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A B S T R A C T

STUDY OF ENERGY GENERATORS

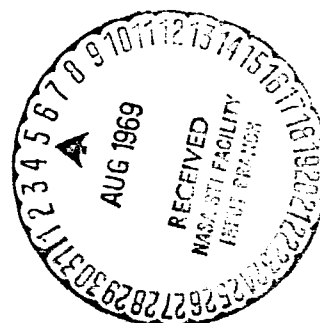
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STUDY OF ENERGY GENERATORS

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1. GENERAL DEVELOPMENT

A. THEORETIC NEUTRONICS

The following important achievements in theoretic neutronics were realized in 1967:

- study of space variations of the neutron flux with energies close to the resonance of uranium and the calculation of the competition between the resonance absorptions of several isotopes (uranium and hafnium isotopes);
- improvements of the so-called Feinberg-Galanine method of heterogeneous calculation, for its application to experimental piles and power reactors;
- a more satisfactory and more precise theory of the experiments of oscillation of a studied fuel in the complex of a critical multiplier;
- development of an original method (called C_n) for resolving the neutron transport equation, this method leading to more precise and definitely more rapid calculations than those obtained by the usual methods.

In the field of high-speed neutrons, two methods were developed. They allow to reduce the margin of inexactitude when determining the parameters of a reactor from the results of integral experiments, such a lack of precision being due to the uncertainty of basic neutron data. Calculations were performed, which used up to several thousands of energy groups, in order to account for the diffusion resonances and to obtain more precise values of the effective cross-section.

B. PHYSICS OF THE EXPOSED FUELS

The study of the evolution of the neutronic properties of fuels, as they are subjected to irradiation delat especially with the reactors of graphite-gas die-stock. Such a study is made in two complementary ways, completing one another: on the one hand, studies of the physics of non-irradiated fuels

containing plutonium (measuring done through substitution or oscillation of uranium-plutonium fuels), on the other hand, direct studies of irradiated fuels (either analyses by mass-spectrometry, which give the evolution of the composition in heavy nuclei, or oscillations showing the total neutronic effect).

The following studies were carried out:

- interpretation of the experiments in substituting uranium-plutonium fuels in the Cesar critical assembly at temperatures between 20° and 200°C;
- development of new methods of interpretation of oscillation experiments, in order to obtain a good precision as to the effective production and absorption cross-sections;
- interpretation of the analyses of the exposed fuels in terms of the effective capture cross-section of different heavy nuclei present. A first synthesis of the totality of the results, which already have been obtained through these studies, permitted to determine the neutron balance of the reactors in the course of the evolution of their fuel, as well as the mean exposure for the unloading of the latter, especially in graphite lattice.

C. STUDIES OF PROTECTION

A number of programs has been developed for calculating the decrease of the activity of fission products after stopping the reactors. The code of Monte Carlo Zeus IV tridimensional monocinetics has been applied extensively and the experience thus acquired, allowed to develop a similar code of polycinetics during the testing; that code will be employed in the problems of protection of the high-speed neutrons die-stock.

A method of weighing was studied, which will enable the programs of Monte-Carlo to compete with the methods of numerical integration in the monodimensional problems.

D. TECHNOLOGY

1. WELDING AND MACHINING FROM DISTANCE

The techniques of welding and machining from distance of tubular assemblies, upon which is based the conception of structures of the type EL-4-reactors, have been subjected to new developments.

Thus new devices were created, or are in the process of being assembled, as stipulated in an agreement between C.E.A. and a German industrialist.

(legend for the illustration page 44: Machine for soldering locally by means

of electrom bombardment).

2. WELDING BY ELECTRON BOMBARDMENT IN MANUFACTURING HEAVY BOILERS.

Such welding procedure is the object of continuous research and development for using it in the welding of reactor casings. One of the essential characteristics of such procedure is that it permits welding without considerable over-all deformation and, therefore, appreciable stress; such characteristic will open access to very important markets in mechanics and in heavy-boiler manufacturing. Certain units, welding in vacuum chamber, were developed in 1967; they permit welding large-size structures.

2. NATURAL URANIUM-GRAPHITE-GAS DIE-STOCK

A. STUDY OF GRAPHITE MODERATED NATURAL URANIUM LATTICES.

The critical pile-up pulse Marius was used for precisising certain points of the neutron balance of the reactors of the graphite-gas die-stock; among those points:

- the effects of the internal or external cans;
- the study of the 170 mm channel for the Bugey lattice;
- the measuring of the initial conversion factor on different lattices.

One can point to three large series of measurements in the Cesar critical pile-up pulse:

- end of measurements at 20°C through oscillation over uranium-plutonium fuels;
- study of the lattices subjected to "dégavage",* which are characteristical of the graphite-gas die-stock in their real geometry;
- end of measurements by substitution over the uranium-plutonium fuels at medium temperatures (between 20 and 200°C).

All of the experimental results, which were obtained on the lattices of the graphite-gas die-stock of Marius, Cesar and power reactors, were compared to the new handbook of calculations. The good general agreement permitted to use that new handbook for calculating the performances of the cores of new power plants, particularly the Fessenheim.

On the other hand, studies of kinetics and control of the reactors have been developed subsequently to the establishment of new calculating codes. Those

* The "dégavage" of a lattice consists in abstaining from loading with fuel all of the available channels of a reactor, in order to raise the ratio moderator-fuel, without modifying the pile-up pulse.

studies have led to a new way of monitoring the reactor Bugey 1 and to the improvement of certain monitoring devices in the reactors of the type Saint-Laurent 1.

B. THERMIC STUDIES

The behavior of reactors in operation was especially studied; some additional experimental studies were made of the fuels of the reactors Bugey and Fessenheim.

The thermometry and the processing of the thermo-electric informations of the reactors Chinon 2, Chinon 3 and Saint-Laurent 1 were studied and developed jointly with Electricité de France. A statistical survey was made of temperature measurements in the reactor, in order to obtain a synthetic knowledge of fuel behavior and to improve monitoring instructions.

Studies of operation in transient state are being done at the present time, in order to determine the behavior of the fuel and of the pile-up pulse, either in local perturbations such as the unloading procedure, or in total motions, such as power rise and shut-downs of the reactor. Some interesting results have already been obtained with the Chinon 2.

C. STUDIES OF MECHANICS

1. Study of the graphite pile-up pulse structure:

Detailed studies, which were made with the co-operation of Electricité de France, have led to the final development of the design of a pile-up pulse for the power plant Bugey 1, based upon a scheme which was conceived end 1966.

Surveys were done jointly with Electricité de France for pile-up pulses at the power stations Saint-Laurent 1 and Saint-Laurent 2. Following those surveys it seemed advantageous to undertake a complete study of the idea of such a type pile-up pulses, taking in consideration the original propositions, formulated by the industry for a pile-up pulse for the Fessenheim power plant. Further progress, from which certain simplifications are expected, could result from a deeper analysis of the deformations and the stresses which affect the graphite, taking in consideration the creep of the material under radiation. An important program of theoretical and experimental studies, namely of the exposure, was launched with such a purpose.

After a period of theoretical studies and preliminary tests a research was

entrusted to the industry on the behavior of the pile-up pulses in the eventuality of an earthquake; that research was directed to design the set-up of an installation for tests.

2. STUDY OF GRAPHITE JACKETS FOR THE EDF FUEL

The development of the Bugey jackets was continued; especially as to the way the cartridge is supported in the jacket (bed-plate and U-link), many different ways have been tested. Mechanical and aeromechanical conditions of remote handling of fuel have been determined, jointly with Electricité de France. Studies were undertaken in order to assure good behavior of the fuel element, regarding the permanent or transitory, normal or accidental stresses, to which it might be submitted. The resistance of the attaching groove being an essential factor of such behavior, special efforts are dedicated, jointly with the industry, to the selection of the most appropriate grade of graphite. Improvements were brought to some parts of the jackets Chinon 2, Chinon 3 and Saint-Laurent 1, that were suggested by the experience in their utilization and producing. The efforts in that field are directed in the sense of fission ability, and of standardization. It has been possible to obtain satisfactory behavior data of jackets in reactor, by measuring the unloaded jackets of Chinon 2.

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