Brussels, April 23, 1959

HISTORY OF THE JOINT UNITED STATES - EURATOM PROGRAM

A sense of urgency has pervaded the creation and implementation of the joint United States-Euratom program for building nuclear power plants in Europe and carrying out related research and development.

For a pioneer program of such complexity and magnitude, progress has been extremely rapid.

FEBRUARY, 1956 -- U.S. AID FORESHADOWED

The unprecedented experiment in international cooperation was foreshadowed on February 22, 1956, when President Eisenhower, announcing allocation of 20,000 kilograms of enriched uranium for sale or lease outside the U.S. for peaceful purposes, stated:

> "Significant actions are under way to create an international agency and an integrated community for Western Europe to develop the peaceful uses of atomic energy. The United States welcomes this progress and will cooperate with such agencies when they come into existence."

The "integrated community for Western Europe" to which the President referred was the six-nation European Atomic Energy Community (Euratom), then being created by negotiations among Belgium, France, Germany, Italy, Luxembourg and the Netherlands.

MARCH, 1957 -- EURATOM TREATY SIGNED

The Six signed a treaty in Rome on March 25, 1957, which set January 1, 1958, as the day the new Community would officially begin operation.

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FEBRUARY, 1957 -- "THREE WISE MEN" VISIT U.S.

But even before the treaty was signed, Euratom's "Three Wise Men" -- Louis Armand of France, Franz Etzel of Germany and Francesco Giordani of Italy -- visited the United States in February, 1957, to inspect American nuclear installations and meet American leaders.

Their examination of European power needs led them to suggest an objective of building within a decade nuclear power plants with a total generating capacity of 15,000,000 kilowatts.

A joint statement issued by the State Department, then chairman Lewis L. Strauss of the Atomic Energy Commission and the "Wise Men" themselves said the objective was "feasible".

"Under present circumstances, the availability of nuclear fuels is not considered to be a limiting factor," the statement added.

It said the United States "anticipates active association in the achievement of the committee's (Wise Men's) objective, and foresees a fruitful two-way exchange of experience and technical development, opening a new area for mutually beneficial action on both the governemental and the industrial level and reinforcing solidarity within Europe and across the Atlantic."

MAY, 1957 -- "TARGET FOR EURATOM" ISSUED

In May,1957, a formal report from the "Three Wise Men," entitled "A Target for Euratom," stated in part:

"We ... attach particular importance to the statement made by the United States authorities that they do not consider that nuclear fuels will be a limiting factor ... As this statement comes from the country which is the world's biggest producer of enriched uranium, we can be sure that the availability of nuclear fuel will not limit the realization of our target."

The report reiterated what is called the "ambitious target" of installing 15,000,000 kilowatts of nuclear power capacity in the six Euratom countries within 10 years.

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JULY, 1957 --- EURATOM EXPERTS TOUR AEC PLANTS

In July, 1957, 50 industrialists and government officials from the six Euratom nations toured various AEC installations and private plants in the United States. The visit gave them first-hand knowledge of the technology involved in setting up large power-reactor establishments.

JANUARY,1958 --- EURATOM FORMALLY BEGINS OPERATION

When the Community came into life in January,1958, negotiations with the United States followed speedily to formalize the cooperation already agreed upon in principle when the Three Wise Men visited Washington.

MAY-JUNE,1958 -- MEMORANDUM OF UNDERSTANDING SIGNED

At Brussels on May 29 and at Washington on June 12 a "Memorandum of Understanding" was signed which set forth a "program consistent with, and in fact a point of departure towards, the program outlined in 'A Target for Euratom.'"

The program set forth two objectives:

> "A. To bring into operation by 1963, within the European Atomic Energy Community, large-scale power plants using nuclear reactors of proven types, on which research and development has been carried to an advanced stage in the United States, having a total installed capacity of approximately one million kilowatts of electricity and under conditions which approach the conventional range of conventional energy costs in Europe."
>
> "B. To initiate immediately a joint research and development program centered on these types of reactors."

Total capital cost of the power plants, exclusive of fuel inventory, was not to exeed $350,000,000. Of this about $215,000,000 was to be provided by participating European facilities and other capital sources and up to $135,000,000 was to be provided by the U.S. as a long term credit to Euratom.

The research and development program, to last 10 years, was budgeted at about $50,000,000 from each party for the first five years and another contribution from each, probably in the same range, for the second five years.

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JUNE,1958 -- JOINT PROGRAM BEFORE CONGRESS

President Eisenhower presented the program to Congress on June 23, 1958, and stressed its "urgency".

> "I am sure that the Congress, having in mind the political and economic advantages which will accrue to us and our European friends from such a joint endeavor,will wish to consider quickly and favorably the proposed program," the President wrote.

AUGUST,1958 -- CONGRESS APPROVES, PRESIDENT SIGNS COOPERATION ACT

Congress cooperated, quickly, and the "Euratom Cooperation Act of 1958" was signed on August 18 by the President, who commented that "this joint program should prove highly beneficial both to Europe and to the United States."

The Act made the necessary financial provision for the program and authorized the sale or lease to Euratom of 30,000 kilograms of contained uranium 235, enough to fuel the projected reactors for 20 years.

NOVEMBER,1958 -- AGREEMENT FOR COOPERATION SIGNED

On November 8, 1958, an "agreement for cooperation" was signed by the U.S. and Euratom, further elaborating the earlier Memorandum of Understanding. There were two significant changes: it now was agreed that two of the reactors might come into operation as late as 1965; and the reference to"proven" types of reactors was deleted. These changes were designed to liberalize the program, permitting builders to take advantage of knowledge which may be gained in the early years of the building program.

FEBRUARY,1959 -- AGREEMENT ENTERS INTO FORCE

The agreement was to come into force as soon as each party notified the other that it had completed all necessary statutory and constitutional steps; it was to last 25 years. The agreement entered into force on February 18, 1959.

FEBRUARY,1959 -- EURATOM COMMISSIONERS VISIT WASHINGTON

In the same month, Euratom Commissioners Paul H. de Groote and Enrico Medi visited Washington and discussed certain details of the administration of the agreement.

DECEMBER,1958 -- R & D PROJECTS SOUGHT

Meantime, on December 23,1958, AEC and Euratom had jointly issued an invitation for proposals for projects to be undertaken under the joint research and development plan. Proposals could be in any field relevant to the reactor program.

A joint U.S.-Euratom R & D board was set up, with provisional headquarters in Brussels, to receive, evaluate and select proposals and provide technical guidance for any projects contracted for.

APRIL,1959 -- REACTOR PROJECTS SOUGHT

On April 13, 1959, another AEC-Euratom announcement invited private and government enterprises in the six Euratom countries to submit proposals to build and operate nuclear power plants under the Joint Program.

FUTURE DATES

Important dates in the timetable set to speed the reactor construction program were :

June 7,1959 -- those who intend to make proposals were asked to notify AEC or Euratom by this date.

September 1, 1959 -- deadline for submission of proposals.

December 31, 1959 -- target date for selection of proposals by AEC-Euratom.

April, 1960 -- target date for beginning construction.

December 31, 1963 -- target date for completion, except for two plants which may be deferred to December 31, 1965.

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WHY THE JOINT PROGRAM IS IMPORTANT TO THE UNUTED STATES

The joint United States-Euratom program for nuclear power plant building and research and development is important to the U.S. for a large number of reasons. Paradoxically, perhaps the chief reason is that it is important to Europe.

In presenting the program to Congress in 1958, President Eisenhower said:

"The Europeans see atomic energy ... as something which they must develop quickly if they are to continue their economic growth and exercise their rightful influence in world affairs.

"The success of this undertaking, therefore, is of vital importance of the United States, for the 160,000,000 people of the continent of Europe are crucial to North American strength.

"It is therefore gratifying that the reactor research, development, testing and contruction program in the United States has progressed to the point that United States reactors of proven types are available and will be selected for commercial exploitation in the joint program...."

The President expressed his belief that "initiation of this program of cooperation with Euratom represents a major step in the application of nuclear technology for the benefit of mankind." Such peaceful application of the atom is a keystone of American policy.

President Eisenhower also noted that his country and Euratom "have reaffirmed their dedication to the objectives of the International Atomic Energy Agency and the nations participating in it." This again is a vital part of U.S. Policy.

U.S. CONTRIBUTION IS "TRADE,NOT AID"

But not all the scientific benefits of the program will be conferred on countries outside the United States. Writing shortly before the IAEA was established, the noted American physicist Donald J. Hughes summed up the advantages of international cooperation for the U.S. this way:

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"What the U.S. has to gain will not be obvious at first but should become more important as time goes on. The European scientists are very good, and they are moving ahead boldly and rapidly in spite of tremendous material handicaps.

"The rapidity with which they are mastering the atomic energy field and the thoroughgoing nature of their investigations are proof of their ability. In many laboratories I found them investigating fundamentals of neutron physics which we have never had time to study in detail. I became convinced that under the present conditions they will do much more careful work on these fundamentals of reactor physics than we shall do.

"With our help, in very short order they will be producing results of great value to us -- results that will be doubly valuable because they are done with a fresh approach ...

"In the nuclear field we shall be engaging in 'trade, not aid.' The trade will be an exchange of extremely valuable fundamental scientific concepts on which all the economic progress will depend.

"European scientists will also begin to offer competition with us in atomic energy which will have a salutory effect."

Hughes' comments apply equally to the benefits expected by the U.S. from the joint program with Euratom.

NEED TO DEVELOP ATOMIC POWER

Rapid development of economic nuclear power -- the key work is "economic" -- is of great national importance to the United States, perhaps only slightly less so than it is to the Euratom countries. Per capita utilization of energy is both the mainspring and the yardstick of a country's industrial development and such development is essential both for national security and for a healthy domestic economy.

Despite large reserves of conventional "fossil fuels" -- coal, petroleum and natural gas -- and expanding hydropower developments, energy costs will tend to rise in the U.S. unless new sources of power are harnessed. Also it is advicable to conserve fossil fuel reserves, since they are particulary suited and perhaps irreplaceable for certain uses such as the gasolinefueling of cars and planes.

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On the other hand, nuclear power is rapidly demonstrating special capabilities in propelling naval vessels and work is already well advanced on the American-built "Savannah"-- the world's first nuclear-powered commercial vessel.

Additionally, nuclear power has a considerable potential in the propulsion of certain projected types of aircraft and in the heating of homes and factories.

EXPANDING OVER-ALL ENERGY REQUIREMENTS

With its growing population and advancing industrialization, the United States constantly needs more and more energy. Power consumption for all purposes rises annually. In the field of electrical power alone, capacity and output double about every 10 years. American power-planners want nuclear energy to absorb its share of the load.

Expressed in trillions of standard BTUs (British Thermal Unit -- the amount of heat needed to raise one pound of water one degree Fahrenheit in temperature), the U.S. in the mid-1950s was consuming annually for all purposes 11,900 from coal, 16,300 from petroleum, 9,000 from natural gas and 1,500 from hydropower -- a total of 38,700 trillion BTUs.

In a quarter-century national power requirements will more than double. AEC estimates for all types of energy consumption in 1980 are 25,000 from coal, 30,000 from petroleum, 21,000 from natural gas, 4,000 from hydropower and 6,000 from nuclear power -- a total of 86,000 trillion BTUs, of which nuclear power would provide nearly seven per cent.

In the field of electrical power alone, nuclear reactors are expected to play an even more important role. Present nuclear installations in the U.S. provide only a minute fraction of the nation's electrical power needs. But the AEC has estimated that by 1980 it may contribute about 225 million kilowatts to a national total of 700 million kilowatts of installed capacity in utility plants.

(Note: European power requirements for the future are outlined in a separate paper in this series.)

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NEED TO COMPETE COMMERCIALLY

Despite the vast promise of atomic energy, it can become a major source of power in a free-enterprise country only when it becomes economically competitive with conventional power costs. In this connection, the joint U.S.-Euratom research and development program, centered on reactors which the U.S. will help to build in Euratom countries, can be of vast assistance to the United States. Knowledge gained in actual operation of reactors totalling 1,000,000 kilowatts of electrical capacity will serve to complement U.S. domestic reactor development.

On both sides of the Atlantic there are factors which should help to cut nuclear power costs as technology progresses.

Because of their higher concentration, nuclear fuels are cheaper to transport than are conventional fuels. Thus to build a nuclear plant distant from any source of conventional fuel or water-power may eventually prove cheaper than to build a conventional plant, despite the higher cost of nuclear installations.

Also, the capital cost of nuclear plants is expected to be reduced in terms of kilowatt-hours by building larger plants than any yet functioning and by utilizing less costly components and a more knowledgeable approach to safety needs.

Though still much more expensive, nuclear fuel may eventually become cheaper than conventional, largely through the ability of "breeder" reactors to produce more fissionable fuel than they consume.

DIFFERENT POSITIONS OF U.S.-EURATOM

The day when nuclear power can compete in cost with conventional power will almost certainly dawn sooner for Europe than for the United States, because the latter enjoys considerable cheaper conventional power. European conventional power costs between 10 an 15 mills per kilowatt-hour.

Cost of power from the reactors projected under the joint U.S.-Euratom program will range, it is hoped, between 10 and 14 mills per kilowatt-hour and thus should become immediately competitive.

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The experience gained in running commercially-competitive nuclear power plants will be of immense interest to those utility groups in the United States which plan eventually to incorporate nuclear power into their electric systems.

The cost-to-consumer factor is naturally a major consideration to such industries which are, of course, sometimes hesitant to commit large capital sums to building giant new reactors without waiting for the fullest knowledge obtainable from the operation of smaller-scale experimental reactors throughout the country.

The interchange of knowledge planned under the joint program will give American scientists another source of information to check against their own data and to provide new lines of thought, not only in the field of cost-cutting but in every other type of development which can make reactors more efficient.

European atom specialists are working on many of their own experimental concepts and, as Hughes and many other have pointed out, their work is of a very high standard and extremely thorough.

PROGRAM BENEFITS BOTH PARTIES

The pooling of reactor skills can only be of benefit to both parties.

In his Congress message President Eisenhower put it this way:

"The elements which combine to make such a joint program possible are the same that led to the first break-through in the development of atomic energy 15 years ago: the intimate association of European and American scientists and the close association between European and American engineers and industries."

THE UNITED STATES ATOMIC ENERGY COMMISSION

The United States Atomic Energy Commission is a civilian authority, in operation since January 1, 1947, which has full authority over its country's atomic energy program and administers bilateral and other international agreements to which the U.S. is a party. Its Commissioners direct American atomic work in all the various fields of peaceful uses of atomic energy, ranging from basic research through reactor technology and the production and use of radioisotopes in industry, medicine and agriculture, and in the military field -- a task inherited from the wartime atomic pioneers.

Its activities -- many of which are carried on under contract by big and small industries and by universities throughout the United States -- involve a budget of around two billion dollars a year.

In developing nuclear power reactors in the U.S., the AEC plays a major coordinating role in partnership with private enterprise. A recent AEC report stated:

> "The United States program as a whole has an essential unity in that reactors built at any time depend on the technology developed up to that time in other civilian plants, regardless of administrative arrangements. Technological contributions are made also by a crossflow of unclassified data from military reactors."

(An instance of the latter statement: the first full-scale power reactor in the country, the 60,000-kilowatt plant at Shippingport, Pa., which went into operation in 1957, owes much of its design to theories already proved valid by the U.S. atomic submarine Nautilus.)

To further reactor development, the AEC is carrying on a multi-installation Power Demonstration Reactor Program in which the Commission and industrial groups cooperate to build plants under negotiated contracts which involve varying degrees of governmental financial participation. The Commission and utility groups cooperate through the program to assure development, construction and operation of full-scale reactor power prototype plants of types of which further development may lead to the production of economic nuclear power.

The program is directed towards obtaining as much industrial participation as possibile in the construction of complete prototype power reactors so as to enlist cost-cutting incentives at a stage in development when economies are of major importance, and to help provide manufacturers and utilities with experience in constructing and operating nuclear power plants.

Reactor development is only one of the multifarious activities of the AEC; it is, however, the one most directly concerned in participation in the joint U.S.-Euratom program for plant-building, research and development.

Present Chairman of the AEC is John A. McCone.

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LAYMAN'S GLOSSARY

ACCELERATOR -- "Atom-smasher" or device which, by using either electric or magnetic forces, accelerates heavy particles of atoms to very high speeds, thus increasing their energy.

ACTIVITY -- The rate of disintegrating nuclei of a radioactive substance. The unit of activity is a curie.

ALPHA PARTICLE -- Nucleus of an atom of helium gas. Streams, known as "alpha rays", of such particles are emitted by some radioactive substances.

ATOM -- Smallest particle of an element which retains the chemical characteristics of the element. Its size is in the magnitude of a tenth of a millionth of a millimeter.

ATOMIC (nuclear) ENERGY -- Energy produced from the nucleus of an atom. There are two known ways to produce such energy in appreciable amounts. One is through fission of nuclei of the heaviest elements, e.g. uranium. The other is through fusion of nuclei of the lightest elements, e.g. hydrogen. The former principle is used in atomic reactors and in the atom-bomb; the latter has only been used, to date, in the hydrogen bomb.

ATOMIC NUMBER -- The number of electrons rotating about the nucleus of the atom of any element.

ATOMIC STRUCTURE -- The atom consists of a central nucleus carrying a positive electrical charge around which electrons, or fundamentally negatively-charged particles, move in orbit. The nucleus is composed of protons and neutrons, the former positively charged and the latter carrying a neutral or virtually no charge.

The number of electrons and the number of protons in an atom is the same and is known as the "atomic number". The sum of the numbers of protons and neutrons is the "mass number."

The number of neutrons in an atom can vary and such variants are isotopes of the element.

ATOMIC WEIGHT -- Weight of an atom of an element, expressed on a scale in which the weight of an oxygen atom is 16.

BETA PARTICLE -- Free electron usually emitted during certain types of radioactive disintegration, generally at high speed.

BREEDER REACTOR -- Nuclear reactor which produces more fissile atoms than it consumes. Sometimes used to denote a reactor which produces the same kind of fissile material as it consumes, regardless of whether there is a net gain or net loss of fissile material.

BRITISH THERMAL UNIT (BTU) -- Amount of heat required to raise by one degree Fahrenheit the temperature of one pound of water at or near its point of maximum density.

BURN-UP -- Depletion of duel used in a reactor; usually stated by percentage or in megawatt-days per ton.

CHAIN REACTION -- When a nucleus captures a neutron and fission occurs, several fresh neutrons are released; these in turn cause fission in other fissile atoms which release yet more neutrons to cause further fissions, and so on. This is a chain reaction.

CERN -- European Nuclear Research Center, at Meyrin, near Geneva, where international scientific teams from a dozen countries carry out research in the physical sciences.

CLADDING -- Material used to encase the fuel elements of a nuclear reactor.

CONTAMINATE -- To render harmfully or dangerously radioactive.

CONTROL RODS - Components of a reactor -- usually made of cadmium or baron -- used to slow a chain reaction. When the control rods are inserted among the fuel elements, neutrons are absorbed by the rods so that fewer are left free to create further fissions.

COOLANT -- Material used in a reactor to prevent the fuel elements from becoming dangerously hot, and to transfer the heat to the turbo-generators.

CONVERSION FACTOR -- Radio between the number of newly-generated fissionable atoms in a reactor and the number of used fissionable atoms.

Thus, if the factor is greater than unity, more fissionable material is being produced than consumed.

CORE (of a nuclear reactor) -- The central part of the reactor, containing the atomic fuel and the moderating material.

COSMIC RAYS -- Radioactive radiation which is continually bombarding the earth from outer space.

CRITICAL -- Term used to describe the condition in which a chain reaction is maintained. A reactor is said to "go critical" when a chain reaction starts.

CRITICAL MASS -- Smallest mass of fissile material in which a chain reaction can take place.

CURIE -- Unit of activity of radioactive substances. One curie equals the activity of one gram of radium, or about 40,000,000,III atoms splitting per second.

CYCLOTRON -- A type of accelerator, invented by American physicist E.O. Lawrence in 1932, which increases the energy of atomic particles by repeatedly passing them through magnetic field.

DECONTAMINATE -- To remove radioactive impurities.

DIFFUSION PLANT -- Factory where natural uranium is enriched in the isotope U-235. The uranium is converted into a type of gas (uranium hexaflouride) and passed through a series of many thousands of membranes. Uranium hexaflouride molecules bearing the lighter uranium-235 pass through the membranes more readily than those bearing the heavier uranium-238.

DOSIMETER -- Apparatus used to measure radiation doses.

ELECTRON -- Smallest atomic particle and lightest component of matter. It is the fundamentally negatively-charged element of electricity and one or more electrons are present in every atom of every substance.

ELECTRON VOLT (eV) -- Unit of energy. One electron volt equals the energy acquired by an electron when it is accelerated by being passed through an electric field having a drop in electric potential of one volt.

ELEMENT -- One of the basic substances which make up the universe. There are 92 elements known to occur in nature and others have been produced artificially.

ENEA -- European Nuclear Energy Agency, with headquarters in Paris, a 17-nation body which is a subsidiary of the Organization for European Economic Cooperation. Established in 1957, the ENEA seeks to harmonize the atoms-forpeace programs of member states and facilitate exchange of information and scientists.

ENRICHED FUEL -- Uranium which contains a higher percentage of isotope U-235 than is found in nature. This isotope is present in nature in a concentration of one part in every 140 parts of U-235.

EURATOM -- European Atomic Energy Community, with temporary headquarters in Brussels, a six-nation body established in 1958 to centralize and rationalize the development of atomic industry within its member states. These are Belgium, France, the Federal Republic of Germany, Italy, Luxembourg and the Netherlands.

FAST REACTOR -- Nuclear reactor in which most fissions are caused by neutrons moving at the high speeds they possess at the time of their release through previous fissions. Such a reactor has no moderator.

FISSIONABLE MATERIAL -- Material which disintegrates to produce a chain reaction when hit by neutron particles. Such matter - uranium-233, uranium-235 and plutonium -- is used to fuel nuclear reactors.

FUEL ELEMENTS -- Rods, or slugs, of atomic fuel in a nuclear reactor.

FUSION -- Compounding light nuclei into heavier nuclei, thus releasing great amounts of energy. On a large scale this has, to date, only been accomplished in the use of the hydrogen bomb -- an uncontrolled reaction -- but scientists of many countries are constantly seeking methods to control such a reaction and employ it for peaceful purposes.

GAMMA RADIATION -- Electro-magnetic radiation similar to X-rays, emitted by atomic nuclei, generally in radioactive decay.

GEIGER (or Geiger-Muller) COUNTER -- A device for counting photons, or charged particles, by means of the ionization they produce in a gas. Thus the presence and degree of radioactivity in a substance may be detected.

GLOVE-BOX -- Closed container in which small quantities of radioactive materials can be handled safely.

HALF LIFE -- Time required for half the atoms present in a radioactive substance to disintegrate. Half-lives may vary from less than a millionth of a second to many million years, depending on the isotope.

HEAVY HYDROGEN -- Hydrogen in which the atoms have an atomic weight of twice that of ordinary hydrogen atoms.

HEAVY WATER -- Water in which the hydrogen atoms present are of heavy hydrogen.

IAEA -- International Atomic Energy Agency, with headquarters in Vienna, a 69-nation body established in 1957 to coordinate the world's research and development of atomic energy for peaceful purposes.

ION -- Atom or molecule which has taken up or emitted one or more electrons and thus become electrically charged.

IONIZATION -- Formation of ionized, or electrically-charged, particles.

IONIZING RADIATIONS -- Radiations, such as alpha and beta rays, which charge atoms electrically.

IRRADIATED FUEL -- Atomic fuel that has been used in a nuclear reactor.

ISOTOPES -- Atoms of the same element, identical chemically but differing in atomic weights and nuclear properties. Radioisotopes are radioactive isotopes.

MESONS -- Unstable atomic particles found in cosmic radiation.

MODERATOR -- Material in a nuclear reactor used to reduce the speed of the fast neutrons produced by fission as much as possible without absorbing them.

MOLECULE -- Smallest portion of a substance capable of independent existences while retaining the properties of the original substance.

NATURAL URANIUM -- Element of uranium found in nature. It contains both non-fissile uranium-238 and fissile uranium- 235 in the ratio of 139 parts to one, and also contains minute quanties of uranium-234.

NUCLEUS -- Central, and largest, particle of an atom.

NEUTRON -- Atomic particle found in the nucleus of an atom. It has no electric charge. When fission takes place, neutrons are released.

NEUTRON FLUX DENSITY -- Density of neutron emission from atoms which have been fissioned in a nuclear reactor.

ORGANIC COMPOUNDS -- Compounds of carbon, oxygen and hydrogen, in varying proportions. Such compounds, such as terphenyl, are sometimes used as moderators.

PICLE BARREL -- Mass of fissionable material too small to maintain a chain reaction, used by research workers to produce a brief nuclear reaction upon irradiation from outside.

PLUTONIUM -- Atomic fuel created by bombarding uranium-238 with neutrons.

PROTON -- Atomic particle found in the nucleus of an atom. It has a positive electric charge.

BARE EARTHS -- Elements of successive atomic numbers, from 57 through 71. They have a high rate of neutron absorption which makes them potentially valuable as control elements in a reactor.

REACTOR -- Device in which nuclear fission produces heat. Most reactors have a core containing the fuel elements, the moderator if any and the control rods; the coolant, a liquid or gas which carries the heat out of the core, circulates through it.

REFLECTOR -- Component of a reactor which surrounds the core. Composed of an element with a low neutron-absorption rate, it "reflects" stray neutrons back into the fuel elements.

ROENTGEN -- Unit of radiation dosage (named after the discoverer of X-rays). About 600 roentgens would kill a man in a short time. An international scientific agreement states that 0.3 roentgens per week can be tolerated by humans without danger to their health.

THERMAL BREEDER -- Breeder reactor in which a moderator is used to decelerate neutrons produced in fission.

THERMAL REACTOR -- Nuclear reactor in which neutrons are decelerated by a moderator before causing fission.

THORIUM -- Element which when bombarded by neutrons is converted into the atomic fuel uranium-233.

TRACERS -- Radioisotopes used in small quantities for tracing, by detecting their radiation, the path through a living organism of some substance to which they are attached.

TRANSMUTATION -- Natural or artificial transformation of a nucleus into another with a different atomic number.

TRANSURANIC ELEMENTS -- Elements (such as plutonium) not found in nature but produced by artificial means, having a greater atomic weight than uranium.

URANIUM -- Element which, in its natural state, contains one part of its fissile isotope, uranium-235, to every 139 parts of its non-fissile isotope, uranium-238. Uranium-238 can be converted into the nuclear fuel plutonium, and thorium can be converted into the nuclear fuel uranium-233.

X-RAYS -- Electromagnetic rays of very short wavelength and great power of penetration, capable of destroying living tissue.

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