AEC

UNITED STATES
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Division of Public Information

20 YEARS OF NUCLEAR PROGRESS

BACKGROUND MATERIAL

RELEASE AT WILL AFTER
NOVEMBER 15, 1962

Fermi Biography

ENRICO FERMI, 1901 -- 1954

Enrico Fermi, the brilliant Italian scientist who won the Nobel Prize for physics in 1938 and who headed the group of pioneer nuclear physicists that achieved the world's first controlled release of nuclear energy on Dec. 2, 1942, was born in Rome, Sept. 29, 1901.

Son of a railroad official, he studied at the University of Pisa from 1918 to 1922, and later at the Universities of Leyden and Göttingen. He became professor of theoretical physics at the University of Rome in 1927. Two years later, he was made a member of the Italian Academy.

Fermi became the leading figure of a group that revolutionized modern Italian physics and whose influence was felt in science throughout the world. His work at the University of Rome began the career that led him to equal fame as a theoretical and an experimental physicist.

Although preeminent in physics, Fermi also made major contributions to statistics of electron gas, the statistical model of the atom itself and fundamental contributions to the understanding of radioactivity.

In 1934, Fermi began to bombard atomic nuclei with neutrons, using small amounts of radon gas and beryllium as his source of neutrons. With simple equipment, elements beginning with the lightest (hydrogen) were bombarded and the chemical end products

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analyzed. Moving up the periodic table, Fermi and his associates came finally to uranium, then the heaviest known element. They found that the neutron bombardment had produced more than one element, and that at least one of the radioactive products seemed to be none of the existing elements close to uranium.

Their first report (May, 1934) did not claim discovery of a new element but described evidence they had found that such an element might be produced. Later analysis showed that the Fermi group actually had split the uranium atom but did not realize it at the time.

In a second series of experiments, it was discovered that by passing neutrons through other elements, they could be slowed down and the amount of artificial radioactivity produced could be increased greatly.

Fermi and members of his group obtained an Italian patent on this discovery. The patent rights were assigned to a friend in the United States, G. M. Giannini, who obtained an American patent in 1940. The status of this patent was not clarified until 1953 when the U. S. Atomic Energy Commission awarded $300,000 to the inventors.

These two series of experiments by Fermi were the essential precursors that led to the building of the world's first nuclear reactor. This work also brought him the Nobel Prize for physics in 1938.

In 1928, Fermi married Laura Capon, daughter of a highly respected and cultured Jewish family in Rome. He used the opportunity offered by the trip to Sweden to receive the Nobel Prize to get his family out of Italy, then under the Fascist regime of Mussolini. He brought his wife and two children - a daughter, Nella, and a son, Giulio - to the United States.

Fermi became a professor of physics at Columbia University. By this time, the phenomenon of nuclear fission was established and the tremendous release of energy involved had been calculated. Dr. George B. Pegram, dean of graduate studies at Columbia, designated Fermi to discuss the possible military potential of nuclear fission with Army and Navy officials in Washington in the spring of 1939.

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Fermi was not successful in getting direct government backing for the work. But he was among those who persisted in the attempt to alert defense officials to the possibilities of a nuclear bomb. The result was the historic Einstein letter to President Roosevelt in 1939 which began: "Some recent work ... by E. Fermi and L. Szilard leads me to expect that the element uranium may be turned into a new and important source of energy ..."

This letter led to the project that was to become the Manhattan Engineer District (MED) and produce the first nuclear weapon.

Working first at Columbia University and then at the MED operations at the University of Chicago, known as the "Metallurgical Laboratory," Fermi was placed in charge of building the world's first nuclear reactor. Success came on Dec. 2, 1942, in a dark racquets court under the West Stands of the University's Stagg Field, when the first self-sustaining nuclear chain reaction was achieved with this reactor.

Later, Fermi was transferred to the weapon design laboratory at Los Alamos, New Mexico, as chief of the advanced physics department. When the war ended, the University of Chicago established the Institute for Nuclear Studies. Fermi joined its staff along with some other scientists who had worked at the "Met.Lab."

For his work on the nuclear bomb, Fermi was awarded the Medal of Merit in 1945. The Presidential citation read, in part:

"First man in all the world to achieve nuclear chain reaction and as associate director of the Los Alamos Laboratory, Manhattan Engineer District, Army Service Forces, his essential experimental work and consulting service involved great responsibility and scientific distinction..."

Although Stagg Field stadium has been torn down, the plaque placed there on the fifth anniversary in 1947 remains at the site. It reads:

"On December 2, 1942, man achieved here the first self-sustaining chain reaction and thereby initiated the controlled release of nuclear energy."

On the 10th anniversary, 1952, Fermi spoke again at a gathering of many of the men who had been in the racquets court on the historic occasion.

At the Institute, the great physicist continued his investigations, concentrating on the particles that make up the nucleus. He was interested particularly in the short-lived particles - the mesons - which make up part of the "glue" that holds the nucleus together.

He was a consultant in the design of the synchrocyclotron at the University of Chicago and used this particle accelerator (atom smasher) in his studies. In the last year of his life, 1954, Fermi made an important contribution to nuclear physics by a correct interpretation of a phenomenon involving the behavior of polarized beams of protons.

Fermi became ill with cancer and died in his Chicago home on Nov. 28, 1954.

Posthumously in 1954, he was the first recipient of what is known now as the Fermi Award, presented annually by the President of the United States. This first award, signed by President Eisenhower, said: "An Award of Merit to Enrico Fermi for his contributions to basic neutron physics and the achievement of the controlled nuclear chain reaction."

He was awarded numerous honorary degrees by universities in the United States and abroad and was a member of many scientific societies, including the National Academy of Sciences and the Royal Society of England. Fermi was a member of the General Advisory Committee to the U. S. Atomic Energy Commission from its organization late in 1946 until August, 1950.

Fermi was a good "team worker" and more than 100 of the 240 publications that bear his name were produced in collaboration with his colleagues. Among the nine books he wrote, one -- done early in his career in Italy -- was a text on physics for high schools. His works are being collected and published by the University of Chicago Press.

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(Note to Editors: The following tributes to Fermi are reprinted with permission of the copyright holders of the works cited.)

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He gave to science all he had and with him disappeared the last universal physicist in the tradition of the great men of the 19th century, when it was still possible for a single person to reach the highest summits, both in theory and experiment, and to dominate all fields of physics. -- Emilio Segre in ENRICO FERMI, COLLECTED PAPERS, University of Chicago Press, 1962.

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Fermi's name is written large in the history of basic neutron physics, and he will be remembered as long as civilization endures for his achievement of the first controlled nuclear chain reaction. This feat merits the adjective "Promethean" for it was the bringing of a new energy source to mankind. -- Lewis L. Strauss, MEN AND DECISIONS, Doubleday & Co., 1962.

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No one who had more than casual acquaintance with Fermi failed to recognize in him a man of really extraordinary intelligence and mental brilliance... He habitually associated with young people and remained young in spirit throughout his life... At the laboratory, he was among the first to arrive and last to leave, inspiring his co-workers by his outpouring of boundless intelligence and energy during each day. -- Samuel K. Allison, BIOGRAPHICAL MEMOIRS, Vol. 30, National Academy of Sciences, Columbia University Press, New York, 1957.

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2 0 Y E A R S O F N U C L E A R P R O G R E S S

BACKGROUND MATERIAL

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NOVEMBER 15, 1962

NOTE TO EDITORS: This is the major backgrounder for use in connection with the 20th anniversary of the world's first nuclear chain reaction, achieved in Chicago on December 2, 1942. It is a capsule history of 20 years progress in nuclear science and technology, primarily as reflected in programs administered by the U.S. Atomic Energy Commission, many of which were initiated by its wartime predecessor, the Manhattan Engineer Project.

TWENTY YEARS OF NUCLEAR PROGRESS

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A. THE EARLY PERIOD

1. The Fermi Pile.

One of the major events that ushered in the atomic age took place on December 2, 1942 -- 20 years ago. The enormous energy of the atom, calculated from the discovery of fission less than four years earlier, was brought under man's control.

At 3:25 p.m. that day, the world's first nuclear reactor "went critical;" that is, a controlled self-sustaining fission chain reaction was achieved.

Twenty years later - 1962 - there are several hundred reactors operating or being build in half a hundred countries. Chairman Glenn T. Seaborg of the U.S. Atomic Energy Commission affirms that more scientific progress has been made in these two decades than in all previous history of science.

Congress has appropriated more than $30 billion to develop and operate the U.S. nuclear energy program. AEC appropriations for the 1963 fiscal year totalled $3.1 billion.

The scene on December 2, 1942, was the closely guarded racquets court under the University of Chicago's Stagg Field Stadium. The key figure was the late Dr. Enrico Fermi, brilliant Italian physicist, who led a team of nuclear pioneers to this success.

(THE FIRST PILE* by C. Allardice and E. Trapnell gives details of the tense days and hours that preceded the historic event.)

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* Nuclear reactors were called "atomic piles" in the early days, a term descriptive of layers of graphite interspersed with uranium piled one upon the other until sufficient fissionable material was present to initiate a nuclear chain reaction.

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Few outside the racquets court knew what had happened or its significance. The United States had been at war almost a year. It was assumed that Hitler understood the potential of a nuclear fission bomb and was pressing its development. Censorship imposed in the United States by the scientists themselves in 1939 became a major operation to protect the most important military secret of World War II.

The U.S. crash program was managed by the Army's Manhattan Engineer District (MED), wartime predecessor of the U.S. Atomic Energy Commission. All available U.S. resources were being mobilized, with important help from Great Britain and Canada, to win a technological race that might decide the outcome of the war.

The Fermi success came at one of the many crises in the project. To make a bomb, fissionable material in pure form had to be manufactured on an industrial scale. One such material was the naturally fissionable uranium isotope 235 (U-235) but efforts to separate it from the abundant uranium 238 (U-238) were going badly.

The other possibility was the man-made fissionable element, plutonium, discovered in 1940 by a University of California team led by Dr. Seaborg. Its bomb potential had been confirmed. Pounds were required. The available supply was in millionths of an ounce produced in a cyclotron. A machine that could control the bombardment of natural uranium with neutrons to manufacture plutonium in quantity was a crucial need. The crude Fermi pile of natural uranium and graphite gave the answer.

2. <u>1942-1945. A Bomb is Made</u>.

Confident of success, Fermi and his colleagues were designing reactors to make plutonium even before their first "pile" went critical. Problems of a moderator to slow down the neutrons so they would split U-238 atoms and of a coolant to control the tremendous heat of nuclear reaction were tackled. On December 23, 1942, President Franklin D. Roosevelt approved plans to scale up a laboratory operation to a vast industrial complex in an incredibly short time.

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It was too hazardous to continue work in the improvised laboratory at the University of Chicago. The historic first reactor was dismantled, modified, and by March 1943 had been rebuilt in the Argonne Forest Preserve, near the present Argonne National Laboratory. Later, a second reactor using heavy water as a coolant and moderator was built at this location.

By February 1943, design was underway for a semi-works comprising an air-cooled reactor and a chemical separation plant to be built at Oak Ridge, Tenn., the first of the large MED bomb project installations. This reactor went critical at dawn on November 4, 1943, with Fermi and others from the Chicago group present. Known as "X-10," it was to become famous as the world's first "wholesale" producer of radioisotopes. It still is an important source of radio-isotope supply.

Continuing difficulties in separating U-235 and the time required to build X-10 led to an historic decision in April 1943. Without waiting for results of the pilot operation at Oak Ridge, it was decided to scale up the laboratory production of plutonium one billion times in the form of three huge water-cooled reactors and three chemical separation plants to be built in the 400,000-acre desert area being acquired at Hanford, Washington.

Site work on the first Hanford reactor began late in August 1943. Thirteen months later, "B Pile" was in operation. Fermi had inserted the first uranium fuel slug on Sept. 13, 1944.

By January 1945, early operating troubles with the plutonium reactors had been solved. The complex chemical separation of plutonium from other products of the fission process and from the unburned uranium was successful. Plutonium was being produced on an industrial basis. Six months later, plutonium made at Hanford was the material used in the world's first atomic bomb detonated July 16, 1945 in the desert at Alamogordo, New Mexico.

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By this time, sufficient uranium 235 had been made at Oak Ridge to make a bomb and the device exploded over Hiroshima on August 6, 1945 used this material. The bomb dropped two days later on Nagasaki was a plutonium device. The war ended August 14.

The success at Stagg Field on December 2, 1942 had proved vital to the development of nuclear weapons. The Free World was to rely principally on the U.S. supply of such weapons to keep the peace and maintain superiority in this field after the Soviet Union achieved nuclear weapon capability in August 1949.

3. The Interim Period - 1946.

Before it turned over its work to the civilian Atomic Energy Commission at the end of 1946, the MED completed the other two plutonium producing reactors at Hanford and constructed two small reactors for experimenting with fast neutrons at Los Alamos, New Mexico, the last of three large centers built for the wartime project. Both Los Alamos reactors were "firsts." One used plutonium as fuel and the other enriched uranium.

Even before the war ended, scientists were turning their thoughts to future development of reactors and to shaping a national nuclear energy program. In November 1944, a committee on which Fermi served recommended that attention be focused on designing reactors to produce electric power and that the United States keep its lead in nuclear research. The committee stressed that a world-wide organization would be needed to control the use of this new source of energy.

A more formal group, the MED Committee on Post-War Policy, urged that the United States maintain superiority in nuclear weapons, put nuclear development under a national authority, explore the possibility of using reactors in naval propulsion, and encourage industrial development and fundamental research.

On October 3, 1945, President Truman outlined a national program which contemplated military control. In

1946, after an historic debate, Congress passed the Atomic Energy Act of 1946 which gave control to a civilian commission. The law became effective on August 1 and Truman appointed the first five members of the new Atomic Energy Commission with David E. Lilienthal designated as Chairman.*

The law established a government monopoly in the nuclear field and set up a special Congressional committee, the Joint Committee on Atomic Energy (JCAE), to oversee AEC operations. The late Senator Brien McMahon of Connecticut, who had championed civilian control, became the first JCAE Chairman.

Meanwhile, despite the exodus of scientists back to their universities and laboratories, important events were taking place. The MED decided to sponsor two reactor projects in Fiscal Year 1947.

One was a fast neutron reactor which became the first experimental "breeder" (EBR-I), i.e., a reactor designed to produce more fissionable material than it consumed. The other, a helium-cooled high temperature power reactor, did not get beyond the design stage.

Radioisotopes were made available for use outside of the MED project. The first shipment - carbon 14 produced in the X-10 reactor - left Oak Ridge on Aug. 2, 1946, for a cancer hospital in St. Louis, Missouri.

Other important MED decisions had included plans to make national laboratories of the research centers at Argonne and Oak Ridge, to establish a nuclear power laboratory at Schenectady, New York and to authorize the Brookhaven National Laboratory, a research center for the Northeastern states, to be built on Long Island. Its central facility was to be a versatile research reactor. The new Atomic Energy

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* Succeeding chairman have been: Gordon Dean 1950-1953; Lewis L. Strauss 1953-1958; John A. McCone 1958-1961; and Glenn T. Seaborg 1961 to date.

Commission carried out these plans.

The Oak Ridge Institute of Nuclear Studies (ORINS) was organized at Oak Ridge to stimulate nuclear research and training in southern universities. ORINS submitted its first contract to the Army on October 31, 1946.

4. The AEC Takes Over - 1947.

At midnight on Dec. 31, 1946, the newly created civilian U.S. Atomic Energy Commission assumed responsibility for the national nuclear energy program and began the takeover of the huge complex of plants and laboratories in which more than $2 billion had been invested.

There were eight reactors in operation, three for plutonium production at Hanford, four research reactors -- two each at Los Alamos and Argonne Forest -- and the radioisotope producer, X-10, at Oak Ridge.

The first years of AEC management were devoted primarily to rehabilitation and improvement of the hastily built wartime facilities. Manufacture of fissionable material and development of weapons were put on a permanent basis. Serious trouble with the Hanford plutonium reactors, due to expansion of the graphite blocks used as the moderator, was overcome and plutonium production was increased.

The foundations for steady advances in reactor technology were laid. The experimental breeder reactor was authorized, the ship propulsion project (submarine) expanded, need for a material testing reactor was studied, and a large desert area in Idaho was selected for the National Reactor Testing Station (NRTS).

In the 1950-1953 period, following U.S. detection of a Soviet nuclear test in 1949, the entire national program gained momentum. The Congress authorized more than $3 billion for new installations and facilities. Reactor development was an important part of this expansion.

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In December 1951, the world's first useful nuclear electricity was produced at NRTS when a small generator hooked up with the newly completed breeder reactor lighted four 200-watt bulbs and supplied power for shop machines. The powerful Materials Testing Reactor started operating in Idaho in 1952.

The "submarine in the desert" became a reality as the land-based prototype thermal reactor for the first nuclear-powered ship, the USS NAUTILUS, was completed in Idaho. Several experimental reactor projects were authorized, including development of the sodium cooled graphite moderated concept. The Oak Ridge School of Reactor Technology was established in 1950.

The importance of reactors in radioisotope production was shown in the increase in quantity and variety available. By 1948, the X-10 reactor at Oak Ridge could make substantial quantities of carbon-14 in a few weeks -- many, many times more than previously available. The cost was about $10,000 per millicurie. It was calculated then that it would require hundreds of cyclotrons to turn out a similar amount of carbon-14 and the cost would run into millions of dollars.

A surge of industrial and popular interest in nuclear power resulted in inauguration in 1951 of the Commission's industrial participation program. Utility companies in large numbers teamed up with reactor and component manufacturers in study groups that eventually totalled 25, with 81 companies participating. Some $8 million in private funds was spent on these studies. First reports of these teams were termed "cautiously optimistic."

In 1953. the breeding principle was established in the Idaho experimental reactor. The homogeneous reactor was tested at Oak Ridge and its heat operated a 150 kilowatt generator. The submarine prototype was brought to substantial power and construction of the USS NAUTILUS was well underway.

That same year. the JCAE held extended hearings on

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nuclear power development, which laid the foundation for revision of the original Atomic Energy Act of 1946. (See page 14)

B. AEC PROGRAMS

1. For the National Defense.

The Atomic Energy Act of 1946 and its 1954 revision require that all AEC activities shall be subject at all times to the "paramount objective" of making the maximum contribution to the "common defense and security."

In fulfilling this obligation, the United States has become the principal nuclear armorer of the Free World. The United Kingdom has a limited nuclear weapons program and recently France has acquired a measure of weapon capability. Since the first Soviet detonation in 1949, the USSR has developed a program comparable to that of the United States.

About 70% of current AEC expenditures are for the weapons program. The devices are designed in the Los Alamos and Livermore laboratories, engineered at Sandia Laboratory, and tested in proving grounds in the Pacific and in Nevada. Production reactors supply the plutonium and the material for hydrogen bombs. A large industrial effort supports the weapons program.

The MED and the Navy tested the effects of nuclear weapons on warships in the Pacific in 1946 but the first trial of improved devices came at Bikini in the Marshall Islands in 1948. In 1951, the principle of fusion bombs was proved. The Soviets matched this a short time later.

Steady progress was made in increasing the efficiency and versatility of nuclear weapons. By 1953, the Army, Navy and Air Force had devices tailored to their respective needs. These, including nuclear warheads for missiles and rockets, are being improved.

During the entire period of postwar development of nuclear weapons, the United States has tried continuously

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to get the Soviet Union to agree to a workable formula for control of nuclear weapon manufacture. As a step toward that objective, proposals for banning tests have been discussed since 1955. The AEC has provided technical leadership in these negotiations which continue to this day. Soviet obsession with secrecy has been the major factor preventing an agreement on any type of international control plan or test ban which would provide workable safeguards against violation.

2. The Versatile Radioisotope.

The Fermi "pile" established that the controlled release of nuclear energy, made possible by reactors, results in three products: heat, neutrons and radioisotopes formed from the splitting of uranium atoms in the fission process. The same is true for reactors using plutonium or U-233 (derived from thorium) as fuel.

The heat makes possible the generation of electric power.

The vast quantities of neutrons produced in reactors have been a major factor in the rapid advance of nuclear science and technology in the past 20 years. For some 10 years prior to 1942, only small quantities of neutrons were available.

Reactors are the primary source of radioisotopes and the most widespread and important peaceful applications of nuclear energy today are the hundreds of uses of radioisotopes.

Some important radioisotopes are recovered from the fission products of chain reaction -- the wastes or "ashes" of nuclear reactor operation. Among them are strontium 90 and cesium 137. Hundreds of others are made by exposing isotopes of various elements to neutron bombardment in a reactor.

Sometimes a radioactive form of the element is the result, such as cobalt 60. In other cases one form of an

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element is transmuted into a radioactive form of another. For example, stable sulphur 32 is transmuted into radioactive phosphorus 32, a radioisotope widely used in medicine and agriculture.

The many uses of radioisotopes in research, medicine, agriculture and industry have been widely publicized. The popular and technical literature on the "tagged" or "tracer" atom is voluminous.

Radioisotopes are the basis for most of the new discipline of nuclear medicine. They constitute a diagnostic tool to study body processes and disease which early in the atomic era was hailed as the "greatest advance since invention of the microscope."

In agriculture, it was said as early as 1950 that radioisotopes had made possible more knowledge of when, how and where plants use fertilizer than had been discovered in the previous half century. Today, radioisotopes show the way to greater crop yields, better knowledge of soils, and greater effectiveness in combating insect pests and animal and plant diseases.

In the life sciences, the radioisotope has made it possible to add much to basic and applied knowledge in such areas as genetics and photosynthesis.

In industry, radioisotopes are finding ever-widening use. Radioisotope gauges control the quality of many manufactured products; "tracer" isotopes follow the course of chemical reactions; radioisotopes are used like X-rays to detect flaws in wells and castings. Radioisotope research also promises to extend the shelf life of large classes of foods such as meats, fruits and fish.

In 1962, the 100,000th shipment of radioisotopes left Oak Ridge and the total amount of useful radiation, measured in curies, has increased even more importantly, setting a record in 1961.

As of September, 1962, there were more than 7,000 licensed users of radioisotopes in the United States. Some 1500 were physicians and 1500 were hospitals and other medical institutions. Other major classes of users were: industrial firms - 2114; federal and state laboratories - 1485.

Perhaps the most far-reaching new advance in radioisotope use is the generation of electric power directly from the heat given off during the decay of radioactive substances.

Two of the four transmitters of the Navy navigational satellites TRANSIT IV-A and B were powered by 2.7 watts of electricity produced from the decay heat of plutonium 238. The scientific principle involved is not new but its application to radioisotopes is just in its infancy.

Today, work on isotopic generators or "atomic batteries" to deliver up to 500 watts electrical power is in progress. Already isotopic power has operated the instruments in unmanned weather stations near the Arctic Circle and in the Antarctic and a navigational buoy in the Chesapeake Bay.

These new "atomic batteries" fill a long-felt need for a rugged, reliable, unattended power source for use in remote locations and promise to be of great use in filling in present gaps in the accumulation of weather data.

3. Toward Economic Nuclear Power.

The story of controlled release of the power of the atom which began with the Fermi Pile in December 1942 became known to the public in mid-1945. The tight censorship on most nuclear matters was lifted cautiously following the use of the first atomic bombs in August 1945.

Almost immediately there appeared a rash of optimistic forecasts of quick development of cheap electric power in plants using nuclear reactors instead of the conventional coal and oil-fired furnaces. The reality of technical problems dissipated such dreams.

In 1953, the AEC decided to build at Shippingport, Pa., a huge laboratory to advance nuclear power technology in the form of a 60 mwe (megawatts electrical) pressurized water reactor plant. This was the world's first large plant designed exclusively to produce power. It went into operation in 1957. Four smaller projects were authorized in 1954 to explore economic feasibility of other systems. These five reactors constituted the AEC's Five-Year-Plan.

On August 17, 1954, the Atomic Energy Act of 1954 became law. It made possible a three-fold development in the U.S. civilian program: (1) international cooperation to extend peaceful uses of nuclear energy; (2) wider and more independent industrial participation in the program, especially in nuclear power development; and (3) greater Commission effort to make technical knowledge available so as to broaden the base for nuclear education and training.

One result of the legislation was greatly increased interest in all types of nuclear reactors. The growing supply of enriched uranium-235 focused attention in the United States on reactors using this type of fuel. Reactors using enriched fuel could be much smaller than those using natural uranium, thus reducing capital cost. The enriched fuel gave a higher efficiency in heat production but it cost more than natural uranium.

The AEC Five-Year-Plan and the 1954 law paved the way for the Commission to launch in January 1955 the Power Demonstration Reactor Program (PDRP). The goal was to encourage American industry to design, construct and operate experimental nuclear power plants. As this program has developed, government help has been supplied in several forms such as research and development work on specific reactors, waiver of fuel use charges and AEC ownership of the reactor part of a plant with the utility purchasing the steam produced by the reactor.

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Under the PRDP program, as of October 1962, ten plants have been built or are under construction. Not counting AEC basic research and development, total estimated investment in these plants will be $412.2 million -- $250.3 million in private funds and $161.9 million supplied by the Commission.

Steady progress in nuclear reactor technology made it possible for the Commission to announce in 1958 as one of the major objectives of its reactor power program, the achievement of competitive nuclear power in high cost areas of the United States by the end of 1968.

This year - 20 years since the first nuclear reactor operated - a California utility* decided it would be economic to build a large nuclear power plant. No government assistance is being asked. Several manufacturers are offering plants ranging upward from 300 megawatts electrical capacity that they believe will achieve economic nuclear power in high cost areas.

The Commission considers that its goal - competitive nuclear power in high cost areas - is close to realization. Success of the proposed California plant could make the goal a reality.

High cost areas in this country, however, embrace only a small part of the present 187,000 megawatt generating capacity of U.S. utilities. It is recognized that further and substantial cost reductions are necessary before nuclear power becomes generally competitive with U.S. coal and oil-fired plants.

One encouraging factor is that nuclear plants now in operation are exceeding their designed capacity. For example, the pressurized water reactor in the Yankee plant

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* Pacific Gas and Electric plans to build a 325 mwe boiling water type nuclear plant at Bodega Bay, California, north of San Francisco.

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