# PATENT SPECIFICATION

614,386

*Convention Date (France): May 2, 1939.*
*Application Date (in United Kingdom): April 30, 1940. No. 7782/40.*
*Complete Specification Accepted: Dec. 15, 1948.*
*(Under Section 6 (1) (a) of the Patents &c. (Emergency) Act, 1939, the proviso to Section 91 (4) of the Patents and Designs Acts, 1907 to 1946 became operative on May 1, 1948).*

Index at acceptance:—Class 39(i), P.

COMPLETE SPECIFICATION

## Apparatus for the Production of Energy by Nuclear Fission

We, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE, formerly known as LA CAISSE NATIONALE DE LA RECHERCHE SCIENTIFIQUE, an official and autonomous organisation created by decree of the Government of the French Republic, of 13, Quai d'Orsay, Paris, France, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to means for stabilising an apparatus producing energy by atomic nuclear disintegration.

Specification No. 7662/40 describes the construction of such an apparatus constituted by a mass of uranium or thorium (or compounds) having a predetermined configuration and which was under the action of an (external or internal) source of neutrons.

A succession of nuclear fissions of uranium was produced which took the form of unlimited branching chains liberating considerable amounts of energy. It has been stated in this application that it is useful to stabilise this reaction in order to prevent the liberation of uncontrollable amounts of energy which might make the reaction explosive by the introduction into the mass of elements slowing down all or a fraction of the liberated neutrons.

It has also been pointed out in the said application that there existed certain critical conditions of operation and particularly a critical mass of uranium or of its compound. Keeping the other factors constant there exists for every factor determining these conditions a critical value for which the device changes from unlimited branching to limited branching of the chain reaction.

It has also been pointed out in the said application how the starting and stopping of the reaction and the extraction of the liberated energy could be effected.

The present invention relates to a new method making it possible to obtain the stabilisation of the reaction in another way than the one consisting in the autostabilisation of the temperature of the device produced by the introduction of bodies which slow neutrons down.

This method can be substituted for the method of autostabilisation described in the above mentioned specification in order to provide an apparatus for the production of energy or the other applications mentioned in the said specification.

This method of stabilisation—which is again adapted for limiting the rate of energy liberation—is based upon the fact, which is known per se, that these chains take a certain time to develop themselves.

The principle of the method according to the present invention is to let the unlimited chain reactions branch themselves until sufficient energy is liberated and then to stop this branching by regulating one or several of the factors the original values of which gave the self-propagating character to the chains. Then the conditions for the unlimited branching are established once more and again interrupted as before.

The repetition of these operations—periodically or not—enables the obtention of a regular, considerable and controllable liberation of energy.

These momentary and repeated interruptions of the branching chain reactions are obtained by making alternately the operating conditions or some of them pass above and below their critical values; they can be effected in different ways.

It is for instance possible to constitute the mass of uranium (or its compounds) of several distinct parts which are momentarily and periodically caused to approach each other and separated from each other in order to provide within

limited and determined periods the conditions of the unlimited branching of the chains.

The mass containing uranium can for instance consist of a fixed part and of a movable part which is periodically separated from and moved towards the fixed part by means of any suitable mechanical means.

One could also periodically cause to approach towards and recede from the mass containing uranium parts of the external diffusing envelope (made for instance of iron) passing thus once more alternately above and below the critical conditions.

One can also, for instance, introduce periodically into all the mass or a part of it a screen or another member made of a material absorbing the neutrons.

In this way one could for instance displace inside the whole or a part of the mass a movable member which would alternately present to the mass one of its parts which strongly absorbs the rapid or slow neutrons, then another of its parts which absorbs less or not at all the said neutrons. This element could be, for instance, a rotatable disc, one or several sectors of which would consist of iron, for instance, the other sector or sectors consisting of a layer of water, borated water, cadmium, boron or other substances, in a more or less thick layer.

One could also pass periodically certain gases such as hydrogen, deuterium or water vapour, deuteroxide, cadmium or mercury through the mass or as well pass through the mass vapours or gases of periodically changing composition.

It is also possible to submit the mass to periodic vibrations.

It may be stated once more that these different forms of execution are given by way of non-limitative examples only.

The form of execution under consideration could take into account the appreciable amount of time which can elapse between the absorption of a neutron by uranium and the emission of a part of the neutrons due to this absorption.

In order to avoid too considerable differences between the amounts of energy liberated in every cycle, it may be necessary to arrange in the device or near it a source of neutrons of sufficient intensity. The number of neutrons introduced at every moment of the cycle by this source into the device could be controllable, for instance, by conveniently changing the intensity of the source or by any other means.

In order to avoid this non-uniformity one could also make use of a relay system which will progressively decrease the branching of the chains, as the liberation of energy and the corpuscular and/or electromagnetic rediation associated therewith increases and which will stop the development of the branching as soon as the liberation of energy has attained the desired value.

These relay systems may be controlled by thermometric instruments or by devices such as ionisation chambers or counters for electrons or other particles which can be placed near the mass containing the uranium; they could thus influence one of the mechanisms mentioned above or in the above cited patent application.

One could also stop the chain reaction by using the variations of density or of composition which may be produced by the increase of temperature due to the development of the chain in every cycle.

It should be mentioned that this method of stabilisation could be combined with the introduction of elements for the slowing down of all or a fraction of the neutrons inside the mass of uranium or its compound (hydrogen for instance) and also, if required, of elements (such as cadmium) absorbing a part of the emitted neutrons, the said introduction of the former more particularly forming the subject matter of the above mentioned specification.

One could also combine this method with one or several of the apparatuses proposed in the said specification and more particularly those which decrease the critical mass.

The following is given by way of non-limitative example.

When a system is considered which contains an element slowing down the neutrons and in which the chains are propagating in the system by fissions due to slow neutrons, the time between the emission of a neutron and its absorption as a slow neutron will be about one ten-thousandth of a second. When the number of neutrons is increased in the average by a factor of only 1.007 for every branching, one hundred successions are necessary to double the number of neutrons present in the system. The energy which is liberated per unit of time will, therefore, double every 0.01 second. When the device contains a movable screen absorbing slow (or rapid) neutrons and when this screen abruptly penetrates into the system every half second (with an approximation of 1/100 second) a chain branching up to a multiplying factor of $10^{15}$ will develop during the half second in which the screen is

outside the apparatus, then the chain will be stopped by the sudden introduction of the screen into the system.

The time during which the screen will be inside the system will not necessarily be equal to the time during which it will stay outside.

In order to regulate the average liberation of energy, one could influence, automatically or not, the time during which the chains are developing and/or the interval between two developments of the chain reaction.

Of course, in all that is stated above, the mass of uranium (or of a compound of uranium) can be replaced by thorium (or a compound of thorium) or by all substances or mixtures of substances having similar fissile properties without departing from the scope of the invention.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. Apparatus for the production of nuclear energy comprising a mass of basic substance such as uranium or thorium capable of giving rise, by fission under the action of slow neutrons, to the emission of new rapid neutrons, the mass comprising, in a homogeneous or heterogeneous distribution a moderating substance for the neutrons, such as deuterium or helium, in sufficient proportion to bring the said rapid neutrons to the state of slow neutrons before they meet other atoms of the basic substance, thus realising self-propagating fission chains, said mass being optionally associated with neutron diffusing or absorbing substances or screens, the said apparatus comprising means to modify and bring back to its original state, successively and repeatedly, the spatial distribution of one or more of the constituting substances for the purpose of alternately arresting and re-establishing the conditions of self-propagation.

2. Apparatus as claimed in claim 1, in which the mass of basic substance is divided into at least two independent adjacent portions capable of relative movement, mechanical means being provided to bring apart said portions with respect to one another and bring them back to their original position, successively and repeatedly.

3. Apparatus as claimed in claim 1, in which the mass of basic substance is provided with recesses, means being provided to introduce into the said recesses and extract from the latter, successively and repeatedly, neutron moderating, absorbing or diffusing substances.

4. Apparatus as claimed in claim 3, comprising screens formed of a neutron absorbing or diffusing substance and linked to a mechanism adapted to make them penetrate into and extract them from the said recesses.

5. Apparatus as claimed in claim 4, in which the screens are formed of rotatable discs comprising a non-absorbing sector, for instance made of iron, and an absorbing sector, for instance comprising cadmium or a sheet of water, said discs being partially engaged in the mass of basic substance.

6. Apparatus as claimed in claim 1, comprising movable side walls made of a neutron diffusing substance, said walls being linked to a mechanism adapted to move them successively and repeatedly away from and back towards the mass of basic substance.

7. Apparatus as claimed in any of the preceding claims, in which the means for modifying the spatial distribution of one or more of its constituting masses or substances are placed under the control of means for measuring the energy or the temperature developed inside the apparatus or of means for measuring the changes of specific gravity or composition of the basic substance.

Dated the 30th day of April, 1940.

CARPMAELS & RANSFORD,
Agents for Applicants,
24, Southampton Buildings,
London, W.C.2.

PUBLISHED BY :-
THE PATENT OFFICE,
25, SOUTHAMPTON BUILDINGS,
LONDON, W.C.2.