

- [54] **METHOD AND MEANS FOR UTILIZING ACCELERATED NEUTRAL PARTICLES**
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- [22] Filed: **Aug. 31, 1971**
- [21] Appl. No.: **176,584**

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- [52] U.S. Cl. **250/499, 250/251, 250/501, 313/61, 176/1**
- [51] Int. Cl. **G21g 3/00**
- [58] Field of Search **250/84, 84.5, 41.3, 499, 250/501, 502; 313/61; 176/1**

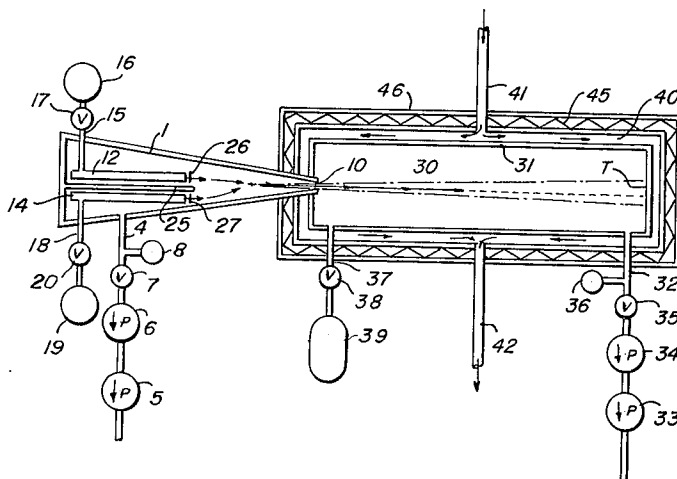
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[57] **ABSTRACT**

The invention resides in the utilization of radiant energy by bringing together accelerated positive ions and accelerated electrons or accelerated negative ions to produce accelerated neutral particles the energy of which may then be converted to heat on bombardment of particles of an appropriate reactant, or utilized in other ways as in neutral particle radiography.

14 Claims, 6 Drawing Figures



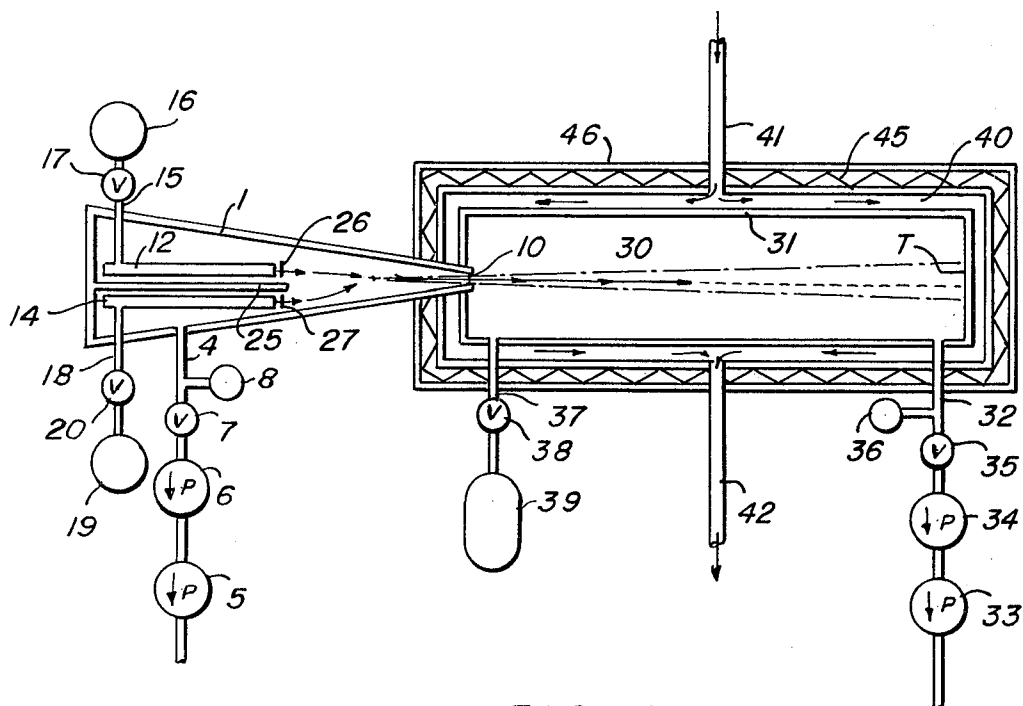


FIG. 1.

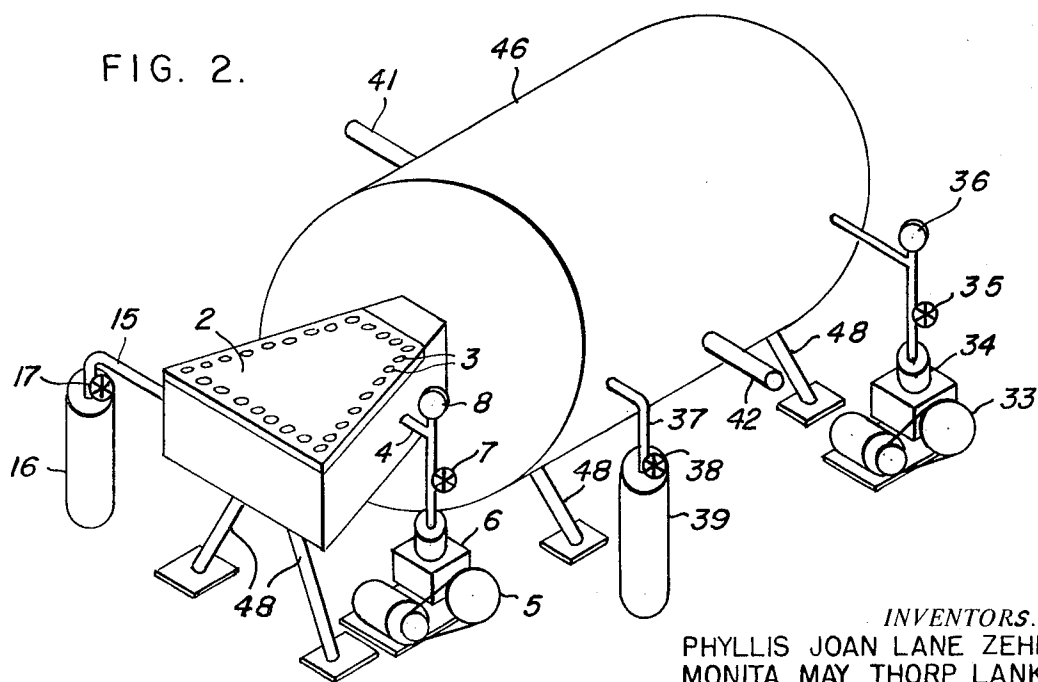


FIG. 2.

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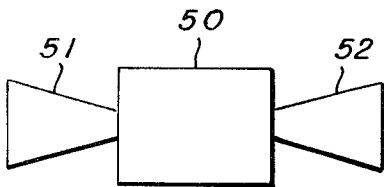


FIG. 3.

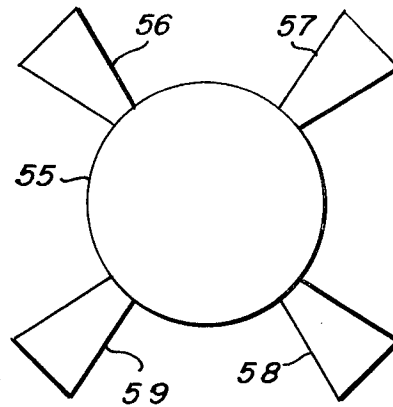


FIG. 4.

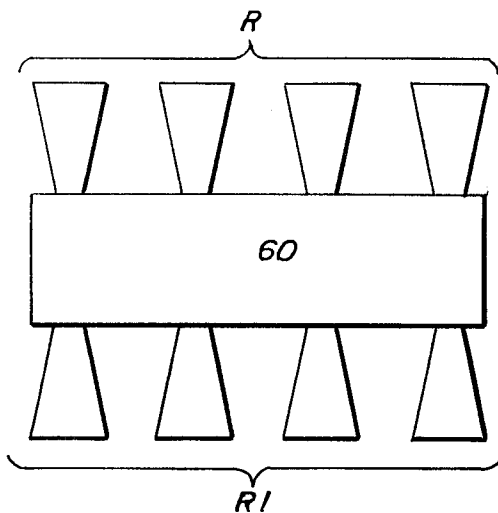


FIG. 5.

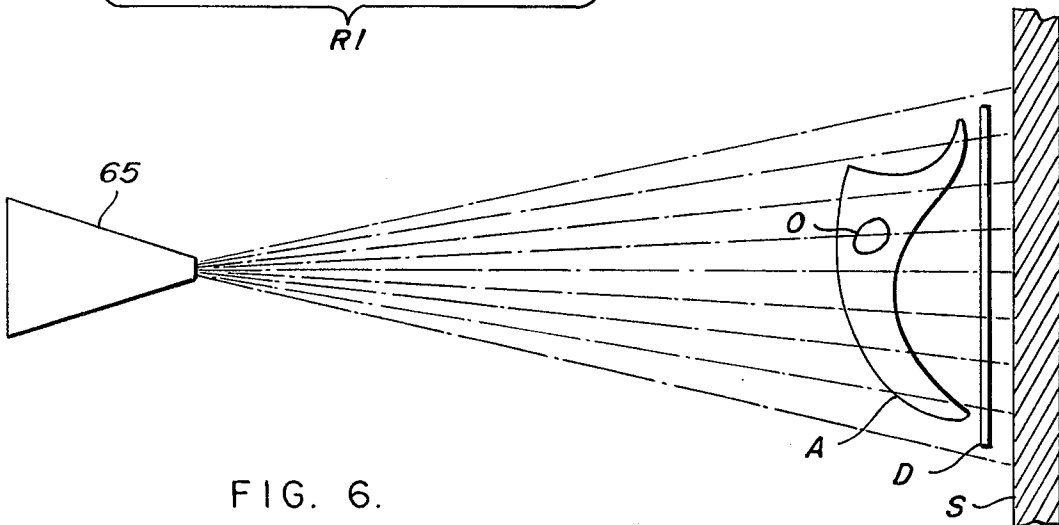


FIG. 6.

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METHOD AND MEANS FOR UTILIZING ACCELERATED NEUTRAL PARTICLES

BACKGROUND OF THE INVENTION

1. Field of Invention:

The invention relates to accelerated particles of radiant energy having opposite electrical potential relative to each other which are brought together to form a united particle beam in which the particles mutually neutralize each other as to potential without deceleration for useful purposes such as generation of heat by bombardment of an appropriate static and/or accelerated neutral reactant in an adjacent novel reaction chamber, in neutral particle radiography or the like.

2. Description of Prior Art

Radiant energy particle generators are well known and various types of apparatus have been developed for accelerating such particles to a desired velocity in a predetermined direction as in U.S. Pat. Nos. 2,735,019, 3,287,592, and 3,393,316, such particles having electric charges either positive or negative, depending on the nature and operation of the particle generators employed, and so far as we are informed these and similar particle generators and accelerators have been used as tools in nuclear physics research but there has not been suggested means for converting the energies derived from reactions of neutralized particles to states useful in performing work, such as heat for generation of electricity, the energy of the particles having heretofore been dissipated in other ways and its potential availability for useful purposes has been lost.

SUMMARY OF THE INVENTION

The invention resides primarily in the provision of a method of and means for bringing together in a common accelerator chamber converging synchronously scanning streams of accelerated particles of opposite potential and without appreciable deceleration allowing each respective stream to neutralize the electrical potential of the other and form a resultant neutral particle stream which is then directed out of the chamber in a scanning beam of neutral reactant particles for utilization in the performance of desired functions, such as the generation of heat by bombardment of an appropriate reactant by the neutral particle beam, radiographic examination or for other purposes.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. 1 is a diagrammatic longitudinal section of particle generators, accelerators, and synchronous charged particle beam spreading devices utilized to produce a unique variable directional beam of neutralized reactant particles in combination and association in accordance with the invention with a novel reaction chamber embodying heat generating and recovery means.

FIG. 2 is a diagrammatic perspective view of the apparatus illustrated in FIG. 1.

FIG. 3 is a diagrammatic illustration of a modified arrangement where in two neutral particle generator and accelerator assemblies or units are associated with a single reaction chamber.

FIG. 4 represents the employment of a still large number of neutral particle generator and accelerator units associated with a circular reaction chamber, or it may be deemed to represent an even larger number of

such assemblies associated with a spherical reaction chamber constructed in accordance with the same principles.

FIG. 5 diagrammatically illustrates the disposition of a plurality of the neutral particle accelerator assemblies arranged in opposed ranks along the sides of an elongated rectangular reaction chamber.

FIG. 6 is a diagrammatic representation of the manner in which one of our neutral particle generator and accelerator assemblies may be utilized for neutral particle radiography examinations.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now more particularly to FIGS. 1 and 2 of the drawings the apparatus shown therein comprises an accelerator chamber 1 which may be substantially pyramidal, having a removable access opening closure 2 secured thereto in sealed relation through the utilization of bolts or cap screws 3. Connected through the wall of the chamber to its interior through pipe 4 is a vacuum roughing pump 5 and a vacuum diffusion pump 6 by operation of which the interior of the chamber may be evacuated to a pressure of the order of 10^{-6} mm. (Hg), a valve 7 controlling the pipe while a gauge 8 connected therewith permits the pressure in the chamber to be ascertained.

At its apex the accelerator chamber has an opening sealed by a suitable window 10 which is transparent to accelerated neutral radiant energy particles when directed toward it in a high velocity beam, iron being preferably used for the window material when isotopes of hydrogen are the source of accelerated neutral particles. Contained within the chamber is a positive ion generator and accelerator 12 which may be of any usual or well known character capable of generating ions and accelerating them to high velocity in a stream directed generally toward the window 10, while generally paralleling the accelerator 12 is a generator and accelerator unit 14 capable of producing and accelerating in a stream of like velocity either electrons, or if preferred negative ions.

Connected with the positive ion generator and accelerator unit 12 through a pipe 15 from externally of the accelerator chamber is a source of reactant material represented by tank 16 which is admitted to the unit under control of a valve 17, while a similar arrangement of a pipe 18, tank 19 and valve 20 afford means for introducing a source of negative ions to the generator and accelerator unit 14 or an electron generator and accelerator may be substituted for these elements if electrons are to be used as the negative particles. A showing of electrical connections with these units is omitted from the drawings as superfluous, such connections being well known in the art and hence not requiring illustration.

A partition 25 of insulating material is interposed between the positive and negative ion generator and accelerator units 12 and 14 to maintain the electrical and radiational integrity of each, while adjacent their respective exit ports for the accelerated particle streams are synchronous scanning devices 26, 27 of known character, which operate in a novel manner electrically and magnetically in synchronism upon the ionized particle streams to direct the latter within predetermined courses constantly translatable in all directions transversely of the direction of the streams and preferably

generally converging in the direction of window 10 to meet in the vicinity of some intermediate point such as the point P. The potential carried by the positive ions generated in unit 12 is thereupon neutralized by the potential of the electrons or negative ions generated in unit 14 and the resulting neutral particles, still travelling at high velocity, then pass through window 10, in the apparatus illustrated in FIGS. 1 and 2, to a novel reaction chamber 30 now to be more fully described.

This reaction chamber, like the neutral particle accelerator chamber just described, is designed to be evacuated to a like low pressure and it is constructed accordingly, preferably of highly corrosion resistant materials, and of course, with all joints and connections fully sealed. It comprises a cylindrical inner casing 31 into one end of which the neutral particle accelerator housing projects, window 10 thus giving into the interior of casing 31. Connected with the latter also, through a pipe 32 is a mechanical vacuum roughing pump 33, a vacuum diffusion pump 34 for increasing the vacuum beyond the capacity of pump 33 and a valve 35, controlling the passage through the pipe, a pressure gauge 36 connected with the pipe affording reading of the pressure in the casing which, as indicated, should be of the order of 10^{-6} mm. (Hg). Also connected with the interior of casing 31 is a pipe 37 controlled by a valve 38 and fed by a storage receptacle 39 normally containing a supply of suitable, preferably gaseous or volatile, reactant, such as, for example molecular hydrogen when the material employed for generating positive ions in unit 12 is also an isotope of hydrogen.

Surrounding and completely containing the casing 31 is a jacket 40 spaced from the outer wall of the casing to permit free flow in heat exchange relation with the casing of a liquid or a gaseous heat absorbing medium admitted through a pipe 41 leading into the jacket for discharge therefrom through an exit pipe 42 from which it may be directed through appropriate conduits, (not shown) to other apparatus such as turbines or the like for converting heat to electrical energy or for other useful purpose.

To minimize wasteful dissipation of heat from the jacket 40 it is preferably enclosed in a heat insulating and radiant energy absorbing shield 45 confined within an outer covering 46 and the whole apparatus is supported from a floor surface on appropriately positioned legs 48.

All parts of the apparatus which confine or encounter radiant energy particles are preferably made of materials relatively inert thereto such as carbon steel, high strength or corrosion resistant steel or other metal or alloy, with the parts except for the bolted access panel 2 preferably of welded and tested construction to minimize leakage under the high vacuum conditions maintained in the accelerator and reaction chambers.

Performance of the preferred embodiment of the invention just described will be apparent to those skilled in the art from what has been herein disclosed, and the specific series of steps now to be set forth will be recognized as merely examples of procedures which may be employed in the practical application of our invention.

Thus, there may be supplied to the positive ion generator 12 from the storage tank 16 gaseous hydrogen in the form of deuterium (D_2), while the negative particle generator 14 may be selected and arranged to project

electrons (e^-). The velocity of each of the charged particles is substantially increased within their respective sections of the accelerator chamber to the order of a fraction of the speed of light, while temperatures of the order of 200° to $5,000^\circ F.$ may be attained in the production of electrons and positively charged deuterium ions. After emergence from the respective accelerators, the streams of positively ionized deuterium and negatively charged electrons are synchronously and constantly altered by the positive and negative beam scanners 26, 27, to change the directional characteristics of the resulting neutralized particle beam. The beam is thus continuously scanned through a rectangular pyramid having its apex about the neutralizing point P in the accelerator chamber and its base centrally located in a projected rectangular target area T on the inner plane wall of casing 31 opposite window 10 through which the neutralized particles pass to enter reaction chamber 30. Window 10 in the example given is preferably constituted of the element iron which is essentially transparent to the passage of the neutralized deuterium beam. The desired velocity of the neutral particle beam is attained by the variable potential controls provided as an inherent part of each positive ion generator 12 and negative particle generator 14 which need not be shown, being known in the art.

As noted, the reaction chamber, having been evacuated to a pressure of the order of millimicrons, is desirably charged with a gaseous neutral reactant, such for example as molecular hydrogen in the form of molecular deuterium (D_2) from the storage reservoir 39, the amount admitted being controlled manually in response to conditions in the reaction chamber as reflected in readings of the pressure gauge. Hence, as the accelerated and neutralized deuterium particles enter the reaction chamber 30 through the iron window 10 they encounter and collide at high velocity with the relatively static particles of molecular deuterium in the chamber 30, the resultant reaction producing the products normal hydrogen ions and tritium ions and substantial energies of radiation at the point of impact. These energies are thereupon dissipated as heat to the walls of the reaction chamber which for this purpose should be as heat conductive as may be consistent with other structural and chemical necessities so as effectively to transmit the sensible heat absorbed from the radiant energy of the reaction to the fluid medium being circulated through the heat exchange jacket 40. This heat, of course at a considerably lower temperature than momentarily attained at the points of impact of the particles, can then readily be availed of for ordinary heating purposes, electrical energy generation or for directly operating a heat engine if preferred, its utilization after it has been transferred to the fluid medium circulating through the heat exchange jacket 40 constituting no part of the invention. The dimensions of reaction chamber 30 are, of course, sufficient to effectively handle the heats of radiation from reaction without jeopardizing the material integrity of the inner reaction chamber walls.

The admission of particles of reactant, molecular hydrogen in this instance, to the reaction chamber 30 is desirably so controlled that the quantity of particles in the chamber at any instant is approximately such that the mean free path of travel of an accelerated neutral particle therein without encountering a particle of the relative static reactant, is not appreciably greater than

one half of the distance from the entering window 10 to the opposing target T. At that rate of admission of reactant substantially 100 percent reaction of accelerated particles with the relatively static reactant particles is assured, with maximum conversion of particle energy to sensible heat for useful purposes. The gaseous reaction products are withdrawn from the reaction chamber by the vacuum pumps 33, 34 which as will be well understood, are desirably maintained in constant readiness, if not continuously operating, so as to maintain the desired low pressure conditions when the apparatus is operating effectively. To assist in preserving the integrity of the walls of the accelerator chamber and of the reaction chamber by limiting diffusion of particles therethrough they may be coated with tin, cadmium, zinc or other appropriate material if desired, whereby wasteful dissipation of energy otherwise than as sensible heat may be kept at a minimum.

In order to avoid excessive ionization in the neutral particle beam it may be found advisable in some instances to position an electron gun disposed to discharge electrons into the reaction chamber in the general direction of the neutral particle beam to flood the reaction chamber with a surplus of electrons, thereby neutralizing any positive ions in the chamber and maintaining the integrity of the neutral particle beam.

In some instances it may be preferred to employ solid or liquid reactants in reaction chamber 30 for producing the particle reaction and consequent generation of heat. An example of a reaction with a solid is the utilization in place of the evacuated reaction chamber 30 of a solid cast body of an alloy of uranium²³⁵ or plutonium²³⁹ or both in iron, with the radioactive element disseminated uniformly throughout the iron matrix and confined within a heat exchanging jacket comparable to the jacket 40 surrounding the reaction chamber 30 in FIG. 2. Vacuum conditions are not required by the solid mass in this instance and the particle generator and accelerator unit 1 or a plurality of such units should be arranged to direct a beam or beams of accelerated neutral particles directly into the solid reactant bearing mass, eliminating the need for a window such as window 10 in FIG. 1. An accelerated beam of protons neutralized by electrons within the neutral particle accelerator chamber may be utilized to provide the neutralized accelerated beam of normal hydrogen atoms directed into the inert iron matrix containing the uranium²³⁵ or plutonium²³⁹ in quantities below critical mass. Such an accelerated beam of neutral hydrogen atoms should continuously be directionally altered within the mass as a result of the operation of the synchronous scanning devices upon the respective electron and proton streams before being united into a continuously scanning accelerated neutral hydrogen beam. Again, the heat produced from the interaction of the accelerated neutralized hydrogen beam with the reactant uranium²³⁵ or plutonium²³⁹ within the solid alloyed mass should be continuously removed from the core of the reactor as a result of the flow of the heat transfer medium about the core. The iron matrix in this case would be transparent to the flow of the accelerated neutralized beam of normal hydrogen atoms.

In another typical reaction, which might be carried out in the neutral particle accelerator and reaction chamber, accelerated neutralized deuterium particles would enter reaction chamber 30 through the iron win-

dow 10 to react with gaseous nitrogen 14 within the reaction chamber to produce the products carbon 12 plus normal helium plus the energies of reaction.

If preferred, apparatus other than that thus far specifically described may be devised for practicing our invention and we have illustrated diagrammatically in FIGS. 3-5 some of the forms such apparatus may take. Thus, in FIG. 3, a reaction chamber 50 constructed substantially in accordance with the principles heretofore described may be provided with windows or access connections (not shown) at each of its plane circular ends, with particle generator, accelerator and neutralizer units 51, 52, including scanners, disposed respectively for projecting directionally variable scanning high velocity beams of neutralized particles into the reaction chamber along converging paths for interaction within the reaction chamber in the vicinity of a predetermined point of convergence of the beams, or a larger number of units may be employed if desired.

For example, in FIG. 4 a cylindrical reaction chamber 55 may have radially disposed neutral particle accelerator units 56, 57, 58 and 59 or if chamber 55 as illustrated be deemed to represent a spherical chamber an even larger number of units (not shown) may be disposed radially with respect to it at appropriate intervals to insure projection into the reaction chamber of a desired number of high velocity beams of accelerated neutral particles.

In another arrangement illustrated in FIG. 5 a reaction chamber 60 which may be cylindrical, polygonal or any other appropriate shape, may have opposed rows R, R1 or a plurality of particle generator, accelerator and neutralizer units, with scanners, communicating with its interior through generally spaced windows (not shown).

The accessory equipment (not shown) for all these accelerator chambers substantially corresponds to the vacuum pumps, heat exchange fluid supply and discharge means and reactant supply and control apparatus heretofore described in association with the accelerator chamber in the preferred embodiment of the invention, while the several accelerated neutral particle projection units themselves may substantially duplicate in their entireties the unit 1 likewise heretofore described.

As an example of the utilization of our accelerated neutral particle projection apparatus for purposes other than heat generation we have diagrammatically illustrated in FIG. 6 an arrangement of a unit 65, producing a beam constantly scanning highly accelerated neutral particles projecting from its restricted end toward a sensitized detector D, backed by a shield S, whereon particles projecting the profile of an article A to be radiographically examined provide an image of a fault O or other interruption in the physical or chemical homogeneity of the article A as measured by its transparency to high velocity neutral particles.

We claim:

1. The method of producing a low to high velocity neutral particle beam which comprises generating and accelerating to a high velocity a substantially rectilinear stream of positively charged particles, generating and accelerating to a high velocity a substantially rectilinear stream of negatively charged particles, directing them along substantially parallel but converging paths and into a single beam whereby the charges carried by the positively charged particles are neutralized by the

charges carried by the negatively charged particles and combined in a low to high high velocity neutral particle beam.

2. A method in accordance with claim 1 in which said streams of charged particles are synchronously scanned before converging into a scanning neutral particle beam.

3. A method in accordance with claim 1 wherein the accelerated beam of said neutral reactant particles projects into a mass of dispersed relatively static reactant particles which on bombardment by said neutral particles release energy in the form of heat and radiation.

4. A method in accordance with claim 3 wherein the beam of neutral reactant particles projecting into the mass of dispersed relatively static reactant particles is flooded by electrons from an electron gun provided with an appropriate scanning device to encompass the projected beam of neutralized reactant particles within the mass of dispersed relatively static particles.

5. The method as defined in claim 3 wherein said relatively static reactant particles are dispersed in a substantially evacuated chamber and the chamber walls are engaged by a fluid heat exchange medium.

6. The method as defined in claim 3 wherein said relatively static reactant particles are dispersed in a solid mass of a metal transparent to the passage of the accelerated neutral reactant particle beam.

7. A method in accordance with claim 1 in which an accelerated beam is interreacted with the particles in another high velocity neutral particle beam produced in accordance with said method.

8. The method as defined in claim 1 wherein the scanning beam of said neutral particles is directed toward a sensitized surface adapted to be excited by impingement thereon of said particles and a non-homogeneous solid body to be examined radiographically is interposed in said path between the source of said particles and said sensitized surface.

9. Apparatus for projecting along a substantially rectilinear path a directionally variable continuous beam of high velocity neutral reactant particles which comprises disposing adjacent each other means for generating positively charged particles and means for generating negatively charged particles, each such generating means including particle accelerating means, and means for directing the accelerated charged particles in converging streams within a substantially evacuated

chamber whereby without appreciable deceleration said positively charged particles and said negatively charged particles commingle and the positive charges of the positively charged particles are neutralized by the negative charges of said negatively charged particles to thereby project from said apparatus a beam of accelerated neutral reactant particles.

10. In combination with the apparatus defined in claim 9 a pair of continuous synchronous charged particle scanning devices interposed in the path of each of said converging streams for translating transversely of the general direction of the stream the particles therein.

11. In combination with the apparatus defined in claim 9 means for interposing in the path of said neutral particle beam a mass of relatively static reactant particles of a reactant, and means defining a passage for a fluid heat exchange medium in heat exchanging relation with said first mentioned means.

12. In combination with the apparatus defined in claim 9, means defining a substantially evacuated chamber containing relatively static reactant particles of a reactant, means for directing into said chamber said beam of accelerated neutral particles and heat exchange means associated with said chamber defining means providing a passage for a fluid heat exchange medium.

13. In combination with the apparatus defined in claim 9, detecting means excitable by impact of said accelerated neutral particles disposed in the path of said particles and means for supporting in said path between said detecting means and said apparatus a solid body non-uniformly transparent to said accelerated particles.

14. Apparatus as defined in claim 9 including means for interposing in the path of said accelerated neutral reactant particles a mass of relatively static particles of a reactant, means in heat exchanging relation with said first mentioned means defining a passage for a fluid heat exchange medium and at least one additional apparatus as defined in claim 9 disposed to project a stream of accelerated neutral reactant particles into said mass of relatively static reactant particles in a direction different from the direction of projection of accelerated neutral particles therein from said first mentioned apparatus.

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