrF_3 added)	
CLADDING		
NAME/OWNER	(Study)/BURNS & ROE	
OPERATOR		
LOCATION		
PURPOSE	Space propulsion	
REMARKS	A gaseous core reactor using UF_6 as fuel and helium as an internal coolant proposed for space propulsion unit. Core channels are of Al, double tube wall. UF_6 is inside the aluminum tubes, He is in the annulus. Coolant flow is by natural circulation. There is a graphite reflector.	
REFERENCES	Gaseous-fuel reactor. S. Baron Nucleonics 16: 128, 130-33 (August 1958)	

CAVITY REACTORS (GASEOUS CORE) STUDY (GE)

DESIGNER	GE Flight Propulsion Laboratory
TYPE	Gaseous fuel
POWER	Mw(e) Mw(t)
COOLANT	
MODERATOR	
FUEL	
CLADDING	
NAME/OWNER	(Study)/GE
OPERATOR	
LOCATION	
PURPOSE	Space propulsion
REMARKS	Feasibility study of a cavity reactor. The fissionable material exists in the gaseous (plasma) state. The moderating propellant is heated by fissionable fuel and flows out an exhaust nozzle to produce thrust. Fuel and propellant are separated by hydrodynamic methods.
REFERENCES	A gaseous-core nuclear rocket utilizing hydrodynamic retention of fissionable material. J. Grey Presented at the ARS Semi-Annual Meeting, June 8-11, 1959, San Diego, California. (1959)

CAVITY REACTORS (GASEOUS CORE) STUDY (LASL)

DESIGNER	LASL
TYPE	Gaseous fuel
POWER	Mw(e) 500 Mw(t)
COOLANT	
MODERATOR	Graphite (D_2O blanket)
FUEL	Fissionable gas (U^{235} or Pu^{239})
CLADDING	
NAME/OWNER	(Study)/LASL
OPERATOR	
LOCATION	
PURPOSE	Direct electric power, feasibility study.
REMARKS	The reactor is a graphite cylinder filled with a fissionable gas (fission-plasma reactor). Energy released in the fission pulse induces a current in a coil wrapped around the graphite cylinder. A D_2O blanket surrounds the graphite.
REFERENCES	Plasma reactor promises direct electric power. S. A. Colgate, R. L. Aamodt Nucleonics 15: 50-55 (August 1957)

CAVITY REACTORS (GASEOUS CORE) STUDY (NASA)

DESIGNER	NASA
TYPE	Gaseous fuel
POWER	Mw(e) Mw(t)
COOLANT	
MODERATOR	Graphite or D_2O
FUEL	Fissionable gas (U^{235} or Pu^{239})
CLADDING	
NAME/OWNER	(Study)/NASA (Lewis Research Center)
OPERATOR	
LOCATION	
PURPOSE	Nuclear rocket propulsion
REMARKS	Gaseous fuel is in a cavity region surrounded by a reflector-moderator region. Cylindrical geometry was studied as being more applicable than spherical for rocket use. Fuel region is centrally located in cavity region, extending entire length of the cavity. Fuel is contained by flow through vortex tubes; by means of separate coaxial streams in which fuel flow is at low velocity relative to the propellant; and by use of magnetic forces to confine the fuel to a particular region. Study is of a cavity reactor with fuel and cavity regions completely enclosed by a reflector-moderator 100 cm thick.
REFERENCES	Two-dimensional criticality calculations of gaseous-core cylindrical-cavity reactors. R. E. Hyland, others (Lewis Research Center) NASA-TN-D-1575 (March 1963)

SECTION C

CAVITY REACTORS (GASEOUS CORE)

FOREIGN

CAVITY REACTORS (GASEOUS CORE) Experiment (USSR)

DESIGNER	USSR	
TYPE	Gaseous fuel	
POWER	Mw(e)	Mw(t)
COOLANT		
MODERATOR	Be (Graphite reflector)	
FUEL	UF_6 gaseous fuel 90% enriched	
CLADDING		
NAME/OWNER	(Experiment)/USSR	
OPERATOR	USSR	
LOCATION		
PURPOSE		
REMARKS	An experimental reactor using gaseous UF_6 as fuel. Fuel channels are aluminum. Fuel enrichment is 90%. A ground-based experiment has been operated.	
REFERENCES	Experimental reactor with gaseous fissionable substance (UF_6). I. K. Kikoin, others Second U. N. Int'l. Conf. on the Peaceful Uses of Atomic Energy 9 (Part 2): 528-34 (1958)	
	Soviet experimental UF_6 reactor. Review of Soviet literature AID work assignment No. 16. Library of Congress. Aerospace Inf. Div., Washington D.C. NP-12239 (October 18, 1962)	

SECTION D

GAS COOLED REACTORS

DOMESTIC

DESIGNER	AGN
TYPE	GCR, solid homogeneous
POWER	Mw(e) Mw(t) Variable
COOLANT	N_2
MODERATOR	H_2O
FUEL	Enriched UO_2 dispersed in graphite
CLADDING	Ni alloy
NAME/OWNER	GCRE (Gas Cooled Reactor Experiment/AEC
OPERATOR	AGN
LOCATION	NRTS, IDAHO
PURPOSE	Power experiment, mobile plant for array
REMARKS	Has been discontinued. A solid-moderated experiment may be constructed. GCRE reference fuel element design consisted of four concentric cylinders or "plates," each of enriched UO_2 dispersed in a stainless steel matrix and clad with stainless steel. A second fuel element design consisted of highly enriched UO_2 pellets contained in a long tubular can (pin), a 19-pin hexagonal cluster forming an element. The use of uranyl nitrate instead of UO_2 in the cermet matrix was also studied. GCRE-I was water moderated; GCRE-II, which was to have been an advanced backup system, was conceived as a graphite moderated reactor. The GCRE-II design uses a graphite fuel element containing 7 wt% dispersed UO_2. Elements are hexagonal, 32 inches in active length, and each contains 19 coolant tubes. The element is coated with silicon carbide and is canned in a Ni-base alloy
REFERENCES	Conceptual design and feasibility study for the Gas Cooled Reactor Experiment II. G. A. Lindenberger IDO-25530 (Rev.) (1959) Army Gas Cooled Reactor Systems Program. GCRE-I hazards summary report. Addendum III. Aerojet-General Nucleonics IDO-28506 (Add.III) (May 1960)

DESIGNER	AGN
TYPE	GCR
POWER	Mw(e) Mw(t)
COOLANT	Gas
MODERATOR	Yttrium hydride or BeO
FUEL	UO_2
CLADDING	
NAME/OWNER	HDMR (High Density Moderated Reactor)/Study-AEC
OPERATOR	
LOCATION	
PURPOSE	Study
REMARKS	A concept studied in the program for advanced military gas-cooled reactors. Fuel will be in the form of individual rods rather than the ML-1 19-rod cluster.
REFERENCES	Nucleonics Week, July 18, 1963, p. 2. News Release.
	Nucleonics Week, June 27, 1963, p. 3. News Release.

DESIGNER	AGN
TYPE	GCR, mobile skid-mounted, military
POWER	kw(e) 300-500 Mw(t) 3.3
COOLANT	N_2
MODERATOR	H_2O
FUEL	93% enriched UO_2 ceramic elements, pin type
CLADDING	Hastelloy-X
NAME/OWNER	ML-1 (Mobile Low-Power-1)/AEC
OPERATOR	Not selected
LOCATION	NRTS, Idaho (Development plant at Ft. Belvoir, Va.)
PURPOSE	Field power generating unit, prototype
REMARKS	Installation 1961. Reactor coupled to a power conversion system (closed cycle gas turbine power plant). Reactor has been operated up to 44 kw(e) during September 1962; trial power run October 1962. Reactor core consists of 61 fuel elements contained in pressure tubes. Each element contains 19 pins (18 fueled), with 22-inch-long sections fueled with ceramic pellets. In six of the pins the pellets are highly enriched UO_2, in the other 12 pins the UO_2 is diluted with BeO. Pins are clad in Hastelloy-X tubing and contained in an insulated stainless steel jacket. UO_2 enrichment is 93.1%. The nitrogen or air coolant flows through the elements. H_2O is the moderator. Pressure tubes separate the coolant from the moderator. Operation with air as the coolant is planned following operation with nitrogen. Contract for design of ML-1A, a service test model, is being negotiated. AGN is also studying concepts for advanced military gas-cooled reactors, such as the HDMR (High Density Moderated Reactor).
REFERENCES	Army Gas Cooled Reactor Systems Program. Preliminary hazards summary report for the ML-1 nuclear power plant. IDO-28537 (April 1959) Army Gas Cooled Reactor Systems Program. The ML-1 design report. IDO-28550 (May 1960)

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REFERENCES (contd)

Army Gas Cooled Reactor Systems Program. Conceptual design study, 3000 kwe mobile nuclear power plant.
H. C. Carney, Jr.
AGN-TM-383 (April 1961)

ML-1 critical experiments.
D. A. Dingee, J. W. Ray
MND-C-2487 (p. 203-22) (1961)

Army Gas Cooled Systems Program. Final hazards summary report for the ML-1 nuclear power plant.
Aerojet-General Nucleonics
IDO-28560 (Vol. 1) (November 1960)
IDO-28560 (Vol. 2, Supplement 1) (September 1961)

DESIGNER	AGN
TYPE	Smoke fueled reactor, chemonuclear
POWER	Mw(e) Mw(t)
COOLANT	Air
MODERATOR	
FUEL	Smoke from U compound mixed with air (suspension)
CLADDING	
NAME/OWNER	(Study)/AGN
OPERATOR	
LOCATION	
PURPOSE	Chemonuclear reactor study
REMARKS	Use of recoil energy for nitrogen fixation and chemical synthesis. AEC experimental R & D contract. Smoke from a uranium compound mixed with air is kept in suspension by turbulence. AGN has received a 30-month Air Force contract for R & D in the production of hydrazine rocket fuel by the use of nuclear heat in a reactor.
REFERENCES	Nuclear reactor may make chemicals. C & E News 37: 46-7 (August 10, 1959) Nuclear hydrazine program. Final technical engineering report, March 22, 1960-March 22, 1961. J. H. Cusack, others ASD-TR-61-7-840 (July 1961)

DESIGNER	ANL
TYPE	Solid core unmoderated
POWER	Mw(e) Mw(t)
COOLANT	(Gas)
MODERATOR	
FUEL	UO_2-W matrix
CLADDING	Tungsten
NAME/OWNER	(Study)/ANL
OPERATOR	
LOCATION	
PURPOSE	Propulsion, nuclear rocket
REMARKS	The design is being considered as a backup for KIWI-NERVA fueled graphite reactor. Fuels studied will be UO_2 dispersed in a tungsten matrix, and other fuels in a tungsten matrix. Operating power levels and core temperatures will be similar to KIWI, as will specific impulse of about 800 seconds.
REFERENCES	Nucleonics Week, May 9, 1963, p. 3. News Release.

DESIGNER	GD
TYPE	GCR, direct, closed cycle, single loop
POWER	Mw(e) 17.5 Mw(t) 49
COOLANT	He
MODERATOR	Graphite or BeO
FUEL	UO_2 dispersed in diluent, or clad UO_2
CLADDING	Stainless steel
NAME/OWNER	MGCR (Marine Gas Cooled Reactor)/AEC, Maritime Administration
OPERATOR	GD
LOCATION	NRTS, Idaho
PURPOSE	Marine propulsion, prototype
REMARKS	Development. Fuel is UO_2 in BeO as pellets, clad in Hastelloy-X. There are 308 fuel elements in the core, each composed of a 19-rod cluster.
REFERENCES	Maritime Gas Cooled Reactor Program. MGCR prototype preliminary design. Vol. I. General Dynamics GA-1612 (Vol. I) (December 1960)
	Thermal design of the MGCR core. J. T. Rogers, R. Katz GAMD-1542 (August 4, 1960)
	Maritime Gas Cooled Reactor Program. A review of the Maritime Gas Cooled Reactor Program. K. A. Trickett GA-2603 (December 1961)

DESIGNER	GD
TYPE	GCR, closed cycle
POWER	Mw(e) Mw(t) 10
COOLANT	He
MODERATOR	BeO bricks, Hastelloy-X liner
FUEL	70% enriched UO_2-BeO ceramic pellets (Fuel pins)
CLADDING	Hastelloy-X tubes
NAME/OWNER	EBOR (Experimental Beryllium Oxide Reactor)/AEC
OPERATOR	GD (Test operation)
LOCATION	NRTS Idaho
PURPOSE	Prototype
REMARKS	Construction. Target 1964. Larger core and turbo-machinery may be installed later. There is no containment vessel. Contract has been extended to cover land-based electricity generation. The concept is no longer being considered within the MGCR program, but currently is sponsored by AEC's Division of Reactor Development. Core is composed of 36 fuel elements surrounded by 52 reflector elements. Each core element consists of stacked BeO "square annular" blocks held in place by a Hastelloy tubular liner; fuel is in the form of pins inserted inside the core element liner. Ceramic fuel pellets are 70% enriched UO_2 in BeO. Pins are arranged in bundles of 19. Core is mounted in pressure vessel with the major dimension vertical. Coolant flow is downward between pressure vessel and a thermal shield, upward through the core.
REFERENCES	The Experimental Beryllium Oxide Reactor. W. C. Moore ASME Preprint 61-WA-225 (1961) Experimental bases for the design of EBOR. W. C. Moore Power Reactor Experiments, Vol. 1, p. 79-101 International Atomic Energy Agency, Vienna, 1962 Forum Memo, February 1963, p. 21. News Release

DESIGNER	GD
TYPE	GCR, high temperature
POWER	Mw(e) 30-40 (40 with graphite clad core) Mw(t) 115
COOLANT	Helium
MODERATOR	Graphite
FUEL	Highly enriched U-Th carbide coated with graphite
CLADDING	Graphite matrix; graphite sleeve
NAME/OWNER	HTGR (High Temperature Gas Cooled Reactor)/ Philadelphia Electric Company
OPERATOR	Philadelphia Electric Company
LOCATION	Peach Bottom, Pennsylvania
PURPOSE	Power prototype
REMARKS	Construction, target 1964. A three-year development program on the HTGR concept is being conducted by GD for ESADA (New York). Fuel is 93% enriched U and Th carbides dispersed in a graphite matrix. The graphite compacts are contained in a can of low-permeability graphite located within a graphite sleeve. Eight hundred twenty fuel elements, 12 feet long, are arranged in a closely packed core, the elements being supported by a core support plate within a pressure vessel. Helium coolant flow is upward in the spaces between the elements. The hot helium gas flows to two steam generators in independent loops where steam is produced at 1000 F and 1450 psi. Advanced Reactor Development Associates (ARDA) has contracted with General Dynamics to study a 250 Mw(e) HTGR. Members of ARDA are western utility groups.
REFERENCES	HTGR-underlying principles and design. P. Fortescu, others Nucleonics 18: 86-90 (January 1960)

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REFERENCES (contd)

The HTGR, an advanced high temperature gas cooled graphite moderated reactor.
C. L. Rickard
Proc. Symp. on Gas Cooled Reactors, Philadelphia; February 1960, Franklin Institute. (1960)

Application of Philadelphia Electric Company for construction permit and Class 104 license. Peach Bottom Atomic Power Station.. Part A. General Information. Part B. Preliminary hazards summary report. Volume I. Plant description and safeguards analysis. Volume II. Site and environmental information.
Philadelphia Electric Company
NP-9115 (July 1960)

Gas cooled reactors.
Power Reactor Technology 5: 60-70 (June 1962)

Status of the high temperature gas-cooled reactor.
T. LeClair
Power App. and Systems No. 62, p. 371-75 (October 1962)

DESIGNER	GD
TYPE	GCR, advanced type
POWER	Mw(e) 1000 Mw(t)
COOLANT	He
MODERATOR	Graphite
FUEL	Uranium-thorium
CLADDING	
NAME/OWNER	TARGET (Thermal Advanced Reactor Gas Cooled Exploiting Thorium)/AEC
OPERATOR	
LOCATION	
PURPOSE	Exploratory development
REMARKS	An AEC contract has been awarded GD for preliminary design and exploratory development of a 1000 Mw(e) plant based on the HTGR concept. Object is development of a reactor for 1970 operation. The project includes advanced fuel element development and the application of a supercritical pressure steam cycle. GD will also evaluate the feasibility of an interim 100-300 Mw(e) plant of flexible design to test components and to demonstrate breeding capacity.
REFERENCES	Applied Atomics, February 13, 1963, p. 5-6. News Release Nucleonics Week, February 14, 1963, p. 3. News Release

DESIGNER	GE
TYPE	GCR, direct air cycle
POWER	Mw(e) Mw(t) 32
COOLANT	Air
MODERATOR	H_2O (HTRE-2: zirconium hydride)
FUEL	93% enriched U metal
CLADDING	Ni-Cr
NAME/OWNER	HTRE (Heat Transfer Reactor Experiment)/AEC, USAF
OPERATOR	GE
LOCATION	NRTS, Idaho
PURPOSE	Aircraft propulsion experiment
REMARKS	Series has involved two reactor concepts: water-moderated and Zr-hydride moderated reactors. In HTRE-1, the moderator was water, and the core structure was water cooled. Fuel elements were Ni-Cr-UO_2. HTRE-2 was a mechanically modified HTRE-1. HTRE-3 had similar configuration, but moderator was solid Zr-hydride and the core structure was air cooled. HTRE-3 was tested with two J-47 engines in parallel at a 32.4 Mw power level. Active core contained 150 moderator-fuel units, the core being composed of air flow tubes surrounded by a hexagonal moderator tube. Each air-flow tube received a single fuel cartridge of 93.4% enriched UO_2 in a Ni-Cr matrix, clad with Nb-stabilized Ni-Cr alloy. The reactor operated in a horizontal position. Project has been discontinued. GE has carried out conversion studies to a nuclear merchant ship power plant, designated 630 A.
REFERENCES	ANP HTREs fulfill test goals. G. Thornton, B. Blumberg Nucleonics 19: 45-51 (January 1961) Comprehensive technical report, General Electric Direct Air Cycle, Aircraft Nuclear Propulsion Program. D. H. Culver, G. Thornton APEX 901-APEX-921 (June 1962)

DESIGNER	GE
TYPE	GCR, ship propulsion, closed cycle
POWER	Mw(e) (30,000 s.h.p.) Mw(t) 72
COOLANT	Air
MODERATOR	H_2O (BeO reflected)
FUEL	93% enriched U (concentric cylinders)
CLADDING	Ni-Cr alloy (concentric cylinders)
NAME/OWNER	630A/GE
OPERATOR	
LOCATION	Critical experiment: NRTS, Idaho
PURPOSE	Ship propulsion
REMARKS	Conversion of the HTRE studies to a nuclear propulsion plant for a merchant ship. Critical experiment has gone into operation in Idaho. The modified concept would have a core of 85 fuel elements, an alternative design adding an outer ring of elements to give a 127-element core for 63,000 s.h.p. output. Investigation on the substitution of steam for the air coolant is also in progress.
REFERENCES	630A maritime nuclear steam generator scoping study. General Electric Co., Flight Propulsion Laboratory GEMP-108 (December 1961) 630A maritime nuclear steam generator. Progress report No. 4. General Electric Co., Flight Propulsion Laboratory GEMP-175 (January 31, 1963) The 630A critical experiment: description and experimental results. G. D. Pincock, R. E. Wood Trans. American Nuclear Soc. 6 (1): 85-6 June 1963)

DESIGNER	GNEC
TYPE	GCR, D_2O moderated, pressure tube
POWER	Mw(e) 50 Mw(t) 153
COOLANT	CO_2
MODERATOR	D_2O
FUEL	2.05% enriched UO_2
CLADDING	Stainless steel
NAME/OWNER	GCHWR (Gas Cooled Heavy Water Moderated Reactor)/ ECFWCNG
OPERATOR	Tampa Electric Co., Florida Power Corp.
LOCATION	Polk County, Fla.
PURPOSE	Power prototype
REMARKS	Project dropped in June 1961. New proposals for study include D_2O-natural U reactor, which has been refused by the AEC. Fuel elements were designed as 19-rod clusters of slightly enriched UO_2 fuel mixed with BeO, and clad in finned beryllium. The matrix fuel was in the form of cored pellets. A 200 Mw(e) central station would use natural U with Be cladding.
REFERENCES	Interim reference design. Gas cooled, heavy water moderated, pressure tube reactor prototype (GCPTR) General Nuclear Eng. GNEC-74 (September, 1958) Preliminary hazards summary report. Vol. II. Description of reactor and plant. Florida West Coast Nuclear Group GEH-24950 (December 1959) Application for USAEC licenses by Florida West Coast Nuclear Group. Part A. General Information. Part B. Preliminary hazards summary report. Volume 1. Characteristics of site and environment. Volume 2. Description of reactor and plant. Volume 3. Hazards evaluation. American Elec. Power Service Corp., General Nuclear Eng. NP-8251 (December 7, 1959)

DESIGNER	KE/ACF
TYPE	GCR
POWER	Mw(e) 22.3 Mw(t) 85
COOLANT	He
MODERATOR	Graphite
FUEL	2.24% enriched UO_2 annular pellets
CLADDING	Stainless steel
NAME/OWNER	EGCR (Experimental Gas Cooled Reactor)/AEC
OPERATOR	TVA
LOCATION	Clinch River (Oak Ridge), Tennessee
PURPOSE	Power prototype; demonstration and testing
REMARKS	Construction. Target 1964. TVA, Westinghouse and Combustion Engineering have completed an evaluation of a 750 Mw(e) version of the plant, which will use 3% enriched rods clad with stainless steel. The fuel assemblies contain bundles of seven rod-type elements composed of UO_2 pellets in stainless steel jackets. Each bundle is enclosed in a cylindrical graphite sleeve which is part of the assembly. Each active fuel channel contains six fuel assemblies. Helium coolant enters at the bottom of the reactor and leaves at the top. It then flows to two separate loops, each containing its own heat exchanger and blower. Fuel development program will include some work on UC, silicon carbide coatings, and other ceramic fuels, but the major effort will be on the development of beryllium as a cladding material.
REFERENCES	Experimental Gas Cooled Reactor preliminary hazards summary report. Kaiser Eng. ORO-196 (May 1959) Experimental Gas Cooled Reactor preliminary proposal. Kaiser Eng. and Allis-Chalmers Mfg. Co. AECU-4701 (August 1959)

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REFERENCES (contd)

EGCR-descendent of Calder Hall
W. F. Banks
Nuclear Eng. 6: 28-32 (January 1961)

Forum Memo, December 1962, p. 38-9. News Release

Experimental gas cooled reactor final hazards summary report. Volume I. Description and hazards evaluation. ORO-586 (Vol. I) (1962)

DESIGNER	LASL
TYPE	GCR, high temperature, revolving core
POWER	Mw(e) Mw(t) 3
COOLANT	He
MODERATOR	Graphite
FUEL	U-impregnated graphite. High enrichment
CLADDING	
NAME/OWNER	UHTREX (Ultra High Temperature Reactor Exp.)/AEC
OPERATOR	LASL
LOCATION	Los Alamos, N. M.
PURPOSE	Power experiment, replacing TURRET.
REMARKS	Construction. Target 1964. Reactor core is a hollow right circular cylinder with a hole running axially through it. Channels run radially through this hole to the outside edge of the core; uranium-impregnated graphite fuel elements are placed in these channels, each channel containing five elements butted end-to-end. Coolant gas enters core at its axis, flows through the fuel element channels and exits at the periphery. Flow is then through a recuperator, a helium-to-helium heat exchanger, and a blower. The core rotates on its axis for refueling.

REFERENCES

Turret: a high temperature gas cycle reactor proposal.
R. P. Hammond, others
LA-2198 (January 23, 1958)

A preliminary study of the Turret experiment - an operating test of unclad fuel at high temperatures.
R. P. Hammond, J. P. Cody
LA-2303 (March 1959)
Nucleonics 17: 106-9 (December 1959)

Ultra High Temperature Reactor Experiment (UHTREX) hazard report
Los Alamos Scientific Lab.
LA-2689 (March 1962)

DESIGNER	LASL
TYPE	GCR
POWER	Mw(e) Mw(t)
COOLANT	H_2
MODERATOR	(graphite reflected)
FUEL	U^{235} loaded graphite plates
CLADDING	
NAME/OWNER	KIWI/AEC-NASA
OPERATOR	LASL
LOCATION	Nevada Test Station, Jackass Flats, Nevada
PURPOSE	Project Rover reactor test series (nuclear rocket)
REMARKS	KIWI-A tested in 1959; KIWI-A Prime and KIWI-A3 in 1960; KIWI-B1A in 1961. All used gaseous hydrogen propellant. The 1962-63 KIWI-B series will use liquid hydrogen propellant. Six to 10 reactors are scheduled for the KIWI B series, 30 to 40 for NERVA (Nuclear Engine for Rocket Vehicle Application) series as the reactor is integrated into the rocket engine. AGN, with Westinghouse as main contractor, will develop the nuclear engine. RIFT (Reactor-in-Flight) experiments are scheduled for 1966-7. 1968-9 is target for the fully operational system. Westinghouse Astronuclear Laboratory will assume an active role in the design of the B4B series, and any subsequent developmental reactors. The first NERVA reactor designated NRX-A, scheduled for operational testing in August 1965, will be delayed; procurement and fabrication for NRX-A have been in progress since mid-1962. B4B and NRX-A will be very similar in basic concept and in many of their design features, both will use uranium-loaded graphite cores although core designs are believed to be different. Argonne National Laboratory has announced plans for the development of an alternative to KIWI, which would use refractory metal in an unmoderated system. ANL's project will be carried to the point of proving feasibility; there is also emphasis on in-house efforts on cavity reactors in which the fuel is gaseous. The Phoenix program has been started to develop advanced nuclear reactors for space propulsion. The program

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REMARKS (contd) provides for several solid-core reactor designs following KIWI. LASL will phase out of the KIWI series and into Phoebus by about mid-1964. Initial effort will probably be on high temperature operating characteristics rather than on compactness. First power tests in the Phoebus program are scheduled for 1965. Phoebus-1 will have approximately the same configurations as KIWI-B. Specific design work has begun on Phoebus-II. The small fast reactors are of several basic types: uranium-tungsten, uranium carbide, uranium-233, and variations.

REFERENCES

Nuclear rockets. Los Alamos Project Rover.
R. E. Schreiber
Nucleonics 16: 70-2 (July 1958)

A review of Project Rover
R. E. Schreiber
IRE Trans. Nuclear Sci. NS-9: 16-20 (January 1962)

Phoebus may yield 268-pound reactor
F. G. McGuire
Missiles & Rockets 12: 16-17 (April 8, 1963)

DESIGNER	ORNL
TYPE	GCR, direct coupling to reciprocating engine, closed cycle
POWER	Mw(e) 1.5 (20,000 shp) Mw(t) 60
COOLANT	N_2
MODERATOR	Graphite
FUEL	UO_2
CLADDING	Stainless steel capsules
NAME/OWNER	NGE (Nuclear Gas Engine)/AEC
OPERATOR	
LOCATION	
PURPOSE	Ship propulsion
REMARKS	Planned. A preliminary study has been done of a reciprocating engine coupled to a gas cooled reactor, similar to GCR-2 but wi th a smaller core. Dry nitrogen was selected as the reference heat exchange medium and working fluid. Fuel element would be 24 inches long instead of 40 inches.
REFERENCES	Nuclear Gas Engine. A. P. Fraas CF-58-9-12 (September 1958) Design consideration for high pressure gas cooled reactors with small cores. Oak Ridge National Lab. ORNL-CF-58-7-55 (September 1958) A nuclear gas engine for marine propulsion. Oak Ridge National Lab. ORNL-CF-58-9-12 (September 1958) Proc. 1958 Nuclear Merchant Ship Symposium, August 1958. TID-7563 (January 1959)

DESIGNER	ORNL
TYPE	GCR, pebble-bed
POWER	Mw(e) 125 Mw(t) 300
COOLANT	He
MODERATOR	Graphite
FUEL	Graphite spheres fueled with UO_2 and ThO_2. ThO_2 blanket.
CLADDING	
NAME/OWNER	PBRE (Pebble-Bed Reactor Experiment)/ORNL
OPERATOR	
LOCATION	
PURPOSE	Power experiment
REMARKS	A two-region thermal breeder design, study project by Sanderson and Porter, has been turned over to ORNL for research and development. Spherical graphite fuel pellets are presently being evaluated. First phase study: PBRE, 5 Mw(t). Second phase: conceptual design, 330 Mw(e), 800 Mw(t) central station. Radial flow, downflow and upflow studies, large core with axial flow selected for development. Most promising fuel is UC_2-ThC_2. PBRE proposed for installation in HRE-2 facility has been discontinued.
REFERENCES	Preliminary design of a 10 Mw(t) pebble-bed reactor experiment. Oak Ridge National Lab. CF-60-10-63 (November 1960) Design study of a pebble-bed reactor power plant. A. P. Fraas, others CF-60-12-5 (Rev.) (May 1961) Conceptual design of the pebble-bed reactor experiment. Oak Ridge National Lab. ORNL-TM-201 (May 1962)

DESIGNER	THIOKOL
TYPE	GCR, pebble-bed, space vehicle propulsion
POWER	Mw(e) Mw(t)
COOLANT	H_2
MODERATOR	Graphite
FUEL	Fueled graphite pellets, varied diameters
CLADDING	
NAME/OWNER	(Study)/THIOKOL
OPERATOR	
LOCATION	
PURPOSE	Space propulsion
REMARKS	Core structure consists of cylindrical graphite separators enclosing the fuel pellets; differential radial loading prevents increasing power density at core center and reduces flow through the lateral BeO reflector. Thiokol is setting up a unit for research and development in nuclear propulsion for space at Parsipanny-Troy Hills, New Jersey. They are prime contractors in an Air Force contract (with GM and Nuclear Development Corp.) for a nuclear propulsion system study.
REFERENCES	Pebble-bed reactor looks okay for nuclear space vehicles. M. M. Levoy, J. J. Newgard SAE Journal 68: 46-50 (June 1960) Nuclear space vehicles using pebble-bed reactors. M. M. Levoy, J. J. Newgard NP-8586 (1960)

GAS COOLED REACTOR STUDY (ORNL)

DESIGNER	ORNL
TYPE	GCR
POWER	Mw(e) 750 Mw(t) 1908
COOLANT	Helium
MODERATOR	Graphite
FUEL	3% enriched UO_2
CLADDING	Stainless steel
NAME/OWNER	(Study)/ORNL
OPERATOR	
LOCATION	
PURPOSE	Power
REMARKS	Study. Core design specifies 1062 fuel channels and 72 control rods. Fuel assemblies are clusters of seven 1-inch fuel rods, 10-1/2 feet long, inside graphite sleeves. These are two assemblies per channel.
REFERENCES	The ORNL GCR-3, a 750 Mw(e) gas-cooled reactor power plant. M. Bender, W. R. Gall ORNL-3353 (January 28, 1963)

GAS COOLED REACTORS TORY (UCRL)

DESIGNER	UCRL-Marquardt
TYPE	GCR, high temperature, ramjet propulsion
POWER	Mw(e) Mw(t) 150
COOLANT	Air
MODERATOR	Beryllium oxide
FUEL	Highly enriched Be-U oxide ceramic tubes
CLADDING	
NAME/OWNER	TORY/AEC
OPERATOR	UCRL
LOCATION	Nevada Test Site
PURPOSE	Project Pluto (nuclear ramjet) experiment
REMARKS	Zero power, critical December 1960. Prototype plant tests September-October 1961 (TORY-II-A-I). TORY-II-C [600 Mw(t)] development and testing 1961-2; completion target 1963. TORY-II-A-I had a cylindrical core 45 inches long by 32 inches diameter. Tubular fuel elements consisted of a homogeneous mixture of beryllium oxide and enriched uranium. The bundles were contained in unfueled BeO structural elements. Core is air-cooled; the carbon reflector, water-cooled. The ramjet consists of an inlet diffuser, a single-pass straight-through heat exchanger (the reactor), and an exhaust nozzle.

REFERENCES

Summary report on high temperature beryllium-oxide critical experiments.
R. G. Finke
UCRL-6329 (1961)

Nuclear reactors built, being built, or planned in the United States as of December 31, 1961.
TID-8200 (5th revision) (1961)

The Pluto program.
H. L. Reynolds (Lawrence Radiation Lab.)
UCRL-6923 (May 17, 1962)

GAS COOLED REACTOR STUDY (USBM)

DESIGNER	USBM
TYPE	GCR, process heat, pebble-bed concept
POWER	Mw(e) Mw(t) 750
COOLANT	He
MODERATOR	
FUEL	
CLADDING	
NAME/OWNER	(Study)/USBM-AEC
OPERATOR	
LOCATION	
PURPOSE	Feasibility study
REMARKS	U.S. Bureau of Mines program, feasibility investigation of an indirect cycle, helium-cooled reactor to produce process heat for the gasification of coal. A nonnuclear system to serve as a prototype has been designed and constructed.
REFERENCES	High temperature systems for nuclear process heat. J. P. McGee TID-7564 (p. 305) (1958) Indirect cycle nuclear reactor system to furnish process heat. R. C. Dalzell, J. P. McGee Chem. Eng. Prog. 55, Symp. Series #22: 111-18 (1959)

DESIGNER	WEST
TYPE	GCR, nuclear fueled MHD plant
POWER	Mw(e) 500 Mw(t)
COOLANT	He
MODERATOR	Graphite
FUEL	Slightly enriched UC-graphite elements
CLADDING	
NAME/OWNER	(Concept)/WEST
OPERATOR	
LOCATION	
PURPOSE	Study
REMARKS	Concept; large scale electrical power production by magneto-hydrodynamics (MHD). Electron beam ionization in a gas stream by means of a series of electron guns; design basis for a large nuclear-fueled MHD plant. Target for development of the concept is post-1980.
REFERENCES	Nuclear Eng. 8: 48 (February 1963) News Release MHD power generation by nonthermal ionization and its application to nuclear energy conversion. E. J. Sternglass, others Nuclear Energy, March 1963, p. 60-66.

SECTION D

GAS COOLED REACTORS

FOREIGN

DESIGNER	AAEC
TYPE	GCR, high temperature
POWER	Mw(e) 300 Mw(t)
COOLANT	CO_2
MODERATOR	Be or BeO
FUEL	Plutonium-enriched natural uranium. Fuel dispersed in BeO.
CLADDING	(All-ceramic fuel)
NAME/OWNER	(Study)/AAEC
LOCATION	
OPERATOR	
PURPOSE	Power reactor study
REMARKS	System investigation, fuel element studies. Most promising elements incorporate Be, U, and Th. Cermet fuels, Be and BeO matrix elements are undergoing irradiation studies. Concept development target is 1980.
REFERENCES	Nuclear Eng. 6: 96 (March 1961) News Release Tenth Annual Report, 1961-1962. Australian Atomic Energy Commission 1962

GAS COOLED REACTORS BRAZILIAN POWER STATION (BRAZIL)

DESIGNER	Not selected
TYPE	GCR, not firm
POWER	Mw(e) 150 Mw(t)
COOLANT	
MODERATOR	
FUEL	
CLADDING	
NAME/OWNER	BRAZILIAN POWER STATION/CEN
OPERATOR	
LOCATION	Parati, Brazil (Mambucaba River)
PURPOSE	Power
REMARKS	On completion of study, CEN will invite public bids for construction. Target 1965-66
REFERENCES	Applied Atomics, June 13, 1962, p. 8-9.

DESIGNER	USSR
TYPE	GCR, D_2O, 4-reactor station
POWER	Mw(e) 150 (per reactor) Mw(t) 590 (per reactor)
COOLANT	CO_2
MODERATOR	D_2O
FUEL	Natural uranium rods
CLADDING	Mg-Be alloy
NAME/OWNER	CZECHOSLOVAKIA ATOMIC POWER STATION/CZECH Socialist Republic
OPERATOR	Czech. Socialist Republic
LOCATION	Bohunice, Czechoslovakia
PURPOSE	Power
REMARKS	Test operation scheduled for 1970. A second 150 Mw(e) station is planned for Banska Bystrika in the Vah Valley: Russian CO_2-D_2O design.
REFERENCES	A heavy water power reactor with gas cooling. A. I. Alikhanov, others J. Nuclear Energy II, Vol. 3: 77-82 (1956) Engineering and economic aspects of the construction of an atomic power station in Czechoslovakia. A. Sevcick Second U. N. Intl. Conf. on the Peaceful Uses of Atomic Energy 8: 322-8 (1958)

DESIGNER	DANATOM
TYPE	GCR
POWER	Mw(e) 175 Mw(t) 574
COOLANT	CO_2
MODERATOR	Graphite
FUEL	Natural uranium
CLADDING	Magnox, graphite sleeve
NAME/OWNER	BETA/DANATOM
OPERATOR	
LOCATION	
PURPOSE	Design study
REMARKS	Study for a power reactor concept using natural uranium fuel elements. Plant is graphite moderated and cooled by CO_2. Vertical coolant channels are located within the cylindrical graphite structure, the CO_2 flowing in the annular space between the graphite sleeves and the fuel rods. After passing through the heat exchangers, the coolant gas is returned to the reactor. There are 3176 fuel channels in the core.
REFERENCES	BETA: A 175 MW gas cooled nuclear reactor power station. A preliminary design study. DANATOM Danatom-01-60 (March 1960)

DESIGNER	USSR
TYPE	GCR, D_2O moderated
POWER	Mw(e) 70 Mw(t) 300
COOLANT	CO_2
MODERATOR	D_2O
FUEL	Slightly enriched uranium
CLADDING	
NAME/OWNER	NEUBRANDENBERG STATION/East Germany
OPERATOR	
LOCATION	Neubrandenberg, E. Germany
PURPOSE	Power experiment
REMARKS	Construction, target 1964. Station is to be equipped with two 70 Mw(e) reactors by 1965.
REFERENCES	A heavy water, gas cooled reactor. A. I. Alikhanov, others J. Nuclear Energy 3, Part 2: 77-82 (August 1956)

GAS COOLED REACTORS — G-1, G-2, G-3 (FRANCE)

DESIGNER	CEA
TYPE	GCR, G-1, G-2, G-3
POWER	G-1: Mw(e) 1.7 Mw(t) 38 G-2: Mw(e) 32 Mw(t) 200 G-3: Mw(e) 32 Mw(t) 200
COOLANT	G-1: Air G-2: CO_2 G-3: CO_2
MODERATOR	G-1, G-2, G-3: Graphite
FUEL	G-1: Natural U elements G-2: Natural U rods G-3: Natural U rods
CLADDING	G-1: Mg G-2: Mg-Zr alloy G-3: Mg-Zr alloy
NAME/OWNER	G-1, G-2, G-3/CEA-EDF
OPERATOR	CEA, EDF
LOCATION	Marcoule, France
PURPOSE	Plutonium production, central station power
REMARKS	Natural uranium cast bars, clad in magnesium, are contained in horizontal channels in the graphite core. There are two elements per channel. G-1 was air-cooled, with three air circuits for cooling the fuel elements, cooling the thermal shield, and cooling the front and rear faces. G-2 and G-3 use natural uranium metal rods canned in a Mg-Zr alloy, horizontal fuel channel. Coolant is CO_2. G-1 was in operation in 1956 for plutonium production and as a central station prototype. G-2 was in operation in 1959; criticality tests with G-3 were conducted June to August 1962. Both G-2 and G-3 have been up-rated to 30-37 Mw(e) and 240 Mw(t). G-3 is expected to produce 40 Mw(e) for the French national grid.
REFERENCES	Description of reactors G-2 and G-3. Second U. N. Int'l Conf. on the Peaceful Uses of Atomic Energy 8: 334-55 (1958) The World's Reactors, G-2 and G-3. Nuclear Eng.: (insert) (December 1959)

DESIGNER	CEA
TYPE	GCR, D_2O moderated, horizontal pressure tube
POWER	Mw(e) 70 Mw(t) 250
COOLANT	CO_2
MODERATOR	D_2O
FUEL	Natural UO_2 pellets (First core: slightly enriched U)
CLADDING	Be tubes (First core: stainless steel)
NAME/OWNER	EL-4 (Monts d/Arrée Power Station)/CEA
OPERATOR	EDF
LOCATION	Morlaix, Brittany, France. Near Brennilis.
PURPOSE	Power; contribution to the Euratom ORGEL project.
REMARKS	Planned, target 1966. Containment structure will be a prestressed concrete cylinder. Fuel element design for the second loading will be UO_2 pellet pencils in beryllium tubes. Fuel assembly will consist of 19-rod pencils and there are 11 fuel elements to each fuel channel inside the pressure tubes. Cooling is by forced circulation of CO_2.
REFERENCES	EL-4. Choice of principal parameters. B. Bailly du Bois, R. Naudet SPM-620 (March 1960) In French AEC-TR-4194 (Translation) EL-4 – an advanced natural uranium reactor. Nuclear Eng. 8: 312-316 (September 1963)

DESIGNER	CEA
TYPE	GCR, high temperature
POWER	Mw(e) Mw(t) 1
COOLANT	Gas
MODERATOR	BeO (Graphite or water also studied)
FUEL	Enriched UO_2
CLADDING	Ceramic
NAME/OWNER	BRENDA (Pile Chaud)/CEA, SNECMA
OPERATOR	SNECMA
LOCATION	Cadarache, France
PURPOSE	Propulsion; aircraft reactor prototype
REMARKS	Initial construction; recently reported as being dropped.
REFERENCES	Nuclear Power 4: 82 (April 1959) News Release.

DESIGNER	EDF (CEA)
TYPE	GCR
POWER	EDF-1: Mw(e) 60 Mw(t) 290 EDF-2: Mw(e) 170 Mw(t) 700 EDF-3: Mw(e) 375 Mw(t) 1560
COOLANT	CO_2
MODERATOR	Graphite
FUEL	EDF-1: Natural U-Mo alloy hollow rods EDF-2, EDF-3: Natural U hollow rods
CLADDING	EDF-1: Zr alloy cans EDF-2, EDF-3: Mg-Zr alloy cans, graphite sleeve
NAME/OWNER	EDF-1, EDF-2, EDF-3 (Chinon Nuclear Power Station)/EDF
OPERATOR	EDF
LOCATION	Chinon, France
PURPOSE	Power. May be modified for plutonium production.
REMARKS	The Chinon Nuclear Power Station will be a 3-reactor complex with the completion of EDF-3 in 1965. EDF-1 was to go into commercial operation in 1962. Target for EDF-2, which will have no containment building but instead a 3-3/4-inch steel plate pressure vessel, is 1963. EDF-3 will have a prestressed concrete pressure vessel. EDF-4, planned for construction in Normandy, is an optimized version of EDF-3. EDF-1: Square lattice, two-region core with a compact center, more widely spaced periphery, containing approximately 17000 fuel elements, 60 cm long, in 1150 canals with vertical axes. There are 15 elements per canal. U-rod diameter: 1.4-3.5 cm. EDF-2: Hexagonal lattice, uniform configuration. The core has approximately 2350 canals. U-rod diameter: 1.8-4 cm, 60 cm long. There are 12 elements per canal

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REFERENCES

The Chinon Nuclear Power Plant EDF-1 and EDF-2.
M. Roux
Second U. N. Int'l. Conf. on the Peaceful Uses of Atomic Energy 8: 356-79 (1958)

First steps toward conventional nuclear power.
J. P. Roux, C. Bienvenu
J. Brit. Nuclear Energy Soc. 1 (3): 235-59 (July 1962)

DESIGNER	Not selected
TYPE	GCR, optimized EDF-3
POWER	Mw(e) 450-500 Mw(t)
COOLANT	CO_2
MODERATOR	Graphite
FUEL	Natural U
CLADDING	
NAME/OWNER	EDF-4/EDF
OPERATOR	EDF
LOCATION	Loir-et-Cher, Normandy, France
PURPOSE	Power
REMARKS	Planned for 1963 construction. Target 1967. Plans have included study of the "integrated" concept or "monobloc" design, in which heat exchangers are within the reactor's prestressed concrete pressure vessel; steam generators would be below the reactor, with the reactor-exchanger block in an inner cylinder (or monobloc) within the pressure vessel, and main coolant blowers located in the annular space between the two. Coolant gas flow is upward in the annulus and back down through the monobloc.
REFERENCES	Forum Memo, January 1961, p. 14. News Release. Nucleonics Week, February 14, 1963, p. 5. News Release.

DESIGNER	Israel, with French assistance
TYPE	GCR, D_2O moderated
POWER	Mw(e) Mw(t) 24
COOLANT	CO_2
MODERATOR	D_2O
FUEL	Natural uranium
CLADDING	
NAME/OWNER	BEERSHEBA STATION/Israel
OPERATOR	
LOCATION	Negev Desert near Beersheba, Israel
PURPOSE	Pilot power, research
REMARKS	Construction. Target 1964-5
REFERENCES	Nucleonics 19: 26 (February 1961) News Release.

DESIGNER	NPPC(UK)-AGIP
TYPE	GCR, Calder type
POWER	Mw(e) 200 Mw(t) 705
COOLANT	CO_2
MODERATOR	Graphite
FUEL	Natural U
CLADDING	Magnox
NAME/OWNER	LATINA STATION/SIMEA, Euratom participation
OPERATOR	SIMEA
LOCATION	Latina, Italy
PURPOSE	Power
REMARKS	Critical January 1963. Electricity production in May 1963. Fuel is composed of natural uranium metal rods in Magnox cans. The element will be the polyzonal spiral type, with spiral fins and axial flow separators or splitters. There are eight elements per vertical channel, and 2853 fuel channels. Magnox cans have helical fins.
REFERENCES	For basic design see CALDER Latina. Nuclear Eng. 4: 329-40 (October 1959)

DESIGNER	GEC-SC (UK)
TYPE	GCR, Calder type
POWER	Mw(e) 150 Mw(t) 570
COOLANT	CO_2
MODERATOR	Graphite
FUEL	Natural U hollow rods
CLADDING	Magnox
NAME/OWNER	TOKAI ATOMIC POWER STATION/JAPCO
OPERATOR	JAPCO
LOCATION	Tokai-Mura, Japan
PURPOSE	Power
REMARKS	Construction. Basic design is the Calder Hall reactor. A hollow fuel element, canned on the outside only, has been adopted for the Tokai plant. The can is sealed at each end by end plugs, is longitudinally finned with helical swirlers, and is supported inside a graphite sleeve. There are 1916 fuel channels in the graphite moderator, and eight elements per channel.
REFERENCES	For basic design see CALDER Japan's first nuclear power station. P. A. Lindley, others Nuclear Power 5: 104-13 (March 1960)

GAS COOLED REACTORS EDEYRN (UNITED KINGDOM - WALES)

DESIGNER	Not selected	
TYPE	GCR, Calder type	
POWER	Mw(e)	Mw(t)
COOLANT	CO_2	
MODERATOR	Graphite	
FUEL		
CLADDING		
NAME/OWNER	EDEYRN STATION/CEGB	
OPERATOR		
LOCATION	Caernarvonshire, Wales	
PURPOSE	Power	
REMARKS	Planned	
REFERENCES	For basic design see CALDER	

DESIGNER	UKAEA
TYPE	GCR, 4-reactor station
POWER	Mw(e) 35 per reactor Mw(t) 180 per reactor
COOLANT	CO_2
MODERATOR	Graphite
FUEL	Natural U rods
CLADDING	Magnox
NAME/OWNER	CALDER HALL STATION/UKAEA
OPERATOR	UKAEA
LOCATION	Sellafield, Cumberland, England
PURPOSE	Power, plutonium production. Power prototype
REMARKS	Operation 1956. The core of the reactor is composed of graphite blocks in the form of a 24-sided prism. There are 1696 vertical channels to accommodate the fuel elements and through which the CO_2 coolant flows. Fuel elements are solid rods of natural uranium metal encased in a magnesium-alloy can. There are six fuel elements per channel. The heat output of each reactor has been increased to 220 Mw.
REFERENCES	Symposium on Calder Works Nuclear Power Plant. J. Brit. Nuclear Energy Conf. 2: 41-291 (1957) Commissioning and operation of A station; Calder Works. H. G. Davey J. Brit. Nuclear Energy Conf. 3: 101-8 (April 1958)

CHAPEL CROSS (UNITED KINGDOM - SCOTLAND)

DESIGNER	UKAEA
TYPE	GCR, Calder type, 4-reactor station
POWER	Mw(e) 35 per reactor Mw(t) 180 per reactor
COOLANT	CO_2
MODERATOR	Graphite
FUEL	Natural U rods
CLADDING	Magnox
NAME/OWNER	CHAPEL CROSS STATION/UKAEA
OPERATOR	UKAEA
LOCATION	Annan, Scotland
PURPOSE	Power, plutonium production
REMARKS	Operation 1959 (4th reactor in March 1960) Heat output of each reactor (October 1961): 220 Mw
REFERENCES	Chapel Cross. Nuclear Eng. 4: 250-2 (June 1959)

DESIGNER	UKAEA
TYPE	GCR, high temperature
POWER	Mw(e) 28 Mw(t) 100
COOLANT	CO_2, helium studied as alternate
MODERATOR	Graphite
FUEL	1.9% enriched UO_2 sintered pellets
CLADDING	Stainless steel rods
NAME/OWNER	AGR (Advanced Gas-cooled Reactor)/UKAEA
OPERATOR	UKAEA
LOCATION	Windscale, Cumberland, England
PURPOSE	Power prototype
REMARKS	Zero-energy experiment (HERO) critical in February, 1962. AGR critical August 1962. Be cladding, planned for first core, will not be used. Fuel is in clusters of thin rods of ceramic oxide fuel encased in stainless steel. A complete fuel element stringer is composed of four 3-foot-long subassemblies, each contained in a graphite sleeve. Subassemblies are linked to give a complete stringer 50 feet long with a 14-foot fuel section. Each of the stainless steel canned subassemblies contains two 18-inch-long clusters of stainless steel fuel element rods arranged end to end. Each cluster contains 21 rods. In the Be design there were 36 fuel element rods per cluster, and three such clusters per Be fuel element subassembly. The graphite core has 235 main fuel channels. Coolant flow is upward into a collector box above the core. Pressure vessel is of double-shell construction, the inner shell containing the hot gas and the outer shell operating at the cooler inlet gas temperature. Full power operation [28 Mw(e)] in February 1963, with electricity supplied to the national grid.
REFERENCES	Design concept of the AGR. R. V. Moore Elec. Review 169: 774-92(November 17, 1961)

DESIGNER	AEI-JT
TYPE	GCR, Calder type, 2-reactor station
POWER	Mw(e) 138 per reactor Mw(t) 565 per reactor
COOLANT	CO_2
MODERATOR	Graphite
FUEL	Natural U rods
CLADDING	Magnox-A-12 tubes
NAME/OWNER	BERKELEY STATION/CEGB
OPERATOR	CEGB
LOCATION	Berkeley, Gloucestershire, England
PURPOSE	Power
REMARKS	Both reactors in operation in April-May 1962. Berkeley began producing 6000 kw(e) on the No. 1 generator in June 1962. Basic design is the Calder Hall reactor. Fuel elements are stacked vertically in coolant channels bored along the vertical axes of the graphite moderator bricks. Each fuel element consists of a natural uranium slug canned in helically finned magnox tube
REFERENCES	See CALDER Reactors on-the-line. No. 10. Berkeley. Nucleonics 12: (facing page 36) (December 1961)

DESIGNER	UKAERE
TYPE	GCR, high temperature, ceramic system
POWER	Mw(e) Mw(t) 20
COOLANT	Helium
MODERATOR	Graphite
FUEL	Fissile-fertile mixture of enriched U and Th carbides, sintered compacts
CLADDING	Graphite
NAME/OWNER	DRAGON PROJECT/UKAEA - OECD
OPERATOR	UKAERE
LOCATION	Winfrith Heath, England
PURPOSE	Power experiment
REMARKS	Construction. Hot critical experiment (ZENITH) operational in 1959. OECD and UKAEA have proposed to take Dragon a step farther and use data from its operation as a basis for the design of a power production prototype. This could be extrapolated to the development of a Dragon-type power reactor. Project would extend to 1967 under this proposal. Core is composed of fuel-moderator elements, the fuel being a mixture of enriched U and Th with graphite. Fuel element assemblies are clusters of seven hexagonal graphite tubes loaded with graphite fuel boxes containing annular fuel inserts and supporting graphite spines. The all-ceramic core consists of 37 assemblies. The core is divided into a central and a peripheral zone; elements in the outer zone will be changed more frequently. Helium coolant gas flow is upward through the fuel assemblies, over the surface of the graphite cladding tubes, and in the passages formed by the spacer ridges on the graphite tubes. The double-containment structure of the plant consists of an inner steel shell enclosing the reactor and most equipment, surrounded by an outer containment building of sealed concrete. (contd)

REFERENCES

High temperature gas-cooled reactor project.
The Engineer: 415-17 (March 1959)

Research and development aspects of the DRAGON reactor experiment.
L. R. Shepherd, P. J. Marien
Power Reactor Experiments Vol. I, pp. 13-47
International Atomic Energy Agency. Vienna, 1962

The Dragon Reactor.
Power Reactor Technology 6 (1): 74-80 (December 1962)

DESIGNER	APC
TYPE	GCR, Calder type
POWER	Mw(e) 250 per reactor Mw(t) 870 per reactor
COOLANT	CO_2
MODERATOR	Graphite
FUEL	Natural U
CLADDING	Magnox
NAME/OWNER	TRAWSFYNYDD STATION/CEGB
OPERATOR	CEGB
LOCATION	Merionethshire, Wales
PURPOSE	Power
REMARKS	Construction. Target for first reactor 1963, second reactor 1964. Design is based on the Calder Hall design. Fuel is natural uranium rods in magnox cladding. There are 3720 fuel channels, with nine elements per channel.
REFERENCES	For basic design see CALDER The APC's design for Trawsfynnyd. Nuclear Eng. 4: 289-90 (July, August, September, 1959) Trawsfynnyd design features. Nuclear Energy Eng. 13: 489-95 (October 1959)

DESIGNER	APG
TYPE	GCR, Calder type
POWER	Mw(e) 250 per reactor Mw(t) 480 per reactor
COOLANT	CO_2
MODERATOR	Graphite
FUEL	Natural U rods
CLADDING	Magnox
NAME/OWNER	HINKLEY POINT STATION/CEGB
OPERATOR	CEGB
LOCATION	Somerset, England (Hinkley Point)
PURPOSE	Power
REMARKS	Full loading target 1963. CEGB has proposed a second station on the site; final capacity would be 1000 Mw(e).
REFERENCES	For basic design see CALDER Hinkley Point Nuclear Eng. 3: 286 (July 1958)

DESIGNER	APG
TYPE	GCR, advanced Calder type, 2-reactor station
POWER	Mw(e) 289 per reactor Mw(t) 950 per reactor
COOLANT	CO_2
MODERATOR	Graphite
FUEL	Natural U solid rods
CLADDING	Magnox
NAME/OWNER	SIZEWELL STATION/CEGB
OPERATOR	CEGB
LOCATION	Sizewell, Suffolk, England
PURPOSE	Power
REMARKS	Construction. Target 1965. Basic design is the Calder Hall reactor. Fuel element will be a polyzonal helically finned design. Solid and hollow uranium metal elements have been considered. There will be seven elements per fuel channel, and approximately 3800 channels. Both reactors will be in the same building.
REFERENCES	For basic design see CALDER Sizewell nuclear power station. British Power Eng. 2 (2): 86-6 (January 1961) Sizewell nuclear power station. H. S. Arms, others Nuclear Power 6: 61-81 (September 1961)

DESIGNER	GEC-SC
TYPE	GCR, Calder type
POWER	Mw(e) 150 per reactor Mw(t) 530 per reactor
COOLANT	CO_2
MODERATOR	Graphite
FUEL	Natural U rods
CLADDING	Magnox
NAME/OWNER	HUNTERSTON STATION/S. Scotland Electricity Board
OPERATOR	S. Scotland Electricity Board
LOCATION	Ayrshire, Scotland
PURPOSE	Power
REMARKS	Construction. First reactor critical in September 1963. Fuel loading for second reactor scheduled for February 1964. Basic design is the Calder Hall reactor. The fuel element for Hunterston is a polyzonal axial type, having axial fins together with spiral flow separators or swirlers, using the principle of coolant cross-mixing between the fuel element and the channel wall.
REFERENCES	For basic design see CALDER Gas cooled reactor for the South of Scotland Electricity Board. P. J. Grant Nucleonics 16: 108-13 (May 1958)

DESIGNER	NPG
TYPE	GCR, Calder
POWER	Mw(e) 550 (2 reactors) Mw(t) 840 (2 reactors)
COOLANT	CO_2
MODERATOR	Graphite
FUEL	Natural U
CLADDING	Magnox
NAME/OWNER	DUNGENESS STATION/CEGB
OPERATOR	CEGB
LOCATION	Kent, England
PURPOSE	Power. Originally planned as a cross-channel link with EDF.
REMARKS	Construction. Target 1964.
REFERENCES	For basic design see CALDER

DESIGNER	NPG
TYPE	GCR, Calder type
POWER	Mw(e) 560 } two reactors Mw(t) 1668 }
COOLANT	CO_2
MODERATOR	Graphite
FUEL	Natural U
CLADDING	
NAME/OWNER	OLDBURY POWER STATION/CEGB
OPERATOR	CEGB
LOCATION	Oldbury-on-Severn, Gloucestershire, England
PURPOSE	Power
REMARKS	Target 1966. Two-reactor station. Will have prestressed concrete pressure vessels; boilers and core for each of the two reactors will be grouped within a single cylindrical shell. The graphite core and boilers of each reactor unit are contained in a single concrete vessel. The graphite core has 3320 vertical fuel channels. Fuel elements are natural uranium rods clad in magnesium alloy with an extended surface of spiral fins, each element having four radial splitters. Eight elements are stacked in each fuel channel. CO_2 coolant flows from blowers built into the pressure vessel below the four boilers, which are arranged symmetrically around the core. Flow is upward through the core.
REFERENCES	For basic design see CALDER Oldbury: first U. K. concrete pressure vessel. Nuclear Eng. 7: 446-8 (November 1962) Oldbury design appraisal. Nuclear Power 7: 44-50 (November 1962)

DESIGNER	NPPC
TYPE	GCR, Calder type, 2-reactor station
POWER	Mw(e) 150 per reactor Mw(t) 531 per reactor
COOLANT	CO_2
MODERATOR	Graphite
FUEL	Natural U rods
CLADDING	Magnox A-12
NAME/OWNER	BRADWELL-ON-SEA POWER STATION/CEGB
OPERATOR	CEGB
LOCATION	Bradwell-on-Sea, Essex, England
PURPOSE	Power
REMARKS	First reactor critical August 1961; second reactor in April 1962. Full load November 1962. Basic design is the Calder Hall reactor. Fuel elements will be the polyzonal spiral type with spiral fins and axial flow separators. There are eight elements per fuel channel, the channels being vertically in the core. Each core is contained in a spherical steel pressure vessel.
REFERENCES	Bradwell Nuclear Power Station. Nuclear Power 7: 78-105 (April 1962)

DESIGNER	UPC (1st reactor); APG (2nd reactor). (See Remarks)
TYPE	GCR, Calder type
POWER	Mw(e) 1000 (2 reactors) Mw(t)
COOLANT	CO_2
MODERATOR	Graphite
FUEL	
CLADDING	
NAME/OWNER	WYLFA HEAD STATION/CEGB
OPERATOR	
LOCATION	Wylfa Head, N. W. Wales (Anglesey Island)
PURPOSE	Power
REMARKS	Official sanction, 1962. Construction scheduled for 1963. Contracts were awarded the United Power Co. for the first reactor with target for 1967 and to the English Electric-B&W-Taylor Woodrow Atomic Power Group (APG) for the second reactor with target for 1968. The UPC tender has been rejected. CEGB will negotiate with APG for construction of both reactors. Design has been uprated from 800 Mw(e) to 100 1000 Mw(e) (500 Mw(e) per reactor) with the use of prestressed concrete pressure vessels.
REFERENCES	For basic design see CALDER. Applied Atomics, July 10, 1963, p. 1. News Release.

DESIGNER	AEG, DEUTSCH B&W
TYPE	GCR, advanced type
POWER	Mw(e) 100 to 150 Mw(t)
COOLANT	CO_2
MODERATOR	Graphite
FUEL	
CLADDING	
NAME/OWNER	NKW STATION/NKW
OPERATOR	
LOCATION	Wiesmoor, West Germany
PURPOSE	Power
REMARKS	Planned. The company Nordwestdeutsche Kraftwerke AG (NKW) of Hamburg, a member of the SKW study group, has contracted with Guttehoffnungshutte Sterkrade AG and with U.S. General Atomics for studying the details of a nuclear station to be built at Wiesmoor. The 40 Mw(e) reactor will be equipped with a high temperature gas-cooled reactor. A British proposal based on the AGR has also been submitted to NKW. Probable site is Wiesmoor.
REFERENCES	Applied Atomics, December 10, 1959; February 3, 1960. News Releases Nuclear Eng., October 1962, p. 385. News Release

DESIGNER	BBC-KRUPP
TYPE	GCR, high temperature, pebble-bed
POWER	Mw(e) 15 Mw(t) 46
COOLANT	Ne-He
MODERATOR	Graphite
FUEL	20% enriched U carbide in graphite spheres. Th carbide as breeder
CLADDING	
NAME/OWNER	BBC-KRUPP REACTOR/AVR
OPERATOR	AVR
LOCATION	Julich, West Germany
PURPOSE	Power experiment, prototype for 150 Mw(e) plant
REMARKS	Construction; target 1964. The concept was studied by Farrington Daniels, and a further development by Winnett Boyd was designated the Daniels-Boyd Nuclear Steam Generator, which used low-enrichment uranium carbide wafers in a porous graphite sheath for the production of 400 Mw(e). The concept was studied further by Winnett Boyd in association with Arthur D. Little, as well as by Sanderson and Porter and the Oak Ridge Laboratory. The AVR project at Julich, designed and developed by BBC/Krupp of Mannheim, is a pebble-bed, gas-cooled high-temperature reactor for the production of 15 Mw(e). The core will consist of about 100,000 six-centimeter spheres of thorium carbide-uranium carbide in graphite. Reactor control will not be by control rods, but output will be controlled by the coolant gas. Core loading is scheduled for the spring of 1964. The first core will probably be supplied by ORNL. The USAEC has requested funds in its construction authorization bill for a cooperative program with the AVR project. AEC would develop and have fabricated a coated-particle reactor core for irradiation in the AVR pebble-bed reactor. There is also the possibility of Euratom participation in the project.

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REMARKS (contd)

A long-term development program for the pebble-bed concept includes the 15 Mw(e) plant as a first stage; a second stage reactor, also 15 Mw(e) but cycling the high-temperature helium directly to a gas turbine; and a 150 Mw(e) reactor as the final stage, with a target date of 1970.

REFERENCES

Suggestion for an experimental power reactor. An impregnated graphite, nitrogen-cooled reactor and gas turbine, using materials and equipment available now.
F. Daniels
AECD-4095 (April 1950. Declassified with deletions December 1955)

Small gas-cycle reactor offers economic promise.
F. Daniels
Nucleonics 14: 34-51 (March 1956)

Boyd's active circuit gas reactor.
Canadian Chem. Processing 43: 54-6 (May 1959)

Special features of the Brown Boveri-Krupp reactor.
O. Machnig, others
Nuclear Power 6: 63-6 (March 1961)

The AVR high temperature gas-cooled reactor.
H. W. Schmidt
Preprint Paper No. 31. Engineers Joint Council, New York. (1962)

High temperature reactor development by BBC/Krupp
R. Schulten, O. Machnig
Atompraxis 4: 117-122 (April 1963)

SECTION E

HEAVY WATER MODERATED REACTORS

DOMESTIC

DESIGNER	duPont
TYPE	D_2O cooled and moderated, pressurized
POWER	Mw(e) Mw(t) 60
COOLANT	D_2O-H_2O
MODERATOR	D_2O
FUEL	U-Zr alloy
CLADDING	Zircaloy
NAME/OWNER	HWCTR (Heavy Water Components Test Reactor)/AEC
OPERATOR	duPont
LOCATION	Savannah River, Georgia
PURPOSE	Fuel element testing, power reactor conditions
REMARKS	Critical March 1962. The HWCTR can accommodate 12 test fuel elements of natural or slightly enriched uranium in a region near its center; this region is surrounded by a ring of enriched driver elements. The driver fuel tube has a meat composed zirconium—9.3 wt% uranium, 93% enriched, clad inside and out with Zircaloy. The part of the coolant loop within the pressure vessel proper consists of two coaxial tubes so arranged that coolant enters at the top, flows down the annulus to the bottom, reverses direction and goes upward through the test fuel element and out of the pressure vessel.
REFERENCES	A preliminary evaluation of gas cooling of power reactors moderated by heavy water. R. C. Holmes, others DP-307 (August 1958) Heavy Water Components Test Reactor. Savannah River plant. Plans and estimate. DP-412 (October 1959) HWCTR. The Savannah River Components Test Reactor. Nuclear Eng. 5: 221-2 (May 1960)

DESIGNER	GE (Hanford)
TYPE	D_2O cooled and moderated, pressure tube
POWER	Mw(e) 10 Mw(t) 70
COOLANT	D_2O
MODERATOR	D_2O
FUEL	UO_2 swaged rods, spike enrichment of Pu-Al. (UO_2-PuO_2)
CLADDING	Zircaloy-2
NAME/OWNER	PRTR (Plutonium Recycle Test Reactor)/AEC
OPERATOR	GE
LOCATION	Hanford, Washington
PURPOSE	Demonstration, use of Pu fuels in power reactors.
REMARKS	Critical December 1960. Full power [70 Mw(t)] November 1961. Moderator is contained in unpressurized Al calandria tank. There are 85 fuel channels, vertically mounted within the calandria; the inner process tube is of Zircaloy-2 and contains the fuel elements. Initial loading contained two types of elements. The Mark I element is a 19-rod cluster assembly, using a Pu-Al fuel alloy or sintered UO_2 elements. Cladding is Zircaloy-2 tubing. The Mark II element is composed of a rod of UO_2 surrounded by two concentric annular rings of UO_2, in Zircaloy-2 cladding. Heavy water flows vertically upward within the process tubes. Shutdown in June 1962 for refueling. UO_2 elements were gradually replaced with UO_2-PuO_2 mixed oxide elements.
REFERENCES	The Plutonium Recycle Program - a resumé of the concept, program, and facilities. Hanford Atomic Prod. Opn. HW-50700 (June 12, 1957) The Plutonium Recycle Test Reactor final safeguards analysis. N. G. Wittenbrock, others HW-61236 (October 1959)

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REFERENCES (contd)

The Plutonium Recycle Test Reactor.
Power Reactor Technology 3: 53-57 (June 1960)

Measured physics parameters, design features, and operating characteristics of PRTR.
J. R. Triplett, R. E. Peterson
Power Reactor Experiments Vol. II, pp. 213-26
International Atomic Energy Agency, Vienna, 1962

HEAVY WATER MODERATED REACTORS (Study) ORNL

DESIGNER	ORNL
TYPE	D_2O, BWR, vertical pressure tube
POWER	Mw(e) 1000 Mw(t) 8000
COOLANT	H_2O
MODERATOR	D_2O
FUEL	UO_2
CLADDING	
NAME/OWNER	(Study)/ORNL
OPERATOR	
LOCATION	
PURPOSE	Water desalination and power
REMARKS	A reference design for a facility using three 8,333 Mw(t) heavy water moderated, boiling light water cooled reactors to provide 4500 Mw(e) and 2 billion gallons of water per day.
REFERENCES	A large desalinization reactor based on current technology. I. Spiewak Nucleonics 21: 64, 66, 68 (July 1963) Saline water conversion power reactor plants Sargent and Lundy (For Oak Ridge National Laboratory) SL-1998 (January 11, 1963)

HEAVY WATER MODERATED REACTORS PARR SHOALS (WEST)

DESIGNER	WEST
TYPE	D_2O cooled and moderated. Pressure tube (U-tube). Concrete containment vessel.
POWER	Mw(e) 17 Mw(t) 66
COOLANT	D_2O
MODERATOR	D_2O
FUEL	UO_2 pellets 1.5-2.0% enrichment
CLADDING	Zircaloy-2 tubes
NAME/OWNER	PARR SHOALS PLANT (CVTR)/CVNPA
OPERATOR	CVNPA
LOCATION	Parr Shoals, S. Carolina
PURPOSE	Power demonstration prototype
REMARKS	Cold tube design, in which the pressure tube is insulated from the high temperature circulating fluid. Each Zircaloy U-tube has two fuel assemblies consisting of a 19-rod cluster of Zircaloy-clad UO_2 rods. There are 84 fuel assemblies in the core. Two regions of enrichment will be used. Fuel loading, March 1963. Critical March 1963.
REFERENCES	Carolinas-Virginia Tube Reactor reference design II. Westinghouse Electric Corp., Stone & Webster Eng. Corp. CVNA-40 (December 16, 1959) CVTR - pressure-tube reactor. P. G. DeHuff Westinghouse Engr. 31: 98-102 (July 1961) Carolinas-Virginia Nuclear Power Associates. Final hazards summary report. Part B. License application. CVNA-90 (1962) Carolinas-Virginia pressure tube reactor. Nuclear Energy, pp. 424-7, November 1962

SECTION E

HEAVY WATER MODERATED REACTORS

FOREIGN

DESIGNER	AECL
TYPE	D_2O cooled and moderated. Horizontal pressure tube
POWER	Mw(e) 19.3 Mw(t) 83
COOLANT	D_2O
MODERATOR	D_2O (H_2O reflector)
FUEL	Natural UO_2 sintered pellets
CLADDING	Zircaloy-2 tubes
NAME/OWNER	NPD-2 (Nuclear Power Demonstration-2)/AECL, Ontario Hydro
OPERATOR	Ontario Hydro
LOCATION	Des Joachims, Ontario, Canada
PURPOSE	Power prototype
REMARKS	Redesign of NPD-1. Critical April 1962, full design power June 1962. Fuel bundle is composed of seven cylindrical tubes containing UO_2 pellets. Pressure tubes are Zircaloy-2. The reactor vessel, or calandria, containing the heavy water moderator is a tube-in-shell system. Calandria tubes are aluminum. A 68 Mw(e) reactor has also been studied. A design for an "off-the-shelf" concept, HWR-80, has been made.

REFERENCES

The Canadian NPD-2 power station.
I. N. Mackay
Second U. N. Intl. Conf. on the Peaceful Uses of Atomic Energy 8: 313-21 (1958)

Design of NPD and CANDU
I. L. Wilson
AECL-799 (PaperNo. 11) (1959)

HWR - "Off-the-shelf" design for nuclear power.
D. A. B. Chase
Canadian Nuclear Technology 1 (6): 31-8 (1962)

(contd)

REFERENCES (contd)

NPD-2, Canada's prototype power reactor.
A. Wyatt
Nuclear Energy, May 1962, pp. 192-201

Uprated NPD or "HWR-80"
J. L. Olsen
AECL-1599 (pp. 43-53) (September 1962)

Heavy water moderated natural uranium power reactors.
J. L. Gray, others
AECL-1646 (October 1962)

NPD on the line. Reactor file No. 13.
Nucleonics 20: (facing p. 46) (November 1962)

DESIGNER	AECL
TYPE	D_2O cooled and moderated. Horizontal pressure tube. PWR
POWER	Mw(e) 200 Mw(t) 694
COOLANT	D_2O
MODERATOR	D_2O
FUEL	Natural UO_2 sintered pellets
CLADDING	Zircaloy-2 cylindrical tubes
NAME/OWNER	CANDU (Canadian Deuterium Uranium Reactor)/AECL
OPERATOR	Ontario Hydro
LOCATION	Kincardine, Ontario (Douglas Point)
PURPOSE	Power
REMARKS	Construction; target 1964. System will feature on-load refueling. Fuel is in the form of bundles of 19 cylindrical tubes containing UO_2 pellets. Pressure tubes are of Zircaloy-2; calandria is a horizontal cylinder of stainless steel. Coolant flow is in opposite directions in adjacent tubes. Boiling cores for the Candu concept have also been studied, as well as a reactor of intermediate size. Ontario Hydro is considering a complex of four 450 Mw(e) CANDU-type reactors, with the first two planned for 1970. Canadian GE has produced a practical design for an 1800 Mw nuclear power plant, HWR-1800, based on CANDU.

REFERENCES

Basic considerations in the design of a full scale heavy water and natural uranium power reactor.
W. B. Lewis
AECL-785 (March 28, 1959)

Status report on the Douglas Point project.
D. L. S. Bate
AECL-1599 (p. 54-68) (September 1962)

(contd)

REFERENCES (contd)

Heavy water moderated natural uranium power reactors.
J. L. Gray, others
AECL-1646 (October 1962)

Douglas Point nuclear generating station.
Atomic Energy of Canada Ltd.
AECL-1596 (October 1962)

Design and cost estimate of a multiple unit D_2O moderated and cooled nuclear power plant.
N. L. Williams (Canadian General Electric Co., Ltd.)
Canadian Nuclear Association-International Conference, Montreal, May 1963
Nuclear Eng. 8: 343 (September 1963) Abstract

DESIGNER	AECL
TYPE	D_2O (CANDU type)
POWER	Mw(e) 200 Mw(t)
COOLANT	D_2O
MODERATOR	D_2O
FUEL	Natural uranium
CLADDING	
NAME/OWNER	RAJSTHAN STATION/INDIA
OPERATOR	
LOCATION	Rana Pratap Sagar, Rajsthan State, India
PURPOSE	Power
REMARKS	CANDU-type plant, natural uranium fuel, will be designed by AECL. Construction start is scheduled for 1964.

DESIGNER	GAAA-INTERATOM (France)
TYPE	D_2O cooled
POWER	Mw(e) Mw(t) 25-50
COOLANT	D_2O
MODERATOR	D_2O or organic liquid
FUEL	Natural U
CLADDING	
NAME/OWNER	ESSOR (Orgel experiment)/EURATOM
OPERATOR	
LOCATION	Ispra, Italy
PURPOSE	Experimental prototype, contribution to ORGEL
REMARKS	Contract has been awarded. ESSOR will be preceded by a critical experiment (Dutch design) at Ispra. Construction scheduled for 1963; target 1965.
REFERENCES	Description of a specific test reactor for studying the ORGEL system. C. Chassignet, others Power Reactor Experiments, Vol. II, pp. 183-212 International Atomic Energy Agency, Vienna, 1962 See also EURATOM

HEAVY WATER MODERATED REACTORS HALDEN (NORWAY)

DESIGNER	JENER
TYPE	D_2O cooled and moderated, BWR, Cave construction
POWER	Mw(e) Mw(t) 5 [2nd loading, 20 Mw(t)]
COOLANT	D_2O
MODERATOR	D_2O
FUEL	Natural U rods. UO_2 1.5% enriched spike elements. (2nd core UO_2)
CLADDING	Aluminum and stainless steel tubes (2nd core Zircaloy)
NAME/OWNER	HALDEN REACTOR PROJECT/JENER-OEEC
OPERATOR	OEEC
LOCATION	Halden, Norway
PURPOSE	Process steam
REMARKS	Operation 1959. Second core operation March 1962. Proposed conversion to spectral shift control after completion of the OEEC program in 1962-63. Interest is in application to an oceanographic research vessel.
REFERENCES	The Halden Boiling Water Reactor. N. Hidle, O. Dahl HPR-2 (1958) Halden BWR Nuclear Eng. 4: 106-12 (March 1959)

DESIGNER	AB-ATOM ASEA
TYPE	D_2O cooled and moderated. PWR, pressure vessel. Underground construction
POWER	Mw(e) 10 + space heat Mw(t) 65
COOLANT	D_2O
MODERATOR	D_2O
FUEL	Sintered UO_2 pellets
CLADDING	Zircaloy-2 tubing
NAME/OWNER	R/3-ADAM/Swedish State Power Board
OPERATOR	Swedish State Power Board
LOCATION	Agesta, Sweden
PURPOSE	Power, district heating
REMARKS	Construction; target 1963. Critical in July 1963. The project developed from two design studies, designated R-3 and Adam. In the Adam concept, developed by ASEA for house heating purposes, pressure vessel was filled with D_2O. Coolant entered the reactor vessel by 8 pipes through the bottom, flowed upward through the moderator, and was turned downward between the thermal shield and the vessel wall. It was then distributed to the fuel elements through a space between the grid plate and the bottom aluminum casting. After passing the fuel rods the D_2O entered the upper plenum and left the reactor. A fuel element was composed of 19 Al cans containing UO_2 pellets. There were 168 elements in the core. In the R-3 concept developed by AB-Atomenergi for power and heat production, the fuel element contained five subassemblies or bundles composed of 19 individual fuel rods in a supportive shroud of Zircaloy-2. Each fuel rod was built up of UO_2 pellets encased in a Zircaloy-2 can. Coolant flow was upward through the

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REMARKS (contd)

fuel element shrouds, then downward through the moderator and bottom reflector regions to the outlet nozzles. The Agesta PWR has a cylindrical core containing 140 elements secured to the lid of reactor pressure vessel. Elements penetrate bottom core plate into coolant plenum. Coolant flow is from the inlet plenum upward through elements, downward in the moderator space between the elements. The fuel element is composed of 19-rod bundles, with overall Zircaloy-2 tube as cladding. Fuel rods are natural UO_2 pellets in Zircaloy-2 tubes. There is a provision for raising the reactor output to 125 Mw(t) by means of a more powerful core and added heat exchangers (Stage II). R/3-Adam was critical in July 1963.

REFERENCES

R/3-ADAM. Swedish nuclear heat-electric station. Nuclear Eng. 5: 202-5 (May 1960)

HEAVY WATER MODERATED REACTORS MARVIKEN (SWEDEN)

DESIGNER	AB ATOM and ASEA
TYPE	D_2O cooled and moderated. BWR. Integral nuclear superheat
POWER	Mw(e) 200 Mw(t)
COOLANT	D_2O
MODERATOR	D_2O
FUEL	Boiling region: Natural UO_2 pellets Superheat: Slightly enriched UO_2
CLADDING	Boiling region: Zircaloy-2 Superheat: Cr-Nb alloy
NAME/OWNER	Marviken Power Station/Swedish State Power Board
OPERATOR	Swedish State Power Board
LOCATION	Marviken, Sweden. (Norkpoings Bay area)
PURPOSE	Power and space heat
REMARKS	A more advanced BWR with internal superheat (Project BASHFUL) has been under investigation. Original proposal was for a 100 Mw(e) heavy water moderated and cooled BWR with natural uranium fuel. The advanced design envisages the generation of superheated steam to produce 204 Mw(e) net, but it would be capable of producing 160 Mw(e) operating with saturated steam. Superheat elements would require slightly enriched uranium. Tentative choice of cladding material is a chromium-niobium alloy. Boiler elements might be natural UO_2 clad with Zircaloy-2. Features would include pressure-suppression containment. The project has been renamed Marviken-K. The Swedish Parliament has approved construction of a 200 Mw(e) station with a boiling heavy water reactor and integral nuclear super-heat. Target is 1968-69. Preliminary work is reportedly under way on an enlarged reactor type (BASHFUL-1000) of the Marviken type.
REFERENCES	Nucleonics 20 29 (October 1962) News Release. Forum Memo, March 1963, pp. 19-20. News Release.

DESIGNER	AB ATOM
TYPE	D_2O PWR, cross-flow, homogeneous
POWER	Mw(e) 250-400 Mw(t)
COOLANT	D_2O
MODERATOR	D_2O
FUEL	
CLADDING	
NAME/OWNER	PHWRHT (Pressurized Heavy Water Reactor - Homogenized Type)/AB ATOM
OPERATOR	
LOCATION	
PURPOSE	Power reactor study
REMARKS	Concept is based on cross-flow design, using fuel elements laid horizontally across flow of D_2O, providing direct contact between the D_2O and the fuel. Concept is known as the Pressurized Heavy Water Reactor of the Homogenized Type. PHWR-400 is an investigation of concept as a possible choice for full-scale installation for 1970 service. Full-scale reactor evaluation has been done by Nordstjernan group in collaboration with AB Atomenergie and US Westinghouse. A final report on the feasibility of a 250 Mw plant has been completed for AB Atomenergie by Westinghouse, Bechtel, Johnson Co.
REFERENCES	Applied Atomics, May 16, 1962, p. 11-12.

HEAVY WATER MODERATED REACTORS DAVID (SWEDEN)

DESIGNER	ASEA
TYPE	Boiling slurry reactor
POWER	Mw(e) Mw(t)
COOLANT	D_2O
MODERATOR	D_2O
FUEL	Slurry of Th and enriched U oxides in heavy water
CLADDING	
NAME/OWNER	DAVID POWER REACTOR/ASEA
OPERATOR	
LOCATION	
PURPOSE	Conceptual design study
REMARKS	Experimental work is in progress on the concept, which uses a dispersion of thorium and enriched uranium oxides in D_2O as a slurry fuel.
REFERENCES	A boiling slurry reactor concept. O. Lindstrom, B. Widell ASEA Research, No. 7, pp. 239-70 (1962)

HEAVY WATER MODERATED REACTORS SULZER (SWITZERLAND)

DESIGNER	SULZER
TYPE	D_2O cooled and moderated. Pressure tube. Underground construction.
POWER	Mw(e) 6-8 Mw(t) 30
COOLANT	D_2O
MODERATOR	D_2O
FUEL	Natural U; outer annular core has 1% enriched elements
CLADDING	Zircaloy
NAME/OWNER	SULZER PROJECT/Federal Inst. Technology
OPERATOR	Federal Inst. Technology
LOCATION	Zurich, Switzerland
PURPOSE	District heating and power
REMARKS	Construction
REFERENCES	Sulzer project for a prototype heavy water power reactor for location in an underground cavern. P. de Haller, A. F. Fritzsche Second U. N. Int'l. Conf. on the Peaceful Uses of Atomic Energy 9: 16-35 (1958)
	Report on the construction of a nuclear heat and power station for the District Heating Station of the Federal Institute of Technology. Sulzer Bros. NP-7945 (n.d.)

HEAVY WATER MODERATED REACTORS LUCENS (SWITZERLAND)

DESIGNER	SULZER
TYPE	D_2O moderated, gas cooled. Pressure tube.
POWER	Mw(e) 6-7 Mw(t) 30
COOLANT	CO_2
MODERATOR	D_2O
FUEL	0.93% enriched U metal
CLADDING	Mg alloy
NAME/OWNER	EXPERIMENTAL POWER PLANT LUCENS/SNA
OPERATOR	SNA
LOCATION	Lucens, Switzerland
PURPOSE	Power
REMARKS	SNA is sponsoring the project, which has replaced the proposal considered by SNA members THERMATOM, ENUSA and SUISATOM for a D_2O moderated and cooled reactor of Sulzer design. Construction 1962, target 1964. Fuel is slightly enriched uranium metal canned in a magnesium alloy. D_2O is contained in an aluminum tank. The calandria consists of 73 fuel element tubes and 12 control rod tubes. Each fuel element consists of seven uranium rods in finned Mg alloy cans. The fuel element consists of a graphite support inserted in the pressure tube, with seven channels in which the uranium rods are inserted. The core is divided into two areas by the pitch of the fuel elements. The pressure tubes are of Zircaloy-2; coolant flows down the inside of the tube and passes up over the fuel element proper.
REFERENCES	Lucens: Switzerland's experimental pressure tube reactor. Nuclear Eng. 7: 449-51 (November 1962)

HEAVY WATER MODERATED REACTORS SGHWR (UNITED KINGDOM)

DESIGNER	UK/AEA
TYPE	Steam-generating D_2O moderated, H_2O cooled. Pressure tube
POWER	Mw(e) 100 Mw(t)
COOLANT	H_2O
MODERATOR	D_2O
FUEL	1.4% enriched UO_2 (Enrichment unspecified for superheat region)
CLADDING	Zirconium alloy cans (boiling). Stainless steel cans (superheat).
NAME/OWNER	SGHWR (Steam Generating Heavy Water Reactor)/UK AEA
OPERATOR	
LOCATION	Winfrith Heath, Dorset, England
PURPOSE	Prototype, electricity production.
REMARKS	The UK has been studying this reactor concept since 1958. A 100 Mw(e) prototype steam generating plant will be constructed at Winfrith to study and prove the economic feasibility of the concept. The SGHWR core consists of a bank of 112 zirconium alloy pressure tubes set vertically in an aluminum alloy calandria containing the D_2O moderator; each tube is separated from the D_2O by a second tube and a gas gap. Fuel, which is 1.4% enriched U clad in Zircaloy, is contained within the pressure tubes. Light water coolant passes up the channels, where some boils and goes to steam separators and then to the turbine; the remainder goes through an eight-channel superheat region which has been included to test the advantages of superheat. Fuel cladding for the superheat region will be stainless steel. No enrichment for superheat fuel has been specified. At power, the reactor will be controlled by varying the D_2O level in the store tank. Britain's industrial consortia will collaborate and share in design and development of the project. Technical collaboration will also be carried on with Canada and Sweden.

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REFERENCES

Symposium on pressure tube water reactors. British Nuclear Energy Society, Risley, Lancs., England. July 1962.

Forum Memo, March 1963, pp. 15-16. News Release

HEAVY WATER MODERATED REACTORS MZFR (WEST GERMANY)

DESIGNER	SIEMENS
TYPE	D_2O cooled and moderated
POWER	Mw(e) 50 Mw(t) 200
COOLANT	D_2O
MODERATOR	D_2O
FUEL	Natural UO_2 pellets
CLADDING	Zircaloy-2
NAME/OWNER	MZFR (Mehr-Zweck-Forschungs Reaktor)/Soc. Nuclear Research
OPERATOR	Soc. Nuclear Research
LOCATION	Karlsruhe Research Center, Karlsruhe, W. Germany
PURPOSE	Power, research, and isotope production
REMARKS	Planned. Official approval for construction received. Target 1964-65. Boiler will be seamlessly forged rings connected by outside seams. Siemens is also designing a gas-cooled pressure tube reactor for Atomkraft Bayern, for 100 Mw(e) production. Fuel element column consists of two fuel elements joined together. Each element: 37 rodlets containing UO_2 pellets in Zircaloy tube, 10.5 mm ID (0.41 in.) and 0.6 mm thick. Two hundred thirty fuel elements. UO_2 density: 10.5 g/cm^3 Boiler: seamlessly forged rings connected by outside seams, inner thin layer of stainless steel. (Rings: 0.134 m thick) Siemens is studying the possibilities of developing the MZFR type for a Th-U^{233} cycle.
REFERENCES	The Siemens multi-purpose reactor design. A. Zeigler Nuclear Power 6: 71-4 (March 1961)

SECTION F

LIQUID METAL COOLED REACTORS

DOMESTIC

LIQUID METAL COOLED REACTORS STUDY (AEC)

DESIGNER	AC, CE, GE, WEST proposals
TYPE	Liquid metal cooled breeder
POWER	Mw(e) 1000 Mw(t)
COOLANT	Sodium
MODERATOR	
FUEL	Pu
CLADDING	
NAME/OWNER	(Design study)/AEC
OPERATOR	
PURPOSE	Design evaluation
REMARKS	Design study for a 1000 Mw(e) breeder reactor have been awarded to GE, AC, CE, and WEST. Contracts involve a 6- to 8-month study of a sodium-cooled, plutonium-fueled fast breeder to be built in the 1970's, and include design of a 200 Mw(e) prototype for construction in 1967-1968. Oxides, carbides, and alloys will be studied.
REFERENCES	Nuclear News, p. 26 (July 1963)

DESIGNER	AGN
TYPE	Liquid metal; fast reactor. Space power
POWER	kw(e) 300 Mw(t)
COOLAND	Li and K studied
MODERATOR	
FUEL	UC
CLADDING	Nb-Zr
NAME/OWNER	SPUR (Space Power Unit Reactor)/AGN-USAF
OPERATOR	
LOCATION	
PURPOSE	R&D program, space power
REMARKS	Lithium-cooled fast reactor, a nonboiling system; a potassium-cooled boiling system, were studied. Paper study, 300 kwe, scale-up to 1 Mw(e), of a nuclear turboelectric unit. A 5- to 6-year program for AiResearch and USAF. Prototype development target 1963, complete system target 1965-66. AGN is also studying rubidium as a coolant for fast reactors; the first circulating rubidium loop will operate at 1600 F with 100 pounds of Rb. Working fluids studied included Rb, Li, K, Na, and Cs. Development for SPUR (Space Power Unit Reactor) has been placed under a joint AEC-NASA-AF SNAP-50/SPUR program
REFERENCES	Boiling vs. non-boiling liquid metal cooled reactors. D. L. Cochran, K. E. Buck ARS Space Power Systems Conference, Santa Monica, Calif., September 27-30, 1960 SPUR Phase I final report. AiResearch Mfg. Div., Garrett Corp. ASD-TR-61-656

DESIGNER	AI
TYPE	Sodium-graphite thermal breeder
POWER	Mw(e) 5.7 Mw(t) 20
COOLANT	Na
MODERATOR	Graphite
FUEL	U Slugs (2nd loading Th-U elements)
CLADDING	Stainless steel (2nd loading Zircaloy)
NAME/OWNER	SRE (Sodium Reactor Experiment)/AEC, S. Cal. Ed.
OPERATOR	AI, S. California Edison
LOCATION	Santa Susana, California
PURPOSE	Power experiment
REMARKS	Operation 1957. Second core loading 1960. Major modifications are planned for 1963: operation on UC fuel; rating increase from 20 Mw(t) to 45 Mw(t). Currently the power level is restricted to 5 Mw(t) until carbon is removed from the coolant. First core loading for SRE consisted of 43 seven-rod cluster fuel elements of U metal, enriched to 2.8% U^{235}. Rods were jacketed in 304 SS with an NaK thermal bond. Second core loading consisted of five-rod cluster fuel elements containing Th–7.6 wt% U alloy slugs with U^{235} enrichment of 93.1%. Type 304 SS is the cladding material, with an NaK thermal bond. Power limit with Core 2 was set at 5 Mw(t). Reactor instability was noted at 2 Mw(t) operation due to thermal bowing of the fuel elements. Constraint was imposed by means of a helical wire wrap around the fuel clusters, resulting in a reduced power coefficient. Fuel element modifications were completed in January 1962. In July 1963 the SRE critical assembly achieved criticality with a full core loading of 24 UC elements, and the SRE produced power, also in July 1963, with a full-scale UC element in the core. The Power Expansion Program under way with the SRE will permit raising the power level to more than 30 Mw(e) and operating temperatures from 950 to 1200 F. Completion of the program will be in 1964.

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REFERENCES

Operating experience with the Sodium Reactor Experiment.
F. E. Faris, others
Second U. N. Int'l. Conf. on the Peaceful Uses of Atomic Energy 9: 493-509 (1958)

SRE operates again with Core 2 but with 5 Mw(t) power limit.
Nucleonics 20: 12 (January 1962)

Proceedings of the Symposium on Sodium Reactors Technology, May 24-25, 1961, Lincoln, Nebraska.
TID-7623 (June 1962)

A 200 MWe prototype sodium cooled reactor high efficiency power plant.
J. A. Falcon, P. R. Keep
CONF-51-4 (American Public Power Association Annual Convention, Cleveland, April-May 1963)

DESIGNER	AI
TYPE	Sodium-graphite
POWER	Mw(e) 76 Mw(t) 240
COOLANT	Na
MODERATOR	Graphite
FUEL	3% enriched U-Mo alloy rods
CLADDING	Stainless steel
NAME/OWNER	HALLAM NUCLEAR POWER FACILITY/AEC, Consumers Power
OPERATOR	Consumers Power Co.
LOCATION	Hallam, Nebraska
PURPOSE	Power demonstration, 1st round
REMARKS	On-line May 29, 1963. Power level to be increased to 80-81 Mw(e) in June. Reactor core consists of a matrix of moderator-elements into which fuel elements, control rods, and miscellaneous elements are suspended. A moderator element is a log of graphite enclosed in a stainless steel can. Fuel for the first core loading consists of solid cylinders of U—10 wt% Mo in stainless steel tubes. Fuel rods are assembled into 18-rod bundles, with an outer ring of 12 rods and an inner ring of six rods, enclosed in a Zircaloy-2 process tube. Number of fuel assemblies in the initial core is 137. Uranium enrichment is 3.6%. Sodium coolant system consists of three independent circuits, each directly connected to the reactor vessel. The Hallam design has been extrapolated to a 360 Mw(e) and to a 525 Mw(e) study, the 525 Mw(e) central station including super-critical steam generation. Preliminary studies have begun on a 200 Mw(e) prototype SGR, which will use uranium carbide fuel. Second core for the Hallam plant will also use uranium carbide fuel elements.
REFERENCES	The Consumers Public Power District sodium graphite reactor. R. L. Olson NAA-SR-2600 (1958)

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REFERENCES (contd)

75,000 kilowatts of electricity by nuclear fission at the Hallam Nuclear Power Facility.
F. C. Gronemeyer
AI-5275 (1960)

Hallam Nuclear Power Facility prototype for advanced sodium-cooled power stations.
R. W. Dickinson, others
Power Apparatus and Systems No. 58: 1008-11 (February 1962)

Design practice: Hallam.
Power Reactor Technology 5: 39-51 (June 1962)

A high-performance sodium-graphite reactor power plant.
R. W. Dickinson
ASME Preprint 62-WA-261 (1962)

LIQUID METAL COOLED REACTORS AETR (AI)

DESIGNER	AI
TYPE	Sodium cooled. Epithermal breeder
POWER	Mw(e) 360 Mw(t) 900
COOLANT	Na
MODERATOR	Be or graphite
FUEL	Th-U alloy, folded plate elements
CLADDING	Stainless steel or low alloy steel
NAME/OWNER	AETR (Advanced Epithermal Thorium Reactor)/AEC, SAEA
OPERATOR	
LOCATION	
PURPOSE	Power experiment
REMARKS	R&D, pilot plant planned, critical experiments in progress. AI's investigation for the SAEA will be completed in 1963-64, with decision to construct expected then. Fuel studies include Th-U alloys, ThC-UC, paste fuel, ceramic or cermet Th fuels. A full-scale plant has been proposed for 1972-75. SAEA is also considering advanced proposal by AI for a 500 Mw(e) Na-cooled unmoderated reactor.
REFERENCES	Advanced thorium reactor. S. Siegel BNL-483 (p. 9) (1958) Epithermal reactor shows promise for competitive nuclear power. Electrical World 154: 52-4 (July 25, 1960) Nucleonics Week, September 27, 1962, p. 1. News Release. Epithermal thorium reactors. D. T. Eggen TID-7560 (p. 148-71) (1962)

DESIGNER	ANL
TYPE	Liquid metal cooled. Fast breeders: EBR-I; EBR-II.
POWER	EBR-1: Mw(e) - Mw(t) 1.4 EBR-II: Mw(e) 20 Mw(t) 60
COOLANT	EBR-I: NaK EBR-II: Na
MODERATOR	
FUEL	EBR-I: 93% enriched U-Zr, natural U blanket EBR-II: Fissium alloy pins, natural and enriched U
CLADDING	EBR-I: Zircaloy-2 EBR-II: Stainless steel tubes
NAME/OWNER	EBR (Experimental Breeder Reactor)/AEC
OPERATOR	ANL
LOCATION	NRTS, Idaho
PURPOSE	Power experiment
REMARKS	EBR-I was operable in 1951, and the third core (Mark III) was critical in 1957. The Mark III core had fuel rods assembled into hexagonal units of 36 rods each, contained in hexagonal stainless steel tubes. In 1961 EBR-I was shut down for installation of a plutonium core. The Mark IV core was critical on November 27, 1962 on elements consisting of rods of 98.5% Pu, 1.25% Al clad in Zircaloy, surrounded by an inner blanket of natural uranium rods and an outer blanket of natural uranium bricks. The Mark IV core has produced 1.8 kw(e) of power on plutonium fuel. After testing, EBR-1 will demonstrate 1.2 Mw(e) power production. EBR-II criticality is scheduled for late 1963. A concept for a compact plant cooled by boiling mercury has been proposed for direct launch on an advanced Saturn or Nova missile, for soft landing at moon site. The reactor is similar to EBR Mark III. The core fuel rods

REMARKS (contd) are bolted rather than jacketed, and none of the plant's components are shielded. Foldable radiators remove condensation heat from the mercury cycle. System used the Rankine cycle, direct from reactor to mercury-vapor turbine. UC and enriched U fuel rods have been studied. Design power is 1 Mw(e).

REFERENCES

Experimental Breeder Reactor II (EBR-II). Hazard summary report.
L. J. Koch, others
ANL-5719 (May 1957)

EBR-I, Mark-III. Design report.
Argonne National Laboratory
ANL-5836 (March 1958)

Construction design of EBR-II; an integrated unmoderated nuclear power plant.
L. J. Koch, others
Second U. N. Int'l. Conf. on the Peaceful Uses of Atomic Energy 9: 323-5 (1958)

Nuclear power plant for moon outlined.
E. H. Kolcum
Aviation Week 75: 50-53 (July 31, 1961)

EBR-2; a closed cycle fast breeder.
Nuclear Eng. 7: 356-7 (September 1962)

Nucleonics Week, November 29, 1962, p. 5. News Release

DESIGNER	APDA
TYPE	Sodium cooled. Fast breeder
POWER	Mw(e) 60 Mw(t) 200
COOLANT	Na
MODERATOR	
FUEL	25.6% enriched U-Mo alloy pins. Blanket: depleted uranium
CLADDING	Zirconium. Blanket: Stainless steel
NAME/OWNER	ENRICO FERMI ATOMIC POWER PLANT/AEC, Detroit Ed.
OPERATOR	PRDC
LOCATION	Monroe, Michigan
PURPOSE	Power demonstration, first round
REMARKS	Enrico Fermi was taken critical on August 23, 1963. Present plans are to carry out a low-power physics program under the present 1 Mw(t) operating license for 9 months, after which PRDC will apply for a higher-power license. First electricity from Fermi could be generated about 1 year from now. For the future, four alternative types of fuel are being studied: uranium oxide cermet in pin configuration; mixed uranium oxide and plutonium oxide; mixed uranium and thorium metal; and a cermet of uranium oxide in niobium
REFERENCES	Description of developmental fast neutron breeder power reactor plant. APDA-108 (September 1955) Enrico Fermi Atomic Power Plant. A. P. Donnell, others Second U. N. Int'l. Conf. on the Peaceful Uses of Atomic Energy 8: 535-42 (1958) Enrico Fermi power plant. APDA-124 (January 1959)

(contd)

REFERENCES (contd)

Civilian Power Reactor Program. Part III. Status report on fast reactors as of 1959.
TID-8518 (1) Book I

Enrico Fermi Atomic Power Plant revised license application. Part B. Technical information and hazards summary report.
Power Reactor Development Company
NP-10458 (July 1961)

Nucleonics Week, August 29, 1963, p. 1-3. News Release.

DESIGNER	GE
TYPE	Liquid metal cooled; ceramic fuel. Fast breeder
POWER	Mw(e) 500 Mw(t) 1400
COOLANT	NaK or Na
MODERATOR	
FUEL	PuO_2-UO_2 rods
CLADDING	Stainless steel
NAME/OWNER	EFCR (Experimental Fast Ceramic Reactor)/GE-AEC
OPERATOR	
LOCATION	Arkansas
PURPOSE	Power experiment, development
REMARKS	Program has been under AEC sponsorship since 1959; fuel test on Pu-U oxide fuels are in progress. The program calls for construction of a 10-50 Mw(t) experimental fast reactor (EFCR), followed by a prototype in the 100-300 Mw(e) range for operation by 1970, and construction of a 500 Mw(e) reactor to be on-line by 1975. Proposed EFCR for possible construction in Arkansas would be sponsored by the Southwest Atomic Energy Associates, with contributions to capital cost from the W. German government and Euratom. Design studies have included a 500 Mw(e) reactor, with detailed physics and core analysis (Reference FCR design). Fuel would be PuO_2-UO_2 rods in stainless steel cladding. Thermal rating is 1400 Mw(t). Primary coolant system is composed of four sodium loops; reactor and primary lopp would be mounted within a 40-foot diameter primary-system tank.
REFERENCES	Fast oxide breeder-reactor physics. Part I. Parametric study of 300 Mw(e) reactor core. P. Greekler, others GEAP-3721 (December 1961)

(contd)

REFERENCES (contd)

Experimental Fast Oxide Reactor.
M. J. McNelly, others
Power Reactor Experiments. Vol. I, p. 317-43
International Atomic Energy Agency, Vienna. 1962.

Experimental Fast Ceramic Reactor design. Status report as of October 31, 1961.
K. M. Horst, ed.
GEAP-3885 (April 1962)

Development of the Fast Ceramic Reactor.
K. Cohen, B. Wolfe
Nuclear Eng. 7: 358-9 (September 1962)

Development of the Fast Ceramic Reactor.
K. Cohen, B. Wolfe
Nuclear News 6: 11-15 (February 1963)

LIQUID METAL COOLED REACTORS MCR (GM/NDA)

DESIGNER	GM/NDA
TYPE	Liquid metal cooled
POWER	Mw(e) 3
COOLANT	Liquid metal
MODERATOR	
FUEL	
CLADDING	
NAME/OWNER	MCR (Military Compact Reactor)/AEC
OPERATOR	
LOCATION	
PURPOSE	Compact power plant for military applications.
REMARKS	Contract for design, fabrication and operation of the prototype has been awarded to Allison Division of Feneral Motors (prime contractor) and United Nuclear Corporation. MCR will be an extremely light-weight, compact power plant with a high temperature, liquid metal cooled reactor coupled to a power conversion system. The construction fund request was refused by JCAE. No prototype construction is envisaged before 1964.
REFERENCES	Nucleonics Week, July 5, 1962, p. 2. News Release.

DESIGNER	LASL
TYPE	Sodium cooled fast reactor. Pu fuel
POWER	Mw(e) Mw(t) 1
COOLANT	Na
MODERATOR	
FUEL	90% enriched Pu-Fe alloy (Molten Pu)
CLADDING	Ta-W alloy containment
NAME/OWNER	LAMPRE (Los Alamos Molten Plutonium Reactor)/AEC
OPERATOR	LASL
LOCATION	Los Alamos, New Mexico
PURPOSE	Power experiment
REMARKS	Test operation April 1961. Core for LAMPRE I consisted of foot-long thimbles containing the molten Pu-Fe fuel, placed in the sodium coolant. Thimbles were fabricated of a tantalum alloy. A project, originally designated LAMPRE-II but no longer carrying this designation, is under way for the engineering design of a fast reactor core facility; it is a sodium-cooled system for testing advanced core concepts. Facility is designated FRCTF (Fast Reactor Core Test Facility). Aim is for 300 watts/gram Pu. Target: 1967.

REFERENCES

LAMPRE, a molten plutonium fueled reactor concept.
R. M. Kiehn, others
LA-2112 (January 1957)

Los Alamos Molten Plutonium Reactor Experiment. (LAMPRE) hazard report.
E. O. Swickard
LA-2327 (June 1959)

A preliminary study of a Fast Reactor Core Test Facility.
D. B. Hall, others
LA-2332 (August 1959)

DESIGNER	PWAC (CANEL)
TYPE	Lithium cooled. Indirect cycle, potassium vapor turbine
POWER	Mw(e) Mw(t)
COOLANT	Li (K intermediate loop)
MODERATOR	
FUEL	UO_2-Be
CLADDING	Nb-Zr alloy containment
NAME/OWNER	PWAC-IIC/USN-AEC
OPERATOR	PWAC
LOCATION	NRTS, Idaho
PURPOSE	Proof-of-principle, SNAP-50
REMARKS	The LCRE 10 Mw(t) experiment is in the final design stage at CANEL. The program has been canceled. Instead, the AEC will proceed directly to design and develop the SNAP-50 reactor prototype.

REFERENCES

Hazard summary report on critical experiment program No. 1 at CANEL.
Pratt & Whitney Aircraft, Div. United Aircraft Corp.
PWAC-170 (May 24, 1957)

Core-moderated circulating fuel reactor study.
Pratt & Whitney Aircraft, Div. United Aircraft Corp.
PWAC-186 (July 15, 1957)

The P & WA circulating fuel reflector-moderated reactor.
C. C. Bigelow, M. E. Greenstreet
PWAC-189 (Vol. 1) (November 15, 1957)

Volume 2. Appendix A. Design specifications and reference information for the PWAR-6; flying test bed application.
C. C. Bigelow, M. E. Greenstreet, comps.
PWAC-189 (Vol. 2) (November 15, 1957)

(contd)

REFERENCES (contd)

Design criteria for Lithium-Cooled Reactor Experiment (LCRE) at NRTS.
D. T. Hedden
CNLM-4043 (Rev. A) (September 4, 1962)

Preliminary safety analysis report for the Lithium Cooled Reactor Experiment (LCRE)
C. C. Bigelow, P. Cole, others
PWAC-370 (Suppl. 1) (September 29, 1962)

SECTION F

LIQUID METAL COOLED REACTORS

FOREIGN

LIQUID METAL COOLED REACTORS — RAPSODIE (France)

DESIGNER	CEA
TYPE	Sodium cooled. Fast breeder
POWER	Mw(e) Mw(t) 10
COOLANT	Na
MODERATOR	
FUEL	60% enriched UO_2-PuO_2 pins. Natural or depleted UO_2 blanket
CLADDING	SS
NAME/OWNER	RAPSODIE/CEA
OPERATOR	CEA
LOCATION	Cadarche Research Center, France
PURPOSE	Power experiment
REMARKS	Construction; target 1965. Participation in the U.S.-Euratom plutonium recycle program, with the objective of constructing large-scale critical assemblies, design of 100 Mw(e) reactors, and studies leading to the design of fast neutron reactors using the U-Th fuel cycle. In a full-scale reactor with a larger core natural or depleted uranium oxide would be used with plutonium oxide for the core elements. First core will be a ceramic mixture of the oxides UO_2-PuO_2. Core consists of central parts of the fuel lattice--about 50 elements each containing 37 fuel needles. The fertile blanket is formed by the upper and lower parts of the fuel elements (axial blanket) and by about 500 peripheral fertile fuel assemblies
REFERENCES	Rapsodie. G. Vendryes Energie Nucleaire 3: 25-46 (January-February 1961) The fast reactor Rapsodie. C. P. Zaleski, L. Vautrey Power Reactor Experiments, Vol. I, p. 365-8 International Atomic Energy Agency. Vienna. 1962.

(contd)

REFERENCES (contd)

The Rapsodie Project.
J. R. Leduc
TID-7623 (p. 168-70) (1962)

The fast breeder reactor Rapsodie. Volume 1. Test; Volume 2. Figures (In French).
C. P. Zaleski, L. Vautrey
CEA-2193 (1962)

Forum Memo, March 1963, p. 21. News Release.

Rapsodie--a vital fast reactor project.
R. Wustner
Nuclear Eng. 8: 316-21 (September 1963)

DESIGNER	CNEN
TYPE	Sodium cooled. Fast breeder. Mercury binary cycle
POWER	Mw(e) Mw(t)
COOLANT	Na (Hg intermediate loop)
MODERATOR	
FUEL	Th and U^{233} oxides slurry
CLADDING	
NAME/OWNER	RAPTUS (Rapid Thorium-Uranium System)/CNEN
OPERATOR	
LOCATION	Casaccia Center for Nuclear Studies (near Rome), Italy
PURPOSE	Experiment
REMARKS	Long term development project aimed at exploring the thorium-uranium fuel cycle. High temperature sodium heat exchange studies are in progress. Concept proposes a slurry of Th and U^{233} oxides surrounding an array of tubes containing liquid sodium. Italy is also planning to study a fast plutonium breeder using ceramic fuel. Aim of the project is to develop a paste-type fuel consisting of U^{233} and Th oxides in sodium. Program proposes construction of a 60 Mw(e) prototype plant cooled by sodium, the design to include a target commercial-size plant. Features of the target plant will be oxide fuels, integral reprocessing, and a binary mercury-steam power system. The mercury system, as a secondary coolant, would operate a mercury-vapor generator, the other generator turned by steam generated by the condensing mercury vapor. AC may be engaged as nuclear system designer-supplier. CNEN (Italy) and Euratom have reached a joint agreement for a 3-1/2-year period of association covering preliminary development of the RAPTUS concept.
REFERENCES	CNEN program for a mercury binary cycle power plant. A. Forcella Preprint Paper No. 14. Engineers Joint Council, N.Y. 1962. (contd)

REFERENCES (contd)

Fast reactors - a world survey. Nuclear Power 17: 42-49 (December 1962)

Nucleonics Week, July 26, 1962, p. 1. News Release.

Nucleonics Week, November 22, 1962, p. 5. News Release.

LIQUID METAL COOLED REACTORS DOUNREAY (United Kingdom)

DESIGNER	AEA
TYPE	NaK cooled. Fast breeder.
POWER	Mw(e) 15 Mw(t)
COOLANT	NaK (later Na)
MODERATOR	
FUEL	40% enriched U hollow rods (U-Mo alloy)
CLADDING	Niobium (outer) Vanadium (inner)
NAME/OWNER	DOUNREAY FAST REACTOR/UKAEA
LOCATION	Dounreay, Caithness, Scotland
PURPOSE	Power experiment
REMARKS	Dounreay was in operation in 1960, shut down for core modifications, with resumed operation in August 1960 The fuel element is an annular tube of enriched U alloy, 525 mm long and 18.75 mm diameter, clad inside and outside. The upper part of the element, or breeder end-piece, is a 150 mm length of natural uranium. Lattice is star-shaped. The form installed in 1960 has a hexagonal center which is mobile. Core is surrounded by a breeder blanket of uranium as rods clad in stainless steel. Core and blanket are contained in a double-walled stainless steel vessel.

REFERENCES

The Dounreay Fast Reactor - basic problems in design.
H. Cartwright, others
Second U.N. Int'l Conf. on the Peaceful Uses of Atomic Energy 9: 316-22 (1958)

Dounreay.
Nuclear Power 2: 221-48 (June 1957)

Design and construction of the DFR core, reactor vessel, fuel handling equipment, and shielding.
J. Tatlock, others
J. Brit. Nuclear Energy Conf. 6: 166-188 (July 1961)

(contd)

REFERENCES (contd)

The fast breeder reactor.
R. V. Moore, R. Hurst
J. Brit. Nuclear Energy Conf. 6: 161-165 (July 1961)

The Dounreay Fast Breeder Reactor Experiment.
J. L. Phillips, A. G. Frame
Power Reactor Experiments Vol. 1, pp. 295-315
International Atomic Energy Agency. Vienna. 1962.

DESIGNER	AEA
TYPE	Sodium cooled. Fast breeder.
POWER	Mw(e) 200 Mw(t) 500
COOLANT	Na
MODERATOR	
FUEL	Pu-U oxides in SS or Pu-U carbides (See Remarks)
CLADDING	(See Remarks)
NAME/OWNER	PFR (Prototype Fast Reactor)/AEA
OPERATOR	
LOCATION	
PURPOSE	Power prototype
REMARKS	Planned. Critical experiment ZEBRA to be constructed. Prototype construction planned for 1963-4. Design studies on commercial prototype (1968-9) are well advanced. The low-power fast reactor VERA at Aldermaston has been loaded with plutonium fuel. The copper-clad Pu fuel plates are similar to those being manufactured for ZEBRA at Winfrith.
REFERENCES	The Fast Breeder Reactor. R. V. Moore, R. Hurst J. Brit. Nuclear Energy Conf. 6: 161-5 (July 1961) Applied Atomics, May 29, 1963, p. 1. News Release

LIQUID METAL COOLED REACTORS STUDY (W. Germany)

DESIGNER	KRB	
TYPE	Fast breeder program	
POWER	Mw(e)	Mw(t)
COOLANT		
MODERATOR		
FUEL	Pu	
CLADDING		
NAME/OWNER	Fast Breeder Study Program/KRB	
OPERATOR		
LOCATION		
PURPOSE		
REMARKS	In support of the program to develop fast breeder reactors, the Karlsruhe nuclear research center will set up four new experimental research facilities by 1967. These will be a fast zero-energy reactor for up to 300 kg of Pu (SNEAK), to be completed by 1965; a fast subcritical assembly known as SUAK; the Experimental Fast Ceramics Reactor (EFCR) to be constructed in the U.S. in collaboration with the USAEC; and incorporation of a fast neutron core. DEMAG and AI have investigated a zirconium hydride moderated reactor prototype using sodium as a coolant, and UC as fuel. At Karlsruhe, plutonium reactors with He, dry steam, and sodium coolants will be tested. Euratom has signed a 5-year association contract with KRB for joint research on fast breeder.	
REFERENCES	Applied Atomics, March 6, 1963, p. 4-5. News Release.	

DESIGNER	USSR
TYPE	Sodium cooled. Fast breeder.
POWER	Mw(e) Mw(t) 5
COOLANT	Na
MODERATOR	
FUEL	PuO_2 pellets, natural U rods
CLADDING	SS
NAME/OWNER	BR-5 (Soviet Fast Reactor)/USSR
OPERATOR	USSR
LOCATION	Volga Center, Russia
PURPOSE	Power experiment
REMARKS	Critical 1958. The 50 Mw(e) prototype proposed for construction has apparently been dropped in favor of a full-scale project (1000 Mw). Fuel elements are sintered Pu oxide in SS tubes (5 mm OD, wall thickness 0.4 mm, active length 280 mm). Nineteen tubes comprising a fuel element are arranged with helical wire spacers inside hexagonal SS tube (26 mm across flats, 0.5 mm thick). There are 80 hexagonal elements in the core, surrounded by two rows of natural U-loaded tubes as blanket and thermal shield. All are enclosed in SS tube through which the Na coolant flows. Sodium flow is upward through the core from a single inlet at the bottom to a single outlet above the core.
REFERENCES	The Soviet fast reactor BR-5. R. R. Matthews Nuclear Eng. 4: 359-60 (October 1959) Some problems in the operation of the BR-5 fast neutron reactor. M. S. Pinkhasik, others AEC-tr-5266 Translation from a publication of the State Committee of the Council of Ministers of the USSR on the Use of Atomic Energy, Moscow, 1961

REFERENCES (contd)

Operational experience with the BR-5 reactor.
A. I. Leipinskii, others
IAEA Preprint No. CN-15/40 (Conference on Operational Experience with Atomic Power Reactors, Vienna, June 4-10, 1963)
AEC-tr-5890 (Translation)

SECTION G

ORGANIC MODERATED AND/OR COOLED REACTORS

DOMESTIC

DESIGNER	AI
TYPE	OMR
POWER	Mw(e) 50 Mw(t) 160
COOLANT	Organic liquid
MODERATOR	Organic liquid
FUEL	UO_2 pellets (pins)
CLADDING	APM (Aluminum Powdered Metal)
NAME/OWNER	POPR (Prototype Organic Power Reactor)/AEC
OPERATOR	
LOCATION	
PURPOSE	Power demonstration (second round rules)
REMARKS	Proposal by Grand River Dam Authority refused by AEC. Demonstration may be dropped. A proposal was submitted to AEC for a 30 Mw(e), 160 Mw(t) process heat reactor for Packaging Corporation of America's plant at Filer City, Michigan.
REFERENCES	The 50 MWe Prototype Organic Nuclear Plant. C. W. Wheelock, G. S. Budney ASME Preprint 61-WA-226 (1961)
	Preliminary POPR conceptual design excursion study. F. J. Halfen NAA-SR-Memo-6448 (June 196)
	Prototype organic power reactor. Atomics International NAA-SR-7400 (Sect. IV) (November 15, 1962)

DESIGNER	AI
TYPE	Organic moderated and cooled
POWER	Mw(e) Mw(t) 5-15
COOLANT	Organic liquid
MODERATOR	Organic liquid
FUEL	UO_2-SS matrix. 90% enriched plates
CLADDING	SS
NAME/OWNER	OMRE (Organic Moderated Reactor Experiment)/AEC
OPERATOR	AI
LOCATION	NRTS, Idaho
PURPOSE	Power experiment, fuel element development
REMARKS	Operation February 1958. Has been shut down for second core loading. Project will be phased out in mid-1963. Sixteen stainless steel-clad plates make up a fuel assembly. The OMRE, a pressurized system, was specifically designed as a test facility for organics, with no provision for electricity generation. Coolant-moderator liquid was Santowax O.M.
REFERENCES	OMRE Nuclear Eng. 2(21): 521 (December 1957) Conceptual design study of OMRE modifications. W. B. Wolfe NAA-SR-Memo-3881 (July 1959) Organic Moderated Reactor Experiment Safeguards summary. H. L. Slettew, ed. NAA-SR-2323 (February 1, 1958)

DESIGNER	AI
TYPE	Organic cooled and moderated
POWER	Mw(e) 11.4 Mw(t) 45.5
COOLANT	Terphenyl
MODERATOR	Terphenyl
FUEL	1.9% enriched U-Mo-Al alloy (double-annular fuel assemblies)
CLADDING	Al concentric tubes
NAME/OWNER	PIQUA NUCLEAR POWER FACILITY/AEC, City of Piqua
OPERATOR	City of Piqua
LOCATION	Piqua, Ohio
PURPOSE	Power demonstration, 2nd round
REMARKS	Fuel is 1.94% enriched U as a U-Mo-Al alloy in nested double-annular fuel assemblies clad with aluminum. Each assembly contains four sets of coaxial tubular elements stacked to attain full core length in a thin-walled annular stainless steel coolant duct of full core length. Reactor core contains 85 fuel assemblies, 13 of which contain control rods. Initially the normal core loading will be decreased by about 15 assemblies, with dummy assemblies replacing these to reduce excess reactivity. Coolant enters the core from the top, flows downward through the core and then upward in the annulus between the grid support barrel and the pressure vessel to the outlet nozzle. The single coolant loop consists of two coolant pumps, a superheater, and a steam generator. Critical June 1963.
REFERENCES	Engineering design of the Piqua OMR. E. F. Weisner Nuclear Eng. 5: 68-9 (February 1960) Selection of the Piqua OMR fuel element. E. B. Baumeister NAA-SR-4239 (March 15, 1960)

(contd)

REFERENCES (contd)

The Piqua Nuclear Power Facility.
E. F. Weisner
Proc. Organic Cooled Reactor Forum, p. 211-224
(October 1960)
NAA-SR-5688 (December 1960)

Final safeguards summary report for the Piqua Nuclear Power Facility.
Atomics International
NAA-SR-5608 (August 1961)

DESIGNER	AI
TYPE	Organic cooled and moderated
POWER	Mw(e) Mw(t) 40
COOLANT	Terphenyl
MODERATOR	Terphenyl
FUEL	Highly enriched UO_2-SS plates
CLADDING	SS
NAME/OWNER	EOCR (Experimental Organic Cooled Reactor)/AEC
OPERATOR	Phillips Petroleum
LOCATION	NRTS, Idaho
PURPOSE	Power experiment
REMARKS	Construction. Target 1962. This project had been indefinitely deferred with the plant 99% complete. Core design consists of rectangular fuel assemblies composed of two subassemblies. Subassembly contains 28 active plates and one dummy plate, the active plates being of highly enriched UO_2-SS with stainless steel cladding. Conceptual design was by Phillips.
REFERENCES	Experimental Organic Cooled Reactor conceptual design. W. E. Nyer, J. H. Rainwater IDO-16570 (December 1, 1959) Experimental Organic Cooled Reactor. M. R. Dusbabek NAA-SR-5688 (p. 189-210) (December 1960) Experimental Organic Cooled Reactor, preliminary hazards report; addendum. Fluor Corp. IDO-24034 IDO-24034 (Add.) (November 1960) IDO-24034 (Add. 2) (April 1961)

ORGANIC REACTORS DCDR (MARQ)

DESIGNER	Marquardt
TYPE	Organic cooled. Direct cycle
POWER	Mw(e) 5-20 Mw(t)
COOLANT	Diphenyl
MODERATOR	Diphenyl
FUEL	UC
CLADDING	Graphite
NAME/OWNER	DCDR (Direct Cycle Diphenyl Reactor)/Marquardt
OPERATOR	
LOCATION	
PURPOSE	Power and process heat
REMARKS	R & D proposal, conceptual design (Direct Cycle Diphenyl Reactor). Concept for power and/or process heat. Application has been made to the AEC for R & D assistance. Marquardt has also proposed construction of the DCDR as a dual purpose reactor for water desalination and power production; proposals have been sent to the communities of Catalina, San Diego, and Long Beach, Calif.
REFERENCES	Nucleonics Week, September 27, 1962, p. 3. News Release.

DESIGNER	WEST
TYPE	Organic cooled and moderated.
POWER	Mw(e) 50 Mw(t)
COOLANT	Organic liquid
MODERATOR	Organic liquid
FUEL	UO_2 small pellets
CLADDING	
NAME/OWNER	OMFBR (Organic Moderated Fluidized Bed Reactor)/ (Proposal)
OPERATOR	Burlington Vt. Light Department
LOCATION	Burlington, Vermont
PURPOSE	Power
REMARKS	Proposed. Target 1967.
REFERENCES	Atomic development at Westinghouse. Power Eng. 62: 44-50 (December 1958)

SECTION G

ORGANIC MODERATED AND/OR COOLED REACTORS

FOREIGN

DESIGNER	GEC CANADA
TYPE	Organic cooled. D_2O moderated
POWER	Mw(e) Mw(t) 40
COOLANT	Terphenyl
MODERATOR	D_2O
FUEL	Natural UO_2 sintered rods
CLADDING	SAP
NAME/OWNER	OCDRE (Organic Cooled Deuterium Reactor Exp.)/AECL
OPERATOR	AECL
LOCATION	Whiteshell Research Establishment, Manitoba, Canada
PURPOSE	Power prototype
REMARKS	Project has been dropped in favor of the Organic Test Reactor (OTR) which will be the first major facility at Whiteshell.
REFERENCES	The OCDRE program. W. M. Campbell AECL-945 (October 1959)

DESIGNER	EURATOM member firms. ESSOR: GAAA, Interatom, Montecatini
TYPE	Organic cooled, D_2O moderated
POWER	Mw(e) Mw(t)
COOLANT	Organic liquid
MODERATOR	D_2O
FUEL	Natural U alloy or UC-C cermet
CLADDING	Al or SAP
NAME/OWNER	ORGEL (Organique Eau Lourde)/Euratom
OPERATOR	
LOCATION	
PURPOSE	Power
REMARKS	ESSOR, the D_2O reactor designed by GAAA and Interatom, is an experimental reactor for ORGEL, Euratom's development of the organic reactor concept. ECO (Experience Critique ORGEL), designed by Dutch NERATOOM, is under way at Ispra center in Italy. ECO will use U metal rods in Al cans, diphenyl coolant and D_2O moderator. EXPO, the exponential experiment, is also under construction at Ispra. Target for ESSOR is 1965. In ESSOR, the central zone contains 12 channels; four of the peripheral channels are for special tests and related to individual cooling circuits. The other eight, for collective tests, have a common coolant loop. The fueled ring has 44 fuel emplacements; 24 are composed of MTR-type elements. The two zones are separated by a tight compartment, and the ensemble is contained in a suspended tank. There are access chambers above and below the reactor. Tubular fuel elements will probably be used in ORGEL. Active core: 40 Mw(t). Pressure tube (calandria) design: ORGEL.
REFERENCES	ORGEL - a European concept. J. C. Leny Nuclear Eng. 6: 508-12 (December 1961) (contd)

REFERENCES (contd)

Design criteria, engineering features, experimental program for the ECO reactor.
P. Bonnaure, others
Energia Nucleare 9 (9): 529-34 (September 1962)

Description of a specific test reactor for studying the ORGEL system.
C. Chassignet, others
Power Reactor Experiments, Vol. II, p. 183-212
International Atomic Energy Agency. Vienna. 1962

DESIGNER	CNEN
TYPE	OMR
POWER	Mw(e) Mw(t) 30
COOLANT	Organic liquid
MODERATOR	Organic liquid
FUEL	Th-U^{233} fuel cycle. First core highly enriched UO_2 in SS
CLADDING	SS
NAME/OWNER	SORIN REACTOR (Project PRO)/CNEN
OPERATOR	SORIN, Agip
LOCATION	Bologna, N. Italy
PURPOSE	Power prototype
REMARKS	Construction, target 1964. A zero-power experiment ROSPO (Reattore Organico Sperimentale a Potenza O) is in progress at Casaccia; target 1963. Core studies continuing; first fuel plates will be SS-clad, later UO_2 elements will be clad in Al obtained by powder sintering. Elements containing thorium will also be used. Second core for PRO will be designed for 60 Mw(t).
REFERENCES	The CNEN program for reactors with organic liquid and the uranium-thorium cycle. F. Ippolito, others Energia Nucleare (Milan) 8: 196-208 (March 1961) PRO reactor optimization eriteria. S. Baldetti, others Energia Nucleare (Milan) 8: 413-21 (June 1961)

DESIGNER	AI (U.S.)
TYPE	Organic cooled, D_2O moderated
POWER	Mw(e) 30 Mw(t)
COOLANT	Organic liquid
MODERATOR	D_2O
FUEL	UC, spike elements slightly enriched
CLADDING	SAP
NAME/OWNER	DON (Spanish Power Station)/JEN, CENUSA
OPERATOR	JEN, CENUSA
LOCATION	Alberche Valley, north of Madrid, Spain
PURPOSE	Power prototype, testing reactor
REMARKS	Conceptual design by Atomics International completed. Final plans will be developed by JEN. Construction 1965.
REFERENCES	Organic cooled D_2O moderated power reactor study. B. L. Hoffman TID-7575 (p. 108) (March 1959) Nucleonics Week, May 10, 1962, p. 5. News Release. The 22nd project. L. Palacois, G. Velarde (JEN, Madrid) Preprint (Ottowa) Canadian Nuclear Assoc., 1962

DESIGNER	AI (Interatom)
TYPE	OMR, ship propulsion
POWER	Mw(e) (10,000 shp) Mw(t)
COOLANT	
MODERATOR	
FUEL	
CLADDING	
NAME/OWNER	GKSS PROJECT/GKSS
OPERATOR	GKSS
LOCATION	Geestacht, Germany
PURPOSE	Ship propulsion
REMARKS	Construction of a merchant ship was started in 1962; completion scheduled for 1964-5. Euratom will cooperate on the project. GKSS has recently contracted with Deutsch B&W (subcontract to U.S. B&W) for the design of a PWR merchant ship power plant. The B&W study will be based on their compact ship reactor design. Final selection of reactor type may depend upon this study. The fuel element in the Interatom design is a rod or pin of UO_2 pellets contained in finned tubing, 100 rods enclosed in a stainless steel box constituting an element. Later design specifies 3.7% enriched UO_2 in aluminum alloy tubing.
REFERENCES	Reference design for an OMR-powered 38,000 DWT tanker. R. J. Gimera, R. E. Stanbridge NAA-SR-1851 and supplement (March 1957) Maritime organic moderated and cooled reactor. NAA-SR-3859

(contd)

REFERENCE (contd)

The Interatom marine reactor.
F. E. Faris
Nuclear Power 6: 75-6 (March 1961)

Sketch of a ship reactor cooled and moderated with organic substances.
Kernreaktoren fur Schiffsantriebe, p. 33-6
Verlag Karl Thiemig AG. Munich. 1961

ORGANIC REACTORS KBWP (W. Germany)

DESIGNER	AI (Interatom)
TYPE	OMR
POWER	Mw(e) 150 Mw(t)
COOLANT	Organic liquid
MODERATOR	Organic liquid
FUEL	
CLADDING	
NAME/OWNER	KBWP PROJECT/KBWP (Formerly AKS)
OPERATOR	KBWP
LOCATION	Obrigheim, Baden, W. Germany
PURPOSE	Power
REMARKS	Design; project planning completed March 1962. Specifications have been submitted to Euratom-U.S. joint program. The reactor, supplied by Interatom, will be based on the Piqua, Ohio design.
REFERENCES	Applied Atomics, June 13, 1962, p. 1. News Release.

SECTION H

PRESSURIZED LIGHT WATER REACTORS

DOMESTIC

DESIGNER	AEC	
TYPE	PWR	
POWER	Mw(e)	Mw(t)
COOLANT		
MODERATOR		
FUEL		
CLADDING		
NAME/OWNER	SSPWR (Small Size PWR)/AEC	
OPERATOR		
LOCATION		
PURPOSE	Civilian reactor program	
REMARKS	Planned. American Standard was selected for the construction of this plant, which has been postponed indefinitely because of siting problems.	
REFERENCES		

DESIGNER	ALCO
TYPE	PWR
POWER	Mw(e) 2 Mw(t) 10
COOLANT	H_2O
MODERATOR	H_2O
FUEL	93% enriched UO_2 in SS plate
CLADDING	SS
NAME/OWNER	APPR-1 (Army Package Power Reactor-1) or SM-1/AEC, Army
OPERATOR	ALCO
LOCATION	Fort Belvoir, Va.
PURPOSE	Power, remote locations. Prototype for package reactors.
REMARKS	Now designated SM-1. Operation 1957, core II installed in December 1960. Conceptual design studies by ORNL were the basis for the APPR reactors. SM-1 elements are sintered compacts of UO_2 and boron carbide in stainless steel matrix, in the form of stainless steel clad plates.

REFERENCES

ORNL's design for a power reactor package.
R. S. Livingston, A. L. Bloch
Nucleonics 13: 24-7 (May 1955)

A package power reactor for remote locations.
A. L. Bloch
AECU-3170 (1955)

APPR-1. Design, construction, and operation.
APAE-23 (November 1957)

Portable nuclear power plant offers operating flexibility, easy maintenance, and long life for remote industrial, mining, and military sites.
Power 103: 61-3 (January 1959)

(contd)

REFERENCE (contd)

Design analysis of a prepackaged nuclear power plant (1000 ekw). Volume I. Primary and secondary system design. Volume II. Reactor design analysis.
Alco Products Inc.
APAE-42 (Vol. I and II) (February 1959)

Core characteristics of four Army Package Power Reactors.
J. G. Gallagher, others
Nuclear Sci. & Eng. 2 (Supplement): 15-16 (June 1959)

PRESSURIZED LIGHT WATER REACTORS SM-1a (ALCO)

DESIGNER	ALCO
TYPE	PWR
POWER	Mw(e) 1.6 Mw(t) 20 (11.15 Mw space heat)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Highly enriched UO_2 and boron compound in SS matrix plates
CLADDING	SS
NAME/OWNER	SM-1a (Stationary Medium Power-1a)/AEC, DOD
OPERATOR	DOD
LOCATION	Fort Greely, Alaska
PURPOSE	Power and space heat
REMARKS	Critical at site March 1962. Design includes energy-quench vapor containment; vapor container is two concentric cylinders: inner of 3-1/2 feet of concrete sealed at the top, outer is steel. Second core was delivered in November 1962.
REFERENCES	Characteristics of four Army Package Power Reactors. J. G. Gallagher, others Nuclear Sci. and Eng. (Supplement) 2: 15-16 (June 1959) The Army Nuclear Power Program; its reactors, and their application to the less-developed areas of the world. J. K. Bratton Symposium on Small and Medium Power Reactors, Vienna, 1960. Paper SMPR-51 (1960) Hazards report - SM-1A core II. J. R. Combe, others ACNP-62832 (October 18, 1962) (See also APPR)

DESIGNER	ALCO
TYPE	PWR; skidmounted plant
POWER	Mw(e) 1.5 Mw(t) 10 (0.293 Mw space heat)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Highly enriched UO_2-SS cermet flat plates
CLADDING	SS
NAME/OWNER	PM-2a (Portable Medium Power-2a)/AEC, Army
OPERATOR	U.S. Army, Corps of Engineers
LOCATION	Camp Century, Greenland
PURPOSE	Power and space heat
REMARKS	Operation at site in 1961. The U.S. Army Materiel Command has announced plans to dispose of the reactor.
REFERENCES	Hazards summary report - prepackaged nuclear power plant for an ice-cap station (PM-2a). E. M. Reiback, others APAE-49 (Supplement) (April 1960) (See also APPR)

DESIGNER	ALCO
TYPE	PWR
POWER	Mw(e) 7 Mw(t) 28
COOLANT	H_2O
MODERATOR	H_2O
FUEL	93% enriched UO_2 and boron compounds in SS matrix plates
CLADDING	SS
NAME/OWNER	SM-2 (Stationary Medium Power-2)/AEC, DOD
OPERATOR	
LOCATION	Nike-Zeus installations
PURPOSE	Power, remote locations
REMARKS	Design and development. Construction depends on Department of Defense requirements.
REFERENCES	Conceptual design of SM-2 12000 ekw power complex. Alco Products APAE-68 (May 1960) SM-2 core and vessel design analysis. Alco Products APAE-69 (Vol. I, II, and II) (March 1961) (See also APPR)

PRESSURIZED LIGHT WATER REACTORS PL-3 (ALCO)

DESIGNER	ALCO; AC
TYPE	PWR
POWER	Mw(e) 1 Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	
CLADDING	
NAME/OWNER	PL-3 (Portable Low-power-3)/AEC,DOD
OPERATOR	U.S. Navy
LOCATION	Byrd Station, Antarctica
PURPOSE	Power and space heat
REMARKS	New designation is PM-3b. Phase I study and design recommendation has been completed. Contract was awarded to AC, later canceled; instead AC has done a re-evaluation of all work done on PM-3b with the objective of a new design concept for a lighter, more compact portable reactor of at least 1 Mw(e) power rating. Combustion Engineering has done design studies on a BWR plant for Byrd Station.
REFERENCES	PWR preliminary design data for PL-3. Alco Products APAE-115 (Vol. II) (February 1962) Byrd Station study. Final report. Includes Addendum 1. Allis-Chalmers Manufacturing Co. ACNP-62848 and Add. 1 (February 1, 1963)

DESIGNER	BAW
TYPE	PWR, thorium-uranium converter; oil-fired superheat
POWER	Mw(e) 163 Mw(t) 585
COOLANT	H_2O
MODERATOR	H_2O
FUEL	93% enriched UO_2-ThO_2 pellets
CLADDING	SS tubes
NAME/OWNER	INDIAN POINT PLANT/ (CON/ED)
OPERATOR	Consolidated Edison
LOCATION	Indian Point, N.Y.
PURPOSE	Power
REMARKS	Critical August 1962, full power operation January 1963. The PWR is a thorium-uranium converter, using highly enriched U^{235} with fertile Th^{232} as a homogeneous mixture of the oxides, incorporated in rod-type elements clad in SS. Thorium is converted to U^{233} within the core during power operation. There are three different uranium loadings in the radially loaded core. The fuel element is composed of 195 stainless steel tubes containing fuel pellets. Can for the fuel element assembly is Zircaloy-2. Second core (1964) will be an advanced three-region design using slightly enriched UO_2 clad in stainless steel (Westinghouse design); no thorium will be used. CON/ED is planning a second plant, 800-1000 Mw(e) PWR, based on a Westinghouse/Stone & Webster design study; designation is the Ravenswood Reactor. Site will be in Queens, on New York's East River.
REFERENCES	Reactor studies. Final report. Part I. TID-10117 (1955. Declassified March 1957) The Consolidated Edison Thorium Reactor F. Ward BNL-483 (January 1958) Core design and characteristics of the Consolidated Edison Reactor. BAW-9 (Rev. 3) (August 1958)

(contd)

REFERENCES (contd)

The Consolidated Edison Company of New York nuclear electric generating station.
G. R. Milne, others
Second U.N. Int'l. Conf. on the Peaceful Uses of Atomic Energy 8: 483-9 (1958)

Hazards summary report, Consolidated Edison Thorium Reactor.
USAEC Docket 50-3, Exhibit K-5 (Rev. 1)
Babcock and Wilcox Co. (January 1960)

Consolidated Edison Thorium Reactor physics design.
H. S. Barringer, others
BAW-120 (Rev. 1) (July 1960)

Indian Point - Consolidated Edison's thorium converter.
Nuclear Eng. 6: 413-23 (October 1961)

Indian Point on-the-line.
Nucleonics Reactor File No. 14
Nucleonics 21: 45-52 (April 1963)

Consolidated Edison nuclear steam generating station.
Power Reactor Technology 6 (3): 28-40 (June 1963)

Preliminary hazards summary report for the Consolidated Edison Indian Point Reactor, Core B.
Consolidated Edison (N. Y.) and Westinghouse Electric Corporation
NP-12869 (nd)

DESIGNER	BAW
TYPE	PWR, spectral shift control
POWER	Mw(e) 20-30 Mw(t)
COOLANT	H_2O-D_2O
MODERATOR	H_2O-D_2O
FUEL / CLADDING	Exponential experiment will use Al-clad 2.5% enriched UO_2
NAME/OWNER	SSCR (Spectral Shift Controlled Reactor)/AEC
OPERATOR	
LOCATION	
PURPOSE	Power prototype, remote military installations
REMARKS	1 kw experimental facility is under study, using Al-clad 2.5% enriched UO_2 rods, H_2O and D_2O moderator. Burns and Roe has contracted for an R&D study for a combined desalination/nuclear power plant for the New York Atomic Research and Development Authority; study will concentrate on a spectral shift controlled reactor using thorium as the fertile fuel, to produce 100-200 Mw(e) and to purify about 1 million gallons of water per day. Study completion target is April 30, 1963. BAR has also received an AEC contract for a feasibility study of a nuclear desalination/power plant with Key West, Florida specified as the location. Los Angeles Department of Water and Power had applied to the AEC in the spectral shift reactor program, for which funds have been requested in AEC's fiscal 1964 budget. Sierra Pacific Power has requested AEC permission to build a 125 Mw(e) spectral shift reactor on Walker Lake near Reno, Nevada. Design study for a 450 Mw(e), 1516 Mw(t) plant has been completed. Fuel is 3.57% enriched UO_2. The element consists of fuel tubes in four groups surrounding a cruciform control rod channel. The thorium fuel cycle has been studied; it can be started with either highly enriched U or Pu, highly enriched U^{235} having been taken as the feed material for the study. First cycle in the SSCR would use the U^{235} with Th in the form of oxide fuel loaded in four radial and two axial zones, with a Th blanket. Operating parameters for this core would be 407 Mw(e) and 1355 Mw(t). (contd)

REFERENCES

Thorium and uranium fuel cycles for spectral shift controlled pressurized water reactors.
G. K. Rhode, M. C. Edlund
ANS Third Annual Meeting, June 1957
Paper 4-1 (1957)

The Spectral Shift Control Reactor design and economic study.
D. Mars, D. Gans, Jr.
BAW-1241 (December 1961)

The Spectral Shift Control Reactor (a variation of PWR).
M. C. Edlund
Small and Medium Power Reactors. Vol. I, p. 165-78
International Atomic Energy Agency. Vienna. 1961.

Spectral Shift Control Reactor.
J. Coughlin
ASME Preprint 61-PWR-6 (1961)

Spectral Shift Reactor.
Power Reactor Tech. 5 (4): 81-6 (September 1962)

Applied Atomics, February 13, 1963, p. 6. News Release.

Water cooled thorium reactors
H. S. Barringer
TID-7650 (p. 172-93) (1962)

DESIGNER	BAW
TYPE	PWR
POWER	Mw(e) (20,000 shp) Mw(t) 69
COOLANT	H_2O
MODERATOR	H_2O
FUEL	~4% enriched UO_2 swaged rods (Inner assemblies 4.2%, outer assemblies 4.6%)
CLADDING	SS
NAME/OWNER	MSR (Merchant Ship Reactor)/AEC, MA
OPERATOR	Maritime Administration
LOCATION	Land-based prototype: Lynchburg, Va.
PURPOSE	Marine propulsion
REMARKS	Core critical February 1960. Prototype for N.S. Savannah reactors. Savannah is in operation. Fuel rods are each composed of a closed stainless steel tube, full core length, containing UO_2 fuel in the form of pressed and sintered pellets. Fuel elements consist of 164 fuel tubes. There are 32 fuel elements on a square array defined by an egg-crate structure. Reactor coolant makes three passes in the pressure vessel, two of the passes being in the core. First pass is upward outside the core, the second-pass flow is downward through the outer 16 assemblies, and the third pass is upward through the inner 16 fuel assemblies with a small amount of flow in control-rod channels by-passing the third flow. Enrichment is 4.2% for the inner 16 assemblies, and 4.6% for the outer 16 assemblies.
REFERENCES	The power plant for the first nuclear merchant ship (N.S. Savannah). J. W. Landis TID-7563 (p. 11) (August 1958) Nuclear Merchant Ship Reactor, Final Safeguards Report, Description of the N.S. SAVANNAH. G. E. Kulynch BAE-1164, Vol. I (June 1960)

(contd)

REFERENCES (contd)

N.S. Savannah.
Nuclear Eng. 5: 447-51 (October 1960)

Design practice: the N.S. Savannah.
Reactor Power Technology 6 (1): 43-54 (December 1962)

Nuclear Propulsion for Merchant Ships.
A. W. Kramer
U.S. G.P.O, Washington, 1962

Lifetime studies for the N.S. Savannah reactor.
E. E. Gross, others
ORNL-3261, Suppl. (April 1963)

DESIGNER	BAW
TYPE	PWR. Compact plant. Ship propulsion.
POWER	Mw(e) (27,500 shp) Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	1.6-3.1% enriched UO_2
CLADDING	Zircaloy
NAME/OWNER	CNSG(Consolidated Nuclear Steam Generator)/BAW
OPERATOR	
LOCATION	
PURPOSE	Ship propulsion
REMARKS	The concept has been developed by BAW from experience with the Savannah MSR. W. German GKSS has contracted with BAW, through Deutsch B&W, for the design of a reactor to propel a merchant ship, based on this concept. The concept incorporates wet containment, in which the reactor vessel is immersed in water.
REFERENCES	Consolidated Nuclear Steam Generator for merchant ship application. A conceptual design. Babcock & Wilcox Co. BAW-1243 (August 1962) Consolidated Nuclear Steam Generator for marine application. Engineer 214: 789-90 (November 2, 1962) Compact marine reactor. Nuclear Energy, December 1962, p. 465.

DESIGNER	CE
TYPE	PWR, ship propulsion
POWER	Mw(e) Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Enriched UO_2 pellets
CLADDING	SS jackets
NAME/OWNER	S1C (Small Submarine Reactor Prototype)/AEC
OPERATOR	CE
LOCATION	Windsor, Connecticut
PURPOSE	Land-based prototype, submarine reactor.
REMARKS	Operation 1959, prototype for submarine Tullibee (S2C). Tullibee in operation in 1960. A PWR prototype for a 45,000-ton tanker is also under design study for AEC and the Maritime Administration. Later designs include self-pressurization of the reactor and superheating the secondary steam by the primary coolant.
REFERENCES	Nuclear reactors built, building, or planned in the United States as of December 1961. TID-8200 (3rd Rev.) (1961)

DESIGNER	CE
TYPE	PWR. Compact plant. Ship propulsion
POWER	Mw(e) (30,000 shp) Mw(t) 80
COOLANT	H_2O
MODERATOR	H_2O
FUEL	UO_2
CLADDING	
NAME/OWNER	UMP(Unified Modular Plant)/CE
OPERATOR	
LOCATION	
PURPOSE	Ship propulsion study
REMARKS	Design of a compact water-cooled maritime reactor, designated the Unified Modular Plant (UMP); an 80 Mw(t) pressurized water reactor weighing 430 long tons including containment and shielding. Weight advantage is due to arrangement of the components, the heat exchanger being located between the core and the pressure vessel. The compact core has different zones of enrichment.
REFERENCES	Nucleonics Week, December 6, 1962, p. 3. News Release.

DESIGNER	FLUOR
TYPE	PWR
POWER	Mw(e) Mw(t) 40
COOLANT	H_2O
MODERATOR	H_2O
FUEL	1.73% enriched UO_2
CLADDING	Al
NAME/OWNER	ELPHR (Experimental Low Power Heat Reactor)/AEC
OPERATOR	U.S. Department of the Interior/Fluor
LOCATION	Site undetermined
PURPOSE	Process heat
REMARKS	Plant first proposed for Point Loma, California location; project has been indefinitely postponed.
REFERENCES	Comparison and evaluation of reactor package proposals. Experimental Low Temperature Process Heat Reactor project. E. H. Hykan, R. A. Johnson SL-1767 (December 1959)

PRESSURIZED LIGHT WATER REACTOR S3G (GE)

DESIGNER	GE	
TYPE	PWR	
POWER	Mw(e)	Mw(t)
COOLANT	H_2O	
MODERATOR	H_2O	
FUEL		
CLADDING		
NAME/OWNER	S3G(Submarine Advanced Reactor Prototype)/AEC	
OPERATOR	GE	
LOCATION	West Milton, N. Y.	
PURPOSE	Marine propulsion, land-based prototype	
REMARKS	Operation 1958. (S4G: USS Triton - 2 reactors - 1959)	
REFERENCES	Nuclear reactors built, being built, or planned in the United States as of December 31, 1962. TID-8200 (7th Revision)	

DESIGNER	GE
TYPE	PWR. Plutonium production, power
POWER*	Mw(e) 860 Mw(t) 3290
COOLANT	H_2O
MODERATOR	Graphite
FUEL	Enriched U — Coextruded elements
CLADDING	Zircaloy-2 — Coextruded elements
NAME/OWNER	NPR (New Production Reactor)/AEC
OPERATOR	GE
LOCATION	Hanford (Richland), Washington
PURPOSE	Plutonium production; conversion to Pu and power
REMARKS	Construction, target 1963. Washington Public Power Supply System will build the electric generating equipment. Target date for operation of the two generators is October 1965 (1st) and December 1965 (2nd). A pressure-release containment system is used.
REFERENCES	The New Production Reactor. HW-SA-1755 (1959) Utility proposal for power plant addition to Hanford New Production Reactor. United States Congress Joint Committee on Atomic Energy. (July 1962) Basis of design. Hanford New Production Reactor (NPR). W. J. Dowis HW-SA-2981 (April 19, 1963)

* Power-only phase of operation

Revised 1-10-64

PRESSURIZED LIGHT WATER REACTORS D1G (GE)

DESIGNER	GE
TYPE	PWR. Ship propulsion
POWER	Mw(e) Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Highly enriched U
CLADDING	
NAME/OWNER	D1G (Destroyer Reactor Prototype)/AEC
OPERATOR	GE
LOCATION	West Milton, Connecticut
PURPOSE	Land-based prototype, surface ship propulsion. Construction. Prototype for the destroyer Bainbridge reactor (D2G); Bainbridge in operation in 1962; sister ship has been authorized.
REFERENCES	Performance and evaluation of natural circulation power plants. M. M. Schorr KAPL-M-NPA-1 (December 1959)

DESIGNER	GE
TYPE	PWR. Natural convection circulation
POWER	Mw(e) Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	
CLADDING	
NAME/OWNER	NCR (Natural Circulation Reactor)/AEC
OPERATOR	GE
LOCATION	NRTS, Idaho
PURPOSE	Prototype, submarine reactor (S5G)
REMARKS	NCR test plant construction is scheduled for 1963, target 1964, for the S5G reactor.
REFERENCES	Performance and evaluation of natural circulation power plants. M. M. Schorr KAPL-M-NPA-1 (December 1959) Nuclear reactors built, building, and planned in the United States as of December 31, 1961. TID-8200 (5th Rev.) (1961)

PRESSURIZED LIGHT WATER REACTORS — MICHIGAN CHEMICAL (MARTIN)

DESIGNER	MARTIN
TYPE	PWR. Process steam
POWER	Mw(e) Mw(t) 45
COOLANT	H_2O
MODERATOR	H_2O
FUEL	3-4% enriched UO_2 pellets
CLADDING	Al
NAME/OWNER	Michigan Chemical Company Reactor/Michigan Chem.
OPERATOR	Michigan Chem.
LOCATION	Not determined
PURPOSE	Process steam
REMARKS	Planned. No recent information on plans.
REFERENCES	Conceptual design for a process steam reactor. C. Eicheldinger, others MND-RP-558-17 (June 1958)

DESIGNER	MARTIN
TYPE	PWR. Portable, prefabricated plant
POWER	Mw(e) 1 Mw(t) 9.3 (2 Mw space heat)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	93.3% enriched UO_2-SS cermet tube
CLADDING	SS inner and outer
NAME/OWNER	PM-1 (Portable Medium Power-1)/AEC, Air Force
OPERATOR	Martin; transferred to Air Force in 1962
LOCATION	Sundance, Wyoming
PURPOSE	Power and space heat
REMARKS	Critical at site February 1962. PM-1 is a small highly enriched unit to produce 1000 kw(e) and 7 million Btu/hr of thermal energy for space heating. Three types of core elements are included in each fuel bundle: fuel, poison, and dummy. Tubular elements (fuel) contain UO_2 dispersed in and clad with stainless steel, and have unfueled end regions. Number of fuel elements in the core is 741. The burnable-poison elements, which are substituted for the fuel elements as required to provide the desired nuclear characteristics, are unclad and contain natural boron alloyed in stainless steel. Burns and Roe is developing a standardized portable nuclear plant based on the Sundance and McMurdo reactors.
REFERENCES	PM-1 nuclear design analysis. E. A. Scicchitano, R. A. Hoffmeister MND-C-2487 (p. 25-55) (1961) PM-1 nuclear power plant, addendum to hazards summary evaluation. W. Haass, J. Sieg MND-C-1853 (Add. 1) (February 1961)

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REFERENCES (contd)

Reactor file No. 12. PM-1 on-the-line. Nucleonics 20: 37-42 (September 1962)

PM-1 core design Power Reactor Technology 6 (3): 43-46 (June 1963)

DESIGNER	Martin
TYPE	PWR. Package plant
POWER	Mw(e) 1.5 Mw(t) 10
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Highly enriched UO_2-SS cermet
CLADDING	SS
NAME/OWNER	PM-3A (Portable Medium Power 3A)/AEC, Dept. Navy
OPERATOR	Dept. Navy
LOCATION	McMurdo Sound, Antarctica (Prefabrication at Martin plant, Baltimore)
PURPOSE	Power, space heat
REMARKS	Contract award in August 1960. Installation December 1961 at base, and startup in March, 1962.
REFERENCES	Martin design report - Ice Cap Nuclear Power Plant. Vol. I and II. R. J. Akin MND-MPR-1581 (Vol I and II) (1959) The PM-3A Antarctic reactor.. U.S. AEC, U.S. Navy Brochure, distributed 1961. PM-3A nuclear power plant hazards summary report, safety evaluation. T. Dobry MND-M3A-2496-II (Add.) (November 1961)

DESIGNER	MARTIN
TYPE	PWR. Fluidized bed
POWER	Mw(e) 100 Mw(t) 400
COOLANT	H_2O
MODERATOR	H_2O
FUEL	1.6% enriched UO_2, sintered, cylinders
CLADDING	Unclad or coated
NAME/OWNER	FBR (Fluidized Bed Reactor)/Martin/AEC
OPERATOR	Martin
LOCATION	Pilot study, Middle River, Maryland
PURPOSE	Power experiment
REMARKS	Reactor consists of a cylindrical tank with restraining screens placed across each end. The unclad fuel pellets are placed in the tank and water is pumped in from the bottom. Velocity of the flow suspends the pellets. Pellets were prepared by cold compacting followed by sintering, or by the capillary-drop method. Experimental thin nickel cladding by the electroless nickel plating method was investigated. Critical experiment failed to go critical after full loading in April, 1962 because of abrasion of the unclad fuel. 4% enriched pellets will be added to the replacement fuel. Proposal for redesigned fuel elements specifies U-Mo alloy pellets enriched to 6% and coated with SS, Nb, or Al. Studies are also being done on organic liquids as coolant and moderator.
REFERENCES	Fluidized Bed Reactor study. Phase I - feasibility. M. R. Scheve MND-FBR-1696 (February 1959)

PRESSURIZED LIGHT WATER REACTORS MH-1A (MARTIN)

DESIGNER	MARTIN
TYPE	PWR. Two-region core
POWER	Mw(e) 10 (Min.) Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	5% enriched UO_2 pellets (central); 5.4% enriched UO_2 pellets (peripheral)
CLADDING	SS tubes
NAME/OWNER	MH-1A/U.S. Army Corps of Engineers
OPERATOR	U.S. Army Corps of Engineers
LOCATION	Testing: Ft. Belvoir, Va.
PURPOSE	Power for military installations, coastal cities.
REMARKS	To be installed in the Liberty ship Walter F. Perry. Contract has been awarded for design, construction and test operation design completion scheduled for 1962. Core will be two-region enrichment design. Plant is planned for emergency power supply to military installations or coastal cities in war or peacetime. Installation in ship scheduled for 1965.
REFERENCES	The Army Nuclear Power Program; its reactors, and their application to the less-developed areas of the world. Symposium on Small and Medium Power Reactors. Vienna, 1960. Paper SMPR-51 (Vienna, 1960) Forum Memo, September 1961, p. 13. News Release. * Nucleonics Week, October 4, 1962, p. 3. News Release.

PRESSURIZED LIGHT WATER REACTORS A1W (WEST)

DESIGNER	WEST
TYPE	PWR. Ship propulsion
POWER	Mw(e) (35,000 shp) Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Highly enriched U
CLADDING	
NAME/OWNER	A1W (Large Ship Reactor Prototype)/AEC, U.S.N.
OPERATOR	Westinghouse
LOCATION	NRTS, Idaho
PURPOSE	Land-based prototype, ship propulsion
REMARKS	Operation 1958; prototype for aircraft carrier Enterprise (8-reactors) and Long Beach cruiser (2-reactors). Enterprise and Long Beach were in operation in 1961.
REFERENCES	Atomic Industry Reporter, Technology Reports. p. 449-759 November 27, 1957

PRESSURIZED LIGHT WATER REACTORS S1W (WEST)

DESIGNER	WEST
TYPE	PWR
POWER	Mw(e) Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	U-Zr sandwich plates
CLADDING	Zr
NAME/OWNER	S1W (Submarine Thermal Reactor, Mark I)/AEC
OPERATOR	Westinghouse
LOCATION	NRTS, Idaho
PURPOSE	Marine propulsion, land-based prototype
REMARKS	Operation 1953. (S2W: USS Nautilus, 1955) (S2Wa: Conversion of Seawolf)
REFERENCES	Nuclear reactors built, building, or planned in the United States as of December 31, 1962. TID-8200 (7th Revision)

PRESSURIZED LIGHT WATER REACTORS S5W (WEST)

DESIGNER	WEST
TYPE	PWR, 3rd generation
POWER	Mw(e) Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	
CLADDING	
NAME/OWNER	S5W (Submarine Thermal Reactor-5)/AEC, U.S. Navy
OPERATOR	U.S. Navy
LOCATION	
PURPOSE	Submarine propulsion
REMARKS	Operational - in production. Skipjack and subs of Skipjack type
REFERENCES	Nuclear reactors built, being built, or planned in the United States as of December 31, 1962. TID-8200 (7th Revision)

DESIGNER	WEST
TYPE	PWR, seed and blanket
POWER	Mw(e): 60; second core 150 Mw(t): 231; second core 525
COOLANT	H_2O
MODERATOR	H_2O
FUEL	92.3% enriched U-Zr plates (core); sintered natural UO_2 rods (blanket)
CLADDING	Zircaloy-2
NAME/OWNER	SHIPPINGPORT ATOMIC POWER STATION/AEC, Duquesne
OPERATOR	Duquesne Light Co.
LOCATION	Shippingport, Penn.
PURPOSE	Power demonstration
REMARKS	Operation 1957. Seed II installed in 1960. Seed III (partial refueling, 32 enriched seed elements inserted with original blanket elements) installed 1962; Seed IV was installed November 1962. Second core installation is scheduled for the summer of 1964. Reactor core is composed of an annular seed region containing plates of U^{235} alloyed with Zircaloy-2 and clad with Zircaloy-2, and an inner and outer blanket region of assemblies of UO_2 rods jacketed in Zircaloy-2. Fuel assemblies in both regions are square in cross section. Planned second core will also be of the seed-and-blanket type. Seed will be annular and will consist of 20 highly enriched fuel clusters each containing a hafnium control rod. The blanket will consist of 77 fuel clusters of natural uranium oxide. Seed elements are compartmented plates, the fuel wafers being ZrO_2-UO_2 and the cladding Zircaloy-4. Three different enrichments will be used. Blanket fuel elements will also be compartmented, the fuel wafers being UO_2 and cladding Zircaloy-4. Admiral Rickover has proposed a 500 Mw(e) advanced version of Shippingport.

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REFERENCES

Progress in nuclear energy. Series II. Reactors.
R. A. Charpie, others
McGraw-Hill Book Co., New York (1956)

Shippingport pressurized water reactor.
AEC
Addison-Wesley. 1958.

Shippingport station - a pioneering project in atomic power.
Westinghouse Eng. Issue. March 1958.

Operating experience: Shippingport.
Power Reactor Technology 5: 61-72 (September 1962)

DESIGNER	WEST
TYPE	PWR
POWER	First core: Mw(e) 110 Mw(t) 392 Second core: Mw(e) 134 Mw(t) 482
COOLANT	H_2O
MODERATOR	H_2O
FUEL	3.4% enriched UO_2 cylinders
CLADDING	SS tubes
NAME/OWNER	YANKEE ATOMIC ELECTRIC PLANT/AEC, YAEC
OPERATOR	YAEC
LOCATION	Rowe, Massachusetts
PURPOSE	Power demonstration, 1st round
REMARKS	Full power January 1961. 485 Mw(t) and 136 Mw(e) have been achieved with second core; reactor has operated at a high of 165 Mw(e). The third core may incorporate chemical shim (see ENRICO FERMI, Italy). Fuel element for the first core is a closed stainless steel tube containing 3.4% enriched UO_2 cylindrical ceramic pellets. Pellets are placed in the tubes in groups of 25, separated by perforated stainless steel disks. A fuel rod assembly is composed of nine subassemblies made up of a 6 x 6 square of fuel rods. Assemblies are open, not contained in boxes. Core structure is open, there being no walls between fuel assemblies. Coolant flow is downward in parallel flow through spaces between the thermal shield and vessel wall, between thermal shield and core barrel, and between barrel and core baffle; then upward in a single pass through the core, confined by the core baffle. Yankee was shut down in September 1963 for its second refueling.
REFERENCES	Preliminary hazards summary report. Part B. License application. Yankee Atomic Electric Co. YAEC-60 (April 1957)

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REFERENCES (contd)

The start-up experiment program for the Yankee reactor.
J. M. Gallagher, Jr., others
YAEC-184 (June 1961)

Design practice: Yankee nuclear power station.
Power Reactor Technology 4: 47-55 (June 1961)

DESIGNER	WEST
TYPE	PWR, closed cycle. Hook-on reactor.
POWER	Mw(e) 4.5 Mw(t) 20
COOLANT	H_2O
MODERATOR	H_2O
FUEL	3.7% enriched UO_2 sintered pellets
CLADDING	SS
NAME/OWNER	SAXTON HOOK-ON REACTOR/Saxton Nuclear Exp. Corp.
OPERATOR	Saxton Nuclear Exp. Corp.
LOCATION	Saxton, Penn.
PURPOSE	Power experiment
REMARKS	Critical April 1962. The initial core is composed of 21 fuel assemblies. Each assembly contains approximately 72 individual stainless steel fuel rods filled with sintered pellets of enriched UO_2. Initial enrichment has been established at 5.7%. Fuel rods, each with a fuel length of 36.6 inches, are incorporated in the fuel follower (bottom) section of each control rod assembly. These fuel rods have slightly enriched UO_2 pellets. Control-rod drive mechanisms are bottom-mounted. The reactor vessel is of multilayer construction. Westinghouse will study chemical shim in this reactor; full power operations with chemical shim having started in March 1963.
REFERENCES	The Saxton experimental power reactor. W. E. Shoupp, others Power Reactor Experiments. Vol. II, p. 229-51 International Atomic Energy Agency. Vienna. 1962. Saxton experimental power reactor. E. W. Powell, others Nuclear Eng. 7: 393-97 (October 1962)

PRESSURIZED LIGHT WATER REACTORS — CONNECTICUT YANKEE (WEST)

DESIGNER	WEST
TYPE	PWR, four-loop system
POWER	Mw(e) 462 Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	
CLADDING	
NAME/OWNER	CONNECTICUT YANKEE STATION/Conn. Yankee Atomic Power
OPERATOR	Connecticut Yankee Atomic Power Co.
LOCATION	Haddam Neck, Connecticut
PURPOSE	Power. AEC round 3A assistance will be requested.
REMARKS	Construction start planned for fall of 1963; target 1967. Construction proposal by Connecticut Yankee Atomic Power Company has been accepted by AEC as basis for negotiating financial assistance contract. Collapsed stainless steel cladding may be specified for the fuel.
REFERENCES	Nucleonics Week, December 20, 1962, p. 1. News Release

PRESSURIZED LIGHT WATER REACTORS MALIBU PLANT (WEST)

DESIGNER	WEST
TYPE	PWR, four-loop system
POWER	Mw(e) 462 Mw(t) 1475
COOLANT	H_2O
MODERATOR	H_2O
FUEL	3.8% enriched UO_2 pellets
CLADDING	SS
NAME/OWNER	MALIBU PLANT/Los Angeles Dept. Water and Power
OPERATOR	LADWP
LOCATION	Malibu Beach, California
PURPOSE	Power
REMARKS	Westinghouse offer for a 490 Mw(e) gross, 462 Mw(e) net PWR was accepted by LADWP. Heavy construction targeted for start in 1964, criticality by January 1, 1968, and on-line target for the reactor set at mid-1968. LADWP has filed a proposal with AEC under modified third-round rules for research-development and design assistance; the proposal has been accepted by AEC.
REFERENCES	Nucleonics 21: 21 (March 1963) News Release. Forum Memo, March 1963, p. 9. News Release.

PRESSURIZED LIGHT WATER REACTORS — SOUTHERN CALIFORNIA EDISON (WEST)

DESIGNER	WEST
TYPE	PWR, closed cycle
POWER	Mw(e) 395 Mw(t) 1150
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Enriched UO_2 pellets
CLADDING	Zircaloy or SS
NAME/OWNER	SOUTHERN CALIFORNIA EDISON PLANT/S. Cal. Edison
OPERATOR	Southern California Edison
LOCATION	Camp Pendleton, California
PURPOSE	Power
REMARKS	Planned. Camp Pendleton site was released by the Navy in December 1962. Target 1965-66. Basic three-loop reactor; varying plant size is achieved by varying vessel and core size and the number of loops; loop components remain the same. San Diego Gas & Electric will contribute to plant costs in return for share of power produced.
REFERENCES	Southern California Edison reactor characteristics. Nucleonics 18: 18 (June 1960) Nucleonics Week, December 13, 1962, p. 2. News Release.

DESIGNER	WEST
TYPE	PWR, supercritical once-through tube reactor. Pressure tube
POWER	Mw(e) 1000 Mw(t)
COOLANT	H_2O
MODERATOR	Graphite
FUEL	2.8% enriched UO_2 (pellet) rods or UO_2 central rod, three concentric rings
CLADDING	Modified austenitic SS tubes; SS inside and outside each ring.
NAME/OWNER	SCOTT-R (Supercritical Once-Through Tube Reactor)/ Westinghouse
OPERATOR	
LOCATION	
PURPOSE	Development of concept
REMARKS	Preliminary design for a 50 Mw(t) Superheat Power Experiment (SPX) has been completed; construction planned for 1963-64. A 300 Mw(e) prototype is proposed for 1965-68 development and construction, with construction of 1000 Mw(e) plant proposed in the 1970's. Conceptual design of SCOTT-R incorporates about 650 pressure tubes for supercritical and reheat flow channels. Within each pressure tube and in direct contact with the coolant is a fuel assembly of slightly enriched UO_2 clad in stainless steel, fabricated into concentric annular rings. The reheat tubes contain slightly enriched rods clad in stainless steel. System is direct cycle with once-through heat transfer. The reference design can be installed in a relatively small vapor container; size of the plant depends on the ability to interconnect and control a number of pressure tubes within a single graphite-moderator mass. A feasibility study contract for a 1000 Mw(e) PWR has been awarded to Westinghouse by AEC.

(contd)

REFERENCES

The role of a superheat power experiment in the development of supercritical steam nuclear-fired power plants.
J. H. Wright, others
ASME Preprint 62-WA-345 (December 1962)

The SCOTT-R development program.
J. H. Wright
Westinghouse Eng. 23: 50-53 (March 1963)

DESIGNER	WEST (Evaluation study with Stone & Webster)
TYPE	PWR, chemical shim control. Three-region core. Oil-fired superheat.
POWER	Mw(e) 650 Mw(t) 2850
COOLANT	H_2O
MODERATOR	H_2O
FUEL	3.2% enriched UO_2 (center), 3.6% enriched UO_2 (intermediate), 4.0% enriched UO_2 (outer) (Fuel elements of the spring clip type)
CLADDING	SS first core; later Zircaloy
NAME/OWNER	RAVENSWOOD PLANT/Consolidated Edison
OPERATOR	Consolidated Edison
LOCATION	Queens, New York City, N. Y.
PURPOSE	Power
REMARKS	CON/ED has proposed construction of privately financed plant based on a study conducted by Westinghouse and Stone & Webster. Containment dome will be a four-layer structure: two carbon steel shells one within the other, a layer of pervious concrete between them, and normal density reinforced concrete outside the outer steel shell. There will be five primary coolant loops. Target 1970.
REFERENCES	Preliminary hazards summary report, Docket 50-204 Ravenswood Nuclear Generating Unit A. Consolidated Edison Co. of N. Y., Inc. 1962. NP-12466 (Vol. I, II, and III)

SECTION H

PRESSURIZED LIGHT WATER REACTORS

FOREIGN

PRESSURIZED LIGHT WATER REACTORS VULCAIN (Belgium)

DESIGNER	BELGONUC
TYPE	PWR, spectral shift. Ship propulsion
POWER	Mw(e) 15 Mw(t) 65 (20,000 shp)
COOLANT	H_2O-D_2O
MODERATOR	H_2O-D_2O
FUEL	7% enriched UO_2 pellets or 5.5% enriched UO_2 pellets
CLADDING	7% enriched UO_2 pellets: SS 5.5% enriched UO_2 pellets: Zircaloy
NAME/OWNER	VULCAIN/Belgonucleaire
LOCATION	
PURPOSE	Ship propulsion, R & D program
REMARKS	Zero power unit will be built. An agreement for joint development of the concept by Belgonucleaire and the UKAEA has been signed. The study will entail an advanced PWR embodying the principle of spectral shift control. UKAEA's design of the Vulcain concept uses 6% enriched UO_2 fuel pins with SS or Zr cladding, supported in hollow incomplete hexagonal subassemblies, each with a central Zircaloy tube which serves as a guide for the shut-off rod. Neighboring assemblies interlock and are not provided with independent fuel element shrouds. Coolant is initially mainly D_2O, with progressive dilution with H_2O. Primary coolant circulates by pumping at a pressure of 2100 psi, secondary circuit steam circulates by natural convection.
REFERENCES	Project VULCAIN, description and principal characteristics. VN-61-305 (Belgonucleaire, 1961) The Vulcain project and its development processes. P. Maldague Atomwirtschaft 7: 317-21 (June 1962) (contd)

REFERENCES (contd)

The VULCAIN reactor.
P. E. Maldague
Power Reactor Experiments. Vol. II, p. 253-73
International Atomic Energy Agency. Vienna. 1962.

The U.K. Atomic Energy Authority's Nuclear Ship Concepts.
Nuclear Eng. 8: 88-9 (March 1963)

DESIGNER	WEST (US)
TYPE	PWR, two-region system. Advanced Shippingport design
POWER	Mw(e) 10.5 Mw(t) 40
COOLANT	H_2O
MODERATOR	H_2O
FUEL	3.7% enriched UO_2 (inner zone); 4.4% enriched UO_2 (outer zone)
CLADDING	SS tubes
NAME/OWNER	BR-3 (Belgian Reactor-3)/CEN
OPERATOR	CEN
LOCATION	Mol, Belgium
PURPOSE	Power experiment, training
REMARKS	Full power operation October 1962. Basic structural element of the core is SS tubing; 91 UO_2 pellets are contained in each tube, separated into four compartments by spacer disks. Fuel assemblies contain 110 or 111 rods on a square lattice array. The cylindrical core is composed of 32 fuel assemblies. BR-3 has a two-enrichment core, the enrichment varying radially. Inner 16 fuel assemblies have 3.7% enrichment, the outer 16 assemblies having 4.4% enrichment. With discharge of part of the first fuel loading, BR-3 will go critical again in November 1963, with 24 of the first core elements moved from the periphery to the center, and seven new elements, including an experimental element containing UO_2 pellets and UO_2-PuO_2 pencils. The BR-3 will be operated as a spectral-shift experimental facility in connection with the VULCAIN program; spectral shift operations are scheduled to begin in August 1964, and will be completed in 1967.

(contd)

REFERENCES

BR-3. General Description. Design philosophy and plant construction. Core design and testing.
L. Mergan, others
Nuclear Eng. 5: 337-52 (August 1960)

The BR-3 reactor.
W. F. Davis
Westinghouse Eng. 20: 162-5 (November 1960)

PRESSURIZED LIGHT WATER REACTORS — SUBMARINE PROTOTYPE (France)

DESIGNER	FR-ATOM
TYPE	PWR, submarine propulsion
POWER	Mw(e) Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Enriched UO_2
CLADDING	Zr
NAME/OWNER	SUBMARINE REACTOR PROTOTYPE/CEA
OPERATOR	
LOCATION	Prototype development, Cadarache Center, France
PURPOSE	Land-based prototype, submarine propulsion
REMARKS	Critical experiment ALIZE completed at Saclay. The zero-power assembly uses Al-clad 90% enriched U-Al plate elements. A large critical assembly AZURE will be intermediate between ALIZE and full-scale prototype; AZURE critical in 1962. Prototype target 1964; first operational submarine scheduled for 1969. Construction is to start in 1963. The first nuclear submarine will be a missile-carrier.
REFERENCES	Nucleonics 19: 23 (September 1961) News Release. Nucleonics Week, October 11, 1962, p. 5. News Release.

PRESSURIZED LIGHT WATER REACTORS — FRANCO-BELGIAN ARDENNES (France)

DESIGNER	WEST (U.S.)
TYPE	PWR, closed cycle, high pressure
POWER	Mw(e) 242 Mw(t) 825
COOLANT	H_2O
MODERATOR	H_2O
FUEL	3.1% enriched UO_2 pellets
CLADDING	SS tubes
NAME/OWNER	FRANCO-BELGIAN ARDENNES POWER CENTER/SENA
OPERATOR	SENA
LOCATION	Chooz, France (Near Givet)
PURPOSE	Power. U.S.-EURATOM project.
REMARKS	Contract signed, site preparation under way. Plant will be built in a cavern on the banks of the Meuse River. Target 1965.
REFERENCES	The SENA underground PWR. Nuclear Power 7: 79 (February 1962)

PRESSURIZED LIGHT WATER REACTORS STUDY (Italy)

DESIGNER	FIAT, ANSALDO and CNEN
TYPE	PWR, ship propulsion
POWER	Mw(e) (23,000 shp) Mw(t) 74
COOLANT	H_2O
MODERATOR	H_2O
FUEL	
CLADDING	
REMARKS	EURATOM contract with CNEN for a design study of a PWR to power a nuclear tanker based on Fiat-Ansaldo study; Fiat will perform reactor research. FIAT of Turin and ANSALDO of Genoa, with CNEN, are sponsors of an Italian naval nuclear program which provides for the construction of a tanker equipped with a water reactor of all-Italian design and construction. First stage of project, a comparison of four water reactor types, is scheduled for completion in December 1962.
REFERENCES	Forum Memo, April 1961, p. 16 Applied Atomics, September 26, 1962, p. 9. News Release.

PRESSURIZED LIGHT WATER REACTORS ENRICO FERMI (Italy)

DESIGNER	WEST (U.S.)
TYPE	PWR, three-region system. Closed cycle
POWER	Mw(e): Initial 165; 225-270 (with chemical shim) Mw(t): 825 (with chemical shim)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	2.7% enriched UO_2 pellets
CLADDING	SS
NAME/OWNER	ENRICO FERMI NUCLEAR STATION/SELNI, Edison-Volta
OPERATOR	SELNI
LOCATION	Trino, on Po River, Italy
PURPOSE	Power
REMARKS	Core design frozen April 1962. Will pioneer the use of chemical shim - addition of boric acid to coolant in early stages of core life, gradually removing it as reactivity declines. SELNI will also pioneer three-region cores using concentric rings of different enrichment, the enrichment varying from 2.6 to 2.8%. Target for criticality is late 1963.
REFERENCES	European power reactors. Italy. Mech. Eng. 81: 63 (November 1959) Atomic energy in Italy. Nuclear Power 7: 51-78 (February 1962)

PRESSURIZED LIGHT WATER REACTORS NERO (The Netherlands)

DESIGNER	Dutch industry; RCN
TYPE	PWR, ship propulsion
POWER	Mw(e) 60 Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	Enriched UO_2
CLADDING	Al
NAME/OWNER	PROJECT NERO/RCN
OPERATOR	
LOCATION	KRITO (critical experiment) at Petten Research Estab.
PURPOSE	Ship propulsion development study
REMARKS	Nuclear ship propulsion development study, with assistance from EURATOM and Dutch industry. Target for ship installation is 1965. The critical experiment KRITO, under construction at Petten, will be fueled with 3.1 and 3.8% enriched UO_2 pellets in Al tubes. Target for KRITO is 1963.
REFERENCES	Applied Atomics, December 19, 1962, p. 10. News Release.

PRESSURIZED LIGHT WATER REACTORS . GOTAVERKEN (Sweden)

DESIGNER	GOTAVERK (Study group)
TYPE	PWR, ship propulsion
POWER	Mw(e) Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	1% enriched U or U with small addition of Pu
CLADDING	
NAME/OWNER	GOTAVERKEN PROJECT/Gotaverken
OPERATOR	
LOCATION	Sweden
PURPOSE	Tanker propulsion
REMARKS	Study project, cooperation with British and U.S. B & W. Primary system: vertical steel cylinder inside of which the pressure vessel would be suspended. Core design features rotating fuel elements with neutron absorbent shields covering a section of the cylinder surface to control reactor output.
REFERENCES	First Scandinavian project for tanker nuclear propulsion. F. A. Abadie-Maumert Energie Nucleaire 2: 44-5 (January-February 1960) Nucleonics Week, June 28, 1962, p. 5. News Release.

PRESSURIZED LIGHT WATER REACTORS APS-1 (USSR)

DESIGNER	USSR
TYPE	PWR. Pressure tube
POWER	Mw(e) 5 Mw(t) 30
COOLANT	H_2O
MODERATOR	Graphite
FUEL	5% enriched U-Mo-Mg alloy tubes
CLADDING	SS
NAME/OWNER	APS-1 (Soviet Atomic Power Station-1)/USSR
OPERATOR	USSR
LOCATION	Obninsk, USSR
PURPOSE	Power prototype
REMARKS	Operation 1954. Reactor has been in use as a test-bed for the Beloyarsk reactor fuel elements.
REFERENCES	The first atomic power station of the USSR. D. I. Blokhintsev, N. A. Nikolaev Int'l. Conf. on the Peaceful Uses of Atomic Energy 3: 35-55 (1955)

PRESSURIZED LIGHT WATER REACTORS SIBERIAL STATION (USSR)

DESIGNER	USSR
TYPE	PWR, six-reactor station
POWER	Mw(e): 100 per reactor Mw(t):
COOLANT	H_2O
MODERATOR	Graphite
FUEL	Natural U
CLADDING	
NAME/OWNER	SIBERIAN REACTOR STATION/USSR
OPERATOR	USSR
LOCATION	Troitsk, USSR
PURPOSE	Power
REMARKS	First reactor in operation in 1958.
REFERENCES	Catalog of nuclear reactors. H. S. Isbin Second U.N. Int'l. Conf. on the Peaceful Uses of Atomic Energy 8: 561-584 (1958)

PRESSURIZED LIGHT WATER REACTORS VORONEZH (USSR)

DESIGNER	USSR
TYPE	PWR, two-reactor station
POWER	Mw(e): 210 (per reactor Mw(t): 760 (per reactor)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	1.5-2.5% enriched UO_2 (two-zone)
CLADDING	Zr-Nb alloy
NAME/OWNER	VORONEZH STATION/USSR
OPERATOR	USSR
LOCATION	Voronezh, USSR. (Novovoronezh)
PURPOSE	Power
REMARKS	Construction. Target 1965. The second reactor has been up-rated to 360 Mw(e). The first reactor was reported to be in the final stage of construction in early 1963, with construction underway on the second section.
REFERENCES	The Russian 420 MW power station. Nuclear Eng. 2: 431-6 (1957)

DESIGNER	USSR
TYPE	PWR, two-reactor station
POWER	Mw(e): 210 (per reactor) Mw(t): 760 (per reactor)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	1.5% enriched UO_2 and natural UO_2 rods
CLADDING	Zr
NAME/OWNER	LENINGRAD POWER STATION/USSR
OPERATOR	USSR
LOCATION	Leningrad, USSR
PURPOSE	Power
REMARKS	Postponed pending operating experience from the Voronezh station.
REFERENCES	Pressurized water reactors in the USSR. S. A. Skartsov Second U.N. Int'l Conf. on the Peaceful Uses of Atomic Energy 8: 415-20 (1958)

PRESSURIZED LIGHT WATER REACTORS MOBILE REACTOR (USSR)

DESIGNER	USSR
TYPE	PWR
POWER	Mw(e) 2 Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	
CLADDING	
NAME/OWNER	SOVIET MOBILE POWER REACTOR/USSR
OPERATOR	USSR
LOCATION	Obninsk, USSR (Prototype)
PURPOSE	Power, military use
REMARKS	Construction. The reactor fits on four-tracked vehicles; weight is 240 tons exclusive of shielding.
REFERENCES	No current information available

PRESSURIZED LIGHT WATER REACTORS LENIN (USSR)

DESIGNER	USSR
TYPE	PWR
POWER	Mw(e) Mw(t) 90
COOLANT	H_2O
MODERATOR	H_2O
FUEL	5% enriched UO_2 - sintered
CLADDING	Zr alloy or SS
NAME/OWNER	LENIN SHIP REACTOR/USSR
OPERATOR	USSR
LOCATION	Nuclear icebreaker Lenin: three reactors.
PURPOSE	Ship propulsion
REMARKS	Lenin in operation. Second icebreaker planned. Fuel is 5% enriched sintered UO_2 canned in zirconium alloy. Fuel elements are grouped in channels as assemblies of the rod-type fuels. Water in the core makes two passes, being delivered from below into the central channels. It then runs down along the shields and flows into lower openings of the peripheral channel.
REFERENCES	A nuclear icebreaker. A. P. Aleksandrov, others Atomnaya Energiya 5: 277-86 (1958)

PRESSURIZED LIGHT WATER REACTORS STUDY (United Kingdom)

NOTE: The UK AEA has joined Belgonucleaire in the joint development of the Vulcain concept for nuclear ship propulsion. Currently all ship designs have been reported as dropped except the Vulcain concept and the IBR (Integral Boiling Reactor), a pressure tube system

See VULCAIN

PRESSURIZED LIGHT WATER REACTORS VALIANT (United Kingdom)

DESIGNER	RR; VICK
TYPE	PWR, ship propulsion
POWER	Mw(e) Mw(t)
COOLANT	H_2O
MODERATOR	H_2O
FUEL	
CLADDING	
NAME/OWNER	VALIANT SUBMARINE REACTOR/British Admiralty
OPERATOR	British Admiralty
LOCATION	Landbased prototype at Dounreay (Caithness), Eng.
PURPOSE	Submarine propulsion
REMARKS	Keel for ship has been laid. Nuclear motor will be fabricated by Rolls-Royce, Vickers; plant will follow the concept of the PWR designed by Westinghouse (S1W type) for the British submarine Dreadnaught, which underwent sea trials at the end of 1962. An advanced reactor, Neptune, to be used in submarine propulsion has started up at Rolls-Royce nuclear research establishment at Derby. The reactor is designed to operate at very low power.
REFERENCES	Energie Nucleaire 4: 146 (March-April 1962)
	Applied Atomics, February 27, 1963, p. 13. News Release.

SECTION I

STEAM COOLED REACTORS

DOMESTIC

STEAM COOLED REACTORS STUDY (AI)

DESIGNER	AI
TYPE	Boiling superheat. Pressure tube
POWER	Mw(e) 318 Mw(t) 76
COOLANT	H_2O - steam
MODERATOR	Graphite
FUEL	Slightly enriched UC elements in graphite matrix
CLADDING	Thir. SiC coating
NAME/OWNER	
OPERATOR	
LOCATION	
PURPOSE	
REMARKS	Study. Three-region core (annular): central boiling (steam generation); intermediate superheating; outer reheat. The core structure is of graphite columns penetrated by vertical coolant pressure tubes and separate fuel channels; each column contains four fuel channels, each channel is surrounded by four coolant tubes. Coolant pressure tubes are not in direct contact with the fuel elements. Zirconium hydride has been studied as moderator for a BWR steam-superheat system, using slightly enriched fuel for 300 Mw(e).
REFERENCES	Steam-cooled power reactor evaluation: Graphite moderated boiling water steam superheat reactor. Atomics International NAA-SR-6100 (September 1961) Evaluation of zirconium hydride as moderator in integral boiling water-superheat reactors. J. D. Gylfe, others NAA-SR-5943 (March 1962)

DESIGNER	ANL
TYPE	Coupled fast-thermal breeder, steam-superheat (CBSR) Pressure vessel.
POWER	Mw(e) 65 Mw(t) 216
COOLANT	H_2O steam and pressurized water
MODERATOR	H_2O
FUEL	Fast core: PuO_2 and depleted UO_2 Thermal: Natural and depleted UO_2
CLADDING	Fast core: SS Thermal: Zircaloy
NAME/OWNER	CBSR (Coupled Breeder Superheater Reactor)/ANL
OPERATOR	
LOCATION	
PURPOSE	Conceptual design study
REMARKS	Multiregion core design. Fast core: zone 1, SS tubes with PuO_2 and depleted UO_2 pellets; zone 2 (radial buffer zone) depleted UO_2 in SS tubes; fast axial blanket (2 zones) depleted UO_2 pellets in SS tubes. Thermal core: natural UO_2 pellets in Zircaloy tubes; a radial thermal blanket of depleted UO_2; a high density radial thermal blanket of depleted UO_2; Zircaloy as fuel tubes throughout thermal region.
REFERENCES	Conceptual design of a coupled breeding superheating reactor CBSR. R. Avery, others ANL-6286 (March 1961)

DESIGNER	GE
TYPE	BWR, direct cycle. Nuclear superheat
POWER	Mw(e) Mw(t) 12.5
COOLANT	Steam
MODERATOR	H_2O
FUEL	4-5% enriched UO_2 hollow pellets
CLADDING	SS inner and outer
NAME/OWNER	VESR (Vallecitos Experimental Superheat Reactor)/ GE-ESADA
OPERATOR	GE
LOCATION	Vallecitos Laboratory, California
PURPOSE	Development for ESADA
REMARKS	VESR initial operation will be 12.5 Mw(t); 23 Mw(t) will be accomplished by using steam produced by VBWR and a gas-fired boiler. SADE (Superheat Advanced Demonstration Experiment) will have fuel elements contained in individual process tubes which direct cooling steam flow. Cooling will be by a combination of moderator boiling and forced convection cooling with saturated steam. Mark-I core design specified a full core loading of uniformly enriched UO_2 encased in SS. New core design--Mark II--initiated in late 1961 will be composed of a 6 x 6 array of 32 fuel bundles. A fuel bundle consists of nine annular-type fuel elements in a 3 x 3 array. Each fuel element is formed of two concentric tubes containing a stack of hollow, sintered UO_2 pellets. The external cladding is expanded against the inner surface. Each element is enclosed in a process tube which separates the coolant steam surrounding the fuel element surface from the moderator water. Three enrichments will be used, the core average being approximately 5.4%. Fuel bundles for the first core will be of the two-pass series-flow type. Steam flow path is first downward over the outside surface of the element and then upward over the inner surface. Steam is superheated during both passes. Combination boiling-superheat elements are also being studied. (contd)

REFERENCES

The reactor and plant design for ESADA and EVSR.
J. Barnard
ASME Preprint 61-WA-223 (1961)

Preliminary hazards summary report for the Vallecitos Superheat Reactor.
G. L. Murray
GEAP-3642 (February 1961)

The ESADA Vallecitos Experimental Superheat Reactor
D. H. Imhoff
Power Reactor Experiments Vol. II, p. 53-79
International Atomic Energy Agency. Vienna. 1962.

Final hazards summary report for the ESADA Vallecitos Experimental Superheat Reactor.
J. L. Murray, ed.
APED-3958 (October 1, 1962)

STEAM COOLED REACTORS MSSR (GE)

DESIGNER	GE
TYPE	BWR -steam, two-region, fast core
POWER	Mw(e) 74 Mw(t)
COOLANT	Steam in superheat central region; H_2O in conventional core
MODERATOR	H_2O (Fast core is unmoderated)
FUEL	Fast core: 19.6% enriched PuO_2 in depleted UO_2 rods Boiling region: slightly enriched UO_2 rods Buffer: depleted U
CLADDING	Fast core: SS Boiling region: SS Buffer: SS
NAME/OWNER	MSSR (Mixed Spectrum Superheat Reactor)/GE
OPERATOR	
LOCATION	
PURPOSE	Prototype
REMARKS	Development. Core has four concentric regions within a single pressure vessel. The inner, unmoderated, superheating region uses PuO_2 mixed with $U^{235}O_2$ as fuel, with upper and lower reflectors of depleted UO_2 as the inner, unmoderated buffer region. The outer buffer region consists of fuel rods of depleted U, and the boiling water core consists of standard rods. Cladding is either stainless steel or a zirconium alloy. Water boils in outer buffer and boiler regions. After passing through an internal steam separation system, the saturated steam generated in the boiling region goes through the inner superheating region of the core. Current plans call for the construction of a 74 Mw(e) prototype in 1964, for completion in 1967, and a demonstration reactor for on-line operation in the 1970's. (contd)

REFERENCES

Steam cooled power reactor evaluation Mixed Spectrum Superheater.
B. Wolfe
GEAP-3590 (Rev. 1) (November 1960)

Conceptual design for a 75 MWe mixed spectrum superheating reactor power plant.
G. V. Brynsvold, others
GEAP-4016 (February 25, 1962)

STEAM COOLED REACTOR STUDY (NDA)

DESIGNER	NDA
TYPE	Steam-cooled fast breeder. Pressure vessel
POWER	Mw(e): 300 and 40 Mw(t): 841 (core); 35 (axial and radial blanket)
COOLANT	Steam (H_2O and D_2O studies)
MODERATOR	
FUEL	Core: 15.4% enriched PuO_2, UO_2 rod-type elements Blanket: Depleted UO_2
CLADDING	Core: Inconel-X tubes Blanket: SS
NAME/OWNER	(Study)/NDA
OPERATOR	
LOCATION	
PURPOSE	Feasibility study
REMARKS	Conceptual design; 300 Mw(e) central station reactor and a 40 Mw(e) plant studied. Loeffler system is used to produce usable steam. Core consists of PuO_2-UO_2 rods clad in Inconel-X; radial and axial blanket of depleted UO_2. Forced circulation system. UO_2-ThO_2 fuel has also been studied.
REFERENCES	Steam-cooled power reactor evaluation; steam-cooled fast breeder reactor. G. Sofer, others NDA-2148-4 (April 1961) Conceptual design and economic evaluation of a steam-cooled fast breeder reactor. G. Sofer, others NDA-2148-5 (November 1961) The NDA steam-cooled fast reactor concept. Nuclear Power 6: 75 (October 1961)

DESIGNER	NDA
TYPE	Steam-cooled D_2O reactor. Pressure tube
POWER	Mw(e) 298 Mw(t) 767 (fog region); 180 (superheat)
COOLANT	Fog (H_2O)
MODERATOR	D_2O
FUEL	Central: Slightly enriched UO_2 rods Superheat: Slightly enriched UO_2 rods
CLADDING	Central: Zircaloy-2 Superheat: SS
NAME/OWNER	(Study)/NDA
OPERATOR	
LOCATION	
PURPOSE	Study, development
REMARKS	Conceptual design study. Aluminum calandria penetrated by Zircaloy-2 pressure tubes containing the fuel and coolant. Fog-cooled assemblies in the central region, superheater assemblies in the peripheral region. A study by ECNG and BAW for NDA describes a horizontal pressure tube design. NDA is engaged in a Euratom project with CISE (Italy) for the design of a steam-cooled, pressure tube, H_2O-moderated plant, CAN-1, which would use Zircaloy-clad UO_2 elements, light water moderator, and have provisions for nuclear superheat. (See also Italy, CAN)
REFERENCES	Steam cooled reactor feasibility study. Steam Water Reactor (SWR). Vol. I (Sections 1-6) Vol. II (Sections 7, 8) Final report. East Central Nuclear Group, B & W NDA-2562-1 (Vol. I and II) (August 1958)

(contd)

REFERENCES (contd)

Steam-cooled power reactor evaluation, steam-cooled D_2O moderated reactor.
G. Sofer, others
NDA-2161-2 (April 1961)

CAN-1: Fog coolant project.
M. Silvestri, others
Nucleonics 19: 86-8 (January 1961)

SECTION I

STEAM COOLED REACTORS

FOREIGN

STEAM COOLED REACTORS STUDY (Canada)

DESIGNER	AECL
TYPE	D_2O moderated. Pressure tube. Steam cooled, direct cycle
POWER	Mw(e) 200 Mw(t)
COOLANT	Steam (H_2O) (Fog)
MODERATOR	D_2O
FUEL	Natural UO_2 pellets
CLADDING	Zr alloy
NAME/OWNER	(Study)/AECL
LOCATION	
OPERATOR	
PURPOSE	Economic study
REMARKS	A "hot" pressure tube system, similar to CANDU, is being investigated. Fuel rods are solid, cylindrical, natural UO_2 clad in Zircaloy-2. The element is a 19-rod bundle. The pressure tubes and calandria tubes are a zirconium alloy. The pressure tube is surrounded by an insulating gas, and in turn surrounded by the calandria tube. The core volume is larger than CANDU, and the fuel ratings lower.

REFERENCES

Partial economic study of steam cooled heavy water moderated reactors.
AECL, Nuclear Eng. Branch
AECL-1018 (April 1960)

The heavy water moderated spray-cooled reactor.
J. G. Collier, P. M. C. Lacey
Nuclear Power 5: 68 (August 1960)

After CANDU - fog-cooled reactors?
G. A. Pon.
Canadian Chem. Processing 45: 83, 92-4 (October 1961)

Heavy water moderated natural uranium power reactors.
J. L. Gray, others
AECL-1646 (October 1962)

STEAM COOLED REACTORS CAN (Italy)

DESIGNER	CISE/NDA (U.S.)
TYPE	Steam cooled pressure tube, D_2O
POWER	Mw(e) Mw(t) 74
COOLANT	Wet steam (spray)
MODERATOR	D_2O
FUEL	Natural U-Zr alloy hollow rods
CLADDING	Zircaloy-2
NAME/OWNER	CAN-Study/CISE
OPERATOR	
LOCATION	
PURPOSE	Study of steam as a coolant for power reactors
REMARKS	Preliminary design. Cluster and concentric fuel element assemblies calculated. The preferred element consists of two concentric annuli of Zircaloy-canned fuel with three concentric annular coolant flow channels and a solid central Zircaloy rod. Study contract under U.S.-Euratom agreement. (CAN-1). CAN-1 phase has been completed, CAN-2 and CAN-3 studies are in progress. These studies entail heat transfer, heat flux and corrosion investigations. Construction of in-pile loop to be placed in the SORIN reactor is nearly complete.
REFERENCES	Calculation methods for the critical size of a D_2O moderated, wet steam cooled reactor with a natural uranium cluster fuel element. R. Bonalume, others CISE-67 (1959) Energia Nucleare 7: 192-209 (March 1960) Preliminary design studies on fuel elements for a heavy water moderated, wet steam cooled reactor. I. Casagrande, others CISE-68 (May 1959)

(contd)

REFERENCES (contd)

The spray cooled reactor.
J. G. Collier, P. M. C. Lacey
Nuclear Power 5: 68-73 (August 1960)

CAN-1. Fog coolant project.
M. Silvestri, others
Nucleonics 19: 86-8 (January 1961)

The "CAN" research and development program on the application of steam-water mixtures to the reactor cooling.
E. Villani (CISE)
Energia Nucleare (Milan) 9: 84-96 (February 1962)

Investigation of wet steam as a reactor coolant (CAN-2). Volume II. Conceptual design evaluation of a fog-cooled light water reactor. Final Report.
M. Raber, others
UNC-5008-II (August 10, 1962)

Evaluation and interpretation of the experiments on adiabatic two-phase flow performed at CISE under the CAN-1 program.
CISE (Italy)
EURAEC-445 (1962)

Advanced research program on the application of steam-water spray to the cooling of light-water reactors (CAN-2).
CISE (Italy)
EURAEC-475 (1962)

Large-scale and in-pile testing of light water–steam mixtures as reactor coolants (CAN-3).
CISE (Italy)
EURAEC-476 (1962)

See also NDA-5

DESIGNER	Mitchell
TYPE	Steam cooled. Ship propulsion. Indirect cycle. Pressure tube
POWER	Mw(e) (20,000 shp) Mw(t)
COOLANT	Superheated steam
MODERATOR	H_2O (boiling)
FUEL	UO_2 sleeve-type pellets (annular)
CLADDING	SS
NAME/OWNER	SCLMR (Steam Cooled Light Water Moderated Reactor)/
OPERATOR	
LOCATION	
PURPOSE	Ship propulsion
REMARKS	Fuel elements are contained in Zircaloy pressure tubes surrounded by the moderator. Core is composed of 21 fuel assemblies. Mitchell is negotiating with the German shipyard Rheinstahl Nordseewerke of Emden for sale. Mitchell's development is independent of the UKAEA's marine reactor program. Design is designated SCLMR (Steam Cooled Light Water Moderated Reactor). The modular type construction of the plant would make it suitable for a wide range of applications, such as in water distillation plants or power station up to 300 Mw(e).
REFERENCES	Mitchell's SCLMR - design of competitive marine reactor. H. J. Coles Nuclear Eng. 8: 58-63 (February 1963)

SECTION J

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP)

DOMESTIC

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP)

AEC's SNAP program is aimed at the development of compact, lightweight nuclear electric devices for space, sea and land applications. Compact power packages based on the conversion of fission or radioactive decay heat, or on reactor systems, are under development for use in satellites and space vehicles, to power remote scientific stations and navigation devices. Systems based on the conversion of heat from radioactive sources are odd-numbered (SNAP-1, -3, etc). Systems employing nuclear reactors are even-numbered (SNAP-2, -4, etc). Reactor systems under development by Atomics International are based on homogeneous fuel-moderator elements, liquid metal coolants, with the system coupled to a mercury vapor turbine generator.

SNAP-1, a cerium-144 fueled space power unit, was assigned to Martin for development in 1956, with delivery of the first complete unit scheduled for September 1959; this program was subsequently discontinued. Under the basic Martin contract the SNAP-3 program was subcontracted for the development of advanced thermoelectric and thermionic heat-to-electricity conversion systems using radioactive heat sources. Minnesota Mining and Manufacturing delivered a complete thermoelectric generator to Martin in December 1958, and polonium-210 fuel capsules were furnished by AEC's Mound Laboratory. The assembled and tested unit was delivered to the AEC in January 1959, as a proof-of-principle demonstration device. It produced 2.5 watts with a half charge of polonium-210 fuel.

A recent estimate by NASA is that by 1966, radioisotopic power for space missions will require 1400 watts of radioisotopic power. Requirements will probably be met through the use of alpha-emitting isotopes, especially plutonium-238 and curium-244 although the more readily available beta-emitting isotopes (promethium-147, strontium-90, and cerium-144) will be considered if ground handling and other problems are solved and acceptable performance demonstrated.

REFERENCES

Energy conversion systems reference handbook, volume XI: radioisotope system design. Final report 390. Electro-Optical Systems Inc. (Pasadena, Calif) WADD-TR-60-699, Vol. XI (September 1960)

The SNAP program. U.S. AEC's space-electric power program.
G. M. Anderson
Nuclear Eng. 5: 460-3 (October 1960)

(contd)

REFERENCES (contd)

SNAP thermoelectric systems.
A. W. Thiele, M. G. Coombes
ARS Space Power System Conference, Santa Monica, California, September 27-30, 1960
Paper 1330-60
American Rocket Soc., N. Y. (1960)

Nuclear frontiers - 1960
A Forum Report (No. 32)
Proc. Annual Conf. for Members and Guests, San Francisco, California, December 14-16, 1960
E. A. Wiggin, ed.
Atomic Industrial Forum, N. Y. (1961)

SNAP fact sheet.
AEC news release, June 15, 1962

DESIGNATION	SNAP-2 (SER)/AEC-NASA
DESIGNER	AI
TYPE	Reactor system, turboelectric generator
PURPOSE	Auxiliary power, space craft
FUEL	93% enriched UO_2-ZrH fuel-moderator elements
DESCRIPTION	Compact NaK cooled reactor with homogeneous fuel-moderator elements (rods), stainless steel containment, Be and graphite reflector. System is coupled to a mercury vapor turbine generator (Mercury-Rankine cycle).
REMARKS	Demonstration study. Turbine generator equipment is being developed by Thompson Ramo-Woolridge. Project is in the testing stage, with flight test scheduled for 1965.

REFERENCES

The SNAP-2 concept.
H. M. Dieckamp
ARS Space Power Systems Conference, Santa Monica, California, September 27-30, 1960
Paper No. 1324-60
American Rocket Soc., N. Y. (1960)

An enriched UO_2-ZrH critical assembly.
M. V. Davis, others
NAA-SR-5610 (November 1960)

SNAP-2. Nuclear space power system.
J. R. Wetch, H. M. Dieckamp, D. J. Cockeram (AI)
Astronautics 5 (12). 24-5 (December 1960)

Preliminary results on the SNAP-2 experimental reactor.
M. W. Hulin, J. Beall, ed.
NAA-SR-5991 (April 1961)

SNAP-2 power conversion studies.
D. L. Southam
Space Power Systems, p. 291
N. W. Snyder, ed.
Academic Press, N. Y.

DESIGNATION	SNAP-4
DESIGNER	AI
TYPE	Reactor system
PURPOSE	Auxiliary power
POWER	1000-4000 kw(e)
FUEL	Homogeneous fuel-moderator elements of $ZrH-UO_2$
DESCRIPTION	SNAP-2 type reactor, cooled with boiling light water. Single loop.
REMARKS	Development and feasibility study on a reactor for unattended operation in an underwater or remote land location. Design study and component development for an experimental reactor has been started. As now conceived, SNAP-4 output would be 1-2 Mw(e).
REFERENCES	SNAP Fact Sheet. USAEC, News Release, June 1962 Hearing before the U.S. Joint Committee on Atomic Energy. Congress of the United States, 87th Congress, Second Section on Peaceful Uses of Atomic Energy April 10, 1962 (p. 140-143)

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP) SNAP-8 (AI)

DESIGNATION SNAP-8/AEC-NASA

DESIGNER AI

TYPE Reactor system, turboelectric generator

PURPOSE Propulsive power unit experiment

POWER 30 kw(e) 250 kw(t)

FUEL Homogeneous $ZrH-UO_2$ fuel-moderator elements

DESCRIPTION Reactor system; homogeneous fuel-moderator elements of ZrH with U^{235}, Be reflector. Core is a bundle of fuel-moderator elements, steel cladding tubes. NaK is the coolant. Mercury vapor turbine generator power conversion system.

REMARKS Outgrowth of SNAP-2. Critical September 1962. Flight test target is 1966. Lewis Research Center has completed an extensive review of SNAP-8, resulting in a redesign. The new system will have a power-to-weight ratio of 100 for 35 kw operation. A NaK loop will be included to go between the mercury-vapor (in the turbine-alternator) and the condenser. Other alterations include extra radiators and a larger shadow-shield. Space test target is 1968. No mission has been assigned, but system will be investigated in connection with operations of a manned lunar base.

REFERENCES Nuclear power and space.
G. T. Seaborg
IRE Trans. Nuclear Sci. NS-9: 1-8 (January 1962)

DESIGNATION	SNAP-10A
DESIGNER	AI
TYPE	Reactor system, thermoelectric generator
PURPOSE	Auxiliary power; demonstration of thermoelectric power conversion
POWER	500 watts
FUEL	Homogeneous fuel-moderator elements, $ZrH-UO_2$ rods
DESCRIPTION	Compact reactor system with no moving parts; a thermoelectric radiator coupled to the reactor. Beryllium heat transfer and reflector units as alternating disks of fuel--Be arrangement. Zirconium-hydride reactor. Design weight is 750 lb.
REMARKS	Development. System testing. Flight test scheduled in 1963. SNAP-10A re-entry burnup tests using a non-radioactive mockup began in April 1963. AI has received a contract from NASA for a study to determine the design modifications needed to adapt SNAP-type reactors to power a lunar base. SNAP-2 and SNAP-10A reactors will be studied in connection with power for instruments, and SNAP-8 in connection with operations of a manned lunar base.
REFERENCES	Nuclear power and space. G. T. Seaborg IRE Trans. Nuclear Sci. NS-9: 1-8 (January 1962)

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP) SNAP-15A (AI)

DESIGNATION	SNAP-15A
DESIGNER	GD
TYPE	Isotopic power generator
PURPOSE	Auxiliary power, advanced type, probable space application
POWER	4-10 watts
FUEL	Pu^{238}
DESCRIPTION	
REMARKS	Contract awarded to GD by the AEC to design and develop an advanced low-power SNAP-type thermoelectric generator using Pu^{238} fuel. No mission has been selected for the system. GD has also received on AEC contract to develop Pu^{238} fueled generators in the milliwatt range for terrestrial application. The device will be designated SNAP-15A.
REFERENCES	Nucleonics Week, May 23, 1963, p. 2.

DESIGNATION	Pulsing TRIGA
DESIGNER	GD
TYPE	Reactor system, thermoelectric conversion
PURPOSE	Auxiliary power, oceanographic research vessel
POWER	Mw(e) 2-5
FUEL	U-Zr hydride fuel-moderator elements
DESCRIPTION	Portable, self-regulating package plant, based on the pulsing TRIGA. May use thermoelectric elements for direct conversion. Extrapolation based on 25-50 kw(e) reactor for power needs, for oceanographic research craft.
REMARKS	Proposed to the Navy.
REFERENCES	Forum Memo, March 1961, p. 10-11. Nucleonics Week, July 13, 1961, p. 2.

DESIGNATION	STAR (Space Thermionic Auxiliary Reactor)
DESIGNER	GE
TYPE	Reactor system, thermionic converter
PURPOSE	Auxiliary power, space
POWER	70 kw(e)
FUEL	UO_2
DESCRIPTION	Hollow cylinder composed of identical segmented rings, each ring made up of individual fuel segments consisting of the reactor fuel and a thermionic cesium-plasma converter. Control is by the movement of an end converter. A 20 kw(e) prototype proposed by 1964. STAR-C: direct conversion system, liquid metal cooled, U oxide fuel clad with tungsten containing cesiated refractory metal converters
REMARKS	Development at Special Nuclear Systems Operation, Pleasanton. An Air Force contract has been awarded for STAR-R thermionic reactor unit.
REFERENCES	Forum Memo, August 1961, p. 9. News Release. Nucleonics Week, August 1, 1963, p. 3.

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP)

MIXED FISSION PRODUCTS GENERATOR (GIC)

DESIGNATION	Mixed Fission Products Generator
DESIGNER	GIC
TYPE	Isotope power generator
PURPOSE	Auxiliary power, demonstration
POWER	5-10 watts
FUEL	Mixed fission products
DESCRIPTION	Thermoelectric generator system fueled with unrefined mixed fission products derived from reprocessing spent reactor fuels. Generator will be fueled at an AEC installation.
REMARKS	First unit has been under test since August 1962. AEC has ordered a generator with design power output of 5-10 watts. Delivery is scheduled for early 1964.
REFERENCES	Forum Memo, November 1962, p. 17. News Release. Nucleonics Week, January 17, 1963, p. 2.

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP) SNAP-15B (GIC)

DESIGNATION	SNAP-15B
DESIGNER	GIC
TYPE	Isotope power generator
PURPOSE	Auxiliary power, terrestrial use
POWER	--milliwatt range--
FUEL	Pu^{238}
DESCRIPTION	Isotope fueled generator
REMARKS	AEC contract to develop plutonium-238 fueled generators in the milliwatt range.

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP) SNAP-1 (Martin)

DESIGNATION	SNAP-1A
DESIGNER	Martin
TYPE	Radionuclide powered generator
PURPOSE	Auxiliary power
POWER	500 watts from two generators
FUEL	Cerium-144 (Inconel-X sources containing Ce^{144} fuel loading). Ceramic CeO_2 pellets with SiC and CaO. 0.88 megacurie Ce^{144} per generator.
DESCRIPTION	Original contract to Martin for development (1956) was subsequently dropped.
REMARKS	The SNAP-3 program was subcontracted under the basic Martin contract. SNAP-1 design was for a 500-watt system using Ce^{144} fuel and mercury vapor as heat conversion working fluid. SNAP-1A cylindrical core of Inconel-X with tantalum-lined channels containing Ce^{144}.
REFERENCES	SNAP-1 radioisotope-fueled turboelectric power conversion system summary, January 1957 to June 1959. P. J. Dick MND-P-2350 (June 1960) Final safety analyses report. SNAP-1A radioisotope fueled thermoelectric generator. Martin Company (G. P. Dix) MND-P-2352 (June 1960)

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP) — SNAP-3 (MARTIN)

DESIGNATION	SNAP-3
DESIGNER (Principal contract)	MARTIN
TYPE	Radionuclide power generator
PURPOSE	Auxiliary power
POWER	2.7 watts, full output for ~4 years
FUEL	Po^{210} (demonstration); Pu^{238} (Ce^{144}–design)
DESCRIPTION	In the generator, spontaneous decay of the radioisotope generates heat which is transferred to the surrounding containment block. Thermocouples convert some of this heat directly to usable electric energy. The generator has no moving parts. Core material is Hayne Alloy 25.
REMARKS	SNAP-3 model was operable in January 1959, producing 2.5 watts of power with a half charge of Po^{210} fuel. SNAP-3 system development using Pu^{238} as the heat source has resulted in generators for the TRANSIT satellites (U.S. Navy). TRANSIT-4A was orbited in June 1961; TRANSIT-4B (Pu^{238} fueled) in November 1961. Martin has started work on SNAP-9A, using Pu^{238}-carbide fuel, for the first operational TRANSIT-5. A conceptual design based on Ce^{144} has been completed; the system will produce 67 thermal watts for two SNAP-3 type generators, the Haynes Alloy 25 capsule containing 9725 curies in cerium oxide pellets.
REFERENCES	Hazards summary report for a 3-watt polonium-210 fueled thermoelectric generator. Martin Company MND-P-2047 (June 1959. Declassified September 1960) Final safety analysis report. SNAP-3 thermoelectric generator. H. Hagis, G. P. Dix MND-P-2364 (June 1960)

(contd)

REFERENCES (contd)

Conceptual design of a SNAP-3 type generator fueled with cerium-144.
R. J. Wilson
MND-P-2369 (June 1960)

Nuclear safety analysis of SNAP-3 for space mission.
W. Hagis, others
ARS J. 31L 1744-51 (December 1961)

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP) SNAP-7 (MARTIN)

DESIGNATION	SNAP-7
DESIGNER (Prime)	MARTIN
TYPE	Radionuclide power generator, direct conversion. AEC-sponsored
PURPOSE	Auxiliary power
POWER	5-30 watts
FUEL	Sr^{90} (strontium titanate) (17,500 curies)
DESCRIPTION	Cylindrical container and fuel block of Hastelloy-C. A depleted uranium shield is within the double-walled Hastelloy vessel.
REMARKS	7: U.S. Weather Bureau. Installed at unmanned weather station on Axel Heiberg Island, north of the Arctic Circle, September 1961. 5 watts. 7A: Coast Guard. Installed in buoy, Arundel Cove, Md., January 1962. 10 watts. 7B: Coast Guard. For shore-based or floating navigational aid. 30 watts. 7C: Navy. Installed at site near Little America V, Antarctic, 1962. 10 watts. 7D: Probable use by Navy for barge-mounted weather station in the Gulf of Mexico. 30 watts. 7E: AEC contract award for development of experimental navigational beacon to operate on the ocean floor (Atlantic). Sr^{90} generator will use four capsules containing 31,000 curies of strontium titanate fuel, 60 pairs of lead telluride thermoelectric elements to produce 5 watts of electricity at 4.5 volts. Development for the Navy. In service in 1962. Martin is developing a radioisotope-powered underwater sound beacon for the AEC. The device, which will produce a high-pitched signal, is being developed in collaboration with the U.S. Naval Oceanographic Office. It is scheduled for preliminary tests at a depth of 25 feet in Chesapeake Bay early in 1964.

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REFERENCES

Hazards summary report for a 2-watt strontium-90 fueled thermoelectric generator.
Martin Company
MND-P-2048 (June 1959. Declassified September 1960)

Strontium-90 fueled thermoelectric generator power source—5-watt U.S. Navy Weather Station. Final report.
Martin Company, Nuclear Div.
MND-P-2707 (nd)

7A: Strontium-90 fueled thermoelectric generator for 5-watt U.S. Coast Guard light buoy. Final report.
Martin Company
MND-P-2720 (February 1962)

7C: Final safety analysis; 10-watt strontium-90 fueled generator for an unattended meteorological station. SNAP-7C.
Martin Company
MND-P-2614 (February 1962)

7D: SNAP strontium-90 fueled thermoelectric generator power source 30-watt U.S. Navy floating weather station. Final report.
Martin Company, Nuclear Div.
MND-P-2835 (March 15, 1963)

7E: Final safety evaluation of a 10-watt strontium-90 fueled generator for a deep sea application—SNAP-7E.
H. N. Berkow, V. G. Kelly
MND-P-2761 (1962)

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP) — SNAP-9 (MARTIN)

DESIGNATION	SNAP-9
DESIGNER (Prime contract)	MARTIN
TYPE	Radionuclide power generator
PURPOSE	Auxiliary power
POWER	25 watts (90% efficiency in conversion of nuclear heat electricity has been achieved)
FUEL	Pu^{238} carbide
DESCRIPTION	Identical in principle but larger than SNAP-3 (TRANSIT-type) generator
REMARKS	Work has started on a 25-watt SNAP-9A to be used in the operational TRANSIT satellites (Navy). The first TRANSIT-5A, launched from Point Arguello, December 1962, used solar cells. A plutonium-fueled satellite was launched in September 1963. A contract to develop a 20-watt Pu-fueled SNAP device for IMP (Interplanetary Monitor Probe) is under negotiation by AEC and Martin; SNAP-9A may be scaled down to meet NASA's IMP requirements. Target for IMP is 1964 or early 1965. The third IMP will probably be powered by two 25-watt Pu^{238} fueled generators, and may be specified for later missions. The NIMBUS weather satellites will also use radioisotope power sources, NASA tentatively scheduling the first launch for 1966, with a single 250-watt generator. Plutonium-238 or possibly Cm^{244} are being considered as sources. NASA has announced that it will use two 250-watt Pu^{238} or Cm^{233} fueled generators for the OAO (Orbiting Astronautical Observatory) scheduled for launch in 1967. Plutonium-238, Cm^{244}, or Sr^{90} generators are also being considered in a study by Martin Nuclear and Jet Propulsion Laboratory for the Voyager Mars Mission.
REFERENCES	Forum Memo, February 1962, pp. 10-11 (SNAP-9A) News Release. Nucleonics Week, February 14, 1963, p. 4.

DESIGNATION	SNAP-11 (SLLG - Soft Lunar Landing Generator)
DESIGNER (Prime contract)	MARTIN
TYPE	Radionuclide power generator
PURPOSE	Auxiliary power, Surveyor spacecraft.
POWER	25 watts (18.6 watts continuously for 90-day lunar flight)
FUEL	Cm^{242}
DESCRIPTION	Weight 30 pounds. Structural fuel block is Hastelloy-C, with thin-walled tantalum fuel canisters.
REMARKS	NASA will use Cm^{242} generators in project for soft-landing of instrumented packages (spacecraft) on the moon, beginning in 1963 (Surveyor). Martin-AEC contract is for design, construction, and testing. A thermal mockup of the SNAP -11 generator has been fabricated and is undergoing tests. Target 1963-4; flight target 1965. SNAP-13, a low-powered cesium vapor thermionic generator, is being developed to demonstrate feasibility of using a radioisotope heat source. To be designed in line with Surveyor power requirements, alternate to SNAP-11 unit (hard lunar landing). Curium-242 technology is being applied to studies of Cm^{244}. (See also SNAP-9, p. 202.)
REFERENCES	100-watt curium-242 fueled thermoelectric generator-conceptual design. SNAP subtask 5.7 final report. J. B. Weddell, J. Bloom MND-P-2342 (May 1960) 13-watt curium-fueled thermoelectric generator for a six-month space mission. Final report. J. L. Bloom MND-P-2373 (July 1960)

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP) — SNAP-13 (MARTIN)

DESIGNATION	SNAP-13
DESIGNER	
TYPE	Thermionic generator, low power (radioisotope heat source)
PURPOSE	Auxiliary power
POWER	
FUEL	Cm^{242}
DESCRIPTION	Low-power cesium-vapor thermionic generator, to be designed in line with Surveyor power requirement. Alternate to SNAP-11
REMARKS	Tests were to be conducted on an electrically heated unit in FY 1962; a fueled SNAP-13 will be completed in 1963 and work on an improved thermionic unit will extend through 1964.
REFERENCES	See SNAP-11.

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP) DCR (MARTIN)

DESIGNATION	Direct Conversion Reactor (DCR)
DESIGNER	MARTIN
TYPE	Reactor system, thermionic and thermoelectric conversion designs
PURPOSE	Auxiliary power
POWER	1 Mw(e)
FUEL	Thermoelectric system (liquid metal cooled) U-Zr hydride fuel moderator elements. Thermionic system (BWR) UO_2 fuel, Mo clad; thermionic converter elements integral to fuel bundles.
DESCRIPTION	The thermoelectric system would use a liquid metal cooled reactor (phosphorus sesquisulfide or NaK) and homogeneous fuel moderator elements of U-Zr hydride. Advanced approach includes nuclear superheat. The thermionic system is a forced circulation BWR with zirconium hydride as moderator. Fuel would be Mo-clad UO_2, with the thermionic converter units integral to the fuel bundle.
REMARKS	Development. Martin has proposed the concept to the Army.
REFERENCES	Direct Conversion Reactor for space. Nucleonics 20: 5 (January 1962) Nucleonics Week, October 25, 1962, p. 1-2. News Release.

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP) — INTERMEDIATE REACTOR (ORNL)

DESIGNATION	INTERMEDIATE REACTOR
DESIGNER	ORNL
TYPE	Liquid metal cooled (potassium), reactor system
PURPOSE	Auxiliary power, space
POWER	1 Mw(t), 125 kw(e)
FUEL	UO_2
DESCRIPTION	Reactor system using boiling potassium as the heat transfer fluid and direct working fluid. Core is a one-loop system, expected to operate at about 1500 F. Boiling potassium coolant is fed to a potassium turbine, then to a radiator, where it is pumped back into the core.
REMARKS	Development. Reactor is intermediate between SNAP-8 (40 kw(e)) and SNAP-50 (325 kw(e); no SNAP number has been assigned to the program. A reactor experiment is under construction at Oak Ridge. Operational target is 1965.
REFERENCES	Nucleonics Week, November 22, 1962, p. 1-2. News Release. Nuclear News 6: 30 (January 1963) News Release.

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP) SNAP-50 (PWAC)

DESIGNATION	SNAP-50 (SNAP-50/SPUR)/AEC-NASA-AF
DESIGNER (Prime)	PWAC
TYPE	Liquid metal cooled, fast reactor system
PURPOSE	Space, auxiliary power
POWER	300 kw(e) to 1 Mw(e) for experimental flight test (1969-70)
FUEL	UO_2-BeO
DESCRIPTION	High temperature compact reactor, lithium-cooled, potassium vapor turbine. Weight-power goal is 10 lb/kw(e) including weight of reactor, power conversion unit and unshielded radiator.
REMARKS	GE and GD will supplement the thermionic reactor system as a follow-up to SNAP-50. The LCRE (Lithium Cooled Reactor Experiment) which was to have been built at an Idaho facility has been canceled. The program will proceed with SNAP-50 design and development.
REFERENCES	SNAP-50/SPUR reactor development. F. D. Haines Trans. American Nuclear Soc. 6 (1): 88 (June 1963) (Abstract)

DESIGNATION	LAMONT GEOPHYSICAL OBSERVATORY GENERATOR
DESIGNER	RRC
TYPE	Isotope power generator
PURPOSE	Auxiliary power, deep sea installation
POWER	5 watts
FUEL	Cs^{137}
DESCRIPTION	
REMARKS	Manufacture in process. Target 1963. Study contract award from AEC for a thermoelectric generator based on Lamont Generator design, using interchangeable isotopic fuels to produce 20 watts. Fuel will be Ce^{144} initially. Design completion target 1963.
REFERENCES	Forum Memo, November 1962, p. 16. News Release. Nucleonics Week, August 16, 1962, p. 4. News Release.

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP) — WANL SUBMERGED REACTOR UNIT (WEST)

DESIGNATION	WANL SUBMERGED REACTOR UNIT/WEST, Office of Naval Research
DESIGNER	WEST (Astronuclear Laboratory)
TYPE	BWR, thermoelectric power conversion take-off. Natural convection circulation. Boiling sulfur as a coolant may be investigated for high temperature applications.
PURPOSE	Unattended operation, undersea or deep sea submergence, auxiliary power
POWER	Mw(e) 3 Mw(t) 45
FUEL	Fuels studies were Fe- or Nb-UO_2 matrix, BeO-UO_2 matrix, low-enriched UO_2
DESCRIPTION	Feasibility study for power generation by thermoelectric means, the thermoelectric material being an integral part of the fuel element. The reactor is H_2O cooled and moderated, with thermal circulation of the primary coolant. Fuel element designs are variations of rod elements in which the fuel is surrounded by concentric regions of thermoelectric material, conductor, insulators, and cladding. Designs included Fe- or Nb-UO_2 highly enriched fuel matrix, BeO-UO_2 highly enriched fuel matrix, low-enrichment UO_2. A core design using the Fe- or Nb-UO_2 matrix fuel contained 64 bundles of 32 fuel rods each. Generator output under operating conditions was 3200 amp at 160 volts. A 2- or 3-year lifetime at 80% of full power of 10 Mw(t) and 500 kw(e) was postulated.
REMARKS	Feasibility study completed; preliminary design in progress
REFERENCES	Preliminary core design of a 500 kw(e) thermoelectric reactor. R. Markley, E. Schwartz WCAP-1737 (March 1961) Feasibility studies for 3 Mw(e) nuclear thermoelectric power plant. R. A. Clark, others WANL-PR(A)-002 (December 1961)

(contd)

REFERENCES (contd)

Direct conversion thermoelectric reactor studies.
J. C. Danko, others
Preprint paper No. 11. Engineers Joint Council, N. Y. 1962.

Undersea reactor may power ocean-bottom community.
Mach. Design 34: 28 (December 6, 1962) News item.

SECTION J

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP)

FOREIGN

SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP) STUDY (France)

France will develop small nuclear power units similar to U.S. SNAP generators. A pilot plant has beenconstructed at Saclay for separation of Cs^{137} and Sr^{90}. Other studies include research on fission reactors.

SECTION K

MISCELLANEOUS

DOMESTIC

Available information on proposals or projects for which no reactor type has been selected is included in this section, pending more descriptive information.

FLORIDA

Burns and Roe will perform a feasibility and economic study for a light water reactor system for use in a combined salt water conversion and electricity generating plant. Probable site would be Key West.

HAWAII

Hilo Electric Company (Hawaii) has postponed its plans for a 20 Mw(e) reactor.

Hawaiian Electric Company (Honolulu). New study has been initiated on its proposed 100-125 Mw(e) nuclear plant. Re-evaluation covers the BWR plant first considered and will also consider a PWR. Westinghouse General Electric, and Babcock and Wilcox have been requested to provide data for the current study. (To serve the island of Oahu) Site: Kahe valley. Target is 1966.

REFERENCES Nucleonics Week, February 7, 1963, p. 1. News Release.

Nucleonics Week, August 22, 1963, p. 5. News Release.

MINNESOTA

Minnesota Power and Light (Duluth) has proposed to the electrical cooperatives group Northern Minnesota Power Association that they participate in constructing a nuclear plant in northern Minnesota. A 300 Mw(e) plant, possibly a BWR, may be considered

REFERENCE Nucleonics 21: 22 (March 1963) News Release.

NEVADA

Sierra Pacific Power and Nevada Power have contracted with Stone and Webster for an economic feasibility study of a jointly built nuclear power plant of 250 Mw(e) or over. Sierra Pacific has been reported as probable candidate for participation in AEC's 150 Mw(e) spectral shift reactor prototype. Site mentioned was on Walker Lake near Reno.

NEW JERSEY

Competitive tenders will be invited from General Electric Company and from Westinghouse Electric Corporation for a nuclear power plant planned by the Jersey Central Power and Light Company. A 500 Mw(e) nuclear station is expected to be in operation by 1969, with construction start scheduled for early 1965.

NEW YORK

ESADA (Empire State Atomic Development Association, Inc.) of New York plans a large nuclear plant, with completion scheduled for 1968.

The New York State Atomic Research and Development Authority has contracted with Burns and Roe for a site survey and a feasibility study of a water desalination plant using nuclear heat. The site would be on Long Island.

Long Island Lighting Company has been reported as a probable candidate for participation in AEC's 150 Mw(e) spectral shift prototype reactor.

Niagara Mohawk Power Corporation is preparing specifications for bids on components for a 500 Mw(e) nuclear power plant to be built near Oswego, N. Y., for 1968 operation. The reactor will be either a PWR or a BWR. Contracts will be awarded early in 1964.

SECTION K

MISCELLANEOUS

FOREIGN

Available information on proposals or projects for which no reactor type has been selected is included in this section, pending more descriptive information.

AUSTRALIA

Siemens (West Germany) has been selected as consultant to study a 5-20 Mw(t) PWR for testing and training purposes, and later to become part of a group evaluating a number of reactor types for a decision on Australia's first commercial-size plant.

AUSTRIA

The AKEW, a study group composed of Austrian utilities, has been formed with the possible objective of a 15-20 Mw(t) reactor for training, testing, and some power production.

Contract for collaboration in the design of Austria's first nuclear power station has been concluded between the Austrian Atomic Energy Study Company (SGAE) and Siemens-Schuckertwerke AG of Erlangen, West Germany. A PWR concept is being studied.

CANADA

Ontario Hydro is considering construction of a nuclear power station consisting of a complex of four 450 Mw(e) CANDU reactors (1800 Mw(e) station). Target for the first two units is 1970. Sites being considered are on Lake Huron and Lake Erie.

DENMARK

The Arctic Mining Company A/S (Denmark) is investigating the possible use of a 22 Mw(e) nuclear power plant to exploit a molybdenum ore deposit in Greenland.

EGYPT

See UNITED ARAB REPUBLIC.

FORMOSA

The Thaiwan Electricity Society (Formosa) has announced plans to construct a 200-250 Mw(e) nuclear power station, with assistance from the USAEC.

INDIA

An Italian nuclear naval program provides for the construction of a tanker equipped with a water reactor of Italian design and construction. First stage of the project, to be concluded in December 1962, is the comparison of four types of water reactors. Sponsors of the program are Societa Fiat of Turin and Societa Ansaldo of Genoa, with CNEN.

JAPAN

The Japan Atomic Power Co. (JAPCO) has taken options on a site near Tswinga City in Fukui Prefecture, for a proposed large nuclear plant using a water reactor. Target for construction start is 1963, target 1968. The reactor will be purchased from a U.S. company.

Japan's first nuclear ship is to be in operation by 1970; a water-cooled system with a 30-35 Mw(t) capacity has been suggested by a special advisory committee to the Japanese AEC.

The Tokyo, Chubu, and Kansai electric power companies have announced plans to construct nuclear power stations, each having a capacity of about 300 Mw(e).

PAKISTAN

Pakistan's AEC has announced plans to build two nuclear power plants, a 50 Mw(e) light water unit in East Pakistan and a 100 Mw(e) natural uranium, heavy water plant in the western part of the country, probably in the Karachi area. Bids have not been requested.

POLAND

Poland has announced plans for a 300 Mw(e) station for the early 1970's and an 800 Mw(e) plant by 1980. Also announced is the construction of a nuclear research station at Gdansk for marine propulsion projects.

UNITED ARAB REPUBLIC

UAR has considered the possible construction of an $85-million 150 Mw(e) nuclear power station in the Nile Valley.

WEST GERMANY

West Germany's fast breeder program includes evaluation of advanced reactor development progress at the Karlsruhe Research Center, with selection of type to be made by 1965. The selected reactor will be constructed in 1965-70. Oxide and carbide fuels will be studied, as well as helium and water vapor as coolants. Interatom has received a contract for design and development of a sodium-cooled metal-hydride experimental reactor.

Also in West Germany, discussions are reported to be underway concerning the possibility of constructing a small nuclear power station at Weismoor, near Aurich, in the center of West Germany's largest greenhouse and fruit production area. The proposed station will be a 40 Mw(e) prototype. Firms invited to bid by NKW are General Atomic Division, General Dynamics Corporation, and a British consortium. General Atomic and its German licensee Gutehoffnungshutte AG will collaborate on a proposal based on the HTGR concept. The British proposal, submitted by Babcock & Wilcox, Ltd. in association with Deutsch Babcock and Wilcox Dampfkessel-Werke AG, will be based on AGR.

West Germany and France are reportedly discussing the construction, as a joint project, of a 500 Mw(e) nuclear station somewhere between Strasbourg and Basle, near the River Rhine.

Construction of a high temperature GCR, either an AGR type or a concept such as the Peach Bottom HTGR, has been proposed for East Frisia. Design contracts will be awarded by Arbeitsgemeinschaft Projekt Kernkraftwerk Hamburg

SECTION L

REACTOR INDEX

Designs are indexed by reactor name, place name, and by reactor type, with many cross references. A number of special characteristics are also indexed, such as internal steam separation, carbide fuel, ship propulsion, etc. In the index, the general reactor type and the designer's code are given for each entry.

Examples:

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