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BIBLIOGRAPHY ON URANIUM ISOTOPE SEPARATION

by

R. SCHIEL

1972

Directorate-General Dissemination of Information

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Commission of the European Communities
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A compilation of I 096 abstracts on Uranium Isotope Separation is presented.
The bibliography is subdivided according to different separation methods, to economical aspects, and to already existing bibliographies on isotope separation. In addition, an Author index, and a Report and Patent Number index is given.

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ABSTRACT

A compilation of 1 096 abstracts on Uranium Isotope Separation is presented. The bibliography is subdivided according to different separation methods, to economical aspects, and to already existing bibliographies on isotope separation. In addition, an Author index, and a Report and Patent Number index is given.

KEYWORDS

ISOTOPE SEPARATION
ENRICHMENT
URANIUM
URANIUM HEXAFLUORIDE
URANIUM ISOTOPES
URANIUM 235
URANIUM 238
DIFFUSION
MEMBRANES
CENTRIFUGATION
NOZZLES
ION EXCHANGE
ELECTROMAGNETIC FIELDS
THERMAL DIFFUSION
ECONOMICS

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PREFACE

Since the Euratom Nuclear Documentation System (ENDS) started its service in 1967, a large number of inquiries on uranium isotope separation had to be processed. Compared with the total volume of ENDS, which amounts to 1 200 000 documents now (end 1971), the number of documents in the subject field of uranium isotope separation (about 1 069) is relatively small (less than 0.1%); but it is by far the field with the highest usage rate, i.e. number of inquiries per document.

Therefore it seems justified to spend an extra effort on issuing a bibliography on that topic, although this cannot be considered to be the usual task of ENDS. It is hoped that this bibliography will not only benefit the scientists and technicians working in the field of uranium isotope separation, but that it will draw the attention of potential compilers of bibliographies to the capabilities of ENDS. In other words: There should be no bibliography in the nuclear field for which ENDS did not supply a literature search. In this respect the present bibliography can be considered an example.

Carlo VERNIMB,
Head of Scientific Information Retrieval Service of ENDS.

INTRODUCTION

The abstracts compiled in this bibliography have been derived from several literature searches performed for users of the Euratom Nuclear Documentation System (ENDS). Those searches covered the whole field of uranium isotope separation. Although the separation of atoms lighter than uranium could likewise be of interest for scientists and technicians working in the field of uranium isotope separation, such documents were not included in this bibliography in order not to delay its publication. On the other hand, it has tried to achieve a coverage as complete as possible for the restricted scope of uranium separation. For this purpose documents known (by the users of ENDS) as relevant to the scope but not retrieved by ENDS were included in this bibliography. The same applies to documents not found in ENDS but announced in one of the bibliographies compiled in Chapter 12. These documents are mainly bulletins of industrial firms, etc. not treated in such abstract journals as are the source of ENDS.

The user of this bibliography is informed that he may ask for a monthly updating by the SDI (Selective Dissemination of Information) Service of ENDS. He may address his request to:

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Any hints for the improvement of this bibliography will be appreciated.

The compiler.

ENCYCLOPEDIC INFORMATION ON ISOTOPE SEPARATION

from Encyclopedic Dictionary of Physics, Vol. 4, pp. 118-121
Editor: J. Thewlis, London 1961

Isotopes, stable.

Although a stable isotope is merely an isotope which is not radioactive, the term has come to be used to indicate those isotopes, commonly used in research, that have been separated by use of, say, an electromagnetic separator, or the process of fractional distillation, to various degrees of enrichment.

Stable isotopes separated by fractional distillation include ^{13}C, ^{12}C, ^{18}O, and ^{3}He.

By use of the electromagnetic separator, isotopes of about half of the 61 polyisotopic elements below bismuth in the periodic system are available in enrichment up to 99 per cent.

Isotopes, stable, separation of.

The majority of naturally occurring elements are mixtures of isotopes the separation of which must depend on using the small differences in their physical or chemical properties. In most cases the extent of the separation is dependent upon the ratio of the isotopic masses and consequently is greater for the lighter elements. The demand for separated isotopes of intermediate atomic weight is not great and small quantities for research purposes may be prepared by electromagnetic separation. Separation of the uranium isotopes, being carried out on a very large scale, involves special problems and is treated in a separate article.

Separation is most easily carried out when only two isotopes have to be considered and is most difficult when the components of intermediate mass have to be obtained from a multicomponent mixture. In the methods described below it will usually be assumed that the starting mixture is entirely or mainly composed of two isotopes and the effectiveness of a given stage is expressed in terms of a separation factor, q given by

$$q = C_2(1 - C_1)/C_1(1 - C_2) > 1$$

where C_1 and C_2 are the mole fractions of the desired isotope at the inlet and outlet of the stage respectively.

Electromagnetic separation. The electromagnetic separator is basically a high current mass spectrometer in which provision is made to collect the separated ions on removable cooled surfaces. The resolution of these machines increases with increasing ion path radius and they have been constructed with up to 4 ft radius enabling enrichment factors of several thousands to be obtained.

One of the great advantages of this method over all others is that simultaneous collection of several isotopes may be made. The efficiency of collection, however, is often limited by the

nature of the element being separated and is particularly low for the inert gases. As a means of producing larges quantities of isotopes, electromagnetic separation is severely limited by the high cost of the machine, low throughput and very high running costs.

Thermal diffusion. If a temperature gradient is maintained in a gas mixture there is a tendency for the gases to separate, to an extent determined by the intermolecular forces and molecular weights and which is eventually balanced by back diffusion along the resulting concentration gradient. In binary isotopic mixtures at ordinary temperatures this separation is in a direction such that the heavier component concentrates in the lower temperature region. The single stage separation factors so obtained are usually small, but the separation may be increased greatly by a countercurrent method using a column with a heated central wire and cooled outer tube.

In the thermal diffusion column the temperature gradient is maintained in a radial direction. The heavier isotope tends to concentrate near the outer, cold, wall where the convection current set up by the hot wire is in downward direction. Consequently the heavier component becomes more concentrated in the downward moving gas stream and gas removed from a reservoir at the lower end of the column is enriched in this isotope. Several columns can be used in series to give very high separation factors.

The main advantages offered by the method are versatility, low capital cost, simplicity and its ability to enrich mixtures having low initial concentrations of the desired isotope. As the separation is based on a thermodynamically irreversible process, power consumption is high and this, together with its low throughput, makes it less desirable than other methods for large production plants.

Fractional distillation. The vapour pressures exerted by two isotopes in liquid form differ very slightly from each other so that a small separation may be obtained by distillation. The separation may be greatly increased in practice by using a conventional packed distillation column in which the vapour from the lower part of the column is continuously in contact with the liquid condensed further up, so that the vapour and liquid molecules exchange and the more volatile components tends to accumulate at the top of the column. Such a column is equivalent to a series of single stage units, the length of column corresponding to each unit, h, being that for which the vapour leaving the top of the section has the same composition as vapour which would be in equilibrium with liquid leaving the bottom, under static conditions. This length is called the height equivalent to a theoretical plate.

For a single stage, the separation factor is given by $q = a$ where a is the vapour pressure ratio. If there are n such stages in a column of length L, $n = L/h$, then the total separation factor is given by

$$q_t = a^n = a^{L/h} \doteq \exp\{(a - 1)L/h\}.$$

Values of h of the order of 1 cm are attainable, so that a significant separation of isotopes with a vapour pressure ratio of 1.01 is attainable with a column of about 5 m length.

Distillation is an attractive means of separation when the isotopes may be obtained in the form of a liquid with low boiling point, since the differences in vapour pressure are often only appreciable at low temperatures, and hence is of more use for the light elements. The output of a plant can be quite large and, being based on a reversible process, the power consumption is low.

Chemical exchange. In many exchange reactions of the type

$$^xAB + {}^yAC \leftrightarrows {}^yAB + {}^xAC$$

where ^xA and ^yA are isotopes, it is found that the equilibrium constant differs slightly from unity.

In the above reaction, if the equilibrium constant k, given by

$$k = [^{y}AB]\,[^{x}AC]/[^{x}AB]\,[^{y}AC]$$

is slightly greater than unity, the isotope ^{x}A concentrates preferentially in the substance AC. This type of reaction can be utilized to separate isotopes and is more easily applied if one of the substances is a gas and the other a liquid. In this case the separation is carried out in much the same way as in distillation, using a packed column with the liquid and gas in counterflow.

It is necessary to be able to pass the partially concentrated isotopes in the reverse directions through the column to set up the desired reflux condition. This is easily accomplished if chemical reactions can be devised which reconvert the gas at the top of the column to the liquid compound and vice versa at the bottom end. This type of separation can also be carried out with immiscible liquids, e.g. an amalgam and an aqueous solution of a salt of the metal.

The method is again one based on a reversible process and the resulting low power consumption makes it attractive for large scale work. It is not easily applied to all separations, however, since suitable exchange reactions with high values of $(k - 1)$ must be found together with convenient reconversion reactions.

Isotopes have also been separated by means of gas chromatography and by ion exchange but the methods have never been developed to any great extent. The most successful processes have been laboratory scale separation of the nitrogen isotopes using ion exchange resins and ammonia solutions and the separation of hydrogen isotopes using palladium or chromia/alumina packed columns.

Gaseous diffusion (effusion). While this process finds its greatest application in the separation of the uranium isotopes, the principle may be applied to any gaseous isotope separation and was first used by Hertz for the separation of neon isotopes. The separation depends on fact that the rates of effusion of isotopic gases through a porous membrane are inversely proportional to the square roots of their masses, so that the lighter component of the mixture tends to become more concentrated in the gas which has passed through the membrane. The separation factor for a single stage is given by

$$q = (M_h/M_l)^{1/2}$$

where M_h and M_l are the molecular weights of the heavy and light components respectively.

The small enrichment achieved by this process is increased by having many such stages in cascade. Large throughputs require the use of very large areas of membrane, since the most effective separation takes place when the pore size is very small, of the order of 1/10 the mean free path of the molecules in the gas. The success of the method depends very largely on the properties of the membrane and it is generally less suitable for laboratory use than thermal diffusion.

Electrolysis. There is generally a small difference in isotopic composition between the products of electrolysis and the electrolyte. The difference may be used either in a cascade of single stage cells, useful when the element to be separated is liberated at one electrode in the form of a gas, or in a countercurrent migration method.

The first method is used for the preparation of deuterium from water, since the separation factor for the hydrogen isotopes is particularly high, between 3 and 7. Slightly more hydrogen than deuterium is evolved at the cathode of an electrolytic cell, the proportions depending to some extent on the nature of the electrode material and this results in a gradual concentration of the heavier isotope in the remaining water. Instead of electrolysing each batch until the deuterium concentration has reached the required level, with the consequent wastage of that isotope in the gas evolved during the later stages of the operation, the separation is carried out

using a cascade of cells, the evolved gases being catalytically converted to water and returned to the previous cell. The deuterium-enriched water is passed on to the next stage and in this way its concentration in the water builds up towards the end of the cascade where it may be withdrawn at a predetermined rate.

The isotopes of several metals have been partially separated by countercurrent electromigration in their fused salts or in concentrated solutions of them. The apparatus must be arranged so that the metal liberated at the cathode can recombine with the appropriate substances to form new electrolyte which may diffuse back against the metal ion current. The exchange of ions between the two streams results in a concentration of the more mobile isotope ion at the cathode. Chlorine isotopes have also been partially separated in this way using zinc electrodes and zinc chloride electrolyte.

Cascade operation. In any separation process where several units are run in series and in which concentrated material is continuously withdrawn, several extra design considerations have to be taken into account to obtain maximum efficiency. In the first place, the depleted material must be removed from the plant at a rate equal to the difference between the rate of feed and rate of removal of concentrated material at the positive end of the cascade. To do this the feed is introduced part way along the cascade so that a flow of material proceeds towards both ends, the concentration of the desired isotope being increased towards the positive end and decreased towards the negative end. That part towards the negative end acts as a "stripper", the function of which is to remove most of the desired isotope from the material flowing through it, thus maintaining a constant concentration at the point of feed. The length of this section and its designed efficiency are determined by the abundance and value of the isotope being concentrated.

Secondly, consideration must be given to the size of each unit of the cascade relative to its neighbours, the so-called tapering of the cascade. As the material towards the positive, outlet end increases in concentration, the amount processed by each successive stage decreases, and the size of unit necessary for this is also decreased. Depleted material from each stage may be passed back and mixed with the feed to the previous stage to obtain greater economy, the most depleted material being finally rejected at the negative end of the stripper. The amount of taper can be calculated in general terms so that capital costs, power consumption and hold up of enriched material may be reduced as far as possible.

The following processes have also been considered as means of isotope separation.

Molecular distillation, in which use is made of the difference in the rates of evaporation of molecules from a liquid surface into a high vacuum. The difference depends on the isotopic masses and vapour pressure ratio. The vapour phase, containing a higher concentration of the lighter isotope than the remaining liquid, can then be condensed on a cooled surface immediately above the liquid pool and the process repeated using the condensate in further stages. The method can be applied to liquid metals and has been used to concentrate mercury and lithium isotopes.

Gas centrifuges, in which the isotopic mixture is contained within a hollow rotor rotating at very high speed (of the order of 30 000 rev/min). The heavier component of the mixture concentrates near the outside wall of the rotor, giving a single stage separation factor q, where

$$q = \exp\{(M_1 - M_2)u^2/2RT\}$$

and M_1 and M_2 are the isotopic weights, u the peripheral velocity, R the gas constant and T the absolute temperature. The dependence of q on $(M_1 - M_2)$, the difference in mass, rather than on the ratio of the masses is of significance for the separation of heavy isotopes.

The separation factor for a single centrifuge may be increased by suitable arrangement of baffles inside the rotor to give, in effect, a series of separation stages or by maintaining a convective counterflow up the wall of the rotor and down the axis. In the latter arrangement exchange between the upward and downward moving streams results in an axial concentration gradient which increases with rotor length.

Nozzle separators, in which the gas mixture is passed at high speed through a nozzle, the radial pressure gradient so formed resulting in diffusion of the lighter isotope towards the outer region of the jet. The jet can then be separated into two streams containing the outer and inner portions and these may be used in further stages of a cascade.

Sweep diffusion, in which use is made of the difference in ordinary diffusion rate when a mixture of isotopes diffuses through another gas. If this second gas is a condensible vapour a continuous stream of vapour can be maintained between an evaporating and a condensing surface so that the isotopic mixture is continuously diffusing against the stream. The difference in diffusion rate results in a concentration of the lighter isotope near the evaporator, which may be increased by countercurrent methods.

See also: Mass spectrograph: mass spectrometer.

Bibliography

COHEN K. (1951) *The Theory of Isotope Separation as Applied to the Large-scale Production of* ^{235}U, New York: McGraw-Hill.

JOHNS T.F. (1957) *Progr. Nucl. Phys.* 6, 1.

KISTEMAKER J. *et al.* (Eds.) (1958) *Proceedings of International Symposium on Isotope Separation*, Amsterdam: North Holland.

KOCH J. (Ed.) (1958) *Electromagnetic Isotope Separators and Applications of Electromagnetically Enriched Isotopes*, Amsterdam: North Holland.

F.A. JOHNSON.

1. GAS DIFFUSION

1 THE PLANT OF ISOTOPIC SEPARATION AT PIERRELATTE (FRANCE).

Laurent, C.

Atomes (1962), 187, 125-126 (French).

The isotopic separation of uranium by the gas diffusion method is commented. The difficulties are discussed.

2 AFTER GENEVA CONFERENCE, FRENCH TECHNICIANS GET DEFINITE STATUS ON EUROPEAN MARKET OF ISOTOPE SEPARATION PLANTS.

Fréjacques, C., Galley, R.

L'Usine nouvelle 20(1964)39, 25 (French).

Two years since the opening of the pilot plant of Pierrelatte, and six months after the start of the low power atomic energy plant, some conclusions may be announced: (1) The total success of the "low" plant, the French process of separation, may be considered as perfect. (2) Pierrelatte's aims are not only military, but are specially focused on energy production. (3) The cost of enriched uranium produced on a large scale with an electric current at the French normal price would be only 30% more expensive than the U.S.A. (subsidized) price. (4) Thus, as the price of U.S. uranium will become normal in a few years, a European plant should be built before 1970, and the Pierrelatte techniques will become competitive on the European market.

3 INDUSTRIAL ATOMIC POWER PLANTS I.

Hedde d'Entremont, B.

Ind. et Techn. 48 (1964), 100-105, 15 fig. (French).

From the comprehensive picture of the main industrial concern of the French CEA, the chapters on enriched uranium and on plutonium are summarized. Among the 12 isotopes of U (ranging from ^{227}U to ^{240}U) ^{233}U and ^{235}U are the most important ones for the atomic industry. But natural uranium contains only 0.3% of ^{235}U; and ^{233}U is extracted only in lab, by the Thorex process. A new method of enrichment of ^{235}U, based on gas diffusion, will be applied for industrial production of ^{235}U in a new plant at Pierrelatte. The plutonium is produced during uranium fusion, in the reactors producing electric power. This metal must be rolled and treated in entirely air proof conditions, which are very delicate in order to avoid radiocontamination of workshops and engineers. New workshops at Marcoule and for dissolution at La Hague (Calvados) are being built.

4 ENRICHMENT OF URANIUM (ENRICHISSEMENT DE L'URANIUM).

Nuclear Engineering, 13, No. 143 (4/68), pp. 335-340.

Description des méthodes d'enrichissement de l'uranium : diffusion thermique, diffusion gazeuse et séparation électromagnétique. Problèmes techniques posés par la production de grandes quantités d'uranium.

5 COMMON MARKET ISOTOPE SEPARATION PLANT (USINE DE SÉPARATION ISOTOPIQUE DU MARCHÉ COMMUN).

Applied Atomics, No. 652 (27/3/68), p. 4-5.

Deux projets : l'un est une extension de l'usine de diffusion gazeuse française de Pierrelatte, l'autre, la méthode d'ultracentrifugation d'extraction de l'U^{235}. La Communauté envisage aussi de construire sa propre usine de séparation isotopique.

6 URANIUM ENRICHI.

Nuclélec, No. 1004 (17/7/69), pp. 5678-5682.

Étude de la production d'uranium enrichi par diffusion gazeuse à l'usine de Pierrelatte. La production a été supérieure à celle prévue en 1967. Amélioration en cours. Études en vue d'une usine de faible enrichissement. Séparation isotopique de l'uranium par ultracentrifugation. (L.T.).

Uranium. Combustibles piles nucléaires. Enrichissement combustible piles nucléaires. Séparation diffusion gazeuse. Séparation centrifuge.

7 MANSON BENEDICT CARVES A NUCLEAR CAREER.

Anon.

Chem. Eng. News 44(8), 79-80(1966) (Eng.).

A brief biography is given of this 1966 winner of the Perkin Medal (for development of the gaseous diffusion process for sepg. ^{235}U from ^{238}U).

8 URANIUM ISOTOPE SEPARATION.

Fiocchi, R.

Comit. Nazl. Energia Nucl., Notiziario 11(10), 12 p. (1965) (Ital.); cf. CA 55, 24270g.

Knudsen and Poiseuille theories of passage of gases through orifices are discussed in connection with sepn. of UF_6 contg. different isotopes. The choice between diffusion and centrifuging, as well as the choice of the degree of purity aimed at, is still dependent on economic factors, such as capital cost of plant, cost of fuel and labor.

9 PROCESS AND APPARATUS FOR SEPARATION OF ISOTOPE MIXTURE, ESPECIALLY URANIUM HEXAFLUORIDE.

Troebs, H.

Ger. (East) 49,539 (Cl. B 01d), Oct. 5, 1966, Appl. July 17, 1963; 8 p.

An app. for sepn. by diffusion of UF_6 from a mixt. contg. variable amts. of $^{235}UF_6$ and $^{238}UF_6$ is described.

10 NUCLEAR FUELS.

Suarez Feito, J.

Bol. Geol. Minero 1968, 79(1), 26-83 (Span).

Fundamental processes are considered of interactions between *n* and matter (scattering, capture), nuclear fission (*n* and energy balance), and formation of fission products and of fissionable material. Basic and advanced methods using either acid or alk. media for the treatment of U and Th ores are described, followed by a summary of common purification methods for U solns., such as ion exchange and org. solvent extn. techniques. Fluid-bed and fusion procedures are covered for the recovery of U metal via the steps UO_3, UO_2, UF_4; similar metallurgical techniques are noted for the production of Th. Standard methods for producing enriched ^{235}U are illustrated: centrifugation or gas diffusion of UF_6, subsequent redn. to UF_4, and reaction to UO_2 or U_3O_8. After enumeration of some phys. and chem. properties of U, U oxides, and Th, general fabrication principles of fuel elements are indicated, such as welding and canning techniques.

11 ULTRA-CENTRIFUGE PROJECT. I. URANIUM CONCENTRATION PROCESS.

Weimar, K.L.A. (Neth.).

Chem. Weekbl. 1969, 65(13), 16-19 (Neth.).

After a short description of U concn. processes, such as the gas diffusion method, the basic principles of the ultracentrifuge method are given. In this method, sepn. is accomplished between $^{238}UF_6$ and $^{235}UF_6$ by means of centrifugal force. The sepn. factor is increased by slightly raising the temp. at the lower part of the rotor. Enrichment of $^{235}UF_6$ takes place in an upward direction.

12 SEPARATION OF URANIUM ISOTOPES.

Becker, Erwin, W. (Univ. Karlsruhe, Karlsruhe, Ger.).

Umschau 1969, 69(20), 656-7 (Ger.).

The production of enriched U by gaseous diffusion or centrifugation or by nozzle sepn. processes is considered.

13 PREPARING ENRICHED URANIUM FOR NUCLEAR FUELS.

Jelinek-Fink, P. (Nukl.-Chem. und -Met. G.m.b.H., Wolfgang/Hanau, Ger.).

Haus Tech., Essen, Vortragsveroeff. 1969, 214, 15-28 (Ger.).

For the enrichment of ^{235}U from 0.71% (natural content) to 2-4% (for light-water reactors) or to > 90% (for high-temp. reactors), gas diffusion, ultracentrifuge, and sepg. jet methods have been developed which all are based on the small wt. difference between $^{235}UF_6$ and $^{238}UF_6$. Only gas-diffusion cascade processes, however, are used in a tech. scale at present. It appears that the ultracentrifuge process when appropriately improved might compete with the gas diffusion process; the sepg. jet process presumably would be too expensive. (See 151.)

14 URANIUM ENRICHMENT PROCESS.

Aochi, Tetsuo (Japan).

Kagaku Kogyo 1970, 21(10), 1375-1380 (Japan).

A review is given on U enrichment by gas diffusion, centrifugal sepn., and nozzle sepn. 3 refs.

15 ASPECTS ÉCONOMIQUES DE L'ENRICHISSEMENT DE L'URANIUM PAR DIFFUSION GAZEUSE.

Gaussens, J., Jacques, R., Martin, J.C.

Colloque sur les cycles de combustibles pour les réacteurs de puissance; Baden-Baden - 9-14 Sept. 1963, 30 p.

(See 94.)

16 UNUSUAL SEPARATIONS.

Donatos S.

Chem. Eng., Vol. 71, No. 25, Dec. 7, 1964, pp. 155-168.

In zone refining, producing high-purity substances for transistors continues to be dominant use; probably greatest use of molecular sieves is to effect separation of water from gas and liquid streams; dialysis has been used in recovery of spent caustic soda from industrial wastes in rayon industry, and in separation and recovery of sulfuric, nitric and chromic acids from waste liquors of electrolytic cells; gaseous diffusion was used to separate gaseous uranium compounds $^{238}UF_6$ and $^{235}UF_6$.

17 SÉPARATION DES ISOTOPES.

Fréjacques, C.

Énergie nucléaire, Vol. 6, No. 8, Déc. 1964, p. 531-532.

Isotope separation; problems of uranium isotope separation, production of heavy water, and other isotope separations; processes of gas diffusion and centrifuging are discussed; from economic point of view, it is shown that gas diffusion is interesting only in large facilities; data furnished on centrifugation are insufficient for comparing advantages of two processes. Before 3rd Int. Atomic Conference, Geneva 1964.

18 LE COMMISSARIAT A L'ÉNERGIE ATOMIQUE, ETC.

Génie Civil, Vol. 142, No. 12, June 15, 1965, p. 264-270.

Commission for Atomic Energy, its organization and producing plants; description of uranium and plutonium separating plants at Marcoule, La Hague, and Pierrelatte; techniques employed, as well as technological problems associated with toxicity and corrosive properties of uranium hexafluoride used in gaseous diffusion process are discussed.

19 ADVANCED GAS-COOLED REACTOR WILL USE BRITISH ENRICHED FUEL.

Anon.,

Electl. Rev., Lond., 177, (25), 898 (Dec. 17, 1965).

A.E.A's diffusion separation plant at Capenhurst is to be modernised to supply enriched uranium for the second nuclear power programme. This will make the AGR independent of American fuel. The Government have approved in principle plans involving a capital expenditure of £13.5 million. The Capenhurst plant has been consuming 30 MW and this will rise to 180 MW in the first phase of the programme; consumption could rise to 500 MW by the 1970s.

20 CENTRIFUGE ENRICHMENT FOR EUROPE.

Lawes, G.

New Scient., 41, (641), 640-641 (March. 20, 1969).

It is now virtually certain that Britain, W. Germany and Holland will build a pair of ultra-centrifuge, U enrichment plants. Major technical problems have been overcome and initial technological collaboration will be minimal. Capacity in kg/yr, investment in $/kg/yr, electricity consumption in kWh/kg of SW, kWh price in mills/kWh, and separation cost in $/kg of SW are compared for: gaseous diffusion, nozzle separation, and ultra-centrifuging.

21 TECHNICAL AND ECONOMIC ASPECTS OF URANIUM ENRICHMENT IN EUROPE.

Anon.,

Nucl. Engng. int., 14, (158), 580-583 (July 1969).

A report of the one day international symposium organised by the Netherlands Atoomforum at Utrecht in May which covered: predicting future enrichment capacity needs; comparing the cost of separation by ultracentrifuge and gas diffusion; developing nozzle separation for U enrichment; centrifuge theory; comment on the Foratom Report on Economic Aspects of Uranium Enrichment in Europe; and proposals by the European Commission on enrichment facilities.

22 CLOSE COSTING OF URANIUM ENRICHMENT.

New Scient., 43, (656), 21 (July 3, 1969).

Anon.,

A cost breakdown of ultracentrifuge enrichment published at the recent Netherlands Atoomforum Conference on "Uranium Enrichment in Europe" estimated investment charges for a centrifuge plant of 3 000 tonnes separative work per annum capacity at $115/kg, and $110/kg SWU/y for a 17 000 tonne gaseous diffusion plant. Electricity charges for centrifugation were $\sim$ 1/3 or 0.1 for diffusion by AEG or in Europe. Japanese and German work on diffusion is also mentioned.

23 THE GAS CENTRIFUGE PROJECT.

Barnaby, C.F.

Sci. Jnl, 5A, (2), 55-59 (Aug. 1969).

For U enrichment: principles, competitive with gas diffusion; politics.

24 FUEL CYCLE.

Franklin, N.L.

Nucl. Engng int., 14, 722-724 (Sept. 1969).

Describes current activities of the UKAEA Production Group in nuclear fuel fabrication, reprocessing, supporting services and enrichment supply. For U enrichment, the economics of diffusion and centrifuges have been compared, emphasis in development has been adjusted in favour of the centrifuge, but not excluding diffusion.

25 CHARTS AID STUDY OF FUEL-CYCLE-COST CHANGES FROM PENDING SHIFT IN DIFFUSION PLANT OWNERSHIP.

Anon.

Electl Wld, 172, (19), 34 (Nov. 10, 1969).

Babcock and Wilcox estimates of incremental cost changes for all PWRs (and less accurately) BWRs. Initial enrichment assumed was 3.0%.

26 EXPERIMENTAL STUDY ON THE GASEOUS DIFFUSION PROCESS BY MEANS OF A 10-STAGE CASCADE.

Higashi, K., Doi, H., Saito, T. (Kyoto Univ., Japan, Dept. of Nuclear Engineering).

Energ. Nucl. (Milan), 1970, Vol. 17(2), pp. 98-103.

In order to study the static and dynamic characteristics of the gaseous diffusion process, a laboratory-scale cascade with 10-stages has been built up. This is a triangular cascade (cut: 0.5) consisting of 55 separating elements and 9 compressors. The porcus membranes used were made of sintered nickel and shaped in 50 mm diameter disc-type. The excellent self-controllability of the gaseous diffusion cascade has been confirmed experimentally using it without any control system.

The disagreement between theoretical and experimental results is discussed briefly with respect to equilibrium time.

27 LES MACHINES A PALIERS A GAZ EN ÉNERGIE NUCLÉAIRE (MACHINES WITH GAS BEARINGS IN NUCLEAR ENERGY).

Mech, C. (Société Rateau, 93 - La Courneuve, France).

Énergie nucléaire (F), Vol. 9, No. 8, Déc. 1967, p. 508-514.

La mise au point des compresseurs d'hexafluorure d'uranium gazeux a constitué une étape difficile et déterminante de la construction de l'usine de Pierrelatte. Le Commissariat à l'Énergie atomique a choisi pour les compresseurs de l'usine très haute la technique des paliers à gaz de la société Rateau. L'exécution industrielle a été confiée aux sociétés Alcatel et Rateau, agissant au sein d'un organisme commun. L'article présente cette technique dans certaines de ses applications au domaine nucléaire.

28 LA CORROSION DES MATÉRIAUX MÉTALLIQUES DANS LE PROCÉDÉ DE DIFFUSION GAZEUSE (CORROSION OF METALLIC MATERIALS IN GASEOUS DIFFUSION PROCESS).

Dixmier, J., Hasson, R., Maraval, S., Salle, P., Vincent, L.M. (Commissariat à l'Énergie atomique, Centre d'études nucléaires de Saclay, 91 - Gif-sur-Yvette, France. Services d'études sur la séparation des isotopes de l'uranium).

Rapport CEA-CCNF-1244.

Colloque sur les problèmes concernant la séparation isotopique de l'uranium, Turin, 1-2 oct. 1968.

La réaction de UF_6 avec les métaux est, dans les conditions de procédé, une réaction gaz-solide. Après l'étude des facteurs externes et internes de la corrosion, des produits de la réaction, on doit effectuer une étude systématique détaillée de chaque matériau pour décider de ses possibilités d'emploi. Les études du laboratoire ont porté, entre autres, sur les fers et aciers au carbone, sur les aciers inoxydables, sur les alliages légers et ultra-légers, sur les alliages cuivreux, ainsi que sur le nickel et ses alliages. En ce qui concerne les méthodes expérimentales utilisées, il a fallu concilier une très grande sensibilité, exigée par l'ordre de grandeur des phénomènes, avec les difficultés d'emploi inhérentes aux gaz fluorants. Suivant les cas, les réactions ont été conduites sous atmosphère corrosive statique ou renouvelée. Les mesures cinétiques ont été effectuées soit par gravimétrie discontinue, de grande sensibilité ($5 \times 10(-7)$ g/cm^2) soit par gravimétrie continue, en thermobalances. Une méthode récemment mise au point au laboratoire permet, grâce à l'emploi de quartz piézo-électriques, d'effectuer en continu, sous UF_6, des mesures avec une sensibilité de $4 \times 10(-9)$ g/cm^2, avec une précision de l'ordre de 2 %. Grâce à une méthode d'abrasion ménagée, il est devenu possible de mesurer des pénétrations à mieux que 0,05 microns.

(See 150.)

29 DISPOSITIF RÉGULATEUR (REGULATING DEVICE).

Lackme, C. (Commissariat à l'Énergie atomique, 75 - Paris, France).

Brevet BF 1 510 838.

Commissariat à l'Énergie atomique, 75 - Paris, France, 29 juin 1966.

Dispositif régulateur destiné notamment à maintenir constante la pression en un point d'un circuit parcouru par un débit de fluide liquide ou gazeux variant dans des proportions notables, et en particulier à l'intérieur d'un réservoir situé en amont de ce dispositif par rapport au sens de circulation du fluide.

30 DÉFINITION DES ACTIONS DE TRAVAIL DE SÉPARATION ISOTOPIQUE ET DE BARÊME D'ENRICHISSEMENT DE L'URANIUM (DEFINITION OF THE WORKING CONCEPT OF ISOTOPIC SEPARATION AND THE URANIUM ENRICHMENT STANDARD TABLE.)

Sugier, A. (Commissariat à l'Énergie atomique, Centre d'Études nucléaires de Fontenay-aux-Roses, 92 France).

Bulletin d'information ATEN, Association technique pour l'énergie nucléaire (F.), N° 77, mai-juin 1969, p. 42-47. Rapport CEA-TP-8226. (En français).

Cette étude constitue une synthèse des principaux exposés qui ont paru le mieux définir les actions de travail de séparation isotopique et de barème d'enrichissement de l'uranium. Un rappel succinct des caractéristiques fondamentales des différents types de cascades a permis d'introduire l'expression finale du flux total dans une usine de diffusion gazeuse idéale. Schématiquement, l'approche du problème est la suivante : on conçoit que, lorsqu'un flux donné traverse une unité de séparation et qu'il y subit un certain enrichissement,

le flux sortant a plus de valeur que le flux entrant, un travail déterminé ayant dû être fourni au niveau de séparation. D'où l'introduction de la fonction valeur qui représentera la valeur d'une unité d'uranium en tant que fonction de la concentration en isotope désiré. La variation de cette fonction représentant le travail fourni au niveau de l'unité de séparation sera, par contre, indépendante des teneurs. On a par ailleurs établi un barème américain d'enrichissement de l'uranium.

31 ELECTRICAL ENGINEERING FOR ATOMIC ENERGY.

Cardwell, D.W.

AECD-2335, Sept. 10, 1948, decl. Oct. 7, 1948. 20 p. Document for sale by AEC.

This paper surveys special problems in the field of electrical engineering which were presented by the atomic energy industry. The following topics are discussed: the electromagnetic process and gaseous diffusion processes for isotopes separation, nuclear reactors or piles, radiation detection instruments, high energy particle accelerators and applications of atomic energy (military weapons, isotopes, atomic power). 20 references.

32 URANIUM AND ATOMIC ENERGY.

Dennis, W.H.

Mine and Quarry Engr. 15, 211-8 (1949), July.

The concentration methods used in obtaining U_3O_8, the preparation of the metal from its oxide, and the separation of 235 and 238 are described. The author discusses two methods for separating the isotopes of uranium: namely, gaseous diffusion and electromagnetic. The formation of plutonium (239) is explained and since it is not an isotope, it can be extracted by chemical methods. The makeup of the nucleus is clearly presented along with the principle for transforming atomic mass into energy by nuclear bombardment ($E = MC^2$). A description of the first atomic energy machine employing a chain reaction is given. It was made up of grains of uranium embedded in graphite bricks. Later piles now operating at Clinton and Hanford in the U.S.A., and Great Britain are cubical in structure. Uranium is utilized in the form of long rods encased in aluminium containers which are slid into channels in the graphite pile. The containers protect the uranium from the cooling water. The reaction of the pile is controlled by inserting or removing cadmium rods from the lattice. The breeding principle, industrial utilization, radioactive isotopes and the military usage are also discussed. In conjunction with military usage, the author briefly discusses the critical size and states that the amount of uranium used in the atomic bomb is 135 pounds.

33 ENGINEERING DEVELOPMENTS IN THE GASEOUS DIFFUSION PROCESS.

Manson, B., Clarke, W.

Eds. New York, McGraw-Hill, 1949. 129 p. NNES Div. II, Vol. 16.

This collection of articles by various authors on engineering techniques for gaseous diffusion processes has been divided into four main sections. In part I, special plant instruments and devices are considered and articles on the recording mass spectrometer, the use of ionization chambers to detect traces of radioactive gases, and magnetic gear for torque transfer in closed systems are included. The problems of vacuum engineering are treated in part II and the use of the mass spectrometer for leak detection and other new developments in high-vacuum apparatus and techniques are discussed. Parts III and IV are concerned with the development of heat transfer equipment and the absorption of UF_6 and fluorine, respectively.

34 THE FUTURE OF ATOMIC ENERGY.

Dunning, J.R.

Am. Scientist 38, 60-85 (1950) Jan.

The author describes, in nontechnical language, the fission process in ^{235}U. He then discusses the use of moderators and the problems involved in designing a satisfactory moderator system. Diffusion and electromagnetic separation methods are outlined, and the Oak Ridge and Hanford plants, for the production of ^{235}U and plutonium, respectively, are briefly described. Possible future applications of atomic energy are discussed in the last section. The author concludes that concentrated fuels are necessary for the practical production of atomic energy, and that these fuels will have to be produced by some sort of breeding process. Such a fuel could be utilized in a nuclear power plant similar in design to one suggested by the author.

35 A LINEAR PROGRAMMING MODEL OF THE GASEOUS DIFFUSION ISOTOPE-SEPARATION PROCESS.

Fort, D.M. (RAND Corp., Santa Monica, Calif.).

Oct. 1, 1956. 77 p.

It is shown how the gaseous diffusion process, as applied to the separation of uranium isotopes, may be analyzed in terms of a linear programming model. The gaseous diffusion process involves many "separation elements" arranged in a cascade, with external streams of isotope mixtures of various compositions entering and leaving the cascade at various points. The compositions and flow rates of the various streams are subject to certain well known material balance and separation capacity constraints and to boundary conditions arising from the uni-directional flows within

the individual separation elements: it is not permissible to consider external streams that imply reverse flows. In cases involving five or more external streams, the boundary conditions are not automatically met by all sets of relevant streams. The boundary conditions are derived together with the circumstances under which these conditions need to be explicitly applied. It is shown that by a suitable choice of variables a linear programming model of the separation cascade can be set up that incorporates these boundary conditions as well as the material balance and separation capacity constraints. The model may be incorporated in larger models involving other elements such as nuclear reactor and chemical processing facilities. The equations employed in the present model are those for an "ideal cascade" in steady state operation, which implies that for any given set of external streams, the internal operation of the cascade has been arranged to minimize the required separation capacity and associated resources. For any given set of external streams, no degrees of freedom available relate to the various alternative sets of external streams that may be considered.

36 COMPARISON OF DIFFERENT METHODS APPLICABLE TO THE SEPARATION OF THE URANIUM ISOTOPES.

Urey, Harold C.

[1942?]. Decl. with deletions, Feb. 12, 1957, 22 p., $4.80 (ph. OTS); $2.70 (mf. OTS).

Columbia Univ., New York. Div. of War Research.

The effectiveness of thermal diffusion, Hertz diffusion, Maier diffusion, distillation, and chemical exchange methods for the separation of uranium isotopes is discussed.

37 NEW RESEARCH DEVELOPMENTS FOR INDUSTRIAL SCALE ISOTOPE SEPARATION.

Villani, S.

Energia nucleare (Milan) 4, 187-95 (1957) June. (In Italian).

Separation methods for ^{235}U, ^{2}H, ^{15}N, and ^{10}B are discussed.

38 EXCHANGE OF URANIUM BETWEEN BETA URANIUM PENTAFLUORIDE AND GASEOUS URANIUM HEXAFLUORIDE.

Davis, W. Jr. and Rutledge, G.P.

July 13, 1951. Decl. with deletions Feb. 27, 1957, 27 p.

Contract W-7405-eng-26, $4.80 (ph OTS); $2.70 (mf OTS). Carbide and Carbon Chemicals Co. K-25 Plant, Oak Ridge, Tenn.

K-790 (Del.)

Exchange of U between β UF_6 and gaseous UF_6 has been studied in the temperature range 80 to 140 °C. Series experiments, consisting of exposure of a sample of enriched (17.98 wt.% ^{235}U) UF_6 to several successive samples of normal UF_6, as well as one-exposure experiments have been performed. The decrease in first order rate constants indicates that neither chemical reaction at the gas-solid, interface nor diffusion of UF_6 through an adsorbed gas layer controls the rate of exchange of U between gas and solid. Exchange rates are compatible with a process controlled by diffusion of U in and through the solid. Estimates of the diffusion coefficient vary from 0.3 to 11 $\times$ 10^{-14} sq. cm/hr (on the basis of N_2 surface areas and the assumption of uniform particle size). The effect of temperature is poorly defined by the present data, being equivalent to an activation energy for diffusion of 7.3 $\pm$ 12.5 kcal/mole. Over the temperature range 80 to 140 °C the average value of the diffusion coefficient is 2.6 $\times$ 10^{-14} sq. cm/hr. (auth)

39 THE SEPARATION OF ^{235}U.

Caldirola, P.

Translated by Peters, E.G. from Energia nucleare (Milan) 3, Suppl. 74-81 (1956), 10 p. (IGRL-T/CA-59)

A brief description is presented of the principles on which the centrifugal separation and the "Trenndüse" processes for ^{235}U separation are based. A more detailed description of the gaseous diffusion process for ^{235}U separation is included. (auth)

40 A SUMMARY OF THE SEPARATION OPERATIONS.

Whatley, M.E.

Apr. 11, 1958, 102 p. Contract W-7405-eng-26, $2.75 (OTS).

Oak Ridge National Lab., Tenn.

ORNL-2477

The subjects discussed are: chemical engineering systems, common concepts used in separation operation, distillation, gaseous diffusion, solvent extraction, and ion exchange.

41 IBM-650 PROGRAM FOR THE MATHEMATICAL MODEL OF A MULTICOMPONENT CASCADE.

Denver, L.T. (Goodyear Atomic Corp., Portsmouth, Ohio).

March. 24, 1958, 7 p. Contract [AT(33-2)-1]. $1.80 (ph OTS); $1.80 (mf OTS).

GAT-DM-673

A program has been written for the IBM-650 electronic computer to compute the performance of a three-component gaseous diffusion cascade. The assays are evaluated section-wise from the top of the cascade downward to the point where feed material is introduced into the cascade, and then from the bottom of the cascade upward to this

feed point. An interpolation scheme has been built into this procedure so that the concentration of ^{235}U at the bottom of the enricher portion of the cascade will match the specified assay of the feed materials to seven decimal places. By results obtained from this computer program, the behavior of ^{234}U or ^{236}U can be predicted, and the effects of the separation of ^{235}U from the other components in the cascade system can be seen. (author)

42 EXPERIMENTAL INVESTIGATION OF EFFICIENCY VARIATIONS VERSUS PRESSURE IN THE ISOTOPES SEPARATION BY GASEOUS DIFFUSION METHOD.

Perona, G.(CISE, Milan).

Energia nucleare (Milan) 5, 327-31 (May 1958).

Research work has been conducted at the CISE laboratories to determine the effects of pressure variations on separation efficiency in gaseous diffusion units. An experimental confirmation is given of the Present and De Bethume law and the applicability of this theory to the separation of the uranium isotopes by gaseous diffusion. (author)

43 EFFECT OF URANIUM RECYCLE ON TRANSURANIC ELEMENT BUILDUP.

Arnold, E.D. (Oak Ridge National Lab., Tenn.).

Nuclear Sci. and Eng. 3, 707-25 (June 1958).

The buildup of the important transmutation products in irradiated uranium was calculated. Significant quantities of such products are produced upon irradiation with pile neutrons. These quantities are further increased with subsequent recycle through power reactors. The nuclides are ^{236}U, ^{237}U, ^{237}Np, and ^{238}Pu. Variables included were: irradiation levels of 6×10^{19} to 3×10^{21} n/cm^2; effect of recycle in the range 1 to 400 cycles and infinite recycle; initial fuel enrichment in the range of 0.5 to 3.0% ^{235}U; and the effect of fraction of ^{236}U removed by a gaseous diffusion plant reconcentration of ^{235}U in the range 0 to 100% removal. This last variable depends on the operational characteristics of the diffusion plant. The buildup of transmutation products may have many appreciable effects on the design and operation of fuel recycle. The decay time required will increase as a result of higher concentrations of ^{237}U; chemical separation plants may be required to separate ^{237}Np as well as uranium, plutonium, and fission products; and the buildup of ^{238}Pu in the plutonium product may create additional biological or handling problems. An important conclusion of this work is that all problems resulting from isotope buildup in the ^{235}U buildup chain may be decreased in seriousness by approximately an order of magnitude with removal of about 25% of the ^{236}U by re-enrichment in a gaseous diffusion plant. (author)

44 THE ^{236}U PROBLEM IN THE COMBINED OPERATION OF NUCLEAR POWER REACTIONS AND ISOTOPE SEPARATION PLANTS.

Garrett, G.A. and Levin, S.A. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

12 p. $0.50 (OTS).

Prepared for the Second U. N. International Conference on the Peaceful Uses of Atomic Energy, 1958.

The effect of ^{238}U on the ^{235}U separation process is considered in detail. The calculations are based on a model of the gaseous diffusion isotope separation cascade in which no mixing of streams which differ in ^{235}U concentration takes place. The effect of ^{236}U on the cost of enriched U is calculated and the results are given. A more complex case with alternate modes of operation is also considered.

45 PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON ISOTOPE SEPARATION HELD IN AMSTERDAM, APRIL 23-27, 1957.

Kistemaker, J., Bigeleisen, J., and Nier, A.O.C.

Eds. Amsterdam, North-Holland Publishing Company, 1958, 723 p.

Papers presented at the International Symposium on Isotope Separation held in Amsterdam, 1957, and the pertinent discussions are presented. Papers in English, French, and German are included in the fields of chemical engineering, molecular interactions. chemical exchange, electromigration, distillation, thermal diffusion, diffusion, electromagnetic separation, and the development of ultracentrifuges.

46 SHORTCUT TO URANIUM FUELS.

Chilton, C.H.

Chem. Eng. 65, No. 21, 138-41 (Oct. 20, 1958).

A process flowsheet for production of UO_2 from ore concentrates or scrap and the enrichment of this material with ^{235}U using UF_6 from the gaseous diffusion process is described. The end product from the process is enriched, ceramic-grade UO_2.

47 COLD TRAPS.

Thompson, W.I. (to U.S. Atomic Energy Commission).

U.S. Patent 2 853 859. Sept. 30, 1958.

A cold trap is presented for removing a condensable component from a gas mixture by cooling. It consists of a shell, the exterior surface of which is chilled by a refrigerant, and conductive fins welded inside the shell to condense the

gas, and distribute the condensate evenly throughout the length of the trap, so that the trap may function until it becomes completely filled with the condensed solid. The contents may then be removed as either a gas or as a liquid by heating the trap. This device has particular use as a means for removing uranium hexafluoride from the gaseous diffusion separation process during equipment breakdown and repair periods.

48 NUCLEAR ENGINEERING HANDBOOK.

First Edition. Harold Etherington, ed. New York, McGraw-Hill Book Company, Inc., 1958. 1872 p.

Garrett, G.A.

Gaseous-diff. Sep. Process, pp. 1438-1443.

This handbook is divided into fourteen major sections. These sections include: mathematical data and general tables; nuclear data; mathematics; nuclear physics; experimental techniques; reactor physics; radiation and radiological protection; control of reactors; fluid and heat flow; reactor materials; chemistry and chemical engineering; nuclear power plant selection; mechanical design and operation of reactors and isotopes.

49 ISOTOPE SEPARATION BY DIFFUSION IN A STEAM CURRENT.

Gverdtsiteli, L.G., Kucherov, R.Y., and Tskhakaya, V.K. (U.S.S.R.).
35 p.

Experimental and theoretical investigations were made of the separation of isotopes by diffusion in a stream of auxiliary steam. From an analysis of the results it was concluded that the method can be used for separating the isotopes of a number of gases. The method is recommended for obtaining highly enriched isotopes.

50 RÉALISATION D'UNE CHAINE EXPÉRIMENTALE DE CONCENTRATION ISOTOPIQUE DE L'HEXAFLUORURE D'URANIUM PAR DIFFUSION GAZEUSE.

Albert, H. (Société de recherches techniques et industrielles, Paris).
18 p.

Results obtained from the operation of an experimental gaseous diffusion unit for the separation of uranium isotopes using uranium hexafluoride are presented. The criteria for the selection of various apparatuses for the unit are discussed, and the principal apparatuses chosen are described. The principal difficulties encountered in the set-up and operation of the unit are discussed briefly.

51 APPLICATION OF CONVENTIONAL TECHNIQUES TO THE CONSTRUCTION OF A PILOT PLANT FOR THE ISOTOPIC SEPARATION OF URANIUM BY GASEOUS DIFFUSION.

Roubeix, G. (Société de recherches techniques et industrielles, Paris).
12 p.

The techniques presented are brought up to date according to the status of the knowledge when the pilot plant process was frozen at the end of 1956. The fundamental or applied research which went beyond this date is not included. Under vacuum techniques and surface techniques real leaks, desorption, chemical cleaning and degassing, and the pumping facility are discussed. The handling of UF_6 and measuring and regulating devices are discussed.

52 RE-ENRICHMENT OF DEPLETED URANIUM BY PASSAGE THROUGH A GASEOUS DIFFUSION INSTALLATION.

La Grange, P. and Bilous, O. (Commissariat à l'Énergie atomique, Paris).
26 p.

An economic study is presented of the reutilization of depleted uranium from reactors, whether its ^{235}U content be above or under natural proportions. Reutilization is possible either by mixing with a richer concentrate, or by passing it through a gaseous diffusion plant. The economics of passing it through some typical gaseous diffusion facilities are discussed.

53 INDUSTRIAL METHODS OF ^{235}U ENRICHMENT.

Istvan, K. (State Research Inst., Dept. of Chemistry).

Energia es Atomtech. 11, 466-73 (1958). (In Hungarian).

Electromagnetic, centrifugal, gaseous diffusion, and gas jet separation methods of ^{235}U are described. (See 78.)

54 URANIUM HEXAFLUORIDE GASEOUS DIFFUSION CASCADE INVENTORY CONTROL.

Rutledge, G.P. and Wernecke, A.H. (Goodyear Atomic Corp., Portsmouth, Ohio).

Ind. Eng. Chem. 51, 203-4 (Feb. 1959).

Equipment for determination of uranium-235 in a UF_6 diffusion cascade by utilizing operating vs. static pressure relationships was evaluated. One set of pressure-temperature data was collected during cell recycle operation, and a second set was collected after the compressors were stop-

ped, giving a comparison of static pressures and temperatures. Measurements were made until no further change was evident. A straight-line relationship between average recycle pressure and static conditions exists.

55 URANIUM ISOTOPE SEPARATION: A NEW INDUSTRY.

Geoghegan, G.R.H.

New Scientist 5, 468-72 (Feb. 26, 1959).

The gaseous diffusion separation process used in the British factory at Capenhurst is described, and consideration is given to the economic aspects of the plant. Information is also included on the basic principles of operation of the electromagnetic, gas-phase centrifuge, and jet processes.

56 THE DIFFUSION PROCESS FOR THE ENRICHMENT OF THE LIGHT ISOTOPE OF URANIUM.

Becker, E.W.

Translated by Rigby, B. (U.K.A.E.A., Capenhurst) from Chem.-Ing.-Tech. 29, 363-71 (1957), 17 p.

The principles of the diffusion process for the enrichment of ^{235}U and the methods of achieving favorable operating conditions are shown with reference to the optimal theory of the separation process developed by Cohen, Benedict, Dirac, and others. It is shown that the output of the American diffusion plants, although not known officially, can be estimated from their power consumption. For a depletion of a waste material to one-fifth of natural concentration this gives an output of about 25 tons ^{235}U per year as 20% material and a consumption of about 4 400 tons/year of natural uranium. The economics of the separation process is characterized by a "specific power consumption" ζ = 9 000 kwh/kg U and a "specific investment" ξ = 560 kg U per year. The official American price of ^{235}U corresponds basically to the total cost of power and materials. (author)

57 THE PILOT PLANT FOR ISOTOPE CONCENTRATION OF URANIUM HEXAFLUORIDE BY GASEOUS DIFFUSION.

Albert, H. (Société de recherches techniques et industrielles, Paris).

Bull. Inform. Sci. et Tech., No. 26, 2-8 (Feb. 1959). (In French).

The gaseous diffusion pilot plant for uranium isotope concentration constructed at Saclay is described. The characteristics, as well as the stages of its development, are discussed.

58 THE USE OF CRITICALITY CODES IN NUCLEAR SAFETY CONSIDERATIONS AT THE OAK RIDGE GASEOUS DIFFUSION PLANT.

Newlon, C.E. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

Apr. 6, 1959, 13 p. (KSA-175). $3.30 (ph), $2.40 (mf) OTS.

Paper presented at Fifth Annual Industrial Nuclear Safety Conference, March 9-11, 1959, Aiken, S.C.

The experience of the ORGDP nuclear safety group with criticality codes, which includes the COBRAS, GNU-II, and the PDQ codes, might be summarized by stating that, so far, criticality codes have proven useful in the evaluation of nuclear safety problems which otherwise would have been extremely laborious and in some cases essentially impossible without the use of simplifying assumptions which are only qualitative at best. In general, the results of the machine calculations have been in fairly good agreement with the results of critical mass experiments, certainly when the uncertainties of the basic nuclear input data are considered. Thus, it would appear reasonable to anticipate that criticality codes will play an increasingly important role, not only in nuclear safety evaluations of the ever present criticality problems in a gaseous diffusion plant, but in facilitating the continued development and improvement of criticality control criteria in general. (author)

59 CRITICALITY DATA AND NUCLEAR SAFETY GUIDE APPLICABLE TO THE OAK RIDGE GASEOUS DIFFUSION PLANT.

Henry, H.F., Mallett, A.J., Newlon, C.E., and Pryor, W.A. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

May 22, 1959, 53 p. Contract W-7405-eng-26. $1.50 (OTS).

The available minimum experimental and theoretical criticality information for ^{235}U enrichments of 1% to $\sim$ 90% are presented together with the fundamental nuclear safety control criteria currently in effect at ORGDP. The fundamental nuclear safety criteria remain essentially unchanged from the previous edition of the report with the exception of the extension of nuclearly safe variables under 5% ^{235}U enrichment, the increase of the minimum ^{235}U enrichment considered to be non-reactive from 0.71 to 0.90%, and a statement of a new mass-volume principle. Other additions include guides for computing a solid angle and applying nuclearly safe variables to uranium materials, other than metal, of intermediate densities. (author)

60 THE CONCENTRATION OF ^{235}U: SURVEY OF MOST IMPORTANT METHODS AND PRINCIPLES.

Havlicek, F.I. (Institute J. Stefan, Ljubljana, Yugoslavia).

Energia nucleare (Milan) 6, 521-31 (Aug. 1959). (In Italian).

Diffusion, physical-chemistry, and electromagnetic methods for the separation of uranium isotopes are reviewed. An account is given of the principles on which each is based, a critical examination is made of the possibilities they offer, and a number of experimental devices are described. (author) (trans. 71).

61 SEPARATING ISOTOPES OF URANIUM. DEVELOPMENT OF AN INDUSTRIAL-SCALE PROCESS.

Hurley, F.I. (United Kingdom Atomic Energy Authority, Capenhurst, Ches., Eng.).

Research (London) 12, 417-23 (Oct.-Nov. 1959).

The design problems encountered in establishing the gaseous diffusion process for separating uranium isotopes on an industrial scale are described.

62 GAS CENTRIFUGES.

Groth, W.E. (Univ. of Bonn).

Research (London) 12, 467-74 (Dec. 1959).

The theoretical basis of the centrifugal method is discussed. Various types of thermally controlled countercurrent gas centrifuges are described. Enrichment experiments with three different centrifuge models determined the static enrichments, the dependence of the enrichment on the throughput, and the separation potential of the centrifuges. Experimental separation potentials of the gas centrifuge method were compared with the gas diffusion method for the enrichment of the uranium isotopes. (author)

63 GERMAN PROCESSES FOR URANIUM ISOTOPE ENRICHMENT.

Groth, W. (Universität, Bonn).

Chem. Ing. Tech. 31, 310-18 (May, 1959). (In German).

The gas-diffusion and jet separation processes and the gas centrifuge treatment are described and their economic prospects are compared. For gas centrifuging theoretical and technical details and experimental results with the isotopes of xenon and argon are reported. (author) (trans. 67).

64 SOME PROBLEMS STATED BY THE PUMPING OF AN EXPERIMENTAL CHAIN OF ISOTOPE SEPARATION BY GASEOUS DIFFUSION.

Doré, R.

Vide 14, 183-96 (July-Aug. 1959). (In French and English).

The performance of a pilot plant for isotope separation by gaseous diffusion is discussed relative to the vacuum apparatus and techniques employed for combating desorption and corrosion.

65 POTENTIAL OF THE SHORT BOWL GAS CENTRIFUGE FOR THE ENRICHMENT OF THE ^{235}U ISOTOPE AS COMPARED WITH PUBLISHED FIGURES FOR GAS DIFFUSION.

Zippe, G. (Virginia. Univ., Charlottesville. Research Labs. for Engineering Sciences.

Mar. 1960, 11 p. Contract [AT(40-1)-2400]. (EP-2823-100-6OU). OTS.

An economic comparison was made between the use of the short-bowl gas centrifuge and gas diffusion for the enrichment of ^{235}U.

66 A PROCEDURE FOR DETERMINING THE DEGREE OF ENRICHMENT OF ^{235}U FROM THE ALPHA ACTIVITY OF THE URANIUM ISOTOPES.

Bernhard, F., Blumentritt, G., and Schintlmeister, J.

(Lehrstuhl für Kernspektroskopie der Technischen Hochschule, Dresden).

Atompraxis 6, 154-8 (Apr.-May, 1960). (In German).

If ^{235}U is enriched by diffusion, the ratio between the isotopes ^{234}U and ^{238}U is altered. Measurement of the intensity of the α-rays of these isotopes indicates the degree to which ^{235}U has been enriched. The procedure is especially sensitive to slight enrichment. The measurements can be carried out easily. A proportional counter counts the α-rays emitted from a very thin layer of uranium surrounding the counter at a distance of 14 cm. Because of this considerable distance, the surface of the preparation is 1 900 cm^2. The rays are collimated. The range distribution of the α-rays from the preparation is registered by changing the air pressure in the measurement chamber. The voltage of the counter is adjusted according to the pressure. (author)

67 GERMAN PROCEDURES FOR THE ENRICHMENT OF THE URANIUM ISOTOPE.

Groth, W.

Translated by J.R. Arndt from Chem. Ingr. Tech., 31, No. 5, 310-18 (1959), 15 p.

This paper was previously abstracted from the original language and appears in NSA, Vol. 14, abstract No. 7670. (orig. 63)

68 URANIUM CONCENTRATION.

Yoshitoshi Oyama (Tokyo Inst. of Tech.).

Genshiryoku Hatsuden, 4, No. 3-4, 23-8 (1960). (In Japanese).

A brief survey of the historical background and of the present status of the enrichment methods is given. Gaseous diffusion, centrifugal, and nozzle separation are considered of interest for application in Japan. The ideal and the squared-off cascade concepts are discussed for arriving at an economic evaluation of the ^{235}U plant design. On the basis of cost calculations published by USAEC and the Saclay Nuclear Study Center, the economic bases of the gaseous diffusion method are given, including the estimation of the required capital investment and operating costs for plants installed in France and in Japan, comparing the estimated production costs with the U. S. data. Results indicate that the costs exceed the U. S. values by 50 to 90%. Groth and Zippe's data for UF_6 separation are included in a survey of the centrifuge method for isotope separation, comparing the power and capital costs with those required for the gaseous separation method, without drawing definite conclusions for lack of data. Leroy's survey on the nozzle separation method is expanded by including 20 additional references. Treatment of the jet stream and Becker's experimental data for UF_6 separation is discussed.

69 ACTUAL METHODS FOR THE ENRICHMENT OF ^{235}U.

Martensson, M.

Tek. Tidskr., 89, 487-93 (1959). (In Swedish).

A review of methods for the enrichment of ^{235}U is presented. The separation processes discussed are gaseous diffusion, effusion through a nozzle, and gas centrifugation. Equipment diagrams and principles of operation are included.

70 ISOTOPE SEPARATION.

Walcher, W.

Translated for Oak Ridge Gaseous Diffusion Plant from Ergeb. exakt. Naturw., 18, 155-6, 175-91, 206-13, 219-23, (1939), 60 p. (Includes original, 6 p.).

Selected parts of a review of isotope separation methods were translated. These parts include those dealing with diffusion, thermal diffusion, centrifuge, and a comparative evaluation of methods.

71 (AEC-tr-4753) CONCENTRATION OF ^{235}U: REVIEW OF SOME OF THE MOST IMPORTANT METHODS AND PRINCIPLES.

Havlicek, F.I.

Translated for Oak Ridge Gaseous Diffusion Plant from Energia nucleare (Milan), 6, 521-31 (1959), 38 p.

This paper was previously abstracted from the original language and appears in NSA, Vol. 13, abstract No. 20000. (orig. 60)

72 METHOD OF ISOTOPE SEPARATION.

Girodin, M.G.H.

French Patent 1,240,085. July 25, 1960.

Isotope separation processes are offered in which a reciprocal diffusion is effected between a gas, e.g. UF_6, and an auxiliary gas, e.g. Ar. The two gases are either countercurrently fed on either side of a diffusion barrier or countercurrently fed into a low speed tubular centrifuge. The effluxes are separated into the two constituent gases by freezing.

73 (MLM-1115) MOUND LABORATORY MONTHLY PROGRESS REPORT FOR MAY 1961 (ON PLASTICS, RADIOELEMENTS, ISOTOPE SEPARATION, AND REACTOR FUELS).

Eichelberger, J.F. (Mound Lab., Miamisburg, Ohio).

May 30, 1961. Contract AT-33-1-GEN-53. 18 p.

Formulation of 13 new epoxy-modified polyurethane systems were cast and cured. Results of chemical tests on an epoxy curing exudate are included. Comparison of solvent effects on retention of radioelements by stainless steel was started and data are tabulated for ^{227}Ac, ^{227}Th, and ^{223}Ra. Work on protactinium was resumed after suspension of this project in 1960. Methods for preparation of small quantities of highly enriched U isotopes are being examined. Included in the survey are chemical exchange electromagnetic separation, gaseous and liquid thermal diffusion, gas centrifugation, and photochemical techniques. Continued investigation of viscosities of La and Pr for use in Pu alloys is reported. Phase studies of Au-Pt systems were continued along with studies of Pu bearing glass fibers.

74 MULTICOMPONENT ISOTOPE SEPARATION IN CASCADES.

de la Garza, A., Garrett, G.A., and Murphy, J.E. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

Chem. Eng. Sci., 15, 188-209 (1961).

A theoretical study is presented of multicomponent isotope separation cascades. A theory is developed which leads to the multicomponent analog of the two component ideal cascade. The multicomponent is a matched abundance ratio cascade. Multicomponent analogs are derived for value functions, separative work, and various relationships in two-component isotope separation cascade theory. The theory is applied specifically to the derivation of a multicomponent cost formula which could be used to price ura-

nium containing ^{236}U. The multicomponent matched abundance ratio cascade does not minimize total cascade flow as does the two-component ideal cascade. It is found, however, that for uranium isotope separation the total flow in the matched $^{235}U/^{238}U$ abundance ratio cascade exceeds the minimum by an insignificant fraction for a wide range of ^{236}U concentrations. (author)

75 (CEA-tr-X-291) CONTRIBUTION A L'ÉTUDE DU COEFFICIENT DE PARTAGE DANS LA MÉTHODE DE DIFFUSION GAZEUSE (CONTRIBUTION TO STUDY OF SEPARATION COEFFICIENT IN METHOD OF GASEOUS DIFFUSION).

Tanaka, K.

Translated into French from Nippon Kagaku Zasshi, 79, 740-4 (1958), 24 p.

An approximate calculation of the coefficient of separation during the first phase of separation by the method of gaseous diffusion was attempted by using uranium hexafluoride as an example. The results obtained have shown that in the intermediary domain between r (diameter of the micropore) $< \lambda$ (mean free displacement) and $r > \lambda$; the first order combination of the Knudsen and Poiseuille flows permits an approximate calculation of the coefficient of separation. On the other hand it is known that if $r = 1$, the surface diffusion on the wall of the micropores affects the separation phases for a perfect gas. In the case where the square root of the mean distance l^2 at which a molecule adsorbed at the surface of the wall is approximately equal to the diameter of the opening r, the surface diffusion also affects the separation phases. Under these conditions, the solution of the diffusion equation which takes into consideration the surface diffusion permits the coefficient of diffusion to be found. (trans-author)

76 (NP-tr-817) SOME METHODS OF PRODUCING ENRICHED ^{235}U.

Ho Ping.

Translated from K'o Hsueh T'ung Pao, No. 2, 36-41 (Jan. 26, 1959), 10 p.

Methods for producing uranium are described as gaseous diffusion, supersonic jet pump, super-centrifuge, magneto-ionic expansion, ionic migration, and electromagnetic separation. A comparative table on the methods is included for rate of production, separation factor, cost scale, material, problems, and present progress.

77 (AEC-tr-4983) GAS CENTRIFUGAL SEPARATION.

Akira Kanagawa.

Translated for Oak Ridge Gaseous Diffusion Plant, Tenn., from Genshiryoku Hatsuden, 4, Nos. 3-4, 49-61 (1960), 55 p.

The gas-centrifugal separation method as a uranium enrichment method is discussed from the standpoint of its historical development, theoretical and technical problems, and its economics as compared with the gas diffusion method. The possibilities and problems in the future development of this method are outlined.

78 (CEA-tr-X-397) MÉTHODES INDUSTRIELLES POUR L'ENRICHISSEMENT DE ^{235}U (INDUSTRIAL METHODS FOR ENRICHMENT OF ^{235}U).

Istvan (E.) Kiss.

Translated into French from Energia es Atomtech., 11, 466-73 (1958), 32 p. (Includes original, 8 p.).

In the selection of an industrial method for the enrichment of ^{235}U, the enrichment factor, the chemical and physical characteristics of the materials participating in the enrichment process, the engineering possibilities of the method, and the economics of the method must be considered. The gaseous diffusion process and the centrifugation process for heavy isotopic enrichment are discussed, and the enrichment factors are calculated theoretically. Cascade parameters and equilibrium times are calculated for the two processes. The energy requirements for a gaseous diffusion cascade and the engineering problems of such a plant are reviewed. (orig. 53)

79 AN ANALYSIS OF GASEOUS DIFFUSION SEPARATING UNIT.

Jun Oishi (Kyoto Univ.), Yoichi Matsumura, Kunio Higashi, and Chieko Ike.

Nippon Genshiryoku Gakkaishi, 3, 923-8 (Dec. 1961). (In Japanese).

An analysis was made of two types of gaseous diffusion separating units. One type was such that the flows of unpermeated and permeated gas were rod-like and parallel with each other, and the other was such that the flows were counter-current. The analysis was a numerical calculation, and the characteristics of the separating unit, that is, gas composition, gas flow rate, separation factor, and separative power, were found. Discussions are given on the comparison of the characteristics of several types of separating unit, and it was concluded that the counter-flow type showed the best performance of separation. (auth) (trans. 85)

80 (K-1455) SOME VALUE FUNCTIONS FOR MULTICOMPONENT ISOTOPE SEPARATION—APPLICATION TO A UNIT COST SCALE FOR ^{235}U, ^{236}U, ^{238}U MIXTURES.

de la Garza, A., Garrett, G.A., and Murphy, J.E. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

July 19, 1960. Contract W-7405-eng-26. 76 p.

A theoretical study is presented of multi-component isotope separation cascades. A theory is developed which leads to the multi-component analog of a two component ideal cascade. The multi-component analog is a matched abundance ratio cascade. Multi-component analogs are derived for value functions, separative work, and various

relationships of importance in two component isotope separation cascade theory. The theory is applied specifically to the derivation of a multi-component cost formula which could be used to price U containing ^{236}U. (This cost formula is derived merely as an illustration of the theory and no recognition or commitment on the part of the USAEC is implied.) The multi-component matched abundance ratio cascade does not minimize total cascade flow as does the two component ideal cascade. It is found, however, that for U isotope separation the total flow in the matched $^{235}U/^{238}U$ abundance ratio cascade exceeds the minimum by an insignificant fraction for a wide range of ^{236}U concentrations. (author)

81 (CEA-2009) CINÉTIQUE DES CONCENTRATIONS DANS UNE USINE DE SÉPARATION ISOTOPIQUE (CONCENTRATION TRANSIENTS IN A GASEOUS DIFFUSION PLANT).

Jacques, R., and Bilous, O. (Commissariat à l'Énergie atomique. Centre d'études nucléaires, Saclay, France).
1961, 36 p.

Concentration transients are examined in the case of a gaseous diffusion plant for U isotope separation. An application is made to a plant having two rectifying cascades of different sizes and a stripping cascade. Transients are calculated for a change in the feed concentration, for a change in the transport, and for the shutdown of a group of separating stages in one of the cascades. (trans-author)

82 (K-1508) OPTIMUM FLOW DISTRIBUTION FOR MULTICOMPONENT ISOTOPE SEPARATION IN A SINGLE CASCADE.

Murphy, J.E. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

Jan. 17, 1962. Contract W-7405-eng-26. 34 p.

The separation of isotopic mixtures containing three components in a gaseous diffusion cascade operating over an infinite reservoir is discussed. The flow distribution yielding the smallest total flow per unit product was found and compared with the flow distributions in some other theoretical cascades. Curves are presented to show the number of stages required, the total flow and the concentration gradients for both light and middle isotope separation. (author)

83 (CEA-2010) ÉTUDE SUR SIMULATEUR DES RÉGIMES TRANSITOIRES DES CONCENTRATIONS DANS UNE INSTALLATION DE DIFFUSION GAZEUSE (SIMULATOR STUDY OF CONTROL OF CONCENTRATION TRANSIENTS IN A GASEOUS DIFFUSION PLANT).

Delarousse, P., Trouve, C., and Jacques, R. (Commissariat à l'Énergie atomique. Centre d'études nucléaires, Saclay, France).
1962, 45 p.

A finite difference system is used to describe concentration transients in a gaseous diffusion plant for uranium isotope separation. The equipment used in this study is described and examples are given to illustrate the problems which have been solved with it. (author)

84 (TID-15054) APPLICATION OF MULTICOMPONENT CASCADE THEORY.

Bigelow, J.E., and McTigue, G.E. (Division of Operations Analysis and Forecasting, AEC).

Nov. 1961, 26 p.

A discussion is presented concerning the application of theoretical isotope separation cascades operating on a mixture of three or more isotopes. Attention is directed to stripping ^{232}U from other isotopes associated with a reactor fuel such as that used in the Consolidated Edison Thorium Reactor. Theoretical considerations are presented along with cost calculations.

85 (AEC-tr-5134) ANALYSIS OF A GASEOUS DIFFUSION SEPARATIVE UNIT.

Jun Oishi, Yoichi Matsumura, Kunio Higashi, and Chieko Ike.

Translated for Oak Ridge Gaseous Diffusion Plant, Tenn., from Nippon Genshiryoku Gakkaishi, 3, 923-8 (1961), 16 p.

This paper was previously abstracted from the original language and appears in NSA, Vol. 16, abstract No. 7820. (orig. 79)

86 (CEA-2160) RÉGULATION DES CONCENTRATIONS DANS UNE USINE DE SÉPARATION ISOTOPIQUE (CONCENTRATION CONTROL IN AN ISOTOPE SEPARATION PLANT).

Jacques, R. (Commissariat à l'Énergie atomique. Centre d'études nucléaires, Saclay, France).

1962, 37 p.

Concentration control is examined for the case of a gaseous diffusion plant for uranium isotope separation. The effects of various typical perturbations are described and adequate systems of corrective actions are determined according to selected criteria. (author)

87 (K-1527) A GENERALIZATION OF THE MATCHED ABUNDANCE RATIO CASCADE FOR MULTICOMPONENT ISOTOPE SEPARATION.

de la Garza, A. (Oak Ridge Gaseous Diffusion Plant, Tenn.).
July 20, 1962. Contract W-7405-eng-26. 25 p.

Matched abundance ratio cascades were introduced to the subject of multicomponent isotope separation in cascades. These cascades are formed in such a manner that the abundance ratio of two key components is matched wherever two streams come together, i.e., at all stage links and feed points. For a three-component mixture, for example, there are three (independent) abundance ratios, and accordingly, there are only three matched abundance ratio cascades which may be formed to process the mixture. The matched abundance ratio cascades can be generalized by considering matched abundance ratio cascades whose key components are dummy components, and the separation characteristics of these cascades can be varied by the choice of the molecular weights of the two dummy components. A generalization of the original matched abundance ratio cascades is presented. In so doing, closed and explicit formulas are developed for the usual unknowns in the resolution of the productivity of a three-stream cascade. In this way the laborious computations necessary to balance out a cascade in all the components are practically eliminated. The optimization of cascade design permitted by the previously mentioned variation of the cascade separation characteristics is also discussed briefly for both an end-component and a middle-component separation. (author)

88 MULTICOMPONENT ISOTOPE SEPARATION IN CASCADES.

Clarke, D.J. (United Kingdom Atomic Energy Authority, Cheshire, Eng.).

Chem. Eng. Sci., 17, 709 (Sept. 15, 1962).

The adoption by de la Garza of a matched abundance ratio (matched R) as a mixing criterion in a three-component separation cascade is discussed. It is pointed out that there may be some operation conditions for a real cascade for which the separative power of a matched R cascade would be very different from that of the minimum power cascade. These conditions are associated with small ^{238}U concentrations, and an example is given in which a matched R cascade would lead to practically no separation of ^{235}U and ^{236}U.

89 DETECTION OF EXTRANEOUS MATERIAL DEPOSITIONS IN DIFFUSION PLANT EQUIPMENT.

McCluen, W.D. (Oak Ridge Gaseous Diffusion Plant, Tenn.). 4 p. (TID-17461).

To be published in the Proceedings of the AEC-Contractors Meeting, held in Chicago, October 1962.

Survey techniques were developed to detect inadvertent accumulations of nuclear materials in diffusion equipment. Initial detection was based on gamma radiation from ^{235}U. Subsequent quantitative evaluation relied on monitoring neutron radiation resulting from the collision between alpha particles and fluorine atoms. (author)

90 (K-1580) APPLICATION OF A SYSTEM OF BOLTZMANN EQUATIONS TO THE SEPARATION OF A BINARY GAS MIXTURE. (PART) II.

Hanan Rubin (TRG, Inc., New York).

Aug. 27, 1963. For Oak Ridge Gaseous Diffusion Plant, Tenn. Contract W-7405-eng-26. 24 p.

The separation of a binary gas mixture by diffusion through a porous barrier is studied theoretically. The structure of the barrier is averaged out, and a system of Boltzmann equations is approximated by H. Grad's method of moments. Viscosity effects are included, and the results obtained are similar to those of Present and de Bethune for a capillary. A precise comparison with their results is given. (author)

91 (AEC-tr-5986) ISOTOPE SEPARATION AND ENRICHMENT.

Bier, K., Fischer, W., and Dickel, G.

Translated by L.L. Smith (Savannah River Lab., Aiken, S. C.) from Chem. Ing. Tech., 34, 580 (1962), 8 p.

The enrichment of ^{235}U by the partition diffusion method and the problems involved are discussed. The state-of-the-art of uranium isotope separation by the gas centrifuge and partition jet methods is described briefly. The use of ion migration in the pre-enrichment of ^{46}Ca in ^{47}Ca prior to calutron enrichment is considered, and the migration model for explaining the measured mass effects is discussed. The problem of deriving a useful theory of thermal diffusion separations is considered; the invariant theory of the separative tube cascade was developed which uses separation work rather than separation efficiency. The results of centrifugal separation of argon isotopes in a vortex tube are given which were used to derive the separation mechanism.

92 PRINCIPLE OF GAS-CENTRIFUGAL SEPARATION AND ITS APPLICATION FOR SEPARATION OF ISOTOPES.

Huai-hsin Kan.

Hua Hseuh Tung Pao, No. 10, 534-9 (1961).

Basic principles are explained on the theory of gas centrifuges (GC) in its application for the separation of isotopes. Equations are given for the coefficient of separation of isotopes by thermal diffusion using an ordinary centrifuge and GC. The correlation of the separative power and separation coefficient are examined. Requirements are formulated with respect to materials and composition of certain alloys used in building GC. Methods of transfer of rotation, bearings, and compressions in the GC are briefly discussed. Characteristics are given of the performance of the GC built in the Federal Republic of Germany and eco-

nomical comparison is made of the separation of U isotopes by GC and gas diffusion.

93 APPLIANCE FOR SEPARATING FLUIDS BY DIFFUSION.

Vulpillat, M., and Depaule, S. (to Commissariat à l'Energie Atomique).

British Patent 938,127. Oct. 2, 1963. Priority date Nov. 4, 1959, France.

The appliance described consists of a fluid-tight casing containing a plurality of diffusion elements in the form of sleeves of elongated cross section arranged in side-by-side parallel relation with their larger sides facing one another and separated by spacing means. A primary inlet, an outlet for fluid being treated, and a secondary outlet for the fraction of fluid diffused are provided. The opposite open ends of the interior of the sleeves communicate with the primary inlet and outlet, and the spaces between the facing walls of the sleeves communicate with the secondary outlet. The sleeves may be made entirely of a porous material or they may be made of metal with perforations covered by a porous material. Preferably the diffusion elements are so shaped that projecting parts of the diffusion walls themselves provide the spacing means. Struts may be placed between the diffusing walls to prevent possible deformation. The appliance is suitable for separating isotopes of uranium.

94 (ORNL-tr-134) ECONOMIC ASPECTS OF THE ENRICHMENT OF URANIUM BY GASEOUS DIFFUSION.

Gaussens, J., Jacques, J. R., and Martin, C. (Commissariat à l'Énergie atomique, Paris, France).

Translated by S. Blumkin (Oak Ridge Gaseous Diffusion Plant, Tenn.), from a Paper from the SEAA Colloquium on Fuel Cycles, Baden-Baden, Germany, 34 p.

Some formulas to price enriched or depleted uranium were established as a function of economic (basis costs) and technical parameters (product and reject concentrations, separative work). A graphical method, resolving all the problems of determining the price, is presented. This method was applied to several problems such as plant optimization, acquisition of product by blending, and determination of a price scale for enriched or depleted uranium Results from the established scale are: the immediate neighborhood of the natural abundance is a particular region where the size of the cascade matters little; the establishment of price scales for depleted uranium is delicate and depends first on production policies imposed on the cascade; the price of enriched uranium decreases very strongly if the size of the cascade increases; and the price of enriched uranium is very sensitive to the design of the cascade. It was concluded that it is important to study the structure of the demand before constructing a diffusion cascade so as to conceive a cascade adapted as precisely as possible to this demand. The losses that can be expected from a poor adaptation can be much larger than the gains that can be realized from minimizing the cost of electrical power (choice of site) or of normal UF_6 (choice of supplies of U_3O_8). (author) (see 15)

95 HOW TOLL ENRICHMENT WILL REDUCE FUEL COSTS.

Herron, D.P. (FMC Corp., Santa Clara, Calif.).

Nucleonics, 22, No. 6, 62-3 (June 1964).

Toll enrichment arrangements, in which a reactor operator supplies to a gaseous diffusion plant either natural U or reactor-discharge material partially depleted in ^{235}U, and receives in return UF_6 of the enrichment desired for reactor feed, are discussed. Two separate arrangements are outlined: these differ in the mode of operation of the gaseous diffusion plant. The effects of toll enrichment on fuel costs are calculated.

96 ORGANIZATION AND METHODS USED FOR VACUUM TIGHTNESS AT THE PIERRELATTE ISOTOPE SEPARATION PLANT.

Mongodin, G., Delafosse, J., Deterck, H., Guilbard, C., and Benet, Y.

Vide, 18, 528-9 (Nov.-Dec. 1963). (In French).

The leakproof properties in a gaseous diffusion plant for the separation of ^{235}U involves numerous problems of vacuum techniques. The nature and scope of these problems and the tightness control equipment designed for the Pierrelatte complex are described. The efficiency of the quality control in the manufacture of the equipment is also considered. The use of the helium method for leak detection is discussed. The factors affecting the sensitivity of the method and those affecting the maximum rate of inspection of the components to be tested are examined. (trans-author) (trans. 173)

97 THE SEPARATION OF URANIUM ISOTOPES IN THE FRENCH NUCLEAR PROGRAM.

Couture, P. (Commissariat à l'Énergie atomique, Saclay, France) and Galley, R.

Energie Nucl., 6, 129-34 (May 1964). (In French).

Work done on the separation of ^{235}U in Pierrelatte, France is discussed. The advantages of enriched U over Pu as a nuclear fuel for specific applications are pointed out.

98 CONCENTRATION AND USE OF STABLE ISOTOPES.

Groth, W. (Universität, Bonn).

pp. 239-51 of "Atomstrahlung in Medizin und Technik", Munich, Verlag Karl Thiemig KG, 1964. (In German).

Methods for the concentration of deuterium and ^{235}U are summarized and contrasted. The principles of the dual-temperature method for deuterium enrichment is emphasized. The methods described for ^{235}U enrichment are gaseous diffusion and gas centrifugation. The methods used for the enrichment of isotopes of C, N, and O are indicated.

99 (A/CONF.28/P/89) DEDUCTIONS BASED ON STUDIES OF URANIUM ISOTOPE SEPARATION AND FRENCH ACHIEVEMENTS IN THIS FIELD.

Fréjacques, C., and Galley, R. (Commissariat à l'Énergie atomique, Paris, France).

May 1964, 13 p.

The work carried out in the field of uranium isotope separation, by gaseous diffusion and by ultracentrifugation, is reviewed. An economic estimate of the various parameters involved in the cost is given, and it is shown that only very large gaseous diffusion plants, corresponding to a program of enriched uranium reactors of at least 4 000 Mw(e) to be installed yearly, can give an economically acceptable enriched uranium production. (author) (see 102, 192, 197)

100 PIERRELATTE. THE CHEMICAL PLANTS. PREPARATION OF URANIUM HEXAFLUORIDE.

Level, A.

Énergie Nucl., 6, 225-32 (June 1964). (In French).

The description of the uranium hexafluoride manufacturing plant at the Pierrelatte chemical plant is preceded by a review of the properties and the various preparation methods of the product. Some indications are also given on the plants' operation and the results that were obtained during the first months of operation. Finally, the special security arrangements, due to the toxicity of the products that are handled, are also described. (author) (trans. 148)

101 A TECHNOLOGICAL MONUMENT: PLANT FOR SEPARATION OF ^{235}U AT PIERRELATTE.

Mériel, Y.

Nature (Paris), No. 3351, 255-8 (July 1964). (In French).

The Pierrelatte plant for the separation of ^{235}U by gaseous diffusion is one of the great technological achievements of France. The principles of the separation of U isotopes are briefly summarized. The major problem areas with respect to UF_6 are maintenance of the temperature above 57 °C, corrosive behavior of the gas, and its reactivity with all substances containing hydrogen. The enrichments in ^{235}U attainable at the plant are discussed.

102 REPORTS FROM THE GENEVA CONFERENCE. II. LESSONS DRAWN FROM FRENCH RESEARCH AND ACHIEVEMENTS IN THE SEPARATION OF URANIUM ISOTOPES.

Fréjacques, C., and Galley, R.

Ind. At., 8, Nos. 9-10, 63-7 (1964). (In French).

The accomplishments in the field of the separation of uranium isotopes by gaseous diffusion and by ultracentrifugation are discussed. An economic evaluation is made of the several factors involved in cost estimates. It is brought out that only the very big gaseous diffusion plants, corresponding to a program for the installation of enriched uranium reactors putting out at least 4 000 Mw(e) per year, can expect to produce enriched uranium at an economically acceptable level. (trans-author) (see 99, 192, 197)

103 THE SEPARATION OF URANIUM ISOTOPES.

Fiocchi, R. (CNEN, Ispra, Italy and Universitat Milan).

Comit. Naz. Energia Nucl., Notiziario, 10, No. 10, 19-23 (Oct. 1964). (In Italian).

Problems in the separation of ^{235}U are briefly described. Recent developments on separation methods and progress made in the studies of gaseous diffusion separation are also discussed. (trans-author)

104 ISOTOPE SEPARATION BY GAS CENTRIFUGES.

Boettger, O. (AEG Forschungsinstitut, Frankfurt am Main).

Kerntechnik, 6, 571-6 (Dec. 1964). (In German).

As a measure for separating effect the separation potential is introduced. The principles of operation of a gas centrifuge are shown and the theoretical separation potential given. It was found to depend on the mode of operation what fractions of the theoretical separation potential may be reached. The centrifuge method and the diffusion method for the separation of UF_6 were compared as regards economics. (author)

105 (P-1231(RAND)) A LINEAR PROGRAMMING MODEL OF THE GASEOUS-DIFFUSION ISOTOPE-SEPARATION PROCESS.

Fort, D. (RAND Corp., Santa Monica, Calif.).

Dec. 12, 1957, 26 p. (AD-606605). $2.00 (CFSTI).

A linear programming model of the gaseous diffusion process for separating uranium isotopes is developed using the theoretical or engineering approach. A brief description is given of the physical separation process. It is shown how the physical relationships may be translated into linear programming terms. The application of the model in larger models of the nuclear materials and power industry is considered.

106 (ORNL-TM-1047(p.137-43)) THE GAS CENTRIFUGE.

Evans, E., C.

(Oak Ridge Gaseous Diffusion Plant, Tenn.).

The use of gas centrifuges for radioisotope separations is discussed. Data on the important process parameters for the separation of U isotopes with gaseous diffusion and gas centrifugation are tabulated. Considerations influencing the choice of process gas for gas centrifuge are listed. Special attention is given to the Zippe type centrifuge, which combines the separator, pump, and seal all in one machine.

107 THE GROWTH OF AN INTEGRATED FUELLING SERVICE FOR POWER REACTORS.

Norman, K. J.

pp. 65-76 of Giornate dell'Energia Nucleare 1964.

Milan, Federazione delle Associazioni Scientifiche e Tecniche, 1965.

Facilities for reprocessing and fabricating Magnox-reactor fuel elements, AGR fuel elements, and fuel elements for a steam-generating heavy-water power reactor using UO_2 fuel are described. Facilities for enriching uranium by gaseous diffusion, and for fabricating and processing plutonium, are discussed. The operation of the British fuel-cycle-service system is outlined.

108 REVIEWS OF ISOTOPE SEPARATION RESEARCHES IN JAPAN. ACTIVITIES OF THE SPECIAL COMMITTEE ON ISOTOPE SEPARATION.

Nippon Genshiryoku Gakkaishi, 7, 429-37 (Aug. 1965). (In Japanese).

The Special Committee on Isotope Separation of the Atomic Energy Society of Japan was established in April 1963 and ended in March 1965. Studies were made on the separation of natural isotopes. The isotopes separated included D, ^{6}Li, ^{7}Li, ^{10}B, ^{13}C, ^{15}N, ^{18}O, ^{39}K, ^{40}Ar, and ^{235}U. The methods of separation adopted included gaseous diffusion, ultracentrifuge, thermal diffusion, molecular distillation, chemical exchange and electrophoresis. (author)

109 PIERRELATTE — USINE DE SÉPARATION DES ISOTOPES DE L'URANIUM (PIERRELATTE—PLANT FOR SEPARATION OF URANIUM ISOTOPES).

Commissariat à l'Énergie atomique, Paris. 1964, 38 p.

The design and development of the Pierrelatte Isotope Separation Plant is described. The isotopic enrichment processes used are electromagnetic separation, thermal diffusion, centrifugation, expansion in a shock tube, and gaseous diffusion. The principle of each of these methods is described briefly. The characteristics of the plant are given.

110 (K-OA-1313) TABLES OF 10-10 URANIUM UNIT COST COMPONENTS.

(Oak Ridge Gaseous Diffusion Plant, Tenn.).

Jan. 27, 1965. Contract W-7405-eng-26. 94 p. Dep. mn. CFSTI $3.00 cy, $0.75 mn.

The tables are to be used in calculations involving gaseous diffusion plant operations. The tables list the natural feed cost component and the separative work cost component of uranium at tails assays from 0.10 to 0.65% ^{235}U for a natural feed unit cost of $10.00/kg U as UF_6 and a separative work unit cost of $10.00/kg U. The tables can be used to calculate the unit cost of uranium at other unit costs of natural feed and separative work.

111 AEC, INDUSTRY, UTILITIES EXPLORE PRIVATE ENRICHMENT POSSIBILITIES.

Grant, J.

Nucleonics, 25, No. 2, 54-7, 84 (Feb. 1967).

Views of the AEC, private industry, and public utilities on the possibility of private uranium enrichment are discussed. Some questions considered are: the urgency of private participation in enrichment; availability of classified information; prospects for methods of enrichment other than gaseous diffusion; would a monopoly be created which would damage competition; and would private enrichment bring cheaper fuel costs and if so would savings be passed on to public utilities. A short history of uranium enrichment in the U.S. is given. Other methods of enrich-

ment such as thermal diffusion, electromagnetic, gas centrifuging, and chemical separation are summarized.

112 (K-L-6117-2) FUTURE USE OF FLUORINE AND FLUORIDES IN THE NUCLEAR INDUSTRY.

Smiley, S. H. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

[nd]. Contract W-7405-eng-26. 7 p. (CONF-660907-11). Dep. CFSTI.

From American Chemical Society Meeting, New York.

The preparation and use of inorganic fluorides and fluorine in the nuclear industry is reviewed. The use of fluorides, in particular UF_6, was initiated in the gaseous diffusion concept for separating ^{235}U from its naturally occurring isotopic mixture. The future of fluorides is also associated with the demand for enriched U, and thus for UF_6.

113 (ORO-656) URANIUM HEXAFLUORIDE SPECIFICATIONS STUDIES.

An AEC Program Status Report. (Oak Ridge Operations Office (AEC), Tenn.). July 12, 1967. 41 p. Dep. CFSTI.

The results of studies made by the Uranium Hexafluoride Specifications Study Committee are discussed. Recommendations are also included. Information is included on: need for specifications; current specifications for UF_6 delivered to the AEC; analytical procedures; formation of ^{232}U in power reactors; ^{232}U in gaseous diffusion cascades; formation and separation of transuranic elements; transuranic problem in the gaseous diffusion plants; sorption for removing impurities; and flow tests.

114 URANIUM ENRICHMENT SERVICES CRITERIA AND RELATED MATTERS. HEARINGS BEFORE THE JOINT COMMITTEE ON ATOMIC ENERGY, CONGRESS OF THE UNITED STATES, EIGHTY-NINTH CONGRESS, SECOND SESSION, AUGUST 2, 3, 4, 16, AND 17, 1966.

Washington D.C., Joint Committee on Atomic Energy, 1966. 538 p. GPO $1.75.

Uranium—enrichment services criteria for procurement and reserves of

Reactor fuels—raw material procurement and fabrication of

Isotopes—separation facilities for

Plutonium—production of

Gaseous diffusion plants—operation of

Atomic energy, legal aspects—AEC authorizing legislation, fiscal year 1968

Economics—costs of nuclear fuels.

115 (ORO-658) AEC GASEOUS DIFFUSION PLANT OPERATIONS.

(Atomic Energy Commission, Washington, D.C.).

Feb. 1968. 45 p. Dep. CFSTI. DTIE.

Information is provided on the physical features, operating requirements, economics, potential improvements, and capabilities of each of the three gaseous diffusion plants. The comparative economics of joint versus independent plant operations are discussed. Appendices include: a discussion of separative work as it relates to gaseous diffusion plant operations, the Commission's standard table of enriching services along with formulas used in developing the respective values, and criteria on uranium enrichment services in facilities owned by the AEC.

116 DECREASE OF THE SEPARATION POWER UNIT COST OF AMERICAN GASEOUS DIFFUSION PLANTS.

Blum, J. M.

Énerg. nucl. (Paris), 9, 517-21 (Dec. 1967). (In French).

The United States AEC has published a new table of the separation power units necessary for various possible enrichments of U as a function of the new cost of the separation power unit fixed at $26 for a standard reject rate of the plants of 0.2%. The cost of enriched U in the United States is analyzed on the basis of plant optimization and the results of this new cost table.

117 SOME TECHNOLOGICAL AND EXPERIMENTAL PROBLEMS INVOLVED IN THE CONSTRUCTION OF THE GASEOUS DIFFUSION UNIT AT PIERRELATTE.

Énerg. nucl. (Paris), 9, 489-95 (Dec. 1967). (In French).

Preliminary surveys for the construction of the plant at Pierrelatte, carried out by the French Atomic Energy Commission, or under its direction, have involved a wide range of technical fields. Some of the major technological and experimental problems dealt with in this phase of surveys for the plant are reviewed, and the wide-ranging influence of a scheme like Pierrelatte on the development of advanced techniques in industry is indicated (author)

118 CHARACTERISTICS OF A TAPERED CASCADE FOR ISOTOPE SEPARATION BY GASEOUS DIFFUSION.

Higashi Kunio, Oya Akio, Oishi Jun (Kyoto Univ.).

Nucl. Sci. Eng., 32, 159-65 (1968).

Usually a number of separating stages have to be connected in series to attain the desired degree of isotope separation by gaseous diffusion. Such a series-connected group of stages is called a cascade. The differential equation describing the time-dependence of a tapered cascade in which the interstage flow changes stage by stage is derived and solved under some reasonable assumptions. On the basis of these analytical results, the static and dynamic characteristics of a tapered cascade are discussed. For the same total number of stages, the cascade requiring the largest equilibrium time to reach steady-state condition is described. Also shown is that the so-called ideal cascade is not recommended from the standpoint of dynamic characteristics, although its superiority in static characteristics is familiar. It is pointed out that by a slight reduction of the cut θ from that of the ideal cascade θ_{ideal} the dynamic characteristics are improved to some extent, but the selection of θ greater than θ_{ideal} results in both static and dynamic characteristics being unfavorable. It is also shown that the equilibrium time of a tapered cascade tends to increase with the total number of stages N in proportion to N^2 as in a square cascade. The top stage is not always the last to reach the steady-state condition. A simple method is proposed to predict how the equilibrium time differs in each stage of the cascade. (author)

119 GASEOUS DIFFUSION PLANTS FOR ENRICHED URANIUM PRODUCTION.

Engineer, 225, 642-4 (April 19, 1968).

The U.S. gaseous diffusion plants at Oak Ridge, Paducah, and Portsmouth are briefly described, and the integration of their operation is illustrated. The costs of separative work are discussed.

120 TWO NUCLEAR STUDY GROUPS RELEASE IMPORTANT CONCLUSIONS.

Nucl. News, 11, No. 8, 5-8 (Aug. 1968).

A feasibility study is described which was conducted to determine the desirability of transferring the AEC's uranium enrichment facilities to private industry, It was concluded that private ownership and operation of the AEC's three gaseous diffusion plants is not only feasible but also preferred to continued government operation. The existence of a profit motive under private ownership to advance the technology and reduce costs was cited as the primary reason for advocating the transfer.

121 (K-Trans-37) BASIC RESEARCH ON GASEOUS DIFFUSION SEPARATIONS.

Higashi, Kunio.

Translated for Union Carbide Corp., Nuclear Div., Oak Ridge, Tenn., from a Japanese Thesis. 116 p. Dep. CFSTI.

Studies of the basic aspects of gaseous diffusion separation are discussed. Topics covered include: previous theoretical treatment of gaseous diffusion separation, mechanisms of surface diffusion, separation of a two-component gas with surface diffusion, separation of isotopes by surface diffusion flow, isotope effects on surface diffusion flow, method of selccting optimum operating conditions for gaseous diffusion separation equipment, and flow pattern of gases in gaseous diffusion separation.

122 (CONF-681015-1) POWER OPTIMIZATION FOR GASEOUS DIFFUSION PLANTS.

Levin, S.A. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

[nd]. Contract W-7405-eng-26. 13 p. Dep. CFSTI.

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy.

A method for optimizing the distribution of power over the various groups of stages in a gaseous diffusion plant for a given total plant power level is described. The mathematical model that permits the performance of a gaseous diffusion cascade to be determined is presented. A gaseous diffusion cascade is considered to be made up of many sections connected in series. Each section is composed of a number of identical stages and, therefore, within each section the interstage flows and stage separation factors are constant. The sections of a gaseous diffusion cascade are analogous to distillation columns with constant molal reflux and constant relative volatility and their behavior can be predicted mathematically with the use of equations familiar in distillation theory. The iterative procedure used to calculate the productivity of the gaseous diffusion complex, consisting of a series-parallel arrangement of cascade sections is described in detail. The power optimization problem is then treated. It can be described mathematically as finding the maximum of an objective function involving many variables subject to the constraining relationship of fixed total power input. The solution is obtained by Lagrange's method of undetermined multipliers. In order to employ this method, it is first necessary to relate the interstage flow and separation factor to the stage power input. For a given value of the Lagrange multiplier, an optimum power input, restricted by the maximum stage horsepower, is calculated for each section of the plant, again by an iterative scheme. The value of the Lagrange multiplier is adjusted until the desired total plant power is attained. An application of the model to a hypothetical gaseous diffusion plant is presented, which illustrates the gain that can be achieved from power optimization. (author)

123 (NP-17673) PRIVATE OWNERSHIP AND OPERATION OF URANIUM ENRICHMENT FACILITIES.

Report of a Forum Study Committee. (Atomic Industrial Forum, Inc., New York).

June 1968, 81 p. Atomic Industrial Forum, Inc., New York, $10.00.

In late 1966 a study committee was assigned the task of determining the feasibility of transferring by sale or lease part or all of its gaseous diffusion plants from the AEC to private owner-operators, and if this is feasible and desirable, when and how it could be accomplished. The work of the committee is reported and its recommendations given in detail. The essential recommendations are that each of the three AEC uranium enrichment facilities be sold to separate competing companies at the earliest date at competitively bid prices, and that the new owner-operators accept AEC recommendations on the cost and availability of enrichment services to meet future commercial and government needs.

124 (K-Trans-45) PIERRELATTE.

Hirsch, R. (and others).

Translated for Oak Ridge Gaseous Diffusion Plant, Tenn., from Énerg. nucl. (Paris), 9, 479-88 (Déc. 1967), 28 p.

Dep. CFSTI.

An introduction, a summary of the work involved in the startup and operation of the four Pierrelatte isotope separation plants, and a paper on uranium separation in France and in the world are included. A separate abstract was prepared for the latter.

125 (KFK-859) SEPARATION OF THE URANIUM ISOTOPES: A COMPARISON OF THE PROCEDURES UNDER DISCUSSION TODAY.

Becker, E.W. (Kernforschungszentrum, Karlsruhe, West Germany. Institut für Kernverfahrenstechnik).

Oct. 1968. 24 p. (In German). Dep.

The general construction of uranium isotope separation installations is described. The concepts of value function and separative work used for the characterization of their efficiency were explained. The technical details of the gaseous diffusion method, the gas centrifuge method, and the separating nozzle method, as far as they are from the open literature, are reported. The economic aspects of the three methods are compared.

126 GAS DIFFUSION INSTALLATIONS IN THE USA FOR THE PREPARATION OF ENRICHED URANIUM.

Wuensche, R. (Preussische Elektrizitäts-AG, Hanover).

At. Strom, 14, 137-41 (Oct. 1968). (In German).

The data published in a report by the American Atomic Energy Commission on its gas diffusion installations are summarized. Comprehensive data are given for the first time on the efficiency, the mode of operation and the economics of the installations. Attention is drawn to the possibilities of expanding the installations, and to the estimated costs for new enrichment installations based on the gas diffusion principle. (author)

127 (ORO-665, pp.121-45) U.S. GASEOUS DIFFUSION PLANT CAPABILITIES.

Sapirie, S.R. (Oak Ridge Operations Office (AEC), Tenn.).

Descriptions are given of the gaseous diffusion separation process for uranium enrichment, of the present operation of U. S. gaseous diffusion plants, and of plans for meeting future requirements for uranium enrichment services.

128 (ORO-665, pp.147-59) ENRICHMENT SERVICES ECONOMICS.

Quinn, G.F. (Atomic Energy Commission, Washington, D. C.).

The cost of uranium enrichment services in U. S. gaseous diffusion plants is discussed in terms of factors which influence the overall costs, plant capacities, and predicted charges through FY 1975.

129 ECONOMIC ASPECTS OF A EUROPEAN URANIUM ENRICHMENT INSTALLATION.

Brüchner, H.J. (Allgemeine Elektrizitätsgesellschaft, Frankfurt am Main).

Atomwirt., Atomtech., 14, 72-5 (Feb. 1969). (In German).

Some considerations on the economic aspects of a European uranium enrichment installation are presented. These include the size and cost of a gaseous diffusion plant, cost of alternative enrichment methods, and the financing and legal form of a plant. (trans. 150)

130 WHICH SEPARATION METHOD FOR URANIUM ENRICHMENT?

Dreissigacker, H.L., Schmidt-Keuster, W.J.

Atomwirt., Atomtech., 14, 71-2 (Feb. 1969). (In German).

In studies on methods to assure that the European needs for enriched uranium are fulfilled, the gas diffusion method is of primary importance since it has been tested to the fullest. The progress made in the development of two other separation methods, the gas centrifuge and the separation nozzle methods, is however so encouraging that the decision on the construction of large installation should be deferred until the advantages of the various methods are sufficiently compared. (trans-author)

131 PROSPECTS FOR A EUROPEAN ISOTOPE ENRICHMENT PLANT.

Michaelis, H.

Energ. Nucl. (Milan), 16, No. 3, 44-50 (Mar. 1969).

The development of installed nuclear power by 1980 in the European Community and the assurance for reliable uranium supplies are examined for source diversification, improvement of supply conditions from USA, and construction of an isotope separation plant. The arguments of technological and industrial nature of a plant are explained. The technical characteristics of separation processes such as gaseous diffusion and ultracentrifugation are reviewed. The various economic, financial, and judicial aspects of such undertakings are delineated. (author)

132 (ORO-668) SELECTED BACKGROUND INFORMATION ON URANIUM ENRICHING.

(Atomic Energy Commission, Washington, D. C.).

Mar. 1969, 56 p. DTIE Free.

The seven separate steps of the nuclear fuel cycle (mining and milling, UF_6 conversion, enrichment, fabrication, irradiation, shipping, and reprocessing) are discussed. Typical cost experience for each step is included, with special emphasis placed on the enrichment step and its relation to the over-all fuel cycle. A description of gaseous diffusion plants is presented, including options and costs for increasing uranium enrichment capabilities. Current and long-term operational planning for optimization of power procurement, plant improvements, new plant additions, and level of preproduction are presented. Estimates are given of costs for operation of existing gaseous diffusion plants and capital investments for process improvements to the plants and construction of new plants.

133 (RT/ING-(68)21) OPTIMIZATION OF A GASEOUS DIFFUSION SETUP FOR ENRICHMENT OF URANIUM.

Calori, F., Scuricini, G.B., Venditti, P. (Comitato Nazionale per l'Energia Nucleare, Rome, Italy).

1968, 54 p. (In Italian). Dep.

An optimization is given in order to assess the different arrangements (squared and three/four steps squared-off cascade) for a 700 t U/yr gaseous diffusion enrichment plant. The influence on the main design parameters of the plant is shown for different values of the assumed cost functions. (auth.)

134 EUROPEAN ENRICHMENT PLANT.

Nucl. Eng. Int., 14, 343-5 (Apr. 1969).

Future uranium requirements were assessed and the size of plant needed thus estimated. The economics of the three separation methods, diffusion, the nozzle process, and the gas ultracentrifuge, were studied, and their relative merits observed. The centrifuge process appeared to offer the best prospects.

135 THE SITUATION OF URANIUM ENRICHMENT IN EUROPE.

Scuricini, Giovanni B.

Com. Naz. Energ. Nucl., Notiz., 15, No. 4, 43-5 (Apr. 1969). (In Italian).

After briefly discussing the activities of the Foratom and Euratom Study Groups on uranium enrichment, import aspects, urgency, economics, and need for electric power are reviewed. The economics of the gaseous diffusion and ultracentrifugation processes are discussed.

136 (K-OA-1559) METHOD FOR CALCULATING CASCADE GRADIENTS FOR MULTICOMPONENT SYSTEMS INVOLVING LARGE SEPARATION FACTORS.

Blumkin, S. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

Jan. 15, 1968. Contract W-7405-eng-26. 14 p. Dep. CFSTI.

A mathematical model, involving no limitation as to the magnitude of the separation factor, was derived for the separation of the components of a multicomponent mixture. The model is written for separation by means of permeselective membranes. It is also applicable with little modification to other separative processes involving discrete stages. The method by which the equations are solved to obtain the concentration gradients in a specified cascade is detailed. A Fortran IV code was written to perform the stage calculations for a four-component system with either the stage upflow or the membrane area specified. With minor modifications the program can be extended to a larger number of components.

137 COMPARISON OF THREE SEPARATION METHODS.

Becker, E.W. (Karlsruhe Univ., Ger.).

Nucl. News, 12, No. 7, 46-51 (July 1969).

With the advent of additional nuclear reactors in the next ten years, the requirements of uranium-235 will increase such that existing separation plants will be unable to produce sufficient fuels. The gas diffusion and gas centrifuge processes are now operating. Another method of enriching uranium-235 has been developed which is based on the partial spatial demixing of components of different weights in a gas flowing along curved tracks. Known as the separation nozzle

method, it avoids the fine porous membranes of the diffusion method and the mechanically highly stressed components of the centrifuge. The three methods are described. and compared economically and technically.

138 SELECTED MATERIALS CONCERNING FUTURE OWNERSHIP OF THE AEC'S GASEOUS DIFFUSION PLANTS, JOINT COMMITTEE ON ATOMIC ENERGY, CONGRESS OF THE UNITED STATES, NINETY-FIRST CONGRESS, FIRST SESSION, JUNE 1969.

Washington, D. C., Joint Committee on Atomic Energy, 1969.

502 p. GPO $2.00.

A review is given on the future ownership of uranium-enrichment facilities in the U. S., the national security, competition, regulations, economic aspects, and the alternatives for ownership and operation. All phases of the integrated three-plant AEC operation are discussed. Background information on uranium enrichment and the forecast of growth of nuclear power are given. The industrial community reports in depth on the AEC staff summary report. The possibility of the transfer of the plants to private ownership involves obligations and responsibilities, enrichment services and demands, and economics. Additional plants, cost of services rendered, and foreign demands are also considered should there be private ownership. The report of a Forum Study Committee, Atomic Industrial Forum, Inc., June 1968 on the private ownership and operation of uranium enrichment facilities is given. The summary of the AEC commitments to furnish special nuclear materials to foreign nations for civilian use is presented. An AEC study on comparative cash flow to the U. S. Treasury under assumed ownership by government or private industry and an analysis of U. S. foreign fuel supply policy are also discussed.

139 ENRICHED-URANIUM PRODUCTION PLANNING.

Hatch, D.E., Levin, S.A. (Union Carbide Corp., Oak Ridge, Tenn.).

Nucl. Appl. Technol., 7, 44-54 (July 1969).

The economics of enriched uranium production in USAEC facilities was analyzed and the equations of an optimizing economic model of the enriched uranium industry developed. The objective function that is minimized by the model is the present value of the combined controllable costs of the USAEC and of the users of enriched uranium. The economic system considered is thus unusually comprehensive and the optimization problem correspondingly complex. A basic consideration in developing the optimum operating strategy is that the existing AEC investment in diffusion plant and feed stockpiles may be used to preproduce economically some of the future requirements for enriched uranium. The model was used extensively in USAEC enriched uranium production planning. (auth.)

140 INCREMENTAL COST CONSIDERATIONS RELATED TO PRODUCTION OF ENRICHED URANIUM.

de la Garza, A., Levin, S.A. (Union Carbide Corp., Oak Ridge, Tenn.).

Nucl. Appl. Technol., 7, 456-65 (Nov. 1969).

Fundamental considerations in setting operations of gaseous diffusion plants for minimum cost of enriched product were investigated. The significance of incremental costs is stressed. Information released by the USAEC is used in numerical illustrations. (author)

141 SURFACE DIFFUSION EFFECT IN GASEOUS DIFFUSION.

Fiocchi, R. (Univ., Milan).

pp. 73-83 of Problemi della Separazione Isotopica dell'Uranio. Comitato Nazionale Energia Nucleare, Roma, 1968.

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy. See CONF-681015.

Results of a theoretical study of surface diffusion effects on separation efficiency in gaseous diffusion are presented. The validity of various theories is tested by comparison of predicted results with those obtained experimentally for isotopic mixtures of diatomic and monoatomic molecular gases, multiatomic molecular hydrocarbons, and UF_6. The status of experimental separation programs to test theories is reviewed.

142 OPTIMIZATION OF DIFFUSION PLANT OPERATION.

Avery, D.G., Gunton, R.R., Steele, G.E. (United Kingdom Atomic Energy Authority, Risley, Eng.).

pp. 87-110 of Problemi della Separazione Isotopica dell'Uranio. Comitato Nazionale Energia Nucleare, Roma, 1968.

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy. See CONF-681015.

An analysis of methods available for the UK for production of sufficient enriched U during the next five years is presented. Plans for future extensions to minimize total expenditures on enrichment capacity and U feed material to meet the expanding requirements through the 1970's are described.

143 OPTIMIZATION OF SQUARE AND SQUARED-OFF CASCADES FOR URANIUM ENRICHMENT BY GASEOUS DIFFUSION PROCESS.

Higashi Kunio, Saito Toru, Doi Hideo, Oishi Jun (Kyoto Univ.).

pp. 111-28 of Problemi della Separazione Isotopica dell'Uranio. Comitato Nazionale Energia Nucleare, Roma, 1968.

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy. See CONF-681015.

An approximate formula is proposed for use in optimization of square and squared-off cascades. A broad flexibility is noted in determination of intermediate compositions of the mole fractions of the lighter isotope in product, feed, and waste. The size of the optimum m-steps squared off cascade are obtained by calculating the mole fractions of the lighter isotope in product, feed, and waste. Equations are also given for obtaining the overall separation factor in the i-th step and the number of stages in each step. It is concluded that in most cases the number of steps (fewer than 5) may be sufficient in an enriching section as well as in a stripping section.

144 CORROSION OF METALLIC MATERIALS IN THE PROCESS OF GASEOUS DIFFUSION.

Dixmier, J., Hasson, R., Maraval, S., Salle, P., Vincent, L. (CEA, Paris).

pp. 197-209 of Problemi della Separazione Isotopica dell'Uranio. Comitato Nazionale Energia Nucleare, Roma, 1968. (In French).

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy. See CONF-681015.

Studies were made on the corrosion of metals such as Ag, Ni, stainless steel, and Fe by UF_6. External and internal factors, such as isothermal corrosion, temperature, pressure, purity of the gas, purity of the metal, strains, and choice of materials are discussed. Products of the reaction are also briefly discussed. (see 28)

145 (NP-tr-1869) TECHNICAL PERFORMANCE OF, AND ECONOMIC CONDITIONS FOR GAS CENTRIFUGAL SEPARATION.

(Comparison with Gas Diffusion Method).

Kanagawa Akira.

Translated from Genshiryoka Kogyo, 14, No. 11, 49-54 (Nov. 1968), 14 p. Dep. CFSTI (U. S. Sales Only).

The economic feasibility of a gas centrifuge for the enrichment of uranium is examined. Its separative ability, power requirements, and construction costs are compared with those for the gaseous diffusion method.

146 URANIUM ENRICHMENT.

Avery, D.G. (United Kingdom Atomic Energy Authority, Risley, Eng.).

Phys. Bull. (London), 21, 17-21 (Jan. 1970).

The principal technical features of the gaseous diffusion technique, the gas centrifuge method, and the separation nozzle process used for enrichment of the fissile ^{235}U content of natural uranium and the problems that have to be solved in bringing these techniques to the stage of economic industrial exploitation are discussed.

147 PLANNING FOR FUTURE ENRICHMENT PLANTS.

Allday, C., Avery, D.G., Kehoe, R.B.

pp. 167-79 of Utilizzazione del Combustibile Nucleare. Comitato Nazionale Energia Nucleare, Roma, 1969.

From 10th International Nuclear Energy Conference, Milan, Italy. See CONF-681219.

The United Kingdom and European requirements for enrichment and the plans for meeting them are summarized. A number of factors which arise in optimizing the installation of plant and its subsequent operation are discussed. The problems arising in considering the diffusion, nozzle and centrifuge separation processes are considered. (auth.) (see 182)

148 (LIB/Trans-251) PREPARATION OF URANIUM HEXAFLUORIDE.

Level, A.

Translated by P. Newton (Australian Atomic Energy Commission Research Establishment, Lucas Heights), from Energ. Nucl. (Paris), 6, 225-32 (Jun. 1964), 18 p. Dep. CESTI (U. S. Sales Only).

An abstract of this article, prepared from the original language, appeared as NSA 18, 39389 (1964). (orig. 100)

149 URANIUM ENRICHMENT WITHIN THE FUEL CYCLE IN JAPAN.

Imai Ryukichi (Japan Atomic Power Co., Tokyo).

Genshiryoku Kogyo, 16, No. 1, 12-14 (Jan. 1970). (In Japanese).

Light-water reactors are used in most of the atomic power stations in Japan, and a sound fuel cycle is indispensable to secure the efficient use of nuclear fuel. In this connection, U enrichment, associated with the cycle, is described. Atomic power generation in Japan is supposed to be

40 000 000 to 50 000 000 kW in 1985, and 160 000 000 to 200 000 000 kW in 2000. The amount of U enrichment required depends on diverse factors. By the U.S.-Japan agreement on atomic energy, U enrichment is ensured up to about 1998 for the reactor plants whose construction is started by 1972, and the estimated amount in 161 tons of ^{235}U. The capacity in the U.S. is not necessarily sound and sufficient. The international joint establishment of U enrichment in Europe is also reviewed in this connection. The effort of developing gaseous diffusion and centrifugal separation in Japan is described.

150 (NP-tr-1885) ECONOMIC ASPECTS OF A EUROPEAN URANIUM ENRICHMENT PLANT.

Brüchner, H.J.

Translated by G.H. Wheelhouse (Australian Atomic Energy Commission Research Establishment, Lucas Heights), from Atomwirt., Atomtech., 14, 72-5 (Feb. 1969), 13 p. Dep. CFSTI (U. S. Sales Only).

An abstract of this article, prepared from the original language, appeared as NSA 23, 17704. (author) (Australia) (orig. 129)

151 SUPPLY OF ENRICHED URANIUM.

Jelinek-Fink, P. (Nuklear-Chemie und -Metallurgie GmbH, Wolfgang, Ger.).

pp. 15-28 of Der Nukleare Brennstoffkreislauf. Essen, Vulkan-Verlag Dr. W. Classen (1969). (In German).

From Meeting of House of Technology, Essen, Germany. See CONF-690338.

The use of enriched uranium as a fuel for nuclear reactors is discussed. The concepts underlying all methods for the enrichment of uranium are described. The present and future needs for separation installations and the present enrichment capacities are estimated. The purchase of enriched uranium by the toll enrichment methods is considered. Structure of the separation costs of the U.S. gaseous diffusion installations is evaluated. The European enrichment installations are also considered from the cost structure viewpoint. (see 13)

152 LONG RANGE PLANNING MODEL OF THE USAEC GASEOUS DIFFUSION PLANT.

Stone, Henry (Union Carbide Corp., Oak Ridge, Tenn.), de la Garza, A., Hoglund, R.L.

Nucl. Appl. Technol., 9, 376-95 (Sep. 1970).

A computer model of the existing and possible new USAEC gaseous diffusion plants (GDP) has been developed. The model has been combined with a nonlinear optimization method which permits optimum long range operating plans to be generated. A description of the model is presented with examples of its use in simulation and in generation of optimal long range plans. (author)

153 OBSERVATION OF THE υ_4 BAND URANIUM HEXAFLUORIDE AND THE DETERMINATION OF THIS GAS BY FAR INFRA-RED SPECTROSCOPY.

Chantry, G.W. (National Physical Lab., Teddington, Eng.), Gebbie, H.A., Hamlin, A.G., Lomas, B.C.

Infrared Phys., 10, 95-6 (Jun. 1970).

Reference is made in particular to the determination of UF_6 in diffusion process gas streams, and typically the determination of about 100 parts UF_6 in million parts of nitrogen carrier gas, with significant amounts of other fluorides, such as HF possibly present. An instrument was constructed to monitor UF_6 concentration using the absorption near 625 cm^{-1} due to the υ_3 fundamental. Serious interference from impurities is, however, encountered in this frequency range. At the frequency of 183 cm^{-1} no interference is expected, and if the absorption at this frequency were found to be intense then measurements of attenuation could provide a convenient method for monitoring the UF_6 concentration. With this in mind a study was made of the far intra-red spectra of UF_6 vapour. An NPL/Grubb Parsons modular interferometer, followed by digital Fourier transformation in an Elliott 903B computer was used to obtain the spectra, and the sample had a considerable quantity of HF present as impurity. A typical spectrum is shown. It was found that the υ_4 band is well suited in intensity as a basis of a method for the quantitative analysis of UF_6. Experimental arrangements are indicated.

154 URANIUM ENRICHMENT INDUSTRY.

Avery, D.G., Kehoe, R.B. (United Kingdom Atomic Energy Authority, Risley, Eng.).

J. Brit. Nucl. Energy Soc., 9, 163-9 (July 1970).

An outline is given of the historical development of U isotope separation and of the principles involved. The quantity known as separative work, i.e., the amount of separation an enrichment plant can achieve, is explained. Descriptions of the diffusion process and the nozzle processes are followed by a detailed description of the technology of the centrifuge method. International collaboration in centrifuge development for uranium enrichment is described.

155 OPTIMIZATION OF THE TAIL ENRICHMENT IN A DIFFUSION PLANT.

Balakrishnan, M.R. (Bhabha Atomic Research Centre, Trombay, India).

Energ. Nucl. (Milan), 17, 556-7 (Sept. 1970).

Equations for estimating separative cost in gaseous diffusion plants for UF_6 are developed. The separative work is assumed to consist of two terms, one independent of the separative work load and the other inversely proportional to the total annual separative work requirement. The charge is based on the operating expense per unit of separative work and the annual fixed charge.

156 ISOTOPE SEPARATION BY NOZZLE METHOD.

Droscha, H.

Industriekurier, 23, No. 81, 17 (1970). (In German).

Brief description is given of principles of the gaseous diffusion method, gas centrifuge method, and nozzle method for enrichment of ^{235}U using UF_6.

157 SEPARATION OF URANIUM ISOTOPES.

Pecqueur, M. (CEA, Fontenay-aux-Roses, France).

Bull. Inform. ATEN (Ass. Tech. Énerg. Nucl.), No. 84, 12-26 (July-Aug. 1970). (In French).

Uranium isotope separation is an important item of the fuel cycle. Two processes can be foreseen at present for the construction of a plant. The first is the ultracentrifugation method which offers interesting long term prospects but suffers so far from limited industrial experience. The second is the gaseous diffusion process which can form a sound technical and economic basis for the launching of a large separation unit corresponding to the needs of European countries at the end of the decennium. Following up the experience acquired in its plant at Pierrelatte, France has undertaken large scale studies on gaseous diffusion and by 1972 will possess an exhaustive technical and economic record. The ultracentrifugation process was investigated also although the possible date of industrial application is still uncertain. Moreover, it may prove in the long run that the two processes are more complementary than competitive, gaseous diffusion being used for the high output sections of the cascade and centrifugation for the low output sections, especially if fairly high concentrations (5 or 7 percent) are to be adopted. Many political and industrial problems are involved in the prospect of setting up a multinational unit. (France)

158 (BARC-485) TOLL ENRICHMENT OF URANIUM.

Balakrishnan, M. R. (Bhabha Atomic Research Centre, Bombay, India).

1970, 36 p. Dep. NTIS (U. S. Sales Only).

The results of an analysis made on the economics of toll enrichment are presented. The theory of isotopes separation in diffusion plants is reviewed, factors which contribute to enriched uranium prices, i.e., feed materials and diffusion process costs, and the optimum of tail enrichment are discussed. Finally, tabulated data are presented on the prices of enriched uranium as UF_6 for assay (wt% ^{235}U) values from 0.71 to 95.0 assuming USAEC costs of \$8.00/lb U_3O_8 for natural U, \$2.70/kg U for U_3O_8 to UF_6 conversion, and \$26/kg unit for separative work, and that the tail enrichment is 0.2 wt% ^{235}U.

159 URANIUM ENRICHMENT IN EUROPE. COMPARISON BETWEEN THE REPORTS OF THE EURATOM AND FORATOM STUDY GROUPS.

Scuricini, G.B.

Com. Naz. Energ. Nucl., Notiz., 16, No. 3, 33-7 (March 1970).

(In Italian)

The Euratom and Foratom reports on the economic future of uranium enrichment in Europe are in essential accord; the basic disagreements occur because of the different times at which the two reports were made. The Foratom report was begun in January 1967 and the Euratom report in March 1968. The cost evaluations for the design and construction of enrichment installations are compared. The economic aspects of the gaseous diffusion process, the ultracentrifuge, and the separation nozzle method are considered. It is concluded that the work of the Foratom group be continued in order to prepare work schedules for continuously evaluating the evolution of the cost and market situation.

160 URANIUM ENRICHMENT IN THE U.K.

Geoghegan, G.R.H., Kehoe, R.B.

Atom, London. No. 169, 224-30 (Nov. 1970).

The development of diffusion and centrifuge plants is discussed. Preliminary studies of centrifuge plants had indicated that costs would be prohibitive, but fresh studies in 1967 and 1968 showed that compared with diffusion plants larger centrifuge plants than those previously considered had lower specific capital costs. Improved detail design and a close investigation of manufacturing methods for centrifuges showed that they could be substantially cheapened and that machine life was greater than had previously been assumed. A full comparison study of diffusion and centrifuge plants is given. A tri-national organisation, which is now being set up, consisting of the U.K., the Netherlands and the German Federal Republic and comprising separate companies for the development, construction and operation of centrifuge plants is described. With this organisation it is hoped to combine the best features of machine and plant design, to lower costs for each country and to secure a large share of the European market. It is felt that the centrifuge process offers the greatest potential for a local and viable source of enrichment for the European nuclear power industry.

161 CREATION OF AN INSTALLATION FOR THE ENRICHMENT OF URANIUM IN THE EUROPEAN COMMUNITY.

Baruffa, A.

Neue Tech., B. 10, 237-41 (1968). (In French)

The creation in the European Community of a facility for uranium enrichment involves an examination of commercial, political, and technical problems of considerable difficulty. These considerations include: the enrichment requirements and capabilities of the western world, particularly those of the Community and the availability of enriched uranium supplies from the U.K. or U.S.A.; the technical and industrial aspects; economic aspects; and a comparison of currently used enrichment processes, i.e., gaseous diffusion, ultra-centrifugation, and the gas nozzle process.

162 EFFECT OF FLOW PATTERN IN GASEOUS DIFFUSION PROCESS.

Higashi, K., Doi, H., Saito, T. (Kyoto Univ.).

Nippon Genshiryoku Gakkaishi, 12, 649-54 (Nov. 1970).

(In Japanese)

In the process of uranium enrichment by gaseous diffusion, the scale of operation of the plant e.g., barrier area and power consumption, is highly dependent on the single stage separation factor. The effect of the flow pattern on the separation factor is worth thorough investigation, because it may contribute to reducing the plant size by one-half. The flow patterns of perfect mixing and cross-flow are analyzed. The results should serve in estimating quantitatively any intermediate flow pattern between these two extreme cases. Various flow patterns were realized by connecting in series 1 $\sim$ 10 pieces of barrier made of sintered nickel. Good separation was obtained with cross-flow, as verified by experiments in isotope separation made on nitrogen gas. The applicability of the analysis to the estimation of intermediate flow patterns was demonstrated. Cases of counter-current flow and parallel flow can be dealt with similarly to cross-flow. (author)

163 URANIUM ENRICHMENT BY GASEOUS DIFFUSION OR ULTRACENTRIFUGATION.

Grenon, M.

Sci. Progr. Découverte, No. 3428, 23-32 (Dec. 1970). (In French).

The world requirements of enriched uranium, used as fuel for the almost universally adopted light water reactors, will be of the order of 40 million UTS by 1980, this figure includes 21 to 23 million UTS destined for the United States and corresponding to the saturation of the capacities of the three existing plants (Oak Ridge, Paducah, and Portsmouth). The European requirements are estimated at 12 million UTS by 1980. The most pertinent questions to be answered concern whether the new plant needed before 1980 will be constructed in the United States or in Europe, and if in Europe according to what procedure. (author) (France)

164 URANIUM ENRICHMENT AND THE STAND OF JAPAN.

Kikuchi, S. (Inst. of Physical and Chemical Research, Yamato, Japan).

Karyoku Hatsuden, 21, 922-6 (August 1970). (In Japanese)

Power generation by nuclear energy is increasing rapidly throughout the world. Reactors employed are primarily those using slightly enriched uranium, such as BWR and PWR. First, the situation of nuclear power generation and the supply capacity of enriched uranium by the U. S. are reviewed. To cope with the future demand of such fuel, three alternatives taken by Japan are discussed: use of natural uranium instead of enriched, dependence on the U. S.'s supply, and the construction of enrichment plants in Japan by introducing foreign technology. This latter alternative appears to be desirable. To make possible the introduction of foreign technology, Japan must develop her own technology to a certain extent for actual production. The general scope of uranium enrichment depends upon the practical use of fast breeder reactors. The effort to be made by Japan for her own uranium enrichment is considered in detail: the course to be taken until about 1980; the decision of centrifugal or gaseous diffusion techniques, in which the respective features are taken into consideration; and the necessity for the immediate transition from basic research to the study of industrial production. (Japan)

165 (CONF-700557-3) EXPECTED DEVELOPMENT OF METHODS FOR ENRICHING URANIUM IN EUROPE.

Dreissigacker, H-L.

Translated from Strömungsmechanische Vorgänge in Gaszentrifugen, DFVLR-Kolloquium, om 14. Mai 1970, Porz, Wahn, Germany. 6 p. Dep. NTIS (U. S. Sales Only).

The present technical and economic states of the gaseous diffusion, gas centrifuge, and separation nozzle methods for U enrichment are described, and their potentials for development in Europe are re-assessed from the present-day point of view. The prospects of the three methods are qualitatively assessed and compared, particularly in view of the hoped-for European collaboration in the production of enriched uranium. (author)

166 SOME REMARKS ON THE SQUARING CRITERIA FOR DIFFUSION CASCADE IN ISOTOPIC ENRICHMENT OF URANIUM.

Oliveri, E. (Univ. Palermo, Italy).

Atti Accad. Sci. Lett. Arti Palermo, 28, 45-64 (1967-68). (In Italian).

In an industrial separation cascade for uranium, the diffusion process is repeated many times. Since for practical reasons it is necessary to prearrange the obtainable yield, the ideal diffusion coefficient ($0 = \frac{1}{2}$) has to be replaced by the real one which is obtained by setting up a certain number of squared cascades in which the diffusion constant of each step remains constant. On the basis of a schematic representation of one-step cascades in which a yield P of gram molecules of uranium with a concentration Np of ^{235}U are obtained, a differential formula is derived: $dN/ds = [P/L(Np - N) + mN(1 - N)]$ where $dN/ds = N'_s - N'_{s-1}$, L the cascade constant; P the yield in gram molecules, and N and N' concentration at inflow and outflow. Substituting b for P/Lm one finally obtains the equation

$$m = \log \frac{(N - a_2) \cdot (N_1 - a_1)}{(N - a_1) \cdot (N_1 - a_2)}$$

$$= 2\, m \sqrt{\left(\frac{1 + b}{2}\right)^2 - bN_p\,(s - s_1)}$$

This equation expresses the functional relation between the concentration of the lighter isotope N and the number of steps by which this concentration is attained, where s_t the order of the step, N_t the corresponding concentration and a_1 and a_2 the solution of the equation $N^2 - (1 + b)\,N + bNp = 0$. In squaring the diffusion cascades two problems are of interest: the determination of the optimal working conditions for each individual step and the best division of cascades into a certain number of steps. The first problem reduces itself to the finding of the capacity that would reduce q_t and q_j, the respective capacity values to a minimum. The second problem does not lend itself to an analytical solution and, therefore, an approximation method is applied using the serial development of logx as a tool and breaking up the series after the second term. This study of the squaring operation for the diffusion cascade for isotopic uranium enrichment leads, therefore, to an optimization of gradients. Starting with the theoretical exact optimization equation, a theory of approximation is developed which through a second approximation formula allows the anticipation of the optimal conditions of the entire cascade. Thus a criterion is established for the separation of uranium isotope molecules by a squaring procedure in order to obtain the highest enrichment of the lighter isotope.

167 URANIUM FEED AND SEPARATIVE WORK REQUIREMENTS FOR NUCLEAR POWER PLANTS.

Kuhn, D.W. (Atomic Energy Commission, Washington, D. C.).

pp. 65-78 of Economic Integration of Nuclear Power Stations in Electric Power Systems. Vienna, International Atomic Energy Agency (1971).

From Symposium on economic integration of nuclear power stations in electric power systems, Vienna, Austria (5 Oct. 1970). See STI/PUB-266; CONF-701031.

The demands made on a ^{235}U isotope separations plant by nuclear power stations using enriched uranium, in whole or in part, as fuel are described. The types of reactors considered which require enriched uranium are pressurized and boiling light-water reactors, the advanced gas-cooled reactor, and the high-temperature gas-cooled reactor. A new nuclear power unit must be furnished initially with a complete reactor loading of fuel. Annual requirements for fuel replacement are a small fraction of the initial requirement. This characteristic of nuclear fueling results in a large initial demand on the isotope separations plant followed by smaller requirements for make-up. Enriched uranium requirements are expressed as requirements for diffusion plant feed and separative work. A summary is given of feed and separative work required to date by a number of operating reactors, and these figures are compared with trends in reactors under construction or planned for the future. Considerations which could affect the requirements are discussed, including the effect of operating the diffusion plant at different tails assays, choosing different irradiation levels and hence different ^{235}U enrichments for reactor fuel cycles, increasing the specific power of reactors, and recycling plutonium or ^{233}U in thermal reactors. The requirements for individual reactors are coupled with the forecast of nuclear power capacity to estimate annual and cumulative requirements for natural uranium ore and for isotope enriching services. (author)

168 URANIUM ENRICHMENT AS A COMMERCIAL ACTIVITY.

Avery, D.G. (United Kingdom Atomic Energy Authority, Risley, Eng.).

pp. B.1-11 of Séparation isotopique de l'uranium et son économie. Rueil-Malmaison, France, Société de chimie industrielle (1971).

From Meeting on the uranium isotope separation and the corresponding economics; Paris, France (27 Nov. 1970). See CONF-701133.

Within the next few years decisions will undoubtedly be made in Europe to establish a substantial capability for the enrichment of uranium. The enterprise will operate in an essentially commercial environment. Discussions of this question are presented as seen from the point of view of a commercial organization which is entering the market in the expectation of long-term profit. Both the CEA and the UKAEA have developed diffusion plants but in neither case is the size of the plants suitable for immediate commercial use. The Authority has decided that for the future the gas centrifuge offers better prospects for the large-scale expansion of capacity foreseen in Europe. Many factors contributed to this decision. The long-term technical potential of the system, the price which a commercial organization might have to pay for electrical power, and the real balance between cost and price were considered. (author) (France)

169 SWEDISH STUDIES ON THE ECONOMICS OF URANIUM ENRICHMENT.

Martensson, M. (Aktiebolaget Atomenergi, Nykoeping, Sweden).

pp. D.1-44 of Séparation isotopique de l'uranium et son économie. Rueil-Malmaison, France, Société de chimie industrielle (1971).

From Meeting on the uranium isotope separation and the corresponding economics, Paris, France (27 Nov. 1970). See CONF-701133.

The Swedish work in the field of uranium enrichment has been limited to theoretical studies. Two different studies were carried out in recent years. These investigations are based upon two different computer programs, the purpose of which being to optimize separation cascades for the large-scale production of enriched uranium. One of the programs is designed for a cascade using the gaseous diffusion process and the other for a cascade made up of gas centrifuges. The two programs have some features in common. Both are made up by combining a suitable theory of cascades with the theory of the elementary separation process applicable in each case. The independent variables of the optimization problem and the total cost function are defined. The optimization is carried out following a routine procedure. The results obtained are given. (author) (France)

170 US ENRICHING SERVICES. ECONOMIC CONSIDERATIONS.

Bradley, M.G. (Atomic Energy Commission, Washington, D. C.).

pp. F.1-11 of Séparation isotopique de l'uranium et son économie. Rueil-Malmaison, France, Société de chimie industrielle (1971).

From Meeting on the uranium isotope separation and the corresponding economics, Paris, France (27 Nov. 1970). See CONF-701133.

With the passage of the Private Ownership Act of 1964, private parties in the United States are permitted to own enriched uranium. This enabled the USAEC to take the customer's uranium and to process it in the AEC's gaseous diffusion plants to the desired ^{235}U content. In establishing the $26 unit charge in 1967, the USAEC made an attempt to base this charge on average production cost projections over a reasonable period of time, i.e., 10 years. This 10 year period included the intervals of low annual production with its associated higher unit costs to be averaged with the lower unit costs obtained in the periods of higher production. One factor which unexpectedly had an adverse effect on production costs is that the actual plant productivity is about 8 per cent less than the AEC had anticipated. It was considered necessary to conduct a serious reexamination of these cost factors. The USAEC developed and proposed a new approach for establishing the charge for performing uranium enrichment services. The AEC adopted a change in its enrichment criteria which had the effect of establishing the charge at a level estimated to be equivalent to the enrichment facilities designed, constructed and operated primarily to meet commercial markets, using debt-equity ratios, rates of return on investment, and appropriate allowances for federal corporate income taxes, state and local taxes, and insurance deemed by the Commission to be appropriate for a private industrial enriching enterprise. The proposed increase of about 10% in the current charge represents an increase of 0.05 mills per kilowatt hour, which is about 1% of the total cost of nuclear power. (author) (France)

171 THE MANUFACTURE OF PLUTONIUM.

Ross, K.B. (Atom, 3 (1957), S. 27-35).

Der Artikel berichtet über die Plutoniumherstellung, den Betrieb von Reaktoren und die damit verbundenen Probleme. Die Herstellungsanordnung ist folgende: Gewinnung des Urans aus Erzen oder Konzentraten und Herstellung von Brennstoffelementen. Bestrahlung der Brennstoffelemente in einem Reaktor zur Bildung einer optimalen Menge Plutoniums, Plutoniumextraktion durch Primartrennung von Spaltprodukten und der Hauptmasse des Urans mit anschließendem Reinigungsverfahren und Überführung in Metallform. Während der Bestrahlungsperiode wird das Uran an Isotop-235 angereichert. Das aus dem vorausgegangenen Zyklus gewonnene und gereinigte Material wird in Uranhexafluorid überführt und der Anteil an Isotop-235 in einer Diffusionsanlage angereichert. Dieses angereicherte Material wird in die Brennstoffelementanlage zurückgebracht und tritt damit erneut in den Zyklus ein. Der Reihe nach werden die Angaben von Springfields, Windscale und Capenhurst beschrieben.

172 RECORDING MASS SPECTROMETER FOR PROCESS ANALYSIS.

Nier, A.O. and others. (MDDC Rept 53).

April 1946, 18 p. Price: Microfilm $1.00, Photostat $2.00.

A recording mass spectrometer is described which has been used for making continuous analysis of the process gas stream in the uranium gaseous diffusion plant. The strategic distribution of instruments in the plant assures rapid detection of any inleaking contaminants. The original design was made by members of the Kellex Corporation and production of the standardized model is by the General Electric Company. Photographs, diagrams, and curves accompany the report, which is released through the Journal of Applied Physics.

173 ORGANISATION AND METHODS USED FOR THE VACUUM-TIGHTNESS OF THE ISOTOPE SEPARATION PLANT AT PIERRELATTE.

Mongodin, G., Delatosse, J., Deterck, H., Guilbard, C., and Benet, Y.

United Kingdom Atomic Energy Authority, Capenhurst England. Production Group. 1965, 75 p. Transl. into English from Le Vide, Brussels, No. 108, Nov.-Dec. 1963, p. 528-579. (PG-11(CA)) HMSO: 12s 6d.

The problems involved in achieving vacuum tightness in a gaseous diffusion plant for the separation of ^{235}U are reviewed, and the importance of efficient control equipment for each component is stressed. Details are given on the construction of such a plant. The methods adopted and the instruments used for detection with helium and ammonia, and by pressure rise are described, and the necessity for considering vacuum tightness in design concepts at each level of plant construction is discussed. The various stages where leak testing is important are tabulated. The quantitative characteristics of detection units are defined, their functional characteristics are analyzed, and helium leak test phases are mathematically described. The study demonstrated the need to know the numerical values of the characteristic constants of the detection units, and the importance of verifying sensitivity standards for each test. (Orig. 96)

174 QUELQUES PROBLÈMES TECHNOLOGIQUES ET EXPÉRIMENTAUX POSÉS PAR LA RÉALISATION DE L'UNITÉ DE DIFFUSION GAZEUSE DE PIERRELATTE.

Énergie nucl., 9 (1967), nº. 8, p. 489-495.

Problèmes posés par la mise en œuvre de l'UF_6 — les échangeurs de chaleur — la robinetterie — la chaudronnerie — mesure et automatisme — appareils d'analyses.

175 AEC GASEOUS DIFFUSION REPORT ESTIMATES NEW FACILITY COSTS.

Nucl. industry, 15 (1968), No. 3, p. 34-36.

Unit cost of separative work—estimates suggesting that under some circumstances a major new U. S. gascous diffusion plant could supply enrichment services at prices as low or lower than the AEC's current charge of $26 per kg of separative work.

176 WOHER BEKOMMT EUROPA DAS ANGEREICHERTE URAN.

Atomwirtsch.-Atomtech., 13 (1968), Nr. 4, S. 185-186.

Völlige Abhängigkeit von einem einzigen Lieferland — neue Isotopentrennanlagen in den USA oder europäische Anlagen — neue Verfahren: Ultragaszentrifugentechnik oder Gasdiffusionsprozeß — genaue Untersuchungen nötig.

177 LES PERSPECTIVES DU DÉVELOPPEMENT DE L'ÉNERGIE NUCLÉAIRE EN EUROPE OCCIDENTALE.

Énergie nucl., 10 (1968), nº. 4, p. 249-256.

Influence exercée par des variations dans les caractéristiques de réacteurs ou autres hypothèses annexes sur les besoins cumulés en uranium en l'an 2010 — capacité des installations de diffusion.

178 ARRICCHIMENTO DELL'URANIO-ALCUNI METODI ED IMPIANTI.

Notiziario, 14 (1968), no. 6, p. 49-56. 5 ref.

Metodi di separazione — separazione elettromagnetica — diffusione termica — jet gassoso — centrifugazione gassosa — diffusione gassosa — alcuni impianti di diffusione — Capenhurst (G.B.) — Pierrelatte (Francia) — Oak Ridge (U.S.A.) — Paducah (U.S.A.) — Portsmouth (U.S.A.).

179 PROMPT PRIVATE ENRICHMENT.

Nuclear industry, 15 (1968), No. 6, pp. 13-18.

Forum's Study Committee on Private Ownership and Operation of Uranium Enrichment Facilities recommends selling all of the AEC's gaseous diffusion plants to private industry and completing the changeover by 1972 — cost advantages.

180 DIE VORBEREITUNGEN FÜR DEN BAU EUROPÄISCHER URANANREICHERUNGSANLAGEN MÜSSEN DRINGEND AN DIE HAND GENOMMEN WERDEN.

Atom Pressedienst, (1969), Nr. 1, S. 3.

Internationale Expertengruppe unter der Leitung von Ständerat Choisy, Genf, veröffentlicht aufsehenerregende Empfehlungen — sowohl die Zentrifuge als auch das Trenndüsenverfahren auch bei kleineren Einheitsgrößen relativ wirtschaftlich — dies ist bei der Diffusion nicht der Fall: hier sind nur Großanlagen, welche Milliarden-Investitionen erfordern, wirtschaftlich.

181 ENRICHMENT ISSUES REEXAMINED.

Nucl. Ind., 16 (1969), No. 3, pp. 3-8.

Private ownership and operation of the government's gaseous diffusion plants — separative work requirements for U.S. plants 1975-85 — comparison of prices and costs of separative work — outlook for sale of U.S. enrichment services abroad.

182 PLANNING FOR FUTURE ENRICHMENT PLANTS.

Allday, C., Avery, D.G. and Kehoe, R.B.

Atom, (1969), No. 148, pp. 36-42.

Estimated U.K. requirements for separative work — European enrichment requirements — planning the production of enrichment — fuel cycle integration — diffusion plant considerations — ultra-centrifuge process — nozzle-jet separation plant — idea of a European enrichment plant complex. (see 147)

183 ISOTOPIC COMPOSITION ALONG A DIFFUSION CASCADE WITH A POSTIRRADIATION RECYCLE FLOW. EFFECT OF THE PRESENCE OF ^{236}U ON THE SEPARATIVE WORK.

Henri M. Guéron, Leonard Geller (Stoller).

See CONF-680601.

The recycling of spent uranium in diffusion plants leads to the presence of ^{236}U in the fresh reactor fuel. De la Garza et al. (1) have given a thorough theoretical analysis of the consequences on enrichment plant operation. Garrett and Levin (2) have computed the effect on separative work requirements emphasizing high enrichments. Arnold (3) has shown in a parametric study that the fraction D of the recycled ^{236}U rejected in the waste stream of the re-enrichment plant is the predominant factor in determining the consequences of the presence of this isotope in the fresh fuel.

In the present paper we develop a general expression of this fraction for a cascade having a low enrichment product; we then determine the extra separative work due to the presence of ^{236}U in the recycle flow. A numerical example follows.

The cascade operation is sketched in Fig. 1. Flows of different concentration in ^{235}U are not mixed and the presence of ^{234}U is ignored.

The equations governing the cascade are (2):

$$2\frac{dy}{dn} = \Psi_8(1-y)y - \Psi_6 yz \qquad (1)$$

$$\frac{dz}{dn} = \Psi_6 z(1-z) - \Psi_8 yz - \frac{H_6 - zH}{L} \qquad (2)$$

$$L = \frac{H_8 - yH}{(dy/dn)} \quad , \qquad (3)$$

with

i = 5, 6, 8 representing ^{235}U, ^{236}U, and ^{238}U;

H_i = net mass upflow of isotope i;

L = interstage upflow;

n = stage number;

y and z = weight fraction of ^{235}U and ^{236}U;

$1 + \psi_i$ = stage separation factor from the binary mixture of isotope i, with ^{238}U.

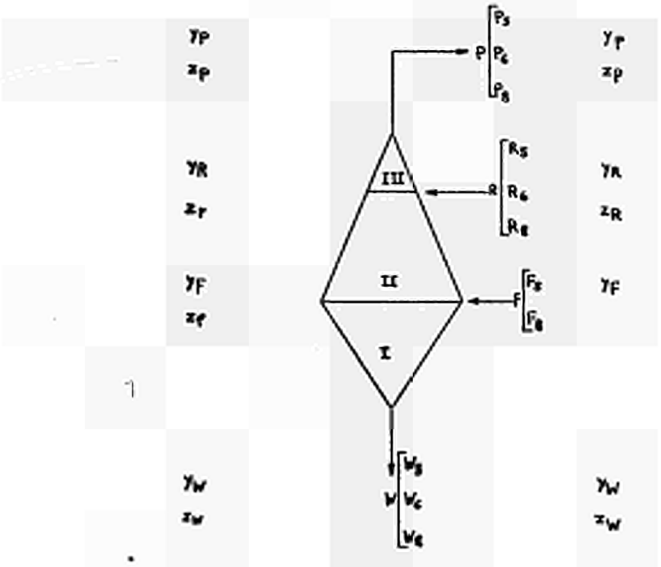
Linearizing equations (1), (2), and (3), eliminating L and n, and integrating, leads to

$$z = \frac{3\dfrac{H_6}{H} - ky^{1/3}}{\dfrac{H_6}{H} - y}\, y \quad , \qquad (4)$$

where $H = -\Sigma_i$ and k is an integration constant to be determined in each zone, using the fact that the composition of the material in the cascade is continuous. Noting that (see Fig. 1 for symbols)

$$\begin{array}{lll} \text{in Region I} & H_i = W_i \\ \text{in Region II} & H_i = P_i - R_i \\ \text{in Region III} & H_i = P_i \end{array} \qquad (5)$$

and assuming F_6 (= 0), F_5, F, R_5, R_6, and R to be known, y_w to be determined by optimization for given fuel cost and unit separative work cost, and y_p to be specified, we obtain P and W by mass conservation, the expression for z in each zone, and the value of the D parameter used by



(1) De la Garza, A., Garret, G.A., and Murphy, J.E.: "Some Value Functions for Multi-Component Isotope Separation – Application to a Unit Cost Scale for U-235, U-236, U-238 Mixtures", K-1455 (July 1960).

(2) Garrett, G.A., and Levin, S.A.: "The U-236 Problem in the Combined Operation of Nuclear Power Reactors and Isotope Separation Plants", A/CONF. 15/P/442, Proc. Intern. Conf. Peaceful Uses At. Energy (1958).

(3) Arnold, E.D.: "Effect of Uranium Recycle on Transuranic Element Buildup", Nucl. Sci. Eng., 3, 707 (1958).

Arnold [1] as a function of the operating characteristics of the cascade

$$\frac{W_6}{R_6} = \frac{\left(\frac{1}{y_R}\right)^{1/3} - \left(\frac{1}{y_P}\right)^{1/3}}{\left(\frac{1}{y_W}\right)^{1/3} - \left(\frac{1}{y_P}\right)^{1/3}} \quad . \qquad (6)$$

The separative work is given by [2] :

$$E = \int_{y_W}^{y_P} \frac{H_5 - Hy}{\left[y(1-y) - \frac{2}{3} yz\right]^2} \, by \quad . \qquad (7)$$

If there is no ^{236}U present, equation (9) reduces to the classical

$$E = W V_W + PV_P - FV_F - RV_R \quad , \qquad (8)$$

with

$$V_i = (2y - 1) \operatorname{Log} \frac{y_i}{1 - y_i} \quad . \qquad (9)$$

Using equations (4) to (7) we find the extra contribution due to ^{236}U to be

$$\Delta E = 4 W_6 \operatorname{Log} \left(\frac{y_W}{y_R}\right) + 4P_6 \operatorname{Log} \left(\frac{y_P}{y_R}\right) \quad , \qquad (10)$$

which constitutes a very small fraction of the total separative work.

Deonigi et al. [3][4] have shown by various examples how the presence of ^{236}U in fresh fuel leads to an increase in the initial enrichment required to reach a given burnup. The cascade effect reduces this penalty. If, on the other hand, an important market for ^{238}Pu develops (for artificial heart batteries, for example), one could take full advantage of the ^{236}U content of spent fuel (by not processing it through the cascade) to produce the ^{237}Np precursor [4].

Numerical example :

$$F = 1\,000 \text{ kg}$$
$$R = 100 \text{ kg}$$
$$F_5 = 7.1 \text{ kg}$$
$$R_5 = 0.800 \text{ kg}$$
$$R_6 = 0.240 \text{ kg}$$
$$y_w = 2.55 \times 10^{-3}$$
$$y_p = 2.10^{-2}$$

leads to:

$P = 292.55$ kg	and	$W = 807.45$ kg
$P_5 = 5.851$ kg		$W_5 = 2.059$ kg
$P_6 = 0.153$ kg		$W_6 = 0.087$ kg
$E = 545.47$ kg		$\Delta E = 0.162$ kg

(1) Arnold, E.D.: "Effect of Uranium Recyle on Transuranic Element Buildup", Nucl. Sci. Eng., 3, 707 (1958).

(2) Garrett, G.A., and Levin, S.A.: "The U-236 Problem in the Combined Operation of Nuclear Power Reactors and Isotope Separation Plants", A/CONF. 15/P/442, Proc. Intern. Conf Peaceful Uses At. Energy (1958).

(3) Deonigi, D.E.: "Formation of Transuranium Isotopes in Power Reactors", BNWL-140, Battelle-Northwest Labs. (Jan. 1966).

(4) Deonigi, D.E., Lang, L.W., and Rohrmann, C.A.: "Power Cost Reduction from Isotope Revenues", Nucl. Appl., 3, 11 (1967).

184 THE SEPARATION OF URANIUM ISOTOPES BY GASEOUS DIFFUSION: A LINEAR PROGRAMMING MODEL.

Fort, D.M. (RAND Corp., Santa Monica, Calif.).

Feb. 2, 1960. 15 p. Rept. No. P-1899. Unclassified report. CFSTI Prices: HC$1.00, MF$0.50.

Prepared for presentation at the International Conference on Operational Research (2nd), Aix-en-Provence, France, Sept. 1960.

Available copy will not permit fully legible reproduction. Reproduction will be made if requested by users of DDC. Descriptors: (*Uranium, Isotope separation), (*Gaseous diffusion separation, Linear programming), (*Linear programming, Gaseous diffusion separation), Mathematical models, Gas flow, Nuclear reactors, Operations research.

The model depicted concerns an idealized version of the gaseous diffusion process in steady-state operation. Three types of relations are taken into account: (a) material balance within the plant, (b) the scale of plant required to generate given material flows, and (c) the irreversible nature of the gaseous diffusion process. The principal intended contribution of this paper is in suggesting the importance of the last consideration in certain applications, and in describing a way to handle it via linear programming. (Author)

185 TRENNUNG DER URANISOTOPEN MITTELS IONENAUSTAUSCHERN.

Ciric, M.

Énergie nucléaire, 10, (1968) 6, 376-80.

Filtriert man Lösungen von vollständig dissoziierten Uranylsalzen (Chlorid, Nitrat, Perchlorat) über den Kationenaustauscher Dowex 50 × 8, so reichert sich das leichte Isotop ^{235}U am Austauscher an. Der Trennfaktor wurde zu 1.0006 bestimmt. Damit ist es möglich, auf genügend langen Austauschersäulen durch Entwicklung der Uranbande eine Anreicherung bis auf 1 bis 2 % ^{235}U, ausgehend vom natürlichen Gemisch mit 0,7 %, zu erzielen.

Angewendet wurden Säulen von 0,5 bis 1,5 cm^2 Querschnitt, gefüllt mit Austauschharz von 0,08 bis 0,2 mm Korngröße. Zur Elution und Entwicklung waren Lösungen von Ammoncitrat und Ammonacetat bei pH 4,4 bis 4,95 geeignet. Das beschriebene Verfahren erlaubt die Anreicherung von 180 mg/h an Uran auf 1 % mit einer Kolonne von 10 cm Durchmesser. Betreibt man mehrere Kolonnen gleichzeitig, so können erhebliche Mengen dieser wertvollen Isotopen-

fraktion gewonnen werden. Ein Kostenvergleich zu den heute technisch angewandten Verfahren der Gasdiffusion steht noch aus.

4 Diagr., 2 Tab., 19 Qu.

186 DIE VERFAHREN ZUR TRENNUNG DER URANISOTOPE.

Becker, E.W. (Univ. Karlsruhe).

Kerntechn., 11, (1969) S. 129-139.

Da das in der Natur vorkommende Uran nur zu 0,7 % aus dem spaltbaren Isotop ^{235}U besteht, ist zur Erhöhung der Leistungsdichte in Kernreaktoren eine Anreicherung dieses Isotops notwendig. Auch beim Betrieb schneller Brutreaktoren mit Plutonium wird man u. U. auf ^{235}U angewiesen sein, das in der westlichen Welt hauptsächlich in den drei Gasdiffusionsanlagen der USA erzeugt wird. Neben diesem Verfahren wurde bisher dem Gaszentrifugenverfahren stärkere Beachtung gewidmet. Die dritte Möglichkeit besteht in der Auftrennung der Isotope $^{235}/^{238}U$ nach dem Trenndüsenverfahren. Durch Einführung der Begriffe „Wertfunktion" und „Trennarbeit" lassen sich die wirtschaftlichen Aspekte miteinander vergleichen. Für kleine Trennanlagen bietet das Gaszentrifugenverfahren Vorteile, da für die Produktion von 3 %igem Material, wie es für Leichtwasserreaktoren benötigt wird, nur 10 bis 20 Gegenstromzentrifugen hintereinander geschaltet zu werden brauchen; jedoch müssen wegen des geringen Durchsatzes viele Einheiten parallel geschaltet werden, was bei den beiden anderen Verfahren nicht notwendig ist.

Trenndüsenanlage und Diffusionsanlage sind „proliferationssicher", da die bei der Genehmigung vorgeschriebene Produktkonzentration nicht durch Umschalten von Trennelementen wesentlich erhöht werden kann.

10 Abb., 2 Tab., 16 Qu.

187 DIE ANWENDUNG DER ULTRAZENTRIFUGE ZUR URANANREICHERUNG IN EUROPA (DE TOEPASSING VAN DE ULTRACENTRIFUGE VOOR DE VERRIJKING VAN URANIUM IN EUROPA).

Ingenieur (holl.) 81, (1969) 16, A 243/A 245.

Zur Urananreicherung werden in Europa drei Verfahren angewandt: die Gasdiffusion, das Trennungsventil und die Ultrazentrifuge. Die Merkmale der Verfahren werden erörtert.

Die Ultrazentrifuge besteht aus einer sich schnell drehenden (50 000 bis 100 000 U/min) Trommel, in der die schwereren Isotopen stärker als die leichteren nach außen geschleudert werden. Das Verfahren ist gekennzeichnet durch sehr große Trommelanzahl, niedrige Stromkosten und eine spezifische Investierung, die bei weiterer Entwicklung viel niedriger als für andere Verfahren werden kann. Bei Annahme einer Trennungsarbeit (a, in kg je kg angereichertes Uran) von 2 bis 6 kg/a je Trommel werden 1975 $\approx$ 2, 1980 $\approx$ 5 Millionen Trommeln erforderlich sein. Die für die Entwicklung der Ultrazentrifuge (deren Leistung der 4. Potenz der Umfangsgeschwindigkeit und der Länge proportional ist) maßgebenden Punkte (Trommelbau, Trommelschnelldrehung, Zusammenbau der Trommeln zu einer „Kaskade") werden im einzelnen aufgeführt. Man glaubt, in Zukunft Anlagen mit Trennungsleistungen von 500 000 bis 2 500 000 kg/a ausbauen zu können; der Bedarf an Trennungsleistung wird bis 1980 auf 9×10^6 kg/a ansteigen (bei 60 000 installierten MW) aufgrund des einschlägigen Schrifttums ist die Entwicklung der Ultrazentrifuge in den Niederlanden wahrscheinlich am weitesten fortgeschritten. Die Kennwerte der verschiedenen, in Europa angewandten Anreicherungsverfahren werden miteinander verglichen.

188 ISOTOPENTRENNUNG (SÉPARATION DES ISOTOPES).

Schindewolf, U. (Tech. Hochsch., Karlsruhe, Leopoldshafen). Atomwirtschaft, Dtsch. (1964), 9, Nr. 11, S. 571-572.

Les installations de diffusion gazeuse de Pierrelatte ont suscité un grand intérêt. La séparation par centrifugation gazeuse se heurte encore à des difficultés. Les installations de production d'eau lourde se développent (Genève 1964).

189 PIERRELATTE OU LE TRIOMPHE DE L'ALUMINIUM SOUDÉ ET DE L'ALUMINIUM COULÉ SABLE.

Cassagne, H., Colas, F., Junière, P.

Rev. Alumin., Fr., (1964), nº 326, 1299-1310.

Emploi de 25 000 t d'Al, en particulier de l'alliage AG 3, pour la fabrication des compresseurs, diffuseurs, échangeurs de t, canalisations et robinetterie, nécessités par le procédé de séparation isotopique de l'U par diffusion gazeuse. Contrôle de l'étanchéité de ces pièces à l'UF_6.

190 ENSEIGNEMENTS TIRÉS DES ÉTUDES ET RÉALISATIONS FRANÇAISES RELATIVES A LA SÉPARATION DES ISOTOPES DE L'URANIUM.

Fréjacques, C., Galley, R.

Bull. Inform., Ass. tech. Energ. Nucl., Fr. (1964), nº 50, 23-7.

En se basant sur l'expérience de Pierrelatte, on donne l'évaluation économique des différents paramètres du coût d'une usine de diffusion gazeuse produisant de l'U enrichi à 0,9 ou à 3 % en fonction de sa taille et on la compare à une usine utilisant la centrifugation gazeuse. Intérêt économique.

191 L'USINE DE SÉPARATION ISOTOPIQUE DE PIERRELATTE.

Belgicatom, Belg. (1965), 10, nº 54, 27.

Quelques indications sur l'usine et la collaboration apportée par l'industrie au CEA.

192 ENSEIGNEMENTS TIRÉS DES ÉTUDES ET RÉALISATIONS FRANÇAISES RELATIVES A LA SÉPARATION DES ISOTOPES DE L'URANIUM.

Fréjacques, C., Galley, R.

In: "Proc. 3rd internation. Conf. peaceful Uses atom. Energy, Geneva, 1964. XII, 3". New York, United Nations, 1965. 28,5 × 22,5. 329-33.

Réalisations effectuées en séparation par diffusion gazeuse et par ultracentrifugation. Estimation économique.

Ibid., 485-96. — Discussion angl., fr., russe, esp. (See 99, 102, 197)

193 ENRICHISSEMENT DE L'URANIUM PAR DIFFUSION GAZEUSE.

Oishi, J.

J. atom. Energy Soc. Jap. (1967), 9, No. 3, 150-2. (En japonais).

194 LES QUATRE USINES DE PIERRELATTE.

Galley, R.

Énerg. nucl., Fr. (1967), 9, nº 8, 480.

L'usine Basse enrichit l'U naturel jusqu'à une *c* en ^{235}U de près de 2 %; elle était démarrée et à l'équilibre des *c* au début de 1965. L'Usine Moyenne produit l'U à une *c* de près de 7 %; en octobre 1965, elle avait permis d'accumuler un stock suffisant pour alimenter les premiers groupes de l'Usine Haute. L'Usine Très Haute, mise en service entre septembre 1966 et mars 1967, élève la *c* de 25 % à plus de 90 %.

195 PROBLEMAS RELATIVOS A LA SEPARACIÒN ISOTOPICA DEL URANIO. SIMPOSIO CELEBRADO EN TURIN LOS DIAS 1-2 DE OCTUBRE DE 1968 (PROBLÈMES RELATIFS A LA SÉPARATION ISOTOPIQUE DE L'URANIUM. COLLOQUE DU TURIN, 1-2 OCTOBRE 1968).

Gispert Benach, M.

Énerg. nucl., Esp. (1969), 13, nº 58, 119-30, bibl. (21 réf.).

Commentaires des mémoires présentés sur les procédés de diffusion gazeuse et de centrifugation et la méthode de la tuyère.

196 MATÉRIAUX NUCLÉAIRES. ASPECTS TECHNIQUES ET ÉCONOMIQUES DE L'ENRICHISSEMENT DE L'URANIUM EN EUROPE. JOURNÉES D'ÉTUDE ORGANISÉE PAR LE NEDERLANDS ATOOMFORUM A BUNNIK LE 30 MAI 1969.

Spilliaert, P.

Énerg. nucl., Fr. (1969), 11, nº 6, 377-8, bibl. (4 réf.).

Aspects techniques du procédé d'ultracentrifugation et son application. Nouvelles perspectives dans la diffusion gazeuse.

197 ENSEIGNEMENTS TIRÉS DES ÉTUDES ET RÉALISATIONS FRANÇAISES RELATIVES A LA SÉPARATION DES ISOTOPES DE L'URANIUM.

Fréjacques, C., Galley R.

Rapp. CEA, Fr., (1964), nº 2648, 14 p. Même art. angl., 13 p.

Estimation économique des différents paramètres intervenant dans les coûts de séparation des isotopes de l'U par diffusion gazeuse et ultracentrifugation. See 99, 102, 192.

198 TRENNUNG DER URANISOTOPE. EIN VERGLEICH DER HEUTE ZUR DISKUSSION STEHENDEN VERFAHREN (SÉPARATION DES ISOTOPES DE L'URANIUM. COMPARAISON DES PROCÉDÉS ACTUELLEMENT EN DISCUSSION).

Becker, E.W. (Inst. Kernverfahrenstech., Univ. Karlsruhe).

In : „33. Physikertag. Karlsruhe, 1968". Stuttgart. Teubner, B.G., 1969. 20 × 14, 221-44, bibl. (17 réf.).

Procédés de la diffusion et de la centrifugation de gaz. Procédé (dû à l'auteur et coll.) de la tuyère de séparation; ce procédé, en cours de perfectionnement, peut déjà remplacer la technique de la diffusion de gaz.

199 URANIUM METALLURGY FROM ORE TO FUEL.

Engng Ming, J.

U.S.A., (1966), 167, nº 11, 90-2.

Présentation succincte des principaux procédés d'enrichissement du minerai par extraction par solvant et par diffusion

gazeuse. Résumé des différentes étapes du traitement et de la préparation des combustibles nucléaires. Données concernant les prix de revient.

200 FORTSCHRITTE AUF DEM GEBIET DER ISOTOPENTRENNUNG IM INDUSTRIELLEN MASSSTAB.

Villani, S. (Energia Nucleare, Suppl. 4, S. 187-95, 1957, ital.).

Die Herst. folgender Isotopen wird besprochen : ^{235}U, D bzw. D_2O, ^{15}N u. ^{10}B. ^{235}U wird als UF_6 in fl. Phase durch Thermodiffusion, in der Gasphase durch Membrantrennung, durch Zentrifugentrennung u. nach dem Trenndüsenverf. gewonnen. Die D-Herst. erfolgt durch Dest. von fl. H_2 oder durch Austauschrk. zwischen H_2 u. H_2O bei 100 u. 600° oder in fl. Phase mit Katalysatoren. Ferner werden der mit hohem Trenneffekt erfolgende D-Austausch zwischen HCl u. W. (industriell noch nicht angewendet) u. die Gegenstromtrennung zwischen W. u. D_2O erwähnt. Zur Anreicherung von ^{15}N werden 2 Verf. angegeben : Austausch zwischen NH_3 u. NH_4^+ u. zwischen NO u. HNO_3. Das letztere Verf. arbeitet bei optimaler 10m HNO_3 Konz. mit einem Trennungsfaktor von 1,055. ^{10}B kann durch fraktionierte Dest. von BF_3 oder chem. Austauschrk. zwischen BF_3 u. therm. dissoziierbaren BF_3-Komplexen in fl. Phase in Form von Salzen oder als Metall hergestellt werden.

201 PHYSIKALISCH-TECHNISCHE GRUNDLAGEN DES REAKTORBAUES. HERSTELLUNG VON BRENNSTOFFELEMENTEN UNTER ANWENDUNG HYDRAULISCHER PRESSEN.

Pischel, H. (Industrieblatt 63, S. 465-70, 522-27, 1963. Stuttgart-Weilimdorf, VDI, dt).

Es werden die allg. Grundlagen des Reaktorbaues besprochen u. dabei bes. auf U-Gewinnung, Isotopentrennung durch Gasdiffusions-, Gaszentrifugen- u. Trenndüsenverf.; künstliche Elemente, Reaktoren, Kernbrennstoffe, Moderatoren, Sicherheits- u. Regelstäbe, Kühlmittel, Abschirmung, Reaktortyp, wie Forschungs-, Leistungs-, heterogene u. homogene sowie therm. u. schnelle Reaktoren, eingegangen. Zur Herst. von Brennelementen werden feste Brennstoffe u. Hüllenwerkstoffe, Strangpressen, Schutzgas, Schutzsalz, Co-extrusion von Pu, Sinterpressen behandelt.

2. MEMBRANE TECHNOLOGY

202 SEPARATION OF URANIUM ISOTOPES BY GASEOUS DIFFUSION. ALUMINA MEMBRANE.

Isomura Shohei, Watanabe Tsunao, Nakane Ryohei, Kikuchi Seishi, Nishujama Atsushi, Ishida Ryuichi, Kamija Eiji (Inst. Phys. Chem. Res., Yamato, Japan).

Nippon Genshiryoku Gakkaishi 1969, 11 (7), 417-8 (Japan).

Properties of the Al_2O_3 membrane prepd. by sintering fine powder of Al_2O_3 were studied. The radius of the capillary of the membrane was $\sim$ 400 Å. No corrosion of the membrane was detected by exposure to UF_6 at 65° for 26 days. Diffusion expts. of UF_6 (pressure : initial 500 torr, final min. 50 torr) at 65° through the membrane showed that the mean sepn. factors and the sepn. efficiencies were 1.0030 and 70.6% for enriched side, and 1.0028 and 65.6% for depleted side, resp., the corresponding pressure to these values being $\sim$ 200 torr.

203 MEMBRANES FOR THE CONCENTRATION OF URANIUM.

Nakane Ryohei.

Kagaku Kogaku 1970, 34 (4), 355-8 (Japan).

Review with 3 refs. on the principle of the concn. of U based on Knudsen's theory on gas diffusion; the requirements of membranes for the concn. of U; the materials, manufg. methods, structure, and performance tests of the membranes; and Ni, alumina, and teflon membranes.

204 NOW JAPAN IS IN THE ENRICHMENT BUSINESS.

Anon., New Scient., 42, (646), 167, (April 24 1969).

Enriched U was made experimentally using gaseous diffusion thanks to perfecting an alumina diffusion membrane. Problems must be overcome before full scale production, particularly to supply the large amount of electricity needed. The Japanese Atomic Energy Commission is also studying ultra centrifuge methods and Pu as a nuclear fuel source.

205 PREPARATION OF HIGH-POROUS SILVER MEMBRANES.

Havlicek, F.I.

"J. Stefan" Inst. Repts., Ljubljana, 3, 135-40 (1956). (Translated from Referat. Zhur. Khim. No. 6, 1958, Abstract No. 17702).

A method for the preparation of highly porous silver membranes for the separation of isotopes is given. The membranes were prepared by leaching Zn out of a 0.2 mm foil of a Ag-Zn alloy. The leaching was done at 900 to 950 °C with a CsCl-HCl solution. As the leaching causes the foils to become brittle, they are placed between copper plates with openings 5 to 10 mm in diameter. The total gap space in the membranes was 10^{-4} cm²/cm². Some results obtained with uranium and hydrogen isotopes are given.

206 PRINCIPAL RESULTS OBTAINED IN FRANCE IN STUDIES OF THE SEPARATION OF THE URANIUM ISOTOPES BY GASEOUS DIFFUSION.

Frejacques, C., Bilous, O., Dizmier, J., Massignon, D., and Plurien, P. (Commissariat à l'Énergie atomique, Paris), 8 p.

The principal problems which occur in the study of uranium isotope separation by the gaseous diffusion process are the development and fabrication of satisfactory porous barriers, the preparation and purification of uranium hexafluoride, problems connected with its use (corrosion, vacuum technology, and gas-tight compression), development of mass spectrometers to measure concentrations of ^{235}U and ^{238}U, and the problems of chemical engineering with respect to the process and the optimum adjustment of relations between the stages. A brief description is given of the results obtained for the solutions of these problems.

207 DÉTERMINATION DU FACTEUR DE SÉPARATION DES ISOTOPES DE L'URANIUM PAR DIFFUSION GAZEUSE (EXPERIMENTAL VALUES OF THE SEPARATION FACTOR FOR URANIUM ISOTOPES IN THE GASEOUS DIFFUSION PROCESS).

Bilous, O., Counas, G. (Commissariat à l'Énergie atomique, Paris), 21 p.

A small twelve-stage gaseous diffusion cascade was built for the measurement of the barrier separation factor for uranium isotopes. The experiments were performed in a wide range of operating conditions, with the mass flow rate of gaseous uranium hexafluoride at the separation inlet of the order of 1 g/sec under mean operating conditions. The experimental results are presented and compared with theory. Within the precision of the measurements, the theoretical values can be adjusted to the experimental data by choosing an adequate fictitious mean pore radius, different from the permeability pore radius, and an adequate value of the mass transfer boundary layer thickness. This adjustment, however, is not entirely satisfactory throughout the whole range of data.

208 SOME TYPES OF MEMBRANES FOR ISOTOPE SEPARATION BY GASEOUS DIFFUSION.

Martensson, M., Holmberg, K.E., et al. (Royal Inst. of Tech., Stockholm), 23 p.

Two types of plane membranes for gaseous diffusion are described. The first type is produced by the electrolytic oxidation of aluminum foil. The second type is made by precipitating a fine aluminum powder on fine-mesh nickel wire gauze followed by compacting and sintering. Testing of the permeability and separation efficiency of both types with H_2-Co_2 and CO_2-N_2 mixtures, respectively, is described. The behavior towards UF_6 is still largely unsettled.

209 CARACTÉRISTIQUES DES BARRIÈRES UTILISABLES POUR LA SÉPARATION ISOTOPIQUE PAR DIFFUSION GAZEUSE (CHARACTERISTICS OF BARRIERS SUITABLE FOR ISOTOPIC SEPARATION BY GASEOUS DIFFUSION).

Massignon, D. (Commissariat à l'Énergie atomique, Paris), 21 p.

The characteristics of barriers suitable for isotopic separation by gaseous diffusion are described mathematically. It is shown how the results given by the experimental methods on structure control of barriers (A/Conf.15/P/1265) can lead to a representation of barriers and will permit the elimination of non-usable industrial barriers by detecting too numerous large pores or microfissures and the existence of leaks at the joints. The discussion is limited to the use of information given by the specific permeability and the separation efficiency. Some examples of routine measurements are given to show how imperfect barriers are detected.

210 (IGRL-T/CA-101) ON THE THEORY OF SEPARATION OF THE CONSTITUENTS OF A MIXTURE OF GASEOUS ISOTOPES BY DIFFUSION THROUGH A POROUS MEMBRANE.

Massignon, D.

Translated by C. Boorman (U.K.A.E.A., Capenhurst) from Chap. 42 of Proc. Intern. Symposium on Isotopes Separation, Amsterdam, 1957, 14 p.

In the theory of Present and de Bethune for separation of gas mixtures flowing through a porous membrane, the pores are long cylindrical capillaries of circular cross-section, and the reflection of the gas molecules against the walls is supposed to follow Knudsen's law. Using for the binary mixtures some methods already known for simple gases, similar separation theories are derived for a porous membrane whose pores may be short, tortuous, and of various cross sections and where the reflection of the molecules may deviate from the usual cosine law. (author)

211 (CISE-66) STUDI SUGLI IMPIANTI A DIFFUSIONE GASSOSA PER L'ARRICCHIMENTO DELL'^{235}U (A STUDY OF THE GASEOUS DIFFUSION PLANT FOR ^{235}U ENRICHMENT).

Perona, G.

Centro Informazioni Studi Esperienze, Milan. April 1959, 63 p.

The gaseous diffusion process for the enrichment of ^{235}U is discussed. The physical principles of the process, the cascade, and selection of the pressures, temperatures, and barriers are described. The gaseous diffusion plant is discussed with a consideration of the preliminary calculation of the plant yield, the diffusor, operating temperature, layout of the plant, control and, cost analysis. The chemical properties of UF_6, its preparation and purification, and the transformation of UF_6 to UF_4 are reviewed. Trans. 214.

212 (CNI-24) SEPARAZIONE DEGLI ISOTOPI DELL'URANIO (THE SEPARATION OF URANIUM ISOTOPES).

Caldirola, P., and Fiocchi, R.

Comitato Nazionale per le Ricerche Nucleari, Milan, Italy. Sept. 1959, 169 p.

All available information on uranium isotopic separation from published papers, private communications, and direct tests and studies is collected. In view of the fact that the characteristic and essential feature of the gaseous diffusion process—the only one presently applied to industrial production—is the preparation of suitable porous barriers and that to this processing the greatest part of the research made in Italy has been devoted, this subject was treated in detail. Other topics were dealt with mainly to obtain an evaluation of the various elements which determine the convenience of building a plant. The probable costs of enriched uranium produced in a possible European plant are also calculated on the basis of different assumptions. This report intends essentially to collect in as complete a fashion as possible all the information presently available, with the aim to facilitate a possible study for the construction of a separation plant. (author) trans. 223.

213 STUDY OF THE SEPARATION OF URANIUM ISOTOPES.

Fréjacques, G.

Énergie nucléaire 1, 217-21 (1959) Sept.-Oct. (In French)

The gaseous diffusion process is discussed with particular attention to the problems of barriers. trans. 217.

214 (AEC-tr-3925) STUDIES ON GASEOUS DIFFUSION PLANTS FOR THE ENRICHMENT OF ^{235}U (STUDI SUGLI IMPIANTI A DIFFUSIONE GASOSA PER L'ARRICCHIMENTO DELL'^{235}U).

Perona, G.

Translated for Oak Ridge Gaseous Diffusion Plant from Report CISE-66. April 1959, 69 p. JCL.

This report has previously been abstracted from the original language and appears in NSA, Vol. 13, as abstract No. 15175. Orig. 211.

215 CONSIDERAZIONI TEORICHE SULLA SEPARAZIONE DI ISOTOPI PER DIFFUSIONE GASSOSA ATTRAVERSO UNA PARETE POROSA (THEORETICAL CONSIDERATION OF ISOTOPE SEPARATION BY GASEOUS DIFFUSION THROUGH A POROUS BARRIER).

Caldirola, P.

Centro Informazioni Studi Esperienze, Milan. 1953, 34 p.

A theoretical treatment of the gaseous diffusion process is given. The problem is stated, and equations for the dynamics of viscous fluids are given. Consideration is then given to limited layers, porous barriers and diffusion layers, elementary theory of isotope separation by diffusion, the coefficient of separation and enrichment, and application to UF_6.

216 CONSIDERAZIONI TEORICHE SULLA SEPARAZIONE DEGLI ISOTOPI MEDIANTE DIFFUSIONE GASSOSA. EFFETTI DELLA STRUTTURA DELLA PARETE (THEORETICAL CONSIDERATION OF THE SEPARATION OF ISOTOPES BY GASEOUS DIFFUSION. EFFECTS OF BARRIER STRUCTURE).

Caldirola, P., and Selmi, L.

Centro Informazioni Studi Esperienze, Milan. 1954, 34 p.

A theoretical treatment of isotope separation by gaseous diffusion is given. The theory of transport of gaseous mixtures is considered and applied to UF_6.

217 (AEC-tr-4029) STUDY ON THE SEPARATION OF ISOTOPES OF URANIUM.

Fréjacques, C.

Translated from Age nucleaire 1, 217-21 (1959), 13 p. JCL.

This paper was previously abstracted from the original language and appears in NSA, Vol. 14, as abstract No. 3717. Orig. 213.

218 SOME PRELIMINARY INVESTIGATIONS BY MEANS OF GAS ADSORPTION ON SINTERED POROUS MEMBRANES FOR THE SEPARATION OF THE URANIUM ISOTOPES BY GASEOUS DIFFUSION.

Lindström, G.B., and Märtensson, M. (Royal Inst. of Tech., Stockholm).

Kolloid-Z. 169, 28-34 (1960), March-April. (In English)

An introductory investigation of the pore structure of a new type of porous membrane, manufactured by a new method, was performed. The membranes, suitable for the separation of the uranium isotopes by gaseous diffusion, are made of aluminum—aluminum nitride powder, obtained by sputtering in an electrical arc. The powder is deposited on a wire gauze, rolled, and sintered. By gas adsorption measurements, the pore radius distribution, the porosity, and the surface area were determined. An attempt was also made to calculate theoretically the permeability and the separation efficiency from the pore radius distribution curve. The influence of the sintering and the rolling pressure was studied, and corrosion studies of the membranes with UF_6 were performed. (author)

219 MANUFACTURE OF A POROUS BODY FOR ISOTOPE SEPARATION.

(to N.V. Philips' Gloeilampenfabrieken).

French Patent 1,198,235. June 8, 1959.

A chemically resistant diffusion barrier for the separation of $^{238}UF_6$ and $^{235}UF_6$ is made by first forming a gel of CaF_2 and an aqueous solution of a decomposable but unattackable gelatinizing agent $Ca(MnO_4)_2$, $Cu(NO_3)_2$, $UO_2(NO_3)_2$, or NH_4NO_3), mixing this gel with more CaF_2, molding or extruding the plastic composition, and finally heating at 100 to 1200 °C. Pore dimensions are influenced by (a) the particle size of the CaF_2, (b) the gel/CaF_2 ratio, (c) time and temperature of heating, and (d) leaching of the final product. (Trans. 225)

220 IMPROVEMENTS IN METHODS OF MANUFACTURING POROUS MEMBRANES.

(to Commissariat à l'Énergie atomique).

British Patent 843,737. August 10, 1960.

A method for the manufacture of porous membranes by evaporating Zn from brass or German silver plates under vacuum is given whereby zinc diffusion and evaporation are increased and alloy grains are made finer. The method involves incorporating Ni and one of the group P, As, and Sb into the alloy and consists of the following steps: (1) The alloy is introduced into molds at 1 000 to 1 050 °C. (2) The ingots are cold-rolled and heated at 600 °C alternately. (3) The bands are annealed in N_2 first at 250 °C and then at 400 °C. (4) After degreasing and scouring, the bands are heated in a vacuum furnace at 10^{-4} mm Hg for 15 min at 650 °C. For optimum results, the alloys should contain 35% Zn, and the resulting porous membranes (with 85% of their Zn contents evaporated off) have a pore size of 100 to 500 A. Procedures are given for porous plate preparation from three specific alloys.

221 IMPROVEMENTS IN OR RELATING TO METHODS OF MANUFACTURING POROUS BODIES FOR THE SEPARATION OF ISOTOPES.

(to Philips Electrical Industries, Ltd.).

British Patent 844,719. Aug. 17, 1960

A method is given for manufacturing porous bodies from CaF_2 for the diffusive separation of the hexafluorides of ^{238}U and ^{235}U; such bodies have the advantages of chemical resistance to fluorides and the required pore size for isotope separation ($\sim$ 0.01 μ). The CaF_2 bodies are prepared by blending granular CaF_2 with an aqueous solution of CaF_2 gel, molding to the desired shape, and heating at 100 to 1 200 °C as in baking ceramics. The jellifying agent dissociates into volatile and/or involatile products, the latter being chemically inert toward fluorides, leaving a porous body of porous size 0.02 to 0.03 μ. The pore size may be varied in the following ways: (1) Finer CaF_2 means smaller pores. (2) Pore size increases with temperature and heating duration. (3) Reduction of gel-fluorspar ratio results in larger pores. Four procedures are given for the manufacture of porous CaF_2 bodies; the jellifying agents are $Ca(MnO_4)_2$, $Cu(NO_3)_2$, $UO_2(NO_3)_2$, and NH_4NO_3, and the temperatures of heating are 170 and 200 °C.

222 IMPROVEMENTS IN OR RELATING TO POROUS MEMBRANES AND METHODS OF MANUFACTURING SUCH MEMBRANES.

(to Commissariat à l'Énergie atomique).

British Patent 849,837. Sept. 28, 1960.

Porous membranes for use as barriers for gaseous diffusion separation of uranium isotopes in the form of UF_6 and other uses may be prepared by coating a fabric of a corrosion-resistant metal (nickel or silver) with a paste of Teflon, fixing the paste on the fabric by pressing, and drying to remove coagulant from the paste. The Teflon paste is prepared by forming an emulsion of Teflon and adding a coagulant to transform the emulsion into a paste; the coagulant may be alcohol, cyclohexanol, acetone, or an aliphatic acid. The mechanical strength of the membrane, improved greatly by the fabric, may be increased still further by adding to the emulsion a filler of powdered nickel, CaF_2, or TiO_2. Several examples are given of the preparation of membranes with and without fillers and their permeabilities. The separation efficiencies of some of the prepared membranes were also measured using CO_2-N_2 mixtures.

223 (AEC-tr-4171) THE SEPARATION OF URANIUM ISOTOPES (SEPARAZIONE DEGLI ISOTOPI DELL'URANIO).

Caldirola, P., and Fiocchi, R. (Comitato Nazionale per le Ricerche Nucleari, Centro di Studi Nucleari, Ispra, Italy).

Translated from report CNI-24. 1959, 124 p. OTS.

This paper was previously abstracted from the original language and appears in NSA, Vol. 14, abstract No. 510. (Orig. 212)

224 IMPROVEMENTS IN POROUS METALLIC MEMBRANES AND METHOD OF MANUFACTURING THEM.

(to Commissariat à l'Énergie atomique).

British Patent 855,203. Nov. 30, 1960.

A method is given for manufacturing porous metallic membranes which are resistant to chemical corrosion. They are suitable for use as diffusion barriers in separation of uranium isotopes as UF_6 and in ultrafiltering in corrosive media. In this method, nickel or nickel oxide powder of average particle size (10 to 25 μ) is mixed with an organic agglomerating agent and the mixture rolled and sintered (sintering being carried out at high temperatures so that the agent decomposes without residue). The agent should be one of the group of halogenated hydrocarbon polymers, especially Teflon, and the mixing of the powder and agent should be carried out in the form of colloidal suspensions, using alcohol to flocculate the mixture to give a paste suitable for rolling and sintering. The sintering should be completed in a reducing atmosphere. An example of this method is given in which a membrane was obtained with a pore radius 0.06 to 0.20 μ and a permeability of 30 to 300 $\times$ 10^{-7} gram molecule/cm^2/min of air per cm of Hg pressure difference.

225 (AEC-tr-4824) MANUFACTURING PROCESS OF A POROUS SUBSTANCE FOR THE SEPARATION OF ISOTOPES.

Translated for Oak Ridge Gaseous Diffusion Plant, Tenn. from French Patent No. 1, 198, 235, Dec. 4, 1959, 9 p.

This paper was previously abstracted from the original language and appears in NSA, Vol. 14, abstract No. 21868. (Orig. 219)

226 (AEC-tr-4992) METHOD FOR THE PRODUCTION OF A POROUS BARRIER FOR ISOTOPE SEPARATION BY MEANS OF DIFFUSION THROUGH THIS BARRIER AND BARRIER MANUFACTURED WITH THE AID OF THIS METHOD.

van der Willigen P.C. and Troelstra S.A. Translated for Oak Ridge Gaseous Diffusion Plant, Tenn. from Dutch Patent 98, 129, June 15, 1961, 9 p.

A method is described for the manufacture of a porous barrier suitable for the separation of hexafluorides for the uranium isotopes ^{238}U and ^{235}U. A barrier of the required form is produced from a plastic mass of powdered calcium fluoride and a binder which is a gel of calcium fluoride prepared with the aid of an aqueous solution of a gelling agent which when heated to 100 to 1 200 °C decomposes leaving a material which is not attacked by hexafluorides.

227 IMPROVEMENTS IN METHODS AND APPARATUS FOR COATING A MACROPOROUS METALLIC SUPPORT WITH A MICROPOROUS METALLIC LAYER.

(to Commissariat à l'Énergie atomique).

French Patent 1,255,382. Jan. 30, 1961.

A method is given for coating a macroporous Ni tube with a layer of microporous Ni in order to obtain a diffusion barrier for isotope separation processes, e.g. the separation of UF_6. The tube, having pores of 1.3 microns, is interiorly coated with a 0.1 to 0.4 mm thick layer of a paste which consists of 50 vol % of Ni formate and 50 vol % of a binder (e.g. a methacrylate or alginate sol). A snugly fitting solid core is inserted in the tube, after which the tube is placed in an evacuable shell which allows a small clearance. The shell is heated at 240 °C and an interior pressure of 10^{-3} mm Hg for 2 hr. Finally the shell is subjected to an exterior pressure of 3 tons/cm^2 and heated at 150 °C, after which the shell and the core are removed. The microporous coating has a pore size of 0.02 microns.

228 (CEA-2180) THÉORIE DE LA SÉPARATION D'UN MÉLANGE GAZEUX PAR DIFFUSION A TRAVERS UNE PAROI POREUSE (THESES) (THEORY OF THE SEPARATION OF A GASEOUS MIXTURE BY DIFFUSION THROUGH A POROUS WALL(THESIS)).

Breton, J.-P. (Commissariat à l'Énergie atomique. Centre d'études nucléaires, Saclay, France).

1962, 75 p.

Submitted to Université of Paris.

The previous theories of separation by gaseous diffusion (Present and de Bethune, Kynch, Bosanquet) were all based on the same model in which the pores are cylindrical capillaries. In the theory presented this model is substituted for by that of a disordered and isotropic bed of identical spheres, which describes more accurately most of the porous media. As the starting point Deriaguine and Bakanov's permeability theory, which expresses the flow of a simple gas in such a bed when the latter is of high porosity, was used. This theory was generalized in the case of medium and low porosities; then a mixture of two gases was considered from which the separation theory was deduced. Results were compared with those of Present and de Bethune. (Author)

229 SEPARATIVE POWER AND OPTIMUM OPERATING PRESSURE OF GASEOUS DIFFUSION SEPARATING UNIT.

Kunio Higashi, Chieko Shimizu, and Jun Oishi (Kyoto Univ.).

Nippon Genshiryoku Gakkaishi, 4, 516-19 (Aug. 1962) (In Japanese).

Separative power was analyzed for a gaseous diffusion separating unit with porous membrane to obtain the optimum operating pressure of a unit. A pore of membrane was assumed to be a circular capillary having uniform radius and length, and the Present-de Bethune model was applied to the flow of binary gas mixture through pores in which the non-separative flow caused by the collision of unlike molecules and the viscous Poiseuille flow as a perturbation were added to the separative Knudsen flow. In a close separation of an isotopic gas mixture at a constant temperature, the flow rate of gas through membrane and the separation factor (the separative power of a separating unit) depend only on the product (gas pressure × pore radius). Numerical calculation of the enrichment of ^{235}U in UF_6 gas showed that when the separative power was plotted against (inlet gas pressure × pore radius) with a parameter of (outlet gas pressure × pore radius), a curve having a maximum point was obtained. The total number of separating units of cascade necessary for a given separative duty is a minimum when the separative power of a unit has a maximum value, and therefore the inlet gas pressure corresponding to a maximum separative power may be considered as a optimum operating pressure from the standpoint of number of separating units. It was noted that the mean free path of gas molecules may become smaller than pore radius under the optimum inlet gas pressure for the outlet gas pressure exceeding a certain value. The correlation between outlet gas pressure and the corresponding optimum inlet gas pressure was expressed in a curve, which can determine the operating condition of a separating unit. (Author)

230 ISOTOPE SEPARATION BY GASEOUS DIFFUSION—A REVIEW.

Eriksson I. and Martenson M. (Kungiliga Tekniska Högskola, Stockholm).

Svensk Kem. Tidskr., 74, 609-17 (1962). (In Swedish).

The Swedish work on isotope separation by means of gaseous diffusion is reviewed. The work was conducted by Ole Lamm and carried out in 1946 to 61 (with interruption during 1952 to 54). The work was mainly exploratory and can be divided into four parts: basic theoretical studies, barrier development studies, uranium hexafluoride technology, and the development of small laboratory cascades. Some characteristic properties of the gaseous diffusion process are discussed in this review and some of the experimental results obtained are briefly described. (Author)

231 ISOTOPE SEPARATION BY GASEOUS DIFFUSION.

Massignon, D. (CEN, Saclay, France).

J. Chim. Phys., 60, 267-76 (Jan.-Feb. 1963). (In French).

The problem posed by isotope separation by gaseous diffusion, passing through a porous wall, is described. The

separation yields of one barrier and one diffusion cell are discussed. The recent principal works in this region are reviewed. (Tr.-author)

232 IMPROVEMENTS IN DEVICES FOR THE SEPARATION OF FLUIDS BY DIFFUSION THROUGH A POROUS WALL OR WALLS.

Bertin, J.-H., Salmon, B., and Guillaume, L. (to Commissariat à l'Énergie atomique).

British Patent 936,421. Sept. 11, 1963. Priority date Feb. 15, 1960, France.

A diffusion cell for the separation of isotopes by gaseous diffusion through a porous barrier is patented. The cell is particularly designed for the separation of U isotopes by diffusion of gaseous UF_6. The gaseous mixture is circulated near porous walls from the cell inlet to the cell outlet. Deflecting members in the central region of the cell along the longitudinal axis of the cell create transverse flow components in the gases. A rectilinear path directly connecting the cell inlet and outlet is provided for the gases along the porous walls. The deflecting members may be helically wound wires, discs, bars, or plates perpendicular to the direction of flow of the gases.

233 (AEC-tr-6129) IMPROVED DEVICES FOR SEPARATING GASES BY DIFFUSION.

Duriau, Y., Gadal, M., and Pecqueur, P.

Translated from Belgian Patent 567,135. Oct. 25, 1958, 12 p.

A device is described for the separation of gases of slightly differing molecular weights by diffusion through at least one porous wall. The device is characterized by the fact that it comprises at least one bundle of porous diffusion tubes mounted on a support in parallel, and connecting an inlet collector of gas to be diffused with an outlet collector for the evacuation of residual gas. The tube bundle is located in a jacket delimiting a space insulated in a tight manner from the inlet and outlet collectors, the space serving for the collection of the fraction of gas diffused through the porous tubes.

234 SEPARATION OF URANIUM ISOTOPES.

Pecqueur, M.

Ann. Mines, 11-30 (Nov. 1963). (In French).

Descriptions are given of electromagnetic separation, heat diffusion, centrifugation and expansion in nozzles as means of enriching UF^6 gas or liquid to obtain ^{235}U and ^{238}U. Parameters and techniques for the gas diffusion enrichment process, including equipment, pressure, gas concentration, charge quantity and barrier pore size were determined. (Rev. Metal Lit., 21, No. 2, Feb. 1964.)

235 METHOD OF MANUFACTURING POROUS BARRIERS.

Calis, M., Charpin, J.E., and Plurien, P. (Commissariat à l'Énergie atomique).

U. S. Patent 3,131,239. Apr. 28, 1964. Priority date Apr. 26, 1957, France.

A method is described for making porous barriers having a very great number of very small pores, for isotopic separation of gases. The method comprises mixing with a thixotropic organic binder a powder of a metal oxide and/or metal with the grain size of the powder being about twice that of the desired pores, shaping the paste, sintering the shaped paste under such conditions that the welding together of the grains is just started, and quickly cooling the sintered product. The sintering conditions must be carefully controlled so that no pores are enlarged or clogged; for alumina, the sintering should be conducted at 1 100 to 1 300 °C, as compared to temperatures of 1 800 °C for the sintering of gastight products. Three examples of the method are described in which alumina, titania, and magnesia barriers were made.

236 IMPROVEMENTS IN OR RELATING TO METHODS AND DEVICES FOR DETERMINING THE MEAN RADIUS OF PORES IN MICROPOROUS BARRIERS.

Gremion, R. (to Commissariat à l'Énergie atomique).

British Patent 961,764. June 24, 1964. Priority date Nov. 29, 1961, France.

The method and equipment for determining the mean radius of pores in microporous barriers such as those utilized in processes for the isotopic separation of uranium hexafluoride are described. The method consists of determining the pressure differential across the barrier and the pressures prevailing on either side of the barrier. Equations are presented for determining the average radius of the pores from the measured values.

237 IMPROVEMENTS IN OR RELATING TO PERMEABLE MEMBRANES.

Eyraud, C., Caunas, G., Eudier, M., and Massignon, D. (to Commissariat à l'Énergie atomique).

British Patent 975,185. Nov. 11, 1964. Priority date Jan. 23, 1960, France.

A method of preparing porous nickel barriers for gaseous diffusion plants is described. A paste of 45 to 55 wt% Ni formate in water containing 2% gum and tragacanth or an alginate, acetone containing 5% methylmethacrylate or collodion, was applied to the tube. This was then heated to 240 °C for 2 hours in a vacuum of 10^{-3} mm Hg. The mean pore radius obtained was 2 centimicrons and the

molecular capacity 7.00 × 10^{-7} molecules of air/cm^2/min/cm Hg/difference in pressure.

238 PRODUCTION OF NUCLEAR FUELS. PART 2. ENRICHED URANIUM.

Ploeger, F., Vietzke, H. (Nuklear-Chemie und -Metallurgie GmbH, Wolfgang, Ger.).

Chem.-Ingr.-Tech., 37, 692-9 (July 1965). (In German).

The uranium 235 isotope can be concentrated in the form of gaseous uranium hexafluoride either by the Calutron process, by the diffusion method with Al_2O_3 membranes, or by means of gas-centrifuges and separating nozzles. The hexafluoride is then converted either to uranium dioxide or the metal for use in nuclear reactors. (Author)

239 EFFECT OF THE SURFACE DIFFUSION ON THE SEPARATION EFFICIENCY IN BRETON-MASSIGNON'S THEORY.

Fiocchi, R. (CNEN, Milan. Univ., Milan).

Energia Nucl. (Milan), 13, 24-31 (1966).

Current theories of isotope separation by gaseous diffusion through porous barriers are almost all based on the model of strongly elongated cylindrical capillary pores. Recently Breton and Massignon have established a consistent separation theory based on the model of a disordered and isotropic pack of identical spheres, which describes more exactly most of the porous barriers. Since the surface migration of adsorbed molecules may play an important role in the separation process, the effect of the surface diffusion on the separation efficiency derived from Breton-Massignon's theory is investigated. This analysis is essentially devoted to the uranium isotope separation: the results are compared with those obtained from previous theories. (Author)

240 METHOD AND APPARATUS FOR MEASURING THE MEAN PORE RADIUS OF A POROUS BARRIER.

Bonnet, J. (to Commissariat à l'Énergie atomique).

British Patent 1,086,297. Oct. 4, 1967. Priority date Sept. 28, 1964, France.

A method and an equipment are described for rapidly measuring the mean radius of pores of microporous membranes such as barriers employed in separating chemically identical hexafluorides from different uranium isotopes. The characteristics of a large number of barriers can be rapidly determined.

241 (CEA-R-3211) ENRICHISSEMENT D'UN MÉLANGE BINAIRE PAR ÉCOULEMENT A TRAVERS UNE PAROI MICROPOREUSE (ENRICHMENT OF A BINARY MIXTURE BY PASSAGE ACROSS A MICROPOROUS WALL).

Marty, C. (Commissariat à l'Énergie atomique, Saclay (France). Centre d'études nucléaires).

June 1967, 48 p. (In French). Dep.

The diffusion of a gas or a vapor in permeable media having small pore radii is discussed. Enrichment phenomena during the diffusion of binary mixtures across porous membranes is of great importance in the industrial development of uranium isotope separation. The laws governing the molecular flow of perfect gases have been established and checked satisfactorily by experiment. Results concerning the separation of binary mixtures at relatively high pressures are unpredictable. It is impossible to elucidate the separation mechanism without a prior knowledge of the gas-solid interface. An experimental study of the adsorption phenomena has been undertaken to determine the textural characteristics of the porous body and the state of the adsorbed molecules. Various dynamic tests involving diffusion of the vapor or liquid phase flow of a binary azeotropic mixture show the importance of the adsorbed phase. (Author)

242 EFFECT OF THE SURFACE DIFFUSION ON THE SEPARATION EFFICIENCY IN GASEOUS DIFFUSION.

Fiocchi, R. (Univ., Milan).

Energ. Nucl. (Milan), 14, 713-16 (Dec. 1967).

The dependence of the theoretical total separation efficiency (due to surface and gaseous diffusion) on different approximations assumed for the factor ζ of Higashi is numerically investigated for the UF_6 isotopic mixture. For one of the most reasonable values of ζ a comparison is established between granular and capillary description of the porous barrier. (Author)

243 SEPARATION OF U ISOTOPES IN FRANCE AND IN THE WORLD.

Pecqueur, M. (CEA, Paris).

Énerg. nucl. (Paris), 9, 480-8 (Dec. 1967). (In French)

The development of the Pierrelatte installation and the history of the isotopic separation of U in France and in the world are outlined. The civil and military reasons for the separation of U isotopes are given. The U isotope separation developments of the United States, England, Russia, China, and France are briefly reviewed. The principal separation procedures—electromagnetic separation, thermal diffusion, the Becker method, and centrifugation—are described in principle. The gaseous diffusion procedure is described

in slightly more detail. The Pierrelatte installation based on the gaseous diffusion procedure is described. Technological difficulties in the design and construction of this installation were connected with the properties of uranium hexafluoride, the barrier, and the compressor and its tightness. The solutions used in each of these areas are indicated. (Trans. 245)

244 SEPARAZIONE ISOTOPICA DELL'URANIO (ISOTOPIC SEPARATION OF URANIUM).

Caldirola, P., and Fiocchi, R.

Serie Trattati. Rome, Comitato Nazionale Energia Nucleare, 1967, 448 p.

The available information on the theoretical principles, construction characteristics, and the economic aspects of the various industrial and experimental procedures for the separation of uranium isotopes is compiled and presented in synthetic form. The characteristics of uranium and its isotopes and the importance of the element in the nuclear industry are first outlined. The chief elements of fluid physics are discussed and the physical principles of the isotopic separation of uranium are given. The theory of gaseous diffusion separation, production and testing of porous barriers for gaseous diffusion separation, theory of cascade separation, combination of cascade separation with gaseous diffusion separation, and isotopic separation by centrifugation are considered. The primary bibliographic sources are reports and original articles from researchers in the countries with a nuclear industry.

245 (K-Trans-45, pp 7-28) URANIUM ISOTOPE SEPARATION IN FRANCE AND IN THE WORLD.

Pecqueur, M.

Translated from Énerg. nucl. (Paris), 9, 481-8 (Déc. 1967).

An abstract of this paper, prepared from the original language, appeared as NSA 22, 23230. (Orig. 243)

246 GAS AND VAPOR SEPARATIONS BY MEANS OF MEMBRANES.

Kammermeyer, Karl (Univ. of Iowa, Iowa City).

Progr. Separ. Purif., 1, 335-72 (1968).

Only material dealing with new concepts, reference to permeability data for both polymeric and microporous media, effects of operating variables on permeability and flow mechanisms, and computer use in iterative calculations for cell performance is included. The use of barriers to separate gas and vapor mixtures is discussed under the categories of microporous barriers and non-porous media, and in each category most of the work discussed is experimental-scale work.

247 (CEA-CONF-1271) THEORY OF ISOTOPIC SEPARATION BY GASEOUS DIFFUSION ACROSS A MEMBRANE. EFFECT OF THE INTERNAL STRUCTURE OF THE MEMBRANE.

Breton, J.-P.

1968, 15 p. (In French) (CONF-681015-4) Dep.

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy.

It is possible to interpret by calculation, at least qualitatively, the influence of the structure of the porous medium on the flux and the efficiency of separation by introducing a distribution coefficient P_c that is a function of the length (λ) of the segments supported by the partition. Unfortunately, it appears that this distribution $P_c(\lambda)$, or the structure of the porous region, cannot be favorable simultaneously to the permeability and to the efficiency of separation. (Tr-author)

248 THEORY OF ISOTOPE SEPARATION BY GASEOUS DIFFUSION THROUGH A MEMBRANE. EFFECT OF THE INTERNAL STRUCTURE OF THE MEMBRANE.

Breton, J.-P. (CEA, Saclay, France).

pp. 21-38 of Problemi della Separazione Isotopica dell'Uranio. Roma, Comitato Nazionale Energia Nucleare, 1968. (In French)

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy. See CONF-681015.

Calculus was used to interpret, at least qualitatively, the effects of the structure of the porous medium on the flow and the efficiency of isotope separation by gaseous diffusion. The distribution $P_c(\lambda)$ of the length of the segments to be supported on the wall was introduced in the calculations. Unfortunately it was found that this distribution $P_c(\lambda)$, or the structure of the porous medium, cannot be favorable simultaneously with the permeability and to the efficiency of the separation. Good agreement, however, between experimental results and theoretical efficiency were obtained. (Tr-author)

249 DETERMINATION OF THE SEPARATION PROPERTIES OF GASEOUS DIFFUSION BARRIERS USING NONISOTOPIC GAS MIXTURES.

Martensson, M. (Aktiebolaget Atomenergi, Stockholm).

pp. 145-72 of Problemi della Separazione Isotopica dell'Uranio. Roma, Comitato Nazionale Energia Nucleare, 1968.

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy. See CONF-681015.

Basic aspects of porous barriers used for isotope separation by gaseous diffusion are considered. Relations between the microstructure of barriers and barrier properties that can be observed directly are analyzed. A method for testing porous barrier is described which is convenient for exploratory investigations. The method also rapidly shows changes in compositions of gases in which the molecular weight rather than the isotopic mass is the basis of separation.

250 DESCRIPTION OF AN EXPERIMENTAL INSTALLATION FOR THE MEASUREMENT OF THE CHARACTERISTICS OF BARRIERS FOR GASEOUS DIFFUSION.

Martin, J.C., Bailly, R., Arbez, C., and Lerat, J.M. (CEN, Saclay, France).

pp. 173-9 of Problemi della Separazione Isotopica dell'Uranio. Roma, Comitato Nazionale Energia Nucleare, 1968. (In French)

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy. See CONF-681015.

An experimental facility, defined as the absolute pilot, for the measurement of the characteristics of barriers for gaseous diffusion is described. The range of parameters it permits to be covered seem definitively sufficient for furnishing to the contractor all the data necessary for the optimization of plants. The pilot installation can function continuously and thus furnish more reliable information than its predecessors. (Tr-author)

251 ECONOMICS OF URANIUM ENRICHMENT BY GASEOUS DIFFUSION.

Martensson, M. (Aktiebolaget Atomenergi, Stockholm).

pp. 275-95 of Economics of Nuclear Fuels. Vienna, International Atomic Energy Agency (1968).

From Symposium on Economics of Nuclear Fuels, Gottwaldov, Czechoslovakia. See STI/PUB-188, CONF-680541.

An economic theory of uranium enrichment by gaseous diffusion must be based on three different areas of scientific knowledge: the theory of separation cascades, in particular square cascades; the theory of diffusion membranes; and the chemistry and physico-chemistry of uranium hexafluoride. In fact, each of these fields is sufficiently known to be used for making up a complete economic theory of the gaseous diffusion process. A computer model is described where the cascade theory and the membrane theory are integrated into one whole. This is done essentially by replacing the enrichment coefficient ε, which is treated as a constant in the cascade theory, by a function of several variables. This function is derived from the membrane theory, i.e., the theory of separation of gaseous mixtures flowing through porous media. The variables of the function are the main working parameters of a gaseous diffusion plant, viz., the fore pressure (the pressure of UF_6 before its passage through the membrane), the back pressure, the working temperature, the mean pore radius characterizing the membrane, and the cut (the ratio of diffused flow to total flow). The third of the three above-mentioned fields is incorporated into the computer model as boundary conditions that restrict the working parameters within limits determined by the chemical and physico-chemical properties of uranium hexafluoride. The purpose of the computer program is to optimize the design (i.e., the number of stages and the stage flow) and the working parameters of a diffusion cascade (made up of one or more cascades) for production of a given amount of uranium with a given enrichment. This optimization means that the least sum is determined by three main cost items: the cost of the feed, the cost of electricity, and the annual fixed plant costs. The latter are in turn a sum of the costs of the different components making up the plant: compressors, diffusers, heat exchangers, pipes, and valves. To complete the computer model, therefore, the costs of these components must be expressed as a function of the stage flow and the main working parameters. These cost functions, which are of a purely empirical nature, are not known in detail but tentative estimates of them are presented. Results of computation are also given. (Author)

252 EXPERIMENTAL STUDY ON THE GASEOUS DIFFUSION PROCESS BY MEANS OF A 10-STAGE CASCADE.

Higashi Kunio, Doi Hideo, Saito Toru (Kyoto Univ.).

Energ. Nucl., Milan, 17, 98-103, (Feb. 1970).

In order to study the static and dynamic characteristics of the gaseous diffusion process, a laboratory-scale crusade with 10-stages was built. This was a triangular cascade (cut: 0.5) consisting of 55 separating elements and 9 compressors. The porous membranes used were made of sintered nickel and shaped in 50 mm Ø disc-type. The excellent self-controllability of the gaseous diffusion cascade has been confirmed experimentally using it with-out any control system. The disagreement between theoretical and experimental results is discussed briefly with respect to equilibrium time. (Author)

253 URANIUM ENRICHMENT INDUSTRY.

Avery, D.G., Kehoe, R.B. (United Kingdom Atomic Energy Authority, Risley, Eng.).

Atom, London, 164, 120-30 (June 1970)

A survey of the historical background of isotope separation and uranium enrichment is given. Four processes of uranium enrichment are discussed; the centrifuge method, the electromagnetic (calutron) method, the thermal diffusion method, the gas diffusion process. The capacity of the

present day gas diffusion plants in U.S.A., U.K., France, Russia and China are considered. A simplified treatment of the diffusion process is given which enables the main design and optimization characteristics to be identified. Membrane development is reviewed and the difficulties of plant design when dealing with UF_6 considered. The nozzle process and the centrifuge method are examined and their economics discussed. The growing demand for uranium enrichment in Europe is considered in the light of the tripartite agreement.

254 PRESENT STATE AND PROBLEMS IN THE DEVELOPMENT OF GASEOUS DIFFUSION TECHNIQUE.

Nakane Ryohei (Inst. of Physical and Chemical Research, Yamato, Japan).

Karyoku Hatsuden, 21, 927-37 (Aug. 1970). (In Japanese)

The situation of gaseous diffusion for uranium enrichment in Japan and problems for the future are reviewed. The relations of separation efficiency and diffusion-barrier pores were examined; the pores of about 100 Å radius were found to be the most efficient. The energy transfer due to the collision of molecules, counter diffusion, and the counter flow of gas affect the efficiency. The plant size to produce the 1 000 tons per year of 5 at. % enriched uranium was calculated taking these factors in consideration. The ideal cascade is square, but the number of barriers and power demands are very large. For practicality, a squared-off cascade is utilized. In Japan, the porous barriers made of alumina or teflon were studied; it was found that their permeating factor did not change in the course of use. The radius of pores attained were equivalent to less than 400 Å according to results of experiment. The fabrication of the pipes for diffusion barrier, with nickel as the supporter material is described. In this connection, plate-type barriers were also considered. The immediate problems in gaseous diffusion are to raise the barrier efficiency by bringing the pore radius down to about 100 Å, and increase the degree of gas permeation, thus reduce the total area of barriers. (Japan)

255 (CONF-700211-11) DEVELOPMENT OF URANIUM ENRICHMENT BY GASEOUS DIFFUSION: PRESENT STATUS AND MOOT POINTS.

Nakane Rychei (Institute of Physical and Chemical Research, Tokyo, Japan).

[nd]. 4 p. Dep. NTIS (U. S. Sales Only).

From Atomic energy society meeting, Tokyo, Japan, (Feb. 13 1970).

Prospects for development of U enrichment plant in Japan are discussed. It is noted that studies should be conducted concerning techniques for producing barriers, development of large compressors, development of cascade components, development of instrumentation, and development of UF_6 production methods.

256 FRENCH CONTRIBUTION TO ECONOMIC STUDIES ON URANIUM ENRICHMENT.

Leduc, C. (CEA, Paris, France).

pp. A.1-14 of Séparation isotopique de l'uranium et son économie. Rueil-Malmaison, France, Société de chimie industrielle (1971). (In French)

From Meeting on the uranium isotope separation and the corresponding economics, Paris, France (Nov. 27 1970). See CONF-701133.

The construction and operation of Pierrelatte have given France a wide experience in the gaseous diffusion field. The technological knowledge acquired covers not only the problems of corrosion, surface treatment, vacuum, passivation, and transfer, but also more general problems such as automation, maintenance, and the optimization of plant operation. Research is carried out on membranes, compressors, exchangers, and UF_6 storage, and on the reliability of equipment, personnel safety, contamination risks and criticality. The specifications of a multinational plant e.g., near a waterway and a source of electricity, flat and stable terrain, together with important economic factors (cost of electricity, plant investments, and running costs) have already been determined. (France)

257 IL SIMPOSIO DI TORINO SULLA SEPARAZIONE ISOTOPICA DELL'URANIO.

Scuricini, G.B.

Notiziario, 14 (1968), no. 12, p. 55-64.

Diffusione gassosa — teoria delle barriere ed esperienze relative — teoria delle cascate e loro ottimizzazione — sistema Trenndüse — ultracentrifughe.

258 SYMPOSIUM D'UTRECHT SUR L'ENRICHISSEMENT DE L'URANIUM.

Renaudin, D.

Bull. Inform. ATEN, Fr., (1969), n° 77, 48-9.

Aspects techniques et économiques de l'enrichissement de l'U en Europe. L'ultracentrifugation, le procédé à tuyère du professeur Becker, une extension des usines américaines employant les barrières poreuses.

259 HERSTELLUNG VON DIAPHRAGMEN, BESONDERS ZUR TRENNUNG VON GASEN DURCH DIFFUSION.

Deutsche Gold- und Silber-Scheideanstalt, vormals Roessler, Deutschland.

Ein sehr feines Pulver, z. B. durch Zers. von Ni-Carbonyl hergestelltes Ni, läßt man in Form einer Suspension auf einem Träger absitzen. Nach Entfernung der Fl. wird das dichte Pulverbett, ggf. nach vorhergehender Kompression, gefrittet. — Trennung von U-Isotopen. (F.P. 1194268 vom 5.4.1958, ausg. 9.11.1959. D. Prior. 5.4.1957).

260 HERSTELLUNG PORÖSER MEMBRANEN DURCH UMHÜLLEN EINES METALLGEWEBES MIT POLYTETRAFLUORÄTHYLEN (I).

Commissariat à l'Énergie atomique, Frankreich (Erfinder: Maire).

Die zur Verarbeitung notwendige Plastizität des I wird durch den Zusatz eines leicht entfernbaren Weichmachers, bes. 40 (cm^3) Vaselinöl in 20 Bzl. auf 100 g I, der mit I-Pulver verknetet oder I-Emulsion geflockt werden kann, verbessert. Der Weichmacher wird aus der Membrane mit einem Lsgm. ausgewaschen. — Nach F.P. 72740 wird I mit abs. A. angeteigt. — Ultrafiltration, Osmose, Trennung von U-Isotopen durch Gasdiffusion. (F.PP. 72142 vom 1.8.1957, ausg. 30.3.1960 u. 72740 vom 15.10.1957, ausg. 28.4.1960. Zusätze zu F.P. 1172527; C. 1963, 12168).

3. CENTRIFUGATION

261 COMMON MARKET ISOTOPE SEPARATION PLANT (USINE DE SÉPARATION ISOTOPIQUE DU MARCHÉ COMMUN).

Applied Atomics, No. 652 (27/3/68), pp. 4-5.

Deux projets : l'un est une extension de l'usine de diffusion gazeuse française de Pierrelatte, l'autre, la méthode d'ultracentrifugation d'extraction de $l'U^{235}$. La Communauté envisage aussi de construire sa propre usine de séparation isotopique.

262 URANIUM ENRICHI.

Nuclélec, No. 1004 (17/7/69), pp. 5678-5682.

Étude de la production d'uranium enrichi par diffusion gazeuse à l'usine de Pierrelatte. La production a été supérieure à celle prévue en 1967. Amélioration en cours. Études en vue d'une usine de faible enrichissement. Séparation isotopique de l'uranium par ultracentrifugation. (L.T.). Uranium. Combustibles piles nucléaires. Enrichissement combustible piles nucléaires. Séparation diffusion gazeuse. Séparation centrifuge.

263 ON REVIENT A LA CENTRIFUGATION.

Martin, C.N.

Science et vie, N° 622 (7/69).

L'ultracentrifugation dans le vide consomme dix fois moins d'énergie que la diffusion gazeuse, mais pose des problèmes particuliers de résistance mécanique (100 000 tours/min, vitesse périphérique 450 m/sec). (B.Z.).

Uranium. Séparation isotopes. Ultracentrifugeuses.

264 URANIUM ISOTOPE SEPARATION.

Fiocchi, R.

Comit. Naz. Energia Nucl., Notiziario 11 (10), 12 p. (1965), (Ital.); cf. CA 55, 24270g.

Knudsen and Poiseuille theories of passage of gases through orifices are discussed in connection with sepn. of UF_6 contg. different isotopes. The choice between diffusion and centrifuging, as well as the choice of the degree of purity aimed at, is still dependent on economic factors, such as capital cost of plant, cost of fuel and labor.

265 NUCLEAR FUELS.

Suarez Feito, Jose.

Bol. Geol. Minero 1968, 79 (1), 26-83 (Span).

Fundamental processes are considered of interactions between *n* and matter (scattering, capture), nuclear fission (*n* and energy balance), and formation of fission products and of fissionable material. Basic and advanced methods using either acid or alk. media for the treatment of U and Th ores are described, followed by a summary of common purification methods for U solns., such as ion exchange and org. solvent extn. techniques. Fluid-bed and fusion procedures are covered for the recovery of U metal via the steps UO_3, UO_2, UF_4; similar metallurgical techniques are noted for the production of Th. Standard methods for producing enriched ^{235}U are illustrated: centrifugation or gas diffusion of UF_6, subsequent redn. to UF_4, and reaction to UO_2 or U_3O_8. After enumeration of some phys. and chem. properties of U, U oxides, and Th, general fabrication principes of fuel elements are indicated, such as welding and canning techniques.

266 ULTRA-CENTRIFUGE PROJECT. I. URANIUM CONCENTRATION PROCESS.

Weimar, K.L.A. (Neth.).

Chem. Weekbl. 1969, 65 (13), 16-19 (Neth.).

After a short description of U concn. processes, such as the gas diffusion method, the basic principles of the ultracentrifuge method are given. In this method, sepn. is accomplished between $^{238}UF_6$ and $^{235}UF_6$ by means of centrifugal force. The sepn. factor is increased by slightly raising the temp. at the lower part of the rotor. Enrichment of $^{235}UF_6$ takes place in an upward direction.

267 URANIUM ENRICHMENT AND GAS CENTRIFUGE.

Tamai Kiyoshi, Tsutsumi Kenichi, Tanaka Masanosuke (Power Reactor and Nucl. Fuel Develop. Corp., Tokai, Japan).

Shinku 1969, 12 (1), 5-17 (Japan).

A lecture is given on enriched U fuel for nuclear power plants. The economics of U power reactors, esp. of light water reactors, present status of mining supplies of raw U in the world, improved industrial techniques and energy balance sheet of U enrichment, and phys.-chem. characteristics and chem. reactivities of UF_6 gas are briefly discussed.

268 GAS CENTRIFUGE FOR THE SEPARATION AND CONCENTRATION OF THE CONSTITUENTS OF GASEOUS MIXTURES.

Oyama Yoshitoshi, Takashima Yoichi (Atomic Fuel Corp.).

Fr. 1,532,334 (Cl. B 01d, B 04b), Jul. 12, 1968, Japan. Appl. Mar. 29, 1966, 7 p.

A centrifuge for the sepn. of gases of different mol. wts. such as $^{235}UF_6$ and $^{238}UF_6$ incorporates: a thermal gradient,

the use of He in the annular space between the rotator and the external chamber to reduce braking, and the exhaust of the gases at 1 torr through small holes in the closures at the extremities of the rotator. The centrifuge includes a rotating cylinder with solid walls rotating within an external chamber. The closures at the extremities of the rotating cylinder are perforated to allow the exhaust of the sepd. gases by vacuum. A thermal gradient is obtained with a heater at the top cylinder closure and the use of a coolant as the bottom closure of the rotating cylinder. Flanges at the extremities of the rotor provide a semiclosure of the He filled annular space.

269 SEPARATION OF URANIUM ISOTOPES.

Becker, Erwin Willy (Univ. Karlsruhe, Karlsruhe, Ger.).

Umschau 1969, 69 (20), 658-7 (Ger.).

The production of enriched U by gaseous diffusion or centrifugation or by nozzle sepn. processes is considered.

270 PREPARING ENRICHED URANIUM FOR NUCLEAR FUELS.

Jelinek-Fink, P. (Nukl.-Chem. und -Met. GmbH, Wolfgang/ Hanau, Ger.).

Haus Tech., Essen, Vortragsveroeff. 1969, 214, 15-28 (Ger.).

For the enrichment of ^{235}U from 0.71% (natural content) to 2-4% (for light-water reactors) or to > 90% (for high-temp. reactors), gas diffusion, ultra-centrifuge, and sepg. jet methods have been developed which all are based on the small wt. difference between $^{235}UF_6$ and $^{238}UF_6$. Only gas-diffusion cascade processes, however, are used in a tech. scale at present. It appears that the ultra-centrifuge process when appropriately improved might compete with the gas diffusion process; the sepg. jet process presumably would be too expensive.

271 URANIUM ENRICHMENT PROCESS.

Aochi Tetsuo (Japan).

Kagaku Kogyo 1970, 21 (10), 1375-80 (Japan).

A review is given on U enrichment by gas diffusion, centrifugal sepn., and nozzle sepn. 3 refs.

272 SÉPARATION DES ISOTOPES.

Fréjacques, C.

Énergie nucléaire, vol. 6, n° 8, déc. 1964, p. 531-2.

Isotope separation; problems of uranium isotope separation, production of heavy water, and other isotope separations; processes of gas diffusion and centrifuging are discussed; from economic point of view, it is shown that gas diffusion is interesting only in large facilities; data furnished on centrifugation are insufficient for comparing advantages of two processes. Before 3rd Int. Atomic Conference, Geneva 1964.

273 CUT-PRICE NUCLEAR FUEL.

Redeker, J.A.

New Scient., 37, (589), 640-643 (Mar. 21, 1968).

Outlines the history of the ultra-centrifuge method of separating U isotopes, reasons for its earlier rejection, describes the method, with reference to papers presented to the Geneva Conference on Peaceful Uses of Atomic Energy, scope demands made on the centrifuge drums, research in Amsterdam and economic potential.

274 NEW MOVE ON THE DUTCH URANIUM PLANT.

Anon.

New Scient., 40, (617), 6-7 (Oct. 3, 1968).

The Netherlands Government considers work on enriching U by ultra-centrifuge has progressed enough to consider constructing a pilot plant in 1969. Cost estimates are about 5 000 million guilders.

275 THE ULTRA-CENTRIFUGE IS BACK IN THE NEWS.

Bogaardt, M., and Theyse, F.H.

New Scient., 40, (629), 206, (Dec. 26, 1968).

Comments on the political background to the proposed joint Dutch-British-German industrial venture to produce slightly enriched U in a European ultra-centrifuge. Brief notes are given of a paper by M. Bogaardt and F.H. Theyse on the centrifuge, at an international symposium on isotopic separation of uranium at Turin in October, which advocated constructing a demonstration plant in the range 20 te USE/yr (tonne units of separative work) to 100 te USW/yr.

276 CENTRIFUGE SYSTEM COULD STIMULATE BRITAIN'S NUCLEAR FUEL EXPORTS.

Franklin, N.L.

The Times, 21 (Jan. 10, 1969).

277 CENTRIFUGE ENRICHMENT FOR EUROPE.

Lawes, G.

New Scient., 41, (641), 640-641 (Mar. 20, 1969).

It is now virtually certain that Britain, W. Germany and Holland will build a pair of ultra-centrifuge, U enrichment plants. Major technical problems have been overcome and initial technological collaboration will be minimal. Capacity in kg/yr, investment in $/kg/yr, electricity consumption in kWh/kg of SW, kWh price in mills/kWh, and separation cost in $/kg of SW are compared for: gaseous diffusion, nozzle separation, and ultra-centrifuging.

278 ULTRA-CENTRIFUGE PROJECT FOR MAKING ENRICHED URANIUM. KISTEMAKER'S GREAT ADVENTURE.

Anon.

Elsevier's Weekblad, 25, No. 15 (April 1969). Capenhurst Transl. 209.

279 NOW JAPAN IS IN THE ENRICHMENT BUSINESS.

Anon.

New Scient., 42, (646), 167, (April 24, 1969).

Enriched U was made experimentally using gaseous diffusion thanks to perfecting an alumina diffusion membrane. Problems must be overcome before full scale production, particularly to supply the large amount of electricity needed. The Japanese Atomic Energy Commission is also studying ultra-centrifuge methods and Pu as a nuclear fuel source.

280 TECHNICAL AND ECONOMIC ASPECTS OF URANIUM ENRICHMENT IN EUROPE.

Anon.

Nucl. Engng int., 14, (158), 580-583 (July 1969).

A report of the one day international symposium organised by the Netherlands Atoomforum at Utrecht in May which covered: predicting future enrichment capacity needs; comparing the cost of separation by ultra-centrifuge and gas diffusion; developing nozzle separation for U enrichment; centrifuge theory; comment on the Foratom Report on Economic Aspects of Uranium Enrichment in Europe; and proposals by the European Commission on enrichment facilities.

281 CLOSE COSTING OF URANIUM ENRICHMENT.

Anon., New Scient., 43, (656), 21, (3 July 1969).

A cost breakdown of ultra-centrifuge enrichment published at the recent Netherlands Atoomforum Conference on "Uranium Enrichment in Europe" estimated investment charges for a centrifuge plant of 3,000 tonnes separative work per annum capacity at $115/kg, and $110/kg SWU/y for a 17,000 tonne gaseous diffusion plant. Electricity charges for centrifugation were $\sim$ 1/3 or 0.1 for diffusion by AEG or in Europe. Japanese and German work on diffusion is also mentioned.

282 FUEL CYCLE.

Franklin, N.L.

Nucl. Engng. int., 14, 722-724, (Sept. 1969).

Describes current activities of the UKAEA Production Group in nuclear fuel fabrication, reprocessing, supporting services and enrichment supply. For U enrichment, the economics of diffusion and centrifuges have been compared, emphasis in development has been adjusted in favour of the centrifuge, but not excluding diffusion.

283 THE ULTRA-CENTRIFUGE PROJECT. 3. THE POLITICAL-ECONOMIC ASPECTS, EUROPE INDEPENDENT OF AMERICA.

Reinshagen, P.

Chem. Weekbl., 65, (13), 19-23, (28 March 1969). Capenhurst Transl. 229.

284 BRITAIN MUST WIN RACE TO DEVELOP THE GAS CENTRIFUGE.

Peters, D.
Engineer, Lond., 230, 5948, 36-37, (22 Jan. 1970).
Reviews development of gas centrifuge for production of atomic fuel and pact between Holland, Germany and Britain to develop cheaper uranium enrichment. On basis of European fuel requirements estimates need for 8×10^6 centrifuges by 1980. Indicates lines for research.

285 CENTRIFUGEUSE A GAZ ET PROCÉDÉ POUR L'ENRICHISSEMENT DE L'^{235}U (GAS CENTRIFUGE AND PROCESS FOR ^{235}U ENRICHMENT).

Doryokuro Kakunenryo Kaihatsu Jigyodan.

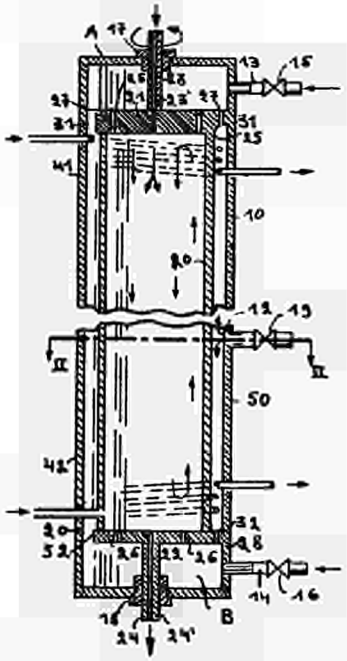
Brevet, BF 1589275 (70/22/42) R.

Inv., Oyama, Y., Takashima, Y., Aoki, S.

Dépôt, 10 Oct. 1968, PVD 169624.

Priorité, 26 Oct. 1967, BJD 68490/67.

Publi., 23 Mars 1970.



Une centrifugeuse à gaz et un procédé d'enrichissement de l'^{235}U utilisant une telle centrifugeuse laquelle comporte un rotor tournant à grande vitesse dans un cylindre externe, des trous dans chaque extrémité du rotor pour éjecter le gaz enrichi et le gaz appauvri, des arbres creux fixes sur les plaques d'extrémités du rotor et des moyens pour extraire un gaz léger inerte du rotor et l'introduire entre le cylindre externe et le rotor pour assurer un balayage vers les extrémités du rotor.

286 SEPARATEUR CENTRIFUGE A GRANDE VITESSE (HIGH SPEED CENTRIFUGAL SEPARATOR).

Mitsubishi Jukogyo, K.K.

Brevet, BF 2001976 (70/07/23) R.

Dépôt, 14 Fév. 1969, PVD 69/03726.

Priorité, 15 Fév. 1968, BJD 9153/68.

Publi., 3 Oct. 1969.

A. L'invention appartient au domaine de la technique des séparateurs.

B. Séparateur centrifuge caractérisé parce qu'il comprend un caisson et un rotor d'une seule pièce monté rotatif dans ce caisson.

C. Une application de l'invention est la séparation des isotopes ^{235}U et ^{238}U.

287 L'ACTUALITÉ NUCLÉAIRE (NUCLEAR ACTUALITY).

Technique moderne (F), 61e année, no 11, Nov. 1969, p. 437-442. (En français)

En 7 paragraphes, présentation des problèmes, des projets, des programmes et de l'avenir de l'énergie nucléaire :

— L'uranium (approvisionnement, récupération, ultra-centrifugation);

— L'eau lourde (production, utilisation des réacteurs à eau lourde);

— Les neutrons rapides (avantages des réacteurs surrégénérateurs);

— Le programme des centrales nucléaires françaises;

— Le développement des centrales nucléaires;

— L'abaissement du prix de revient de l'énergie nucléaire.

288 ON GAS-CENTRIFUGES (SUMMARY).

Beyerle, K., Groth, W., Harteck, P., Jensen, H.J.D., Beggerow, G., Faltings, V., Suhr, A., and Nann, E.

Chemie-Ingenieur-Technik 21, 331-5 (Sept. 1949). (In German)

Details of construction are reported of a centrifuge consisting of many chambers. The operational efficiency of the apparatus is discussed for xenon, krypton, and selenium isotopes, which were used for the purpose of calibration, and for uranium hexafluoride. It is shown that by adding hydrogen to the isotope mixture in the centrifuge, harmful turbulence effects are avoided, so that the separation efficiency is increased.

289 ANG. EN NY METOD FOR ISOTOPSEPARETING (NOTES ON A NEW METHOD OF ISOTOPE SEPARATION).

Nore Bergner.

June 7, 1948. 71 p. (NP-4203).

The small separation constants usually obtained in centrifugal isotopic separation can be augmented considerably by making use of the properties of the potential vortex. The separation factor is the same as the partial pressure ratio between the isotopes, measured at two different distances from the center, and the gas pressure can be increased to very high values in such a vortex. A stable sedimentation equilibrium can be obtained at an arbitrarily selectable radius. The molecular weight of the gas must be low in order for the pressure drop to be reasonable but heavy enough that a sedimentation equilibrium may exist. The radial velocity of the gas should be large enough so that a vortex motion is maintained. A study of the hydro-dynamic conditions for cyclone motion is reported. A general

derivation of formulas required for calculation of vortex separation is made. A sample calculation is carried out for UF_6 separation.

290 SOME ASPECTS OF ISOTOPE ENRICHMENT BY MEANS OF HIGH SPEED CENTRIFUGES.

Klepp, H.

Joint Establishment for Nuclear Energy Research (Norway), 1953. 19 p. (Jener-12).

Some of the basic theoretical aspects of centrifugal separation of isotopes are discussed, including enrichment through reduction of volume or density, combination of batch and cascade enrichments, yields, etc. The enrichment of U is presented as a specific numerical example.

291 ENRICHMENT OF U ISOTOPES IN A COUNTERCURRENT GAS CENTRIFUGE.

Groth, W., Nann, E., and Welge, K.H.

Z. Naturforsch. 12a, 81 (1957), January. (In German)

292 ^{235}U BY CENTRIFUGING GETS NEW TRIAL.

Chem. Eng. 64, No. 7, 144, 146 (1957, July).

The separation of U isotopes by centrifuging is being investigated in Germany. Eight centrifuges have been built for separating $^{235}UF_6$ from $^{238}UF_6$. These machines have a diameter of 7.2 in. and are 47 in. high. They will rotate at a peripheral speed of about 6 000 ft/sec., equivalent to about 32 000 rpm. The centrifugal force is about 100 000 times that of gravity.

293 NEW RESEARCH DEVELOPMENTS FOR INDUSTRIAL SCALE ISOTOPE SEPARATION.

Villani, S.

Energia nucleare, Milan, 4, 187-95, (June 1957). (In Italian)

Separation methods for ^{235}U, H_2, N_{15}, and B_{10} are discussed.

294 (IGRL-T/CA-59) THE SEPARATION OF ^{235}U.

Caldirola, P.

Translated by Peters, E.G., from Energia nucleare, Milan, 3, Suppl. 74-81 (1956), 10 p.

A brief description is presented of the principles on which the centrifugal separation and the "Trenndüse" processes for ^{235}U separation are based. A more detailed description of the gaseous diffusion process for ^{235}U separation is included. (Author)

295 PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON ISOTOPE SEPARATION HELD IN AMSTERDAM. APRIL 23-29, 1957.

Kistemaker, J., Bigeleisen, J., and Nier, A.O.C.

Eds. Amsterdam, North-Holland Publishing Company, 1968, 723 p.

Papers presented at the International Symposium on Isotope Separation held in Amsterdam, 1957, and the pertinent discussions are presented. Papers in English, French, and German are included in the fields of chemical engineering, molecular interactions, chemical exchange, electromigration, distillation, thermal diffusion, diffusion, electromagnetic separation, and the development of ultracentrifuges.

296 ISOTOPE SEPARATION.

Klemm, A.

Atomwirtschaft 3, S. 341-2 (Aug.-Sept., 1958). (In German)

Processes developed in the German Federal Republic for the separation of isotopes are described. These include distillation of liquid hydrogen and dual-temperature exchange for the production of heavy water, gas centrifugation and separation nozzle for uranium enrichment, and other methods for the enrichment of magnesium, lithium, and C^{14}. (Trans. 323)

297 (A/CONF.15/P/1121) THE ENRICHMENT OF URANIUM ISOTOPES WITH ULTRA-CENTRIFUGES.

Kistemaker, J., Los, J., and Veldhuyzen, E.J.J. (Foundation for Fundamental Research on Matter, Amsterdam).

10 p.

The ultra-centrifugation of UF_6 offers a promising method for an economical production of enriched ^{235}U material. The fundamental theory of centrifuges is discussed, and the consequences with respect to constructional considerations and economical aspects are outlined. Results of chemical corrosion tests on various materials are given in connection with the discussion of the mechanical properties of the materials selected for use. (Author)

298 (A/CONF.15/P/1807) ENRICHMENT OF THE URANIUM ISOTOPES BY THE GAS-CENTRIFUGE METHOD.

Groth, W.E., Beyerle, K., Nann, E., and Welge, K.H. (Univ. of Bonn). 17 p.

The design, operation, and theory underlying the operation of gas centrifuges for the separation of uranium isotopes are described.

299 INDUSTRIAL METHODS OF ^{235}U ENRICHMENT.

Kiss Istvan (State Research Inst., Dept. of Chemistry).

Energia es Atomtech., 11, 466-73, (1958). (In Hungarian)

Electromagnetic, centrifugal, gaseous diffusion, and gas jet separation methods of ^{235}U are described.

300 URANIUM ISOTOPE SEPARATION: A NEW INDUSTRY.

Geoghegan, G.R.H.

New Scientist 5, 468-72, (Feb. 26, 1959).

The gaseous diffusion separation process used in the British factory at Capenhurst is described, and consideration is given to the economic aspects of the plant. Information is also included on the basic principles of operation of the electromagnetic, gas-phase centrifuge, and jet processes.

301 (AEC-tr-3412) ENRICHMENT OF URANIUM ISOTOPES BY THE METHOD OF GAS CENTRIFUGATION (ANREICHERUNG DER URANISOTOPE NACH DEM GASZENTRIFUGENVERFAHREN).

Groth, W., Beyerle, K., Ihle, H., Murrenhoff, A., Mann, E., and Welge, K.-H.

Translation of Research Report No. 510 of the Ministry of Industry and Commerce, West German Publishers. Cologne-Opladen, 1958. 74 p. $2.00 (OTS).

The separation of ^{235}U by gas centrifugation of UF_6 is reviewed. The first efforts were in 1941 when a centrifuge was constructed which gave a separation just below theoretical yield. Early work also included the rocking procedure in which an oscillating gas stream can be created between two chambers either by a suitable device from the outside or through the periodic change of rpm of two connected centrifuges spinning oppositely. An enrichment of 5.2% was achieved with four such chambers. Other modifications of the centrifugal principle are described such as the UZIII A and B. Also, experiments using hydrogen for stabilization in the enrichment of various isotopes including those of U are discussed. Apparatus and measuring methods are described. Results are discussed, and recommendations for further development of gas centrifuges are presented. Further experimentation resulted in the development of the ZG 3 and 5, the features of which are described. Chemical investigations of methods for UF_6 purification are also described as well as the preparation of perfluorinated lubricating oils.

302 THE CONCENTRATION OF ^{235}U: SURVEY OF MOST IMPORTANT METHODS AND PRINCIPLES.

Havlicek, F.I. (Institute J. Stefan, Ljubljana, Yugoslavia).

Energia nucleare, Milan, 6, 521-31, (August, 1959). (In Italian).

Diffusion, physical-chemistry, and electromagnetic methods for the separation of uranium isotopes are reviewed. An account is given of the principles on which each is based, a critical examination is made of the possibilities they offer, and a number of experimental devices are described. (Author) (Trans. 325)

303 DIFFUSION IN NEUTRAL AND IONIZED GASES WITH EXTREME PRESSURE GRADIENTS.

Kerrebrock, J.L. (California Inst. of Tech., Pasadena).

p. 193-206 of "1959 Heat Transfer and Fluid Mechanics Institute". Stanford, Calif., Stanford University Press, 1959, 250 p.

Two examples of diffusion in vortex flows are considered as simple cases of the more general problem of diffusion in flows with large pressure gradients normal to the principal flow direction. In the first, the two gases are assumed electrically neutral, and pressure and concentration diffusion are equally important. In the second, diffusion of the electrons of an ionized gas is studied. Diffusion due to electromagnetic body forces is of equal importance with pressure diffusion in this case, while concentration diffusion is negligible. It is found in the first example that the ratio of the radial mass flow of one species to the total radial mass flow is a characteristic value of the diffusion equation. The rates of diffusion are such that significant separation of the isotopes of uranium should be possible in vortices with supersonic tangential velocities. The radial pressure gradient leads to a radial electric field in the second example. A solution is obtained for the case of zero currents. By means of a perturbation technique, the solution is then extended to the case of small currents and induced fields. (Author)

304 THE DEVELOPMENT OF SHORT BOWL ULTRA-CENTRIFUGES.

Gernot Zippe, Beams, J.W., and Kuhlthau, A.R.

Virginia Univ., Charlottesville. Ordnance Research Lab. Progress Report No. 1. Dec. 1, 1958, 27 p. Contract AT(40-1)-2400. (UVA/ORL-2400-58-PR-1). OTS.

Russian developments in ultra-centrifuges for U isotope separation are described. Progress on development of the short-bowl centrifuge is reported. (For preceding period see ORO-202). (See 443)

305 (ORO-216) THE DEVELOPMENT OF SHORT BOWL ULTRA-CENTRIFUGES.

Gernot Zippe.

Virginia Univ., Charlottesville. Research Labs. for Engineering Sciences. Progress Report. Nov. 6, 1959, 22 p. Contract AT(40-1)-2400. (EP-59-2400-2). OTS.

Progress in uranium isotope separation by the ultra-centrifuge method is reported. Construction and life time testing of centrifuge mechanical prototypes are described including operation of two such prototypes for a year. High speed spin tests are also described and materials which yield at 402 ± 0.3 meters/sec were tested. Development of molecular pumps for maintenance of vacuum around spinning rotors is reported as well as research on a scoop system for insertion and extraction of gas from the centrifuge. Preliminary measurements of isotope separation are reported and data on efficiency are included. Also, information on engineering and economic aspects of rotor design are included.

306 GAS CENTRIFUGÉS.

Groth, W.E. (Univ. of Bonn).

Research, London, 12, 467-74, (Dec. 1959).

The theoretical basis of the centrifugal method is discussed. Various types of thermally controlled countercurrent gas centrifuges are described. Enrichment experiments with three different centrifuge models determined the static enrichments, the dependence of the enrichment on the throughput, and the separation potential of the centrifuges. Experimental separation potentials of the gas centrifuge method were compared with the gas diffusion method for the enrichment of the uranium isotopes. (Author)

307 SEPARATION OF THE ISOTOPES OF URANIUM.

Beams, J.W.

Virginia, Univ., Charlottesville. Feb. 5, 1941. Decl. Feb. 1, 1960, 37 p. OTS.

Work on centrifuging uranium isotopes is summarized, and methods of spinning long tubes of small diameter are discussed. Centrifuge and rotor designs are given.

308 (A-54) CONCENTRATION OF ISOTOPES BY FRACTIONAL DISTILLATION IN AN ULTRA-CENTRIFUGE.

Cohen, K.

Columbia Univ., New York. (1941). Decl. Feb. 1, 1960, 43 p. OTS.

The process of fractional distillation in a long ultra-centrifuge is examined theoretically for its suitability as a means of concentrating ^{235}U. The fractionation and transport of such instruments are found, and tables are constructed from which these properties may be predicted. Numerical examples are given showing that the daily production of a column 10 feet long and 1 inch in diameter. spinning at 3,000 rps, is 60 mg of ^{235}U at 4 times normal abundance, or 30 mg at 15 times normal abundance. It is found that, within certain limits, narrow columns are better than wide columns. (Author)

309 (A-1784) REPORT ON THE APPLICATION OF THE COUNTER CURRENT REFLUXING CENTRIFUGE METHOD TO THE SEPARATION OF THE URANIUM ISOTOPES.

Beams, J.W.

Virginia, Univ., Charlottesville. March 31, 1944. Decl. Feb. 1, 1960, 52 p. OTS.

Operational data are given for a centrifuge tube used as a counter-flow refluxing stripper for concentrating U isotopes. The centrifuge and equipment are described in detail.

310 GERMAN PROCESSES FOR URANIUM ISOTOPE ENRICHMENT.

Groth, W. (Universität, Bonn).

Chem. Ing. Tech., 31, 310-18, (May 1959). (In German)

The gas-diffusion and jet separation processes and the gas centrifuge treatment are described and their economic prospects are compared. For gas centrifuging theoretical and technical details and experimental results with the isotopes of xenon and argon are reported. (Author) (Trans. 317)

311 (NYO-7348) APPLICABILITY OF GAS CENTRIFUGE TO ISOTOPE SEPARATION FOR ELEMENTS HEAVIER THAN TITANIUM.

Barker, J.J.

Kidde (Walter) Nuclear Labs., Inc., Garden City, N. Y. Sept. 30, 1956. Decl. Feb. 1, 1960. 52 p. Contract AT(30-1)-1374, Final Report on Task V1-A. (WKNL-71). OTS.

The applicability of the gas centrifuge to the separation of the isotopes of the elements from Ti through U was examined. The suitable elements were determined, and their effects on required centrifuge characteristics were surveyed. The performance of cascades of various sizes with different gases was explored, and the cost of a pilot plant program to develop basic separation data was estimated.

312 (TID-5753) POTENTIAL OF THE SHORT BOWL GAS CENTRIFUGE FOR THE ENRICHMENT OF THE ^{235}U ISOTOPE AS COMPARED WITH PUBLISHED FIGURES FOR GAS DIFFUSION.

Gernot Zippe.

Virginia, Univ., Charlottesville. Research Labs. For Engineering Sciences. March 1960, 11 p. Contract (AT(40-1)-2400). (EP-2823-100-6OU). OTS.

An economic comparison was made between the use of the short-bowl gas centrifuge and gas diffusion for the enrichment of ^{235}U.

313 (A-53) MAIN NUMERICAL RESULTS ON THE SEPARATION OF UF_6 BY CENTRIFUGES.

Cohen, K.

Columbia Univ., New York. March 3, 1941. Decl. Sept. 23, 1960, 7 p. OTS.

Data are given on the theoretical total length of spinning rotors necessary to produce 1 kg/day of ^{235}U enriched UF_6, contained in a continuous working quantity of 10 kg of ^{235}U and ^{238}U mixture in UF_6. Other data on two fractionally distilling centrifuges are given in which the minimum ratios of length to internal radius necessary for production of the specified over-all fractionation factors at calculated efficiencies are included.

314 (A-1778) BRIEF REPORT OF TYPE II CENTRIFUGE OPERATION.

Beams, J.W.

Virginia, Univ., Charlottesville. Feb. 28, 1944. Decl. Sept. 23, 1960, 13 p. OTS.

Results of type II UF_6 centrifuge operation are presented. Data from this type operation in a single unit are useful in predicting the operation of a number of centrifuges in cascade.

315 (A-3391) THE SEPARATION OF THE ISOTOPES OF URANIUM IN UF_6 BY THE REFLUXING COUNTERFLOW CENTRIFUGE METHOD.

Beams, J.W., and Snoddy, L.B.

Virginia, Univ., Charlottesville. July 14, 1943. Decl. Sept. 23, 1960. 44 p. Contract OEMSR-398. OTS.

Results of experiments with tubular centrifuges operated to separate the ^{235}U isotope in UF_6 are presented. The data are tabulated and a comparison of experimental and theoretical values is included.

316 PROGRESS IN TECHNOLOGY. 3. PROCESS CHEMISTRY.

Hall, G.R. (Imperial Coll. of Science and Tech., London). Nuclear Power 6, No. 57, 79-80 (Jan. 1961).

Some developments in the field of reactor-fuel processing are described, particularly with reference to power reactors. The following items are discussed: fuel processing for power reactors in U. S., Windscale second plant, second French plutonium separation plant for EDF reactor fuels, Eurochemic Plant of Belgium, Indian ore processing plant, ^{235}U separation by gas centrifugation, and reactor chemistry.

317 (GAT-Z-5016) GERMAN PROCEDURES FOR THE ENRICHMENT OF THE URANIUM ISOTOPE.

Groth, W.

Translated by J.R. Arndt from Chem. Ingr. Tech., 31, No. 5, 310-18 (1959), 15 p.

This paper was previously abstracted from the original language and appears in NSA, Vol. 14, abstract No. 7670. (Orig. 310)

318 (TID-5230) DEVELOPMENTS IN THE CENTRIFUGE SEPARATION PROJECT.

Beams, J.W. (Virginia, Univ., Charlottesville), Hagg, A.C., (Westinghouse Electric Corp., Pittsburgh), and Murphree, E.V., (Standard Oil Development Co., Elizabeth, N.J.). 1951. Decl. Oct. 29, 1959, 269 p. (NNES-X-1)

The development programs undertaken to devise a gas-centrifuge process for concentration of ^{235}U in UF_6 are described. The theory of separation using cascades of identical countercurrent units is summarized. Early work done at the University of Virginia is reported in detail. The 42- and 132-in. centrifuges developed at Westinghouse are described, and their operation is reviewed.

319 URANIUM CONCENTRATION.

Yoshitoshi Oyama (Tokyo Inst. of Tech.).

Genshiryoku Hatsuden, 4, No. 3-4, 23-8 (1960). (In Japanese)

A brief survey of the historical background and of the present status of the enrichment methods is given. Gaseous diffusion, centrifugal, and nozzle separation are considered of interest for application in Japan. The ideal and the squared-off cascade concepts are discussed for arriving at an economic evaluation of the ^{235}U plant design. On the basis of cost calculations published by USAEC and the Saclay Nuclear Study Center, the economic bases of the gaseous diffusion method are given, including the estimation of the required capital investment and operating costs for plants installed in France and in Japan, comparing the estimated production costs with the U. S. data. Results indicate that the costs exceed the U. S. values by 50 to 90%. Groth and Zippe's data for UF_6 separation are included in a survey of the centrifuge method for isotope separation, comparing the power and capital costs with those required for the gaseous separation method, without drawing definite conclusions for lack of data. Leroy's survey on the nozzle separation method is expanded by including 20 additional references. Treatment of the jet stream and Becker's experimental data for UF_6 separation is discussed.

320 ACTUAL METHODS FOR THE ENRICHMENT OF ^{235}U.

Martensson, M.

Tek. Tidskr., 89, 487-93 (1959). (In Swedish).

A review of methods for the enrichment of ^{235}U is presented. The separation processes discussed are gaseous diffusion, effusion through a nozzle, and gas centrifugation. Equipment diagrams and principles of operation are included.

321 CENTRIFUGES.

Karl P. Cohen (to Atomic Energy of Canada, Ltd.).

Canadian Patent 615,723. Mar. 7, 1961.

A centrifuge and method for separating gases or vapors with molecular weights greater than 250 are described. The design equations for the centrifugal isotope separation of mixtures of the uranium hexafluoride vapors $^{235}UF_6$ and $^{238}UF_6$ and for other gaseous mixtures are presented. The centrifuge is designed to produce a maximum of separative work per unit length of the centrifuge chamber and is characterized by its substantial equilibrium in operation. The centrifuge employed is the continuous flow-through type wherein the centrifuge chamber is rotatably supported by means of tubular shafts arranged coaxially of the vertically disposed rotational axis of the chamber at opposite ends. These tubular shafts serve also as the inlet and outlet, respectively, to and from the centrifuge chamber and the shaft at the upper end of the chamber is employed as a single inlet. The shaft at the lower end of the chamber is divided to provide two parallel or concentric outlet passages for the heavier and lighter separations.

322 REACTOR FUEL PROCESSING.

Stephen Lawroski, ed. (Argonne National Lab., Ill.).

Technical Progress Review, Vol. 4, No. 2 (April 1961), 83 p.

A discussion of the commercial aspects of fuel processing is presented in which industrial participation is outlined and gas centrifugal uranium isotope separation is examined. The incident involving the Redox multipurpose dissolver is discussed in some detail. Information on preparation for fuel processing is outlined and various process flowsheets are presented. In other sections, developments in fuel processing are outlined followed by sections on waste disposal and developments in production of U, Th, Pu, and their compounds.

323 (AEC-tr-4779) ISOTOPE SEPARATION.

Klemm, A.

Translated by Kurt H. Quasebarth for Univ. of Virginia from excerpt of Atomwirtschaft, 3, 341-2 (1958), 5 p. (EP-4422-506-61U).

This paper was previously abstracted from the original language and appears in NSA, Vol. 12, abstract No. 16546. (Orig. 296)

324 METHOD OF ISOTOPE SEPARATION.

Girodin, M.G.H.

French Patent 1,240,085. July 25, 1960.

Isotope separation processes are offered in which a reciprocal diffusion is effected between a gas, e.g. UF_6, and an auxiliary gas, e.g. Ar. The two gases are either countercurrently fed on either side of a diffusion barrier or countercurrently fed into a low speed tubular centrifuge. The effluxes are separated into the two constituent gases by freezing.

325 (AEC-tr-4753) CONCENTRATION OF ^{235}U: REVIEW OF SOME OF THE MOST IMPORTANT METHODS AND PRINCIPLES.

Havlicek, F.I.

Translated for Oak Ridge Gaseous Diffusion Plant from Energia nucleare (Milan), 6, 521-31 (1959), 38 p.

This paper was previously abstracted from the original language and appears in NSA, Vol. 13, abstract No. 20000. (Orig. 302)

326 (MLM-1115) MOUND LABORATORY MONTHLY PROGRESS REPORT FOR MAY 1961 (ON PLASTICS, RADIOELEMENTS, ISOTOPE SEPARATION, AND REACTOR FUELS).

Eichelberger, J.F. (Mound Lab., Miamisburg, Ohio).

May 30, 1961. Contract AT-33-1-GEN-53. 18 p.

Formulation of 13 new epoxy-modified polyurethane systems were cast and cured. Results of chemical tests on an epoxy curing exudate are included. Comparison of solvent effects on retention of radioelements by stainless steel was started and data are tabulated for ^{227}Ac, ^{227}Th, and ^{223}Ra. Work on protactinium was resumed after suspension of this project in 1960. Methods for preparation of small quantities of highly enriched U isotopes are being examined. Included in the survey are chemical exchange, electromagnetic separation, gaseous and liquid thermal diffusion, gas centrifugation, and photochemical techniques. Continued investigation of viscosities of La and Pr for use in Pu alloys is reported. Phase studies of Au-Pt systems were continued along with studies of Pu bearing glass fibers.

327 (TID-13673) THE MAXIMUM SEPARATIVE CAPACITY OF A GAS CENTRIFUGE.

Von Halle, E. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

Nov. 29, 1960. Contract [W-7405-Eng-26]. 16 p. (KOA-748 [Revised]).

A tabulation of values of the maximum separative capacity of a centrifuge as a function of the peripheral speed and operating temperature of the centrifuge is presented. The results are also shown graphically. A derivation of the equation for the maximum separative capacity is given. Values for the density and coefficient of self-diffusion product for UF_6 were calculated from viscosity data.

328 (NP-tr-817) SOME METHODS OF PRODUCING ENRICHED ^{235}U.

Ho Ping.

Translated from K'o Hsueh T'ung Pao, No. 2, 36-41 (Jan. 26, 1959), 10 p.

Methods for producing uranium are described as gaseous diffusion, supersonic jet pump, super-centrifuge, magneto-ionic expansion, ionic migration, and electromagnetic separation. A comparative table on the methods is included for rate of production, separation factor, cost scale, material, problems, and present progress.

329 (AEC-tr-4983) GAS CENTRIFUGAL SEPARATION.

Akira Kanagawa.

Translated for Oak Ridge Gaseous Diffusion Plant, Tenn. from Genshiryoku Hatsuden, 4, Nos. 3-4, 49-61 (1960), 55 p.

The gas-centrifugal separation method as a uranium enrichment method is discussed from the standpoint of its historical development, theoretical and technical problems, and its economics as compared with the gas diffusion method. The possibilities and problems in the future development of this method are outlined.

330 (CEA-tr-X-397) MÉTHODES INDUSTRIELLES POUR L'ENRICHISSEMENT DE ^{235}U (INDUSTRIAL METHODS FOR ENRICHMENT OF ^{235}U).

Istvan, E.K.

Translated into French from Energia es Atomtech., 11, 466-73 (1958), 32 p. (Includes original, 8 p.).

In the selection of an industrial method for the enrichment of ^{235}U, the enrichment factor, the chemical and physical characteristics of the materials participating in the enrichment process, the engineering possibilities of the method, and the economics of the method must be considered. The gaseous diffusion process and the centrifugation process for heavy isotopic enrichment are discussed, and the enrichment factors are calculated theoretically. Cascade parameters and equilibrium times are calculated for the two processes. The energy requirements for a gaseous diffusion cascade and the engineering problems of such a plant are reviewed.

331 THEORETICAL CONSIDERATION OF LIQUID-VAPOR EQUILIBRIUM OF ISOTOPE MIXTURE UNDER CENTRIFUGAL FORCE.

Kazuo Amaya.

Repts. Govt. Chem. Ind. Research Inst., Tokyo, 57, 1-3 (Jan. 1962). (In Japanese).

For estimating concentration efficiency, theoretical expressions for the equilibrium distribution of the components in liquid and vapor phases under centrifugal force were derived. By the use of these expressions, the effi-

ciency of concentration of $^{235}UF_6$ under accessible conditions was calculated for mixtures of $^{235}UF_6$ and $^{238}UF_6$ in various ratios. It is deduced that the efficient concentration of $^{235}UF_6$ will be possible if an appropriate apparatus for successive distillation can be constructed. (Author)

332 ANALYZING GAS CENTRIFUGE FOR FUEL FABRICATION.

Hamel, P. (A. V. Roe Canada Ltd., Toronto).

Can. Nuclear Technol., No. 4, 48-53 (1962).

The theory underlying the application of the gas centrifuge for the industrial scale production of uranium fuel with low enrichment is reviewed. The isotope separation process shows that a rational choice of plant parameters should be made from an over-all optimization study including local economic effects. The theory also suggests that the sectional type cascade arrangement be used. The analytical equations are kept simple for this theory.

333 (MLM-1129) MOUND LABORATORY MONTHLY PROGRESS REPORT FOR JANUARY 1962.

Eichelberger, J.F. (Mound Lab., Miamisburg, Ohio).

Jan. 31, 1962. Contract AT-33-1-GEN-53. 37 p.

Flow curves were run on plastics with applied force of 2.5 to 15 tons. Thirteen adhesive formulations, cast into films, are being evaluated for tensile strength and elongation. Several epoxy-modified Adiprene-polyol systems catalyzed with ferric acetonate were evaluated for possible use as adhesives which cure rapidly at room temperature. The equipment for xenon purification and isotope separation by low-temperature distillation was improved. A computer program that was devised for an ideal cascade of gas centrifuges for uranium isotope separation was revised to include the effects of variable enrichment, flow rates, and total feed. Studies are being made to discover the cause of slow variations in the measured power output of radioactive samples. Techniques for vapor deposition of beryllium on plastic microfilms were investigated. The adsorption of trace radioelements evaporated to dryness on metal and glass surfaces is being studied. The half life of ^{223}Ra is being redetermined by microcalorimetry and alpha counting. Methods are being developed to determine the coincidence correction in proportional counters by following the decay of pure radioisotopes. Ways of determining traces of ^{227}Ac in ^{223}Ra are being investigated. Studies are being made of the physical properties of plutonium-bearing materials. Phase studies were made of the Ce-Pu system by differential thermal analysis and metallographic studies. Rods of various diameters were fabricated from plutonium oxide and uranium oxide glasses. Lead-loaded Neoprene rubber gloves were tested to determine the general characteristics of the material.

334 (AEC-tr-5986) ISOTOPE SEPARATION AND ENRICHMENT.

Bier, K., Fischer, W., and Dickel, G.

Translated by L.L. Smith (Savannah River Lab., Aiken, S. C.) from Chem.-Ing.-Tech., 34, 580 (1962), 8 p.

The enrichment of ^{235}U by the partition diffusion method and the problems involved are discussed. The state-of-the-art of uranium isotope separation by the gas centrifuge and partition jet methods is described briefly. The use of ion migration in the pre-enrichment of ^{46}Ca in ^{47}Ca prior to calutron enrichment is considered, and the migration model for explaining the measured mass effects is discussed. The problem of deriving a useful theory of thermal diffusion separations is considered; the invariant theory of the separative tube cascade was developed which uses separation work rather than separation efficiency. The results of centrifugal separation of argon isotopes in a vortex tube are given which were used to derive the separation mechanism.

335 PRINCIPLE OF GAS-CENTRIFUGAL SEPARATION AND ITS APPLICATION FOR SEPARATION OF ISOTOPES.

Huai-hsin Kan.

Hua Hseuh Tung Pao, No. 10, 534-9 (1961).

Basic principles are explained on the theory of gas centrifuges (GC) in its application for the separation of isotopes. Equations are given for the coefficient of separation of isotopes by thermal diffusion using an ordinary centrifuge and GC. The correlation of the separative power and separation coefficient are examined. Requirements are formulated with respect to materials and composition of certain alloys used in building GC. Methods of transfer of rotation, bearings, and compressions in the GC are briefly discussed. Characteristics are given of the performance of the GC built in the Federal Republic of Germany and economical comparison is made of the separation of U isotopes by GC and gas diffusion. (Trans. 337)

336 SEPARATION OF URANIUM ISOTOPES.

Pecqueur, M.

Ann. Mines, 11-30 (Nov. 1963). (In French).

Descriptions are given of electromagnetic separation, heat diffusion, centrifugation and expansion in nozzles as means of enriching UF_6 gas or liquid to obtain ^{235}U and ^{238}U. Parameters and techniques for the gas diffusion enrichment process, including equipment, pressure, gas concentration, charge quantity, and barrier pore size were determined. (Rev. Metal Lit., 21, No. 2, Feb. 1964.)

337 (JPRS-23767 (p. 7-28)) THE PRINCIPLE OF GAS CENTRIFUGAL SEPARATION AND ITS APPLICATIONS IN ISOTOPIC SEPARATION.

Huai-hsin Kan.

Translated from Hua Hsueh T'ung Pao, No. 10, 534-9 (1961).

This paper was previously abstracted from the original language and appears as NSA 18, 5711. (Orig. 335)

338 CONCENTRATION AND USE OF STABLE ISOTOPES.

Groth, W. (Universität, Bonn).

pp. 239-51 of "Atomstrahlung in Medizin und Technik", Munich, Verlag Karl Thiemig KG, 1964. (In German).

Methods for the concentration of deuterium and ^{235}U are summarized and contrasted. The principles of the dual-temperature method for deuterium enrichment is emphasized. The methods described for ^{235}U enrichment are gaseous diffusion and gas centrifugation. The methods used for the enrichment of isotopes of C, N, and O are indicated.

339 (A/CONF.28/P/89) DEDUCTIONS BASED ON STUDIES OF URANIUM ISOTOPE SEPARATION AND FRENCH ACHIEVEMENTS IN THIS FIELD.

Fréjacques, C., and Galley, R. (Commissariat à l'Énergie atomique, Paris, France).

May 1964, 13 p.

The work carried out in the field of uranium isotope separation, by gaseous diffusion and by ultra-centrifugation, is reviewed. An economic estimate of the various parameters involved in the cost is given, and it is shown that only very large gaseous diffusion plants, corresponding to a program of enriched uranium reactors of a least 4 000 Mw(e) to be installed yearly, can give an economically acceptable enriched uranium production. (Author) (See 342, 408, 415)

340 METHOD OF DOUBLE SIMULTANEOUS CENTRIFUGATION, MEANS EMPLOYED AND PRODUCTS THUS OBTAINED.

Rabissow, G.A.

French Patent 1,330,152. May 13, 1963. Filed Feb. 15, 1962.

The construction of an apparatus in which material to be separated is simultaneously subjected to two different centrifugal forces is described. The apparatus consists of a container that rotates on two different axis. During centrifugation the material can be ionized and the ionized particles subjected to a magnetic field. The apparatus is particularly useful for separating H and U isotopes.

341 STABLE ISOTOPE SEPARATION. II. PRODUCTION PROCESSES.

Linderstroem-Lang, C.U. (Atomenergikommissionens Forsogsanlaeg, Riso, Denmark).

Dansk. Kemi., 43, 165-71 (1962). (In Danish).

The principles of the methods used in heavy water production are summarized, and then individual methods are described in some detail. The production of tritium, lithium isotopes, ^{10}B, other light isotopes, and ^{235}U is discussed. The counter-current gas ultra-centrifuge method is also considered.

342 REPORTS FROM THE GENEVA CONFERENCE. II. LESSONS DRAWN FROM FRENCH RESEARCH AND ACHIEVEMENTS IN THE SEPARATION OF URANIUM ISOTOPES.

Fréjacques, C., and Galley, R.

Ind. At., 8, Nos. 9-10, 63-7 (1964). (In French).

The accomplishments in the field of the separation of uranium isotopes by gaseous diffusion and by ultra-centrifugation are discussed. An economic evaluation is made of the several factors involved in cost estimates. It is brought out that only the very big gaseous diffusion plants, corresponding to a program for the installation of enriched uranium reactors putting out a least 4 000 Mw(e) per year, can expect to produce enriched uranium at an economically acceptable level. (Tr.-Author) (See 339, 408, 415)

343 ISOTOPE SEPARATION BY GAS CENTRIFUGES.

Boettger, O. (AEG Forschungsinstitut, Frankfurt am Main).

Kerntechnik, 6, 571-6 (Dec. 1964). (In German).

As a measure for separating effect the separation potential is introduced. The principles of operation of a gas centrifuge are shown and the theoretical separation potential given. It was found to depend on the mode of operation what fractions of the theoretical separation potential may be reached. The centrifuge method and the diffusion method for the separation of UF_6 were compared as regards economics. (Author)

344 (ORNL-TM-1047 (p. 137-43)) THE GAS CENTRIFUGE.

Evans, E.C. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

The use of gas centrifuges for radioisotopes separations is discussed. Data on the important process parameters for the separation of U isotopes with gaseous diffusion and gas centrifugation are tabulated. Considerations influencing the choice of process gas for gas centrifuge are listed. Special attention is given to the Zippe type centrifuge, which combines the separator, pump, and seal all in one machine.

345 NUCLEAR FUELS.

Amazawa Kyo (Atomic Fuel Corp., Tokyo).

Genshiryoku Kogyo, 11, No. 4, 27-32 (April 1965). (In Japanese).

The large scale search for uranium in Japan was begun in 1954. Uranium bearing minerals were found in many areas, and the Ningyo Toge region was found most suitable for economic mining. The shallow deposits there are chiefly $Ca(UO_2)(PO_4)_2 \times nH_2O$ and the deeper deposits $CaU(PO_4)_2 \times nH_2O$. Uranium is leached from this ore with sulfuric acid (30 to 40 g/l) and a recovery of 80 to 90% is obtained. The uranium is removed from this leach by amine extraction. Succeeding refining steps followed by reduction to the metal are described. Uranium is fabricated in various physical states (metal, alloy, ceramic) and chemical forms (oxides, nitrides, carbides) for use as reactor fuel. Because reactor grade uranium is an expensive and potentially hazardous material, a rigid inspection program has to be maintained. A joint program was initiated with the USAEC to exchange information relating to uranium oxide and carbide type fuels. In anticipation of increased demand for uranium in the future, the separation and concentration of ^{235}U by gaseous centrifugation is being investigated. Test results with argon isotopes were encouraging. The problem of nuclear fuel reprocessing is described briefly followed by a short account of the program for plutonium utilization.

346 PRODUCTION OF NUCLEAR FUELS. PART 2. ENRICHED URANIUM.

Ploeger, F., Vietzke, H. (Nuklear-Chemie und -Metallurgie GmbH, Wolfgang, Ger.).

Chem.-Ingr.-Tech., 37, 692-9 (July 1965). (In German).

The uranium 235 isotope can be concentrated in the form of gaseous uranium hexafluoride either by the Calutron process, by the diffusion method with Al_2O_3 membranes, or by means of gas-centrifuges and separating nozzles. The hexafluoride is then converted either to uranium dioxide or the metal for use in nuclear reactors. (Author)

347 REVIEWS OF ISOTOPE SEPARATION RESEARCHES IN JAPAN. ACTIVITIES OF THE SPECIAL COMMITTEE ON ISOTOPES SEPARATION.

Nippon Genshiryoku Gakkaishi, 7, 429-37 (Aug. 1965) (In Japanese).

The Special Committee on Isotope Separation of the Atomic Energy Society of Japan was established in April 1963 and ended in March 1965. Studies were made on the separation of natural isotopes. The isotopes separated included D, ^{6}Li, ^{7}Li, ^{10}B, ^{13}C, ^{15}N, ^{18}O, ^{39}K, ^{40}Ar, and ^{235}U. The methods of separation adopted included gaseous diffusion, ultracentrifuge, thermal diffusion, molecular distillation, chemical exchange and electrophoresis. (Author)

348 PIERRELATTE — USINE DE SÉPARATION DES ISOTOPES DE L'URANIUM (PIERRELATTE—PLANT FOR SEPARATION OF URANIUM ISOTOPES).

Commissariat à l'Énergie atomique, Paris, 1964, 38 p.

The design and development of the Pierrelatte Isotope Separation Plant is described. The isotopic enrichment processes used are electromagnetic separation, thermal diffusion, centrifugation, expansion in a shock tube, and gaseous diffusion. The principle of each of these methods is described briefly. The characteristics of the plant are given.

349 AEC, INDUSTRY, UTILITIES EXPLORE PRIVATE ENRICHMENT POSSIBILITIES.

Grant, J.

Nucleonics, 25, No. 2, 54-7, 84 (Feb. 1967).

Views of the AEC, private industry, and public utilities on the possibility of private uranium enrichment are discussed. Some questions considered are: the urgency of private participation in enrichment; availability of classified information; prospects for methods of enrichment other than gaseous diffusion; would a monopoly be created which would damage competition; and would private enrichment bring cheaper fuel costs and if so would savings be passed on to public utilities. A short history of uranium enrichment in the U. S. is given. Other methods of enrichment such as thermal diffusion, electromagnetic, gas centrifuging, and chemical separation are summarized.

350 SEPARATION OF U ISOTOPES IN FRANCE AND IN THE WORLD.

Pecqueur, M. (CEA, Paris).

Énerg. nucl. (Paris), 9, 480-8 (Dec. 1967). (In French).

The development of the Pierrelatte installation and the history of the isotopic separation of U in France and in the world are outlined. The civil and military reasons for the separation of U isotopes are given. The U isotope separation developments of the United States. England, Russia, China, and France are briefly reviewed. The principal separation procedures—electromagnetic separation, thermal diffusion, the Becker method, and centrifugation—are described in principle. The gaseous diffusion procedure is described in slightly more detail. The Pierrelatte installation based on the gaseous diffusion procedure is described. Technological difficulties in the design and construction of this installation were connected with the properties of uranium hexafluoride, the barrier, and the compressor and its tightness. The solutions used in each of these areas are indicated. (Trans. 353)

351 SEPARAZIONE ISOTOPICA DELL'URANIO (ISOTOPIC SEPARATION OF URANIUM).

Caldirola, P., Fiocchi, R.

Serie Trattati. Comitato Nazionale Energia Nucleare, Rome, 1967, 448 p.

The available information on the theoretical principles, construction characteristics, and the economics aspects of the various industrial and experimental procedures for the separation of uranium isotopes is compiled and presented in synthetic form. The characteristics of uranium and its isotopes and the importance of the element in the nuclear industry are first outlined. The chief elements of fluid physics are discussed and the physical principles of the isotopic separation of uranium are given. The theory of gaseous diffusion separation, production and testing of porous barriers for gaseous diffusion separation, theory of cascade separation, combination of cascade separation with gaseous diffusion separation, and isotopic separation by centrifugation are considered. The primary bibliographic sources are reports and original articles from researchers in the countries with a nuclear industry.

352 BRIEF DISCUSSION ON A PLANT FOR SEPARATING ^{235}U BY GAS CENTRIFUGATION. ECONOMIC EVALUATION ON A NOVEL GAS CENTRIFUGATION PROCESS BASED ON CERTAIN ASSUMPTIONS.

Kikuchi Hidehiko (Chiyoda Chemical Engineering and Construction Co., Ltd., Japan).

Nippon Genshiryoku Gakkaishi, 10, 441-3 (Aug. 1968). (In Japanese).

Gas centrifugation is presently under extensive study and development. A feasibility study has been made on a number of alternative uranium separation plants of different scale of operation that assumes the use of a conventional type of gas centrifuge that should be operative soon. A plant based on this new gas centrifugation process was examined from the economical standpoint and compared with the conventional plants mentioned above. As a result, it is suggested that this new process, if successfully developed, could be advantageously utilized to build a less expensive plant for separating uranium isotopes. It is further pointed out that data based on the present state of the gas centrifugation art clearly evidences its economic inefficiency against the gaseous diffusion process for separating the isotopes of uranium on a relatively large scale. (Author) (Trans. 359)

353 (K-Trans-45, pp. 7-28) URANIUM ISOTOPE SEPARATION IN FRANCE AND IN THE WORLD.

Pecqueur, M.

Translated from Énerg. nucl. (Paris), 9, 481-8 (Déc. 1967).

An abstract of this paper, prepared from the original language, appeared as NSA 22, 23230. (Orig. 350)

354 (KFK-859) SEPARATION OF THE URANIUM ISOTOPES: A COMPARISON OF THE PROCEDURES UNDER DISCUSSION TODAY.

Becker, E.W. (Kernforschungszentrum, Karlsruhe, West Germany. Institut für Kernverfahrenstechnik).

Oct. 1968, 24 p. (In German). Dep.

The general construction of uranium isotope separation installations is described. The concepts of value function and separative work used for the characterization of their efficiency were explained. The technical details of the gaseous diffusion method, the gas centrifuge method, and the separating nozzle method, as far as they are known from the open literature, are reported. The economic aspects of the three methods are compared.

355 WHICH SEPARATION METHOD FOR URANIUM ENRICHMENT?

Dreissigacker, H.L., Schmidt-Keuster, W.J.

Atomwirt., Atomtech., 14, 71-2 (Feb. 1969). (In German).

In studies on methods to assure that the European needs for enriched uranium are fulfilled, the gas diffusion method is of primary importance since it has been tested to the fullest. The progress made in the development of two other separation methods, the gas centrifuge and the separation nozzle methods, is however so encouraging that the decision on the construction of large installations should be deferred until the advantages of the various methods are sufficiently compared. (Tr.-author)

356 PROSPECTS FOR A EUROPEAN ISOTOPE ENRICHMENT PLANT.

Michaelis, H.

Energ. Nucl. (Milan), 16, No. 3, 44-50 (Mar. 1969).

The development of installed nuclear power by 1980 in the European Community and the assurance for reliable uranium supplies are examined for source diversification, improvement of supply conditions from USA, and construction of an isotope separation plant. The arguments of technological and industrial nature of a plant are explained. The technical characteristics of separation processes such as gaseous diffusion and ultra-centrifugation are reviewed. The various economic, financial, and judicial aspects of such undertakings are delineated. (Author)

357 EUROPEAN ENRICHMENT PLANT.

Nucl. Eng. Int., 14, 343-5 (April 1969).

Future uranium requirements were assessed and the size of plant needed thus estimated. The economics of the three separation methods, diffusion, the nozzle process, and the gas ultra-centrifuge, were studied, and their relative merits observed. The centrifuge process appeared to offer the best prospects.

358 (CEA-CONF-1269) GASEOUS ULTRA-CENTRIFUGE FOR THE SEPARATION OF THE URANIUM ISOTOPES.

Bourgain, le Manach, Berthoumieux.

(nd). 19 p. (In French). (CONF-681015-5). Dep.

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy.

Several prototypes of centrifuges have been perfected in France by the CEA. Their operation is safe and their power of separation is close to the theoretical. With the purpose of increasing the income from the process all efforts lead to the reduction of the investments, the decrease of the electric power, and the increase of the peripheral speeds. The results obtained make it possible to hope that centrifugation will become an economical process in the near future for use in isotopic separation of average amounts. On the other hand we actually can only predict with reservations the competitiveness of this process with gaseous diffusion for large amounts. Only a strong effort in development and industrialization would give a chance to this process. Thus it would appear hardly reasonable to see the limited European means dispersed at the same time on variant forms and different equipment working in parallel. A regrouping and a cooperation are very desirable. Whatever comes of it, even if centrifugation does not develop into an industrial realization, it will make possible theoretical and technological domains the obtaining of useful experience in other branches of industry. Among theoretical studies, we shall cite those related to the mechanics of deformable and nondeformable solids, the studies of pieces in rotation in connection with the mechanics of continuous media, thermal studies, and aerodynamic studies. In the domain of technology we shall cite the metallurgical studies, the studies of bearings and supports, and studies of air- and watertight devices. (Tr.-author)

359 (LIB/Trans-194) BRIEF DISCUSSION ON A PLANT FOR SEPARATING ^{235}U BY GAS CENTRIFUGATION. ECONOMIC EVALUATION OF A NOVEL GAS CENTRIFUGATION PROCESS BASED ON CERTAIN ASSUMPTIONS.

Kikuchi, H.

Translated by P.L. Nicol (Australian Atomic Energy Commission Research Establishment, Lucas Heights), from Nippon Genshiryoku Gakkaishi, 10, 441-3 (1968), 6 p. Dep.

An abstract of this paper, prepared from the original language, appeared as NSA 22, 51149. (Orig. 352)

360 THE SITUATION OF URANIUM ENRICHMENT IN EUROPE.

Scuricini, Giovanni B.

Com. Naz. Energ. Nucl., Notiz., 15, No. 4, 43-5 (April 1969). (In Italian)

After briefly discussing the activities of the Foratom and Euratom Study Groups on uranium enrichment, import aspects, urgency, economics, and need for electric power are reviewed. The economics of the gaseous diffusion and ultracentrifugation processes are discussed.

361 COMPARISON OF THREE SEPARATION METHODS.

Becker, E.W. (Karlsruhe, Univ., Ger.).

Nucl. News, 12, No. 7, 46-51 (July 1969).

With the advent of additional nuclear reactors in the next ten years, the requirements of ^{235}U will increase such that existing separation plants will be unable to produce sufficient fuels. The gas diffusion and gas centrifuge processes are now operating. Another method of enriching ^{235}U has been developed which is based on the partial spatial demixing of components of different weights in a gas flowing along curved tracks. Known as the separation nozzle method, it avoids the fine porous membranes of the diffusion method

and the mechanically highly stressed components of the centrifuge. The 3 methods are described, and compared economically and technically.

362 URANIUM: GAS CENTRIFUGE PROJECTS.

Mining, J. (London), 272, 539-41 (June 20, 1969).

The United Kingdom, Netherlands, and West Germany reached agreement on the development of the gas centrifuge technique for U enrichment. There would be, initially, 2 enrichment plants, each with an annual capacity of 50 tons. They would be built at Capenhurst, U.K. and at Almelo in the Netherlands, and they would go into production in 1972 or 1973. Later the capacity of each plant would be raised to 350 tons. First experimental success in Japan, in producing enriched U by centrifugal separation, was recently achieved by the Power Reactor and Nuclear Fuel Development Corporation with the cooperation of the Tokyo institute of Technology. The centrifuge used has a revolving drum measuring 12 cm ID and was operated at 25 000 rpm. The drum at its external wall reached a rotating speed of 157 m/sec, almost half of the speed of sound. A separation factor of 1:1.015 was achieved. In a scheduled experiment, it is hoped to attain a separation factor of 1:1.069, using a larger centrifuge that is also twice as fast.

363 USE OF THE ULTRA-CENTRIFUGE FOR THE ENRICHMENT OF URANIUM IN EUROPE.

Bogaardt, M.

Atoomenergie, Haar Toepass., 11, 108-10 (April 1969). (In Dutch)

The ultra-centrifuge process, based on a large number of drums, about two million by 1975 and five million by 1980, is discussed. It requires a relatively low investment and low power use, amounting to only about 10% of the gaseous diffusion process. Construction and operating experience in this field is expected to increase from an initial 20 to 100 $\times$ 10^3 kg/year to about 2.5 $\times$ 10^6 kg/year. Pooling of the German, Dutch, and British experience is expected to reduce the production costs to less than the projected $20/kg.

364 (NP-17899) REACTOR DAY 1969 OF THE GERMAN ATOMFORUM.

Winnacker, K. (Deutsches Atomforum e. V., Düsseldorf West Germany).

April 16, 1969, 19 p. (In German) Dep.

A brief review is given of the history and development of reactor technology in Germany. Discussions are given on the following topics: U enrichment studies, particularly through gas centrifugation; fuel cycle studies, including fuel reprocessing, recovered fuel recycle, and radioisotope separation; heavy water production development, of the Heavy Water Reactor (HWR); pebble bed reactor start-up; and development of the Thorium High Temperature Reactor (THTR).

365 GAS CENTRIFUGE PROJECT.

Barnaby, C.F.

Sci. J., 5A, 54-9 (August 1969).

The Netherlands, United Kingdom, and West Germany are co-sponsoring the building of gas centrifuge plants for the enrichment of uranium for reactor fuels. Possible implications of this tripartite scheme in relation to nuclear weapons control are discussed. The technology of uranium enrichment and the economics of the use of gas centrifuges are briefly described.

366 THE INFLUENCE OF A THIRD COMPONENT ON THE CENTRIFUGAL SEPARATION OF THE URANIUM ISOTOPES.

Los, J. (FOM-Instituut voor Atoom en Molecuulfysica, Amsterdam).

pp. 239-45 of Problemi della Separazione Isotopica dell'Uranio. Roma, Comitato Nazionale Energia Nucleare, 1968.

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy. See CONF-681015.

It is shown that addition of a third component to isotopic mixtures of U being separated by centrifugation leads to loss of separative power unless the mass diffusion effect is used by giving the isotopic mixture and the third component opposite radial velocities.

367 SOME CONSIDERATION REGARDING THE DESIGN AND THE OPERATION OF AN ULTRA-CENTRIFUGE ENRICHMENT FACILITY.

Bogaardt, M., Theyse, F.H. (Reactor Centrum Nederland, Amsterdam).

pp. 265-74 of Problemi della Separazione Isotopica dell'Uranio. Roma, Comitato Nazionale Energia Nucleare, 1968.

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy. See CONF-681015.

Considerations important in design of uranium separation facilities based on the ultra-centrifuge are discussed. Information is included on projected plant capacity, demand

for enriched uranium, ultra-centrifuge development and experience, ultra-centrifuge plant costs, and ultra-centrifuge technology growth rates.

368 GAS CENTRIFUGE.

(to Doryokuro Kakunenryo Kaihatsu Jigyodan).

British Patent 1,171,998. 26 Nov. 1969. Priority date 29 March 1966, Japan.

A gas centrifuge for separating isotopes of gases of different molecular or atomic weight is described. The centrifuge comprises a fixed outer chamber and a cylinder inside the chamber which rotates at high velocity. ^{235}U may be separated from UF_6 by feeding it into the cylinder. The ^{235}U collects in the lower end of the cylinder and depleted gas collects in the upper end of the cylinder.

369 (NP-tr-1869) TECHNICAL PERFORMANCE OF, AND ECONOMIC CONDITIONS FOR GAS CENTRIFUGAL SEPARATIONS.

Kanagawa Akira.

Comparison with Gas Diffusion Method. Translated from Genshiryoka Kogyo, 14, No. 11, 49-54 (Nov. 1968).

14 p. Dep. CFSTI (U. S. Sales Only)

The economic feasibility of a gas centrifuge for the enrichment of uranium is examined. Its separative ability, power requirements, and construction costs are compared with those for the gaseous diffusion method.

370 URANIUM ENRICHMENT.

Avery, D.G. (United Kingdom Atomic Energy Authority, Risley, Eng.).

Phys. Bull., London, 21, 17-21 (Jan. 1970).

The principal technical features of the gaseous diffusion technique, the gas centrifuge method, and the separation nozzle process used for enrichment of the fissile ^{235}U content of natural uranium and the problems that have to be solved in bringing these techniques to the stage of economic industrial exploitation are discussed.

371 PLANNING FOR FUTURE ENRICHMENT PLANTS.

Allday, C., Avery, D.G., Kehoe, R.B.

pp. 167-79 of Utilizzazione del Combustibile Nucleare. Roma, Comitato Nazionale Energia Nucleare (1969).

From 10th International Nuclear Energy Conference, Milan, Italy. See CONF-681219.

The United Kingdom and European requirements for enrichment and the plans for meeting them are summarized. A number of factors which arise in optimizing the installation of plant and its subsequent operation are discussed. The problems arising in considering the diffusion nozzle and centrifuge separation processes are considered. (Author) (See 401)

372 URANIUM ENRICHMENT WITHIN THE FUEL CYCLE IN JAPAN.

Imai Ryukichi (Japan Atomic Power Co., Tokyo).

Genshiryoku Kogyo, 16, No. 1, 12-14 (Jan. 1970). (In Japanese)

Light-water reactors are used in most of the atomic power stations in Japan, and a sound fuel cycle is indispensable to secure the efficient use of nuclear fuel. In this connection, U enrichment, associated with the cycle, is described. Atomic power generation in Japan is supposed to be 40 000 000 to 50 000 000 kW in 1985, and 160 000 000 to 200 000 000 kW in 2000. The amount of U enrichment required depends on diverse factors. By the U. S.-Japan agreement on atomic energy, U enrichment is ensured up to about 1998 for the reactor plants whose construction is started by 1972, and the estimated amount is 161 tons of ^{235}U. The capacity in the U. S. is not necessarily sound and sufficient. The international joint establishment of U enrichment in Europe is also reviewed in this connection. The effort of developing gaseous diffusion and centrifugal separation in Japan is described.

373 CARBON FIBERS.

Com. Naz. Energ. Nucl., Notiz., 16, No. 2, 66-9 (Feb. 1970).

(In Italian)

Summaries are presented on research completed and in progress concerning carbon fibers and their possible uses in various sectors of technology, in particular in uranium enrichment processes by gaseous centrifugation (rotating drum processes). (Tr-author)

374 URANIUM ENRICHMENT INDUSTRY.

Avery, D.G., Kehoe, R.B. (United Kingdom Atomic Energy Authority, Risley, Eng.).

Atom, London, 164, 120-30 (June 1970).

A survey of the historical background of isotope separation and uranium enrichment is given. Four processes of uranium enrichment are discussed, the centrifuge method, the electromagnetic (calutron) method, the thermal diffusion

method, the gas diffusion process. The capacity of the present day gas diffusion plants in U.S.A., U.K., France, Russia and China are considered. A simplified treatment of the diffusion process is given which enables the main design and optimization characteristics to be identified. Membrane development is reviewed and the difficulties of plant design when dealing with UF_6 considered. The nozzle process and the centrifuge method are examined and their economics discussed. The growing demand for uranium enrichment in Europe is considered in the light of the tripartite agreement.

375 COOPERATION FOR THE ENRICHMENT OF URANIUM WITH GAS CENTRIFUGES. THE GERMAN-BRITISH-DUTCH TREATY OF ALMELO.

Schmidt-Kuester, W.J.

Atomwirt., Atomtech., 15, 290-2 (June 1970). (In German)

In March, 1970, a preliminary treaty was signed between Great Britain, Holland, and Germany, which concerned cooperation and exchange of confidential information concerning enrichment of uranium using gas centrifuges. After one year, the preliminary treaty will be replaced by a final one following ratification by the three parliaments. Organization of the trinational arrangement is described using a chart. Within a few years, pilot plants with a total separation capability of 350 tons/year will be in operation. One of these with 200 tons/year will be located in England, another one with 100 tons will be located in Holland, and location of the third one will be decided at a later date. Each installation will use various types of centrifuges and equipment, however, at the end of a trial period, a unified concept for final production plants will be developed. Other articles of the treaty govern economic and financial aspects, safety provisions ensuring peaceful use, and the settlement of legal discrepancies between the participating nations.

376 ENRICHMENT OF URANIUM ISOTOPES BY GAS CENTRIFUGATION.

Khan, Sikandar (Atomic Energy Centre, Lahore).

Nucleus, Karachi, 6, 179-84 (Oct.-Dec. 1969).

A brief history of the development of the gas centrifugation method for the enrichment of uranium isotopes and the theory of this process are given. The production cost of enriched uranium by gas centrifugation and other methods is also discussed. (Author)

377 URANIUM ENRICHMENT INDUSTRY.

Avery, D.G., Kehoe, R.B. (United Kingdom Atomic Energy Authority, Risley, Eng.).

J. Brit. Nucl. Energy Soc., 9, 163-9 (July 1970).

An outline is given of the historical development of U isotope separation and of the principles involved. The quantity known as separative work, i.e., the amount of separation an enrichment plant can achieve, is explained. Descriptions of the diffusion process and the nozzle processes are followed by a detailed description of the technology of the centrifuge method. International collaboration in centrifuge development for uranium enrichment is described.

378 ISOTOPE SEPARATION BY NOZZLE METHOD.

Droscha, H.

Industriekurier, 23, No. 81, 17 (1970). (In German)

Brief description is given of principles of the gaseous diffusion method, gas centrifuge method, and nozzle method for enrichment of ^{235}U using UF_6.

379 SEPARATION OF URANIUM ISOTOPES.

Pecqueur, M. (CEA, Fontenay-aux-Roses, France).

Bull. Inform. ATEN (Ass. tech. énerg. nucl.), No. 84, 12-26 (July-August 1970). (In French)

Uranium isotope separation is an important item of the fuel cycle. Two processes can be foreseen at present for the construction of a plant. The first is the ultra-centrifugation method which offers interesting long term prospects but suffers so far from limited industrial experience. The second is the gaseous diffusion process which can form a sound technical and economic basis for the launching of a large separation unit corresponding to the needs of European countries at the end of the decennium. Following up the experience acquired in its plant at Pierrelatte, France has undertaken large scale studies on gaseous diffusion and by 1972 will possess an exhaustive technical and economic record. The ultra-centrifugation process was investigated also although the possible date of industrial application is still uncertain. Moreover, it may prove in the long run that the two processes are more complementary than competitive, gaseous diffusion being used for the high output sections of the cascade and centrifugation for the low output sections, especially if fairly high concentrations (5 or 7 percent) are to be adopted. Many political and industrial problems are involved in the prospect of setting up a multinational unit. (France)

380 (CONF-691051–, pp. 105-53) THE GAS CENTRIFUGE PROBLEM, THE MOMENTUM OF TECHNOLOGY AND INTERNATIONAL COLLABORATION IN NUCLEAR ENERGY.

Barnaby, C.F.

From World security, disarmament and development.

The economic and political implications of developing gas centrifuges for U enrichment are discussed. It is concluded that: gas centrifuges do represent a real threat to world security, specifically as a means for producing fissile material clandestinely for nuclear weapons; the development of this technology would have adverse effects on the arms control negotiations; international collaboration in the development of gas centrifuges is the best security measure; and, if a gas centrifuge plant is constructed, it should be owned and operated by the IAEA.

381 (CONF-691051-, pp. 354-61) CENTRIFUGAL URANIUM ISOTOPE SEPARATION AND NUCLEAR WEAPON PROLIFERATION.

Watson, C.J.H.

From World security, disarmament and development.

The possible threat to world peace represented by an imminent technological development, the separation of U isotopes by the ultra-centrifuge, is examined, and suggestions are made for an international control system which would attempt to prevent the proliferation of nuclear weapons in the coming decades.

382 URANIUM ENRICHMENT IN EUROPE. COMPARISON BETWEEN THE REPORTS OF THE EURATOM AND FORATOM STUDY GROUPS.

Scuricini, G.B.

Com. Naz. Energ. Nucl., Notiz., 16, No. 3, 33-7 (Mar. 1970). (In Italian).

The Euratom and Foratom reports on the economic future of uranium enrichment in Europe are in essential accord; the basic disagreements occur because of the different times at which the two reports were made. The Foratom report was begun in January 1967 and the Euratom report in March 1968. The cost evaluations for the design and construction of enrichment installations are compared. The economic aspects of the gaseous diffusion process, the ultra-centrifuge, and the separation nozzle method are considered. It is concluded that the work of the Foratom group be continued in order to prepare work schedules for continuously evaluating the evolution of the cost and market situation.

383 GAS CENTRIFUGE AND A PROCESS FOR ENRICHING ^{235}U.

(to Doryokuro Kakunenryo Kaihatsu Jigyodan).

British Patent 1,212,449. Nov. 18, 1970. Priority date Oct. 26, 1967, Japan.

A method of enriching and separating ^{235}U without gas condensation is described. The centrifuge used consists of an outer chamber and an inner chamber which rotates relative to the outer chamber. The chambers are arranged in cascades incorporating a supply step, a plurality of enrichment steps and a plurality of recovery steps for separating UF_6 depleted in ^{235}U from UF_6 enriched in ^{235}U.

384 URANIUM ENRICHMENT IN THE U.K.

Geoghegan, G.R.H., Kehoe, R.B.

Atom (London), No. 169, 224-30 (Nov. 1970).

The development of diffusion and centrifuge plants is discussed. Preliminary studies of centrifuge plants had indicated that costs would be prohibitive, but fresh studies in 1967 and 1968 showed that compared with diffusion plants larger centrifuge plants than those previously considered had lower specific capital costs. Improved detail design and a close investigation of manufacturing methods for centrifuges showed that they could be substantially cheapened and that machine life was greater than had previously been assumed. A full comparison study of diffusion and centrifuge plants is given. A tri-national organisation, which is now being set up, consisting of the U. K., the Netherlands and the German Federal Republic and comprising separate companies for the development, construction and operation of centrifuge plants is described. With this organisation it is hoped to combine the best features of machine and plant design, to lower costs for each country and to secure a large share of the European market. It is felt that the centrifuge process offers the greatest potential for a local and viable source of enrichment for the European nuclear power industry.

385 CREATION OF AN INSTALLATION FOR THE ENRICHMENT OF URANIUM IN THE EUROPEAN COMMUNITY.

Baruffa, A.

Neue Tech., B, 10, 237-41 (1968). (In French).

The creation in the European Community of a facility for uranium enrichment involves an examination of commercial, political, and technical problems of considerable difficulty. These considerations include: the enrichment requirements and capabilities of the western world, particularly those of the Community and the availability of enriched uranium supplies from the UK or USA; the technical and industrial aspects; economic aspects; and a comparison of currently used enrichment processes, i.e., gaseous diffusion, ultra-centrifugation, and the gas nozzle process.

386 URANIUM ENRICHMENT BY GASEOUS DIFFUSION OR ULTRA-CENTRIFUGATION.

Grenon, M.

Sci. Progr. Découverte, No. 3428, 23-32 (Dec. 1970). (In French).

The world requirements of enriched uranium, used as fuel for the almost universally adopted light water reactors, will be of the order of 40 million UTS by 1980, this figure includes 21 to 23 million UTS destined for the United States and corresponding to the saturation of the capacities of the three existing plants (Oak Ridge, Paducah, and Portsmouth). The European requirements are estimated at 12 million UTS by 1980. The most pertinent questions to be answered concern whether the new plant needed before 1980 will be constructed in the United States or in Europe, and if in Europe according to what procedure. (Author) (France)

387 URANIUM ENRICHMENT AND THE STAND OF JAPAN.

Kikuchi Seishi (Inst. of Physical and Chemical Research, Yamato, Japan).

Karyoku Hatsuden, 21, 922-6 (Aug. 1970). (In Japanese).

Power generation by nuclear energy is increasing rapidly throughout the world. Reactors employed are primarily those using slightly enriched uranium, such as BWR and PWR. First, the situation of nuclear power generation and the supply capacity of enriched uranium by the U. S. are reviewed. To cope with the future demand of such fuel, three alternatives taken by Japan are discussed: use of natural uranium instead of enriched dependence on the U. S.'s supply, and the construction of enrichment plants in Japan by introducing foreign technology. This latter alternative appears to be desirable. To make possible the introduction of foreign technology, Japan must develop her own technology to a certain extent for actual production. The general scope of uranium enrichment depends upon the practical use of fast breeder reactors. The effort to be made by Japan for her own uranium enrichment is considered in detail: the course to be taken until about 1980; the decision of centrifugal or gaseous diffusion techniques, in which the respective features are taken into consideration; and the necessity for the immediate transition from basic research to the study of industrial production.

388 (CONF-700557-3) EXPECTED DEVELOPMENT OF METHODS FOR ENRICHING URANIUM IN EUROPE.

Dreissigacker, H.L.

Translated from Strömungsmechanische Vorgänge in Gaszentrifugen, DFVLR-Kolloquium, om 14. Mai 1970, Porz, Wahn, Germany. 6 p. Dep. NTIS (U. S. Sales Only).

The present technical and economic states of the gaseous diffusion, gas centrifuge, and separation nozzle methods for U enrichment are described, and their potentials for development in Europe are re-assessed from the present-day point of view. The prospects of the three methods are qualitatively assessed and compared, particularly in view of the hoped-for European collaboration in the production of enriched uranium. (Author)

389 (CONF-700557-1) HISTORY OF THE COUNTERFLOW GAS CENTRIFUGE.

Martin, H.

Translated from Strömungsmechanische Vorgänge in Gaszentrifugen, DFVLR-Kolloquium, am 14. Mai 1970, Porz, Wahn, Germany. 3 p.

The development of counterflow gas centrifuges in Germany from 1936 to the present is briefly reviewed.

390 (CONF-700211-12) PROBLEMS IN CEN TRIFUGE PROCESS.

Takashima, Yoichi (Tokyo Inst. of Tech., Japan).

[nd]. 6 p. Dep. NTIS (U. S. Sales Only).

From Atomic energy society meeting, Tokyo, Japan (Feb. 13, 1970).

The future uranium enrichment needs of Japan for power reactor fuels are estimated, and the feasibility of developing the centrifuge process for isotope separation to meet these needs is discussed. It is concluded that, in spite of the many technical problems which must be solved before centrifuges can be used for uranium enrichment on an industrial scale, progress toward that goal will continue.

391 URANIUM ENRICHMENT AS A COMMERCIAL ACTIVITY.

Avery, D.G. (United Kingdom Atomic Energy Authority, Risley, Eng.).

pp. B. 1-11 of "Séparation isotopique de l'uranium et son économie". Rueil-Malmaison, France. Société de chimie industrielle (1971).

From Meeting on the uranium isotope separation and the corresponding economics, Paris, France (Nov. 27, 1970).

See CONF-701133.

Within the next few years decisions will undoubtedly be made in Europe to establish a substantial capability for the enrichment of uranium. The enterprise will operate in an essentially commercial environment. Discussions of this question are presented as seen from the point of view of a commercial organization which is entering the market in the expectation of long-term profit. Both the CEA and the UKAEA have developed diffusion plants but in neither case is the size of the plants suitable for immediate commercial use. The Authority has decided that for the future the gas centrifuge

offers better prospects for the large-scale expansion of capacity foreseen in Europe. Many factors contributed to this decision. The long-term technical potential of the system, the price which a commercial organization might have to pay for electrical power, and the real balance between cost and price were considered. (Author) (France)

392 NUCLEAR ENERGY IN THE FEDERAL REPUBLIC OF GERMANY AND THE PROBLEM OF URANIUM ENRICHMENT.

Jelinek-Fink, P. (Uranit, Jülich, Ger.).

pp. C. 1-10 of "Séparation isotopique de l'uranium et son économie". Rueil-Malmaison, France. Société de chimie industrielle (1971).

From Meeting on the uranium isotope separation and the corresponding economics, Paris, France (Nov. 27, 1970).

See CONF-701133.

After a short summary on the expected development of German nuclear power capacity, aspects of Anglo-Dutch-German cooperation in the centrifuge field are presented. A trilateral agreement was signed on March 4, 1970 by Germany, the United Kingdom, and the Netherlands on collaboration in the development and exploitation of the gas centrifuge process for producing enriched uranium. During the first phase of the program, two prototype enrichment plants in Capenhurst (G.B.) and Almelo (Netherlands) with a separate work capacity of 50 tons U/yr each will be constructed. Both plants will be expanded to a joint capacity of 350 tons U/yr. The commercial and technical advantages of this program are reported. (Author) (France)

393 SWEDISH STUDIES ON THE ECONOMICS OF URANIUM ENRICHMENT.

Martensson, M. (Aktiebolaget Atomenergi, Nykoeping, Sweden).

pp. D. 1-44 of "Séparation isotopique de l'uranium et son économie". Rueil-Malmaison, France. Société de chimie industrielle (1971).

From Meeting on the uranium isotope separation and the corresponding economics, Paris, France (Nov. 27, 1970).

See CONF-701133.

The Swedish work in the field of uranium enrichment has been limited to theoretical studies. Two different studies were carried out in recent years. These investigations are based upon two different computer programs, the purpose of which being to optimize separation cascades for the large-scale production of enriched uranium. One of the programs is designed for a cascade using the gaseous diffusion process and the other for a cascade made up of gas centrifuges. The two programs have some features in common. Both are made up by combining a suitable theory of cascades with the theory of the elementary separation process applicable in each case. The independent variables of the optimization problem and the total cost function are defined. The optimization is carried out following a routine procedure. The results obtained are given. (Author) (France)

394 VARIOUS PROBLEMS IN INDUSTRIAL DEVELOPMENT OF CENTRIFUGAL SEPARATION METHOD.

Takashima, Yooichi (Tokyo Inst. of Tech.).

Karyoku Hatsuden, 21, No. 8, 938-45 (Aug. 1970). (In Japanese).

Industrial enrichment of uranium-235 with centrifugal separators presents many problems. A large-scale project to produce 1 000 tons of 5% enriched uranium annually was assumed. About 860 000 centrifugal separators are necessary under ideal conditions of 400 m/sec peripheral speed and 70% separation efficiency. In case of the centrifugal separation, the power requirements are less, construction cost is expensive, separation stage requirement is less, circulating amount of UF_6 gas is less, and holdup amount of the UF_6 gas is less in comparison with gaseous diffusion process. In the centrifugal separators, ^{238}U and ^{235}U are separated by pressure diffusion due to steep pressure gradient caused by centrifugal force and gas flow due to density difference. Extraction of separated gases is carried out through shafts or perforated end plates. Helium gas is filled between a rotating cylinder and a stationary outer drum to lessen wind loss. Separation of helium is easy because its properties differ from those of the UF_6. Formation of the centrifugal force field to attain 70% efficiency seems not so difficult. At present, aluminium alloys are used for the rotating cylinders, but FRP is very promising. Wilson shaft seals and pivot bearings are used, but studies are necessary for the solution of problems. Cold-trap process is designed for the separation of the UF_6 and helium gas mixture.

395 WOHER BEKOMMT EUROPA DAS ANGEREICHERTE URAN.

Atomwirtsch., Atomtech., 13 (1968), nr. 4, S. 185-186.

Völlige Abhängigkeit von einem einzigen Lieferland — neue Isotopentrennanlagen in den USA oder europäische Anlagen — neue Verfahren: Ultragaszentrifugentechnik oder Gasdiffusionsprozeß — genaue Untersuchungen nötig.

396 ARRICCHIMENTO DELL'URANIO-ALCUNI METODI ED IMPIANTI.

5 ref.

Notiziario, 14 (1968), n. 6, pp. 49-56.

Metodi di separazione — separazione elettromagnetica — diffusione termica — jet gassoso — centrifugazione gassosa — diffusione gassosa — alcuni impianti di diffusione — Capenhurst (G.B.) — Pierrelatte (Francia) — Oak Ridge (U.S.A.) — Paducah (U.S.A.) — Portsmouth (U.S.A.).

397 IL SIMPOSIO DI TORINO SULLA SEPARAZIONE ISOTOPICA DELL'URANIO.

Scuricini, G.B.

Notiziario, 14 (1968), n. 12, pp. 55-64.

Diffusione gassosa — teoria delle barriere ed esperienze relative — teoria delle cascate e loro ottimizzazione — sistema Trenndüse — ultracentrifughe.

398 DIE VORBEREITUNGEN FÜR DEN BAU EUROPÄISCHER URANANREICHERUNGSANLAGEN MÜSSEN DRINGEND AN DIE HAND GENOMMEN WERDEN.

Atom Pressedienst, Nr. 1, S. 3. (1969).

Internationale Expertengruppe unter der Leitung von Ständerat Choisy, Genf, veröffentlicht aufsehenerregende Empfehlungen — sowohl die Zentrifuge als auch das Trenndüsenverfahren auch bei kleineren Einheitsgrößen relativ wirtschaftlich —, dies ist bei der Diffusion nicht der Fall: hier sind nur Großanlagen, welche Milliarden-Investitionen erfordern, wirtschaftlich.

399 FORATOM URGES EUROPEAN ENRICHMENT PLANT COMMITMENT BY 1972.

Nucl. Ind., 16, no. 2, p. 25-29. (1969).

Foratom recommends pushing ahead with process development at a pace that will permit making a construction commitment by 1972 — centrifuge economics — nozzle enrichment plant costs — potential advantages of the two alternative processes.

400 ALTERNATE ENRICHMENT METHODS.

Nucl. Ind., 15, no. 11/12, p. 69-72. (1968).

Economical jet nozzle uranium enrichment process, as a promising alternative to gaseous diffusion, particularly under European conditions—estimated total investment for the demonstration plant—high power consumption—centrifuge plant feasibility.

401 PLANNING FOR FUTURE ENRICHMENT PLANTS.

Allday, C., Avery, D.G., and Kehoe, R.B.

Atom, no. 148, p. 36-42. (1969). (ref.).

Estimated U.K. requirements for separative work—European enrichment requirements—planning the production of enrichment—fuel cycle integration—diffusion plant considerations—ultra-centrifuge process—nozzle-jet separation plant—idea of a European enrichment plant complex. (See 371)

402 AEC TREIBT DIE GASZENTRIFUGENFORSCHUNG VORAN. (AEC TO BOOST RESEARCH ON GAS CENTRIFUGE.)

Chem. Engng. News 39, 6, 38. (1961).

Es wird über das erweiterte Programm der Atomic Energy Commission (AEC), U.S.A., für die weitere Entwicklung der Gaszentrifugen zur Trennung von Uranisotopen berichtet. Dieses Trennverfahren bietet gegenüber dem Gasdiffusionsverfahren zwei Grundvorteile:

1. Niedriger Verbrauch an elektrischer Antriebsleistung,

2. geringere Anzahl von Maschinen für die geforderte Anreicherung von ^{235}U.

Außerdem eignet sich die Gaszentrifuge auch für kleinere Leistungen. Für die praktische Ausnutzung dieser Vorteile sind viele Probleme, darunter Dauerbetrieb der Zentrifuge, deren Massenherstellung, Gaszu- und -abfuhr bei mehrstufigen Anlagen noch zu lösen. Das 2-bis-3-Millionen-Dollar-Programm für 1961 umfaßt die Fortsetzung der Grundlagenforschung an der Universität, die Entwicklung der Apparate mit Hilfe der Industrie, Aufbau und Betriebnahme von kleineren Gruppen von Gaszentrifugen usw. Im vergangenen Jahr haben deutsche Firmen über die Verwendbarkeit der Gaszentrifuge zur Isotopentrennung berichtet. Alle Daten auf diesem Gebiet werden jedoch in der ganzen Welt wegen der Atomwaffenherstellung streng geheim gehalten. Die AEC bemüht sich, die Teilnahme der Industrien an der Entwicklungsarbeit zu ermöglichen.

403 GASZENTRIFUGE ZUR URANANREICHERUNG? (GAS CENTRIFUGE TO ENRICH OUR URANIUM?)

Canad. Chem. Processing 45, 6, S. 92-94. (1961).

Auszug einer Studie von Peterson, P.K., vorgetragen auf der Canadian Nuclear Conference am 17.5.1961. Die Anreicherung von ^{235}U durch Gaszentrifugen wurde in letzter Zeit in der Öffentlichkeit wieder diskutiert, mehrere Länder befassen sich mit der Entwicklung von Gaszentrifugen, u.a. U.S.A., Kanada, Deutschland, Holland.

Dieses Verfahren würde gegenüber der herkömmlichen Trennung von ^{235}U und ^{238}U mittels Gasdiffusion durch poröse Schichten wirtschaftliche Vorteile bringen, da bei etwa gleichem Investitionsaufwand der Energieverbrauch auf ein Zehntel zurückgehen würde. Außerdem wäre eine solche Anlage flexibler, da durch Zu- oder Abschaltung von in Reihe und parallel geschalteten Zentrifugen Anreicherungsgrad und Durchsatz definiert und einfach geändert werden könnten. Die Trennwirkung einer Gaszentrifuge steigt prop. mit der Trommellänge und mit der 4. Potenz der Umfangsgeschwindigkeit, deswegen werden hohe Drehzahlen angestrebt. Bei gegebenem Trommeldurchmesser bedingt dann ein Betrieb unterhalb der kritischen Drehzahl eine kurze Trommel. Die angestrebte überkritische Fahrweise verlangt u.a. noch Fortschritte in der Lebensdauer der Maschine und der Korrosionsfestigkeit des Trommelwerkstoffs gegen das hochkorrosive UF_6, das bei der Überführung des UO_2 in die Gasform zugesetzt wird. 2 Abbildungen.

404 ISOTOPENTRENNUNG DURCH GASZENTRIFUGEN.

Ebersberg, R.G.

VDI-Nachr. 22, S. 12, 1, (1968).

Aus einer Erweiterung des niederländischen Gaszentrifugen-Zentrums in Duivendrecht wird geschlossen, daß es inzwischen gelungen ist, die Schwierigkeiten, die bisher noch bei der Lagerung und der kritischen Drehzahl des Rotors der Gaszentrifugen bestanden, zu überwinden.

Gaszentrifugen (Rotormaße : 0,22 m Ø, 3 m Länge) werden u.a. zur Anreicherung des ^{235}U im Kernbrennstoff (von 0,7 auf 3%) eingesetzt. Ihr Trenneffekt beruht auf dem Gewichtsunterschied von ^{238}U- und ^{235}U-Molekülen, wobei die Trennwirkung $\sim$ 14mal besser ist als die der herkömmlichen Gasdiffusionsanlagen. Schwierigkeiten ergeben sich daraus, daß die Uranmoleküle in der Form des aggressiven Uranhexafluorids vorliegen. Durch Anordnung der Zentrifugen in Kaskaden soll schließlich die gewünschte Anreicherung an ^{235}U erfolgen.

Die angegebenen Daten beruhen sämtlich auf Vermutungen, da über die Arbeiten mit Gaszentrifugen aufgrund einer von den USA erzwungenen Geheimhaltung sowohl in den Niederlanden als auch in der Bundesrepublik nichts veröffentlicht werden darf.

405 DIE VERFAHREN ZUR TRENNUNG DER URANISOTOPE.

Becker, E.W. (Univ. Karlsruhe).

Kerntechn. 11, 3, S. 129-139 (1969).

Da das in der Natur vorkommende Uran nur zu 0,7 % aus dem spaltbaren Isotop ^{235}U besteht, ist zur Erhöhung der Leistungsdichte in Kernreaktoren eine Anreicherung dieses Isotops notwendig. Auch beim Betrieb schneller Brutreaktoren mit Plutonium wird man u. U. auf ^{235}U angewiesen sein, das in der westlichen Welt hauptsächlich in den drei Gasdiffusionsanlagen der U.S.A. erzeugt wird. Neben diesem Verfahren wurde bisher dem Gaszentrifugenverfahren stärkere Beachtung gewidmet. Die dritte Möglichkeit besteht in der Auftrennung der Isotope $^{235}U/^{238}U$ nach dem Trenndüsenverfahren. Durch Einführung der Begriffe „Wertfunktion" und „Trennarbeit" lassen sich die wirtschaftlichen Aspekte miteinander vergleichen. Für kleine Trennanlagen bietet das Gaszentrifugenverfahren Vorteile, da für die Produktion von 3%igem Material, wie es für Leichtwasserreaktoren benötigt wird, nur 10 bis 20 Gegenstromzentrifugen hintereinander geschaltet zu werden brauchen; jedoch müssen wegen des geringen Durchsatzes viele Einheiten parallel geschaltet werden, was bei den beiden anderen Verfahren nicht notwendig ist.

Trenndüsenanlage und Diffusionsanlage sind „proliferationssicher", da die bei der Genehmigung vorgeschriebene Produktkonzentration nicht durch Umschalten von Trennelementen wesentlich erhöht werden kann. 10 Abb., 2 Tab., 16 Qu.

406 DIE ANWENDUNG DER ULTRAZENTRIFUGE ZUR URANANREICHERUNG IN EUROPA. (DE TOEPASSING VAN DE ULTRACENTRIFUGE VOOR DE VERRIJKING VAN URANIUM IN EUROPA.)

Ingenieur (holl.), 81, 16, A 243/A 245, (1969).

Zur Urananreicherung werden in Europa drei Verfahren angewandt: die Gasdiffusion, das Trennungsventil und die Ultrazentrifuge. Die Merkmale der Verfahren werden erörtert.

Die Ultrazentrifuge besteht aus einer sich schnell drehenden (50 000 bis 100 000 U/min) Trommel, in der die schwereren Isotopen stärker als die leichteren nach außen geschleudert werden. Das Verfahren ist gekennzeichnet durch sehr große Trommelanzahl, niedrige Stromkosten und eine spezifische Investierung, die bei weiterer Entwicklung viel niedriger als für andere Verfahren werden kann. Bei Annahme einer Trennungsarbeit (a, in kg je kg angereichertes Uran) von 2 bis 6 kg/a je Trommel werden 1975 $\approx$ 2, 1980 $\approx$ 5 Millionen Trommeln erforderlich sein. Die für die Entwicklung der Ultrazentrifuge (deren Leistung der 4. Potenz der Umfangsgeschwindigkeit und der Länge proportional ist) maßgebenden Punkte (Trommelbau, Trommelschnelldrehung, Zusammenbau der Trommeln zu einer „Kaskade") werden im einzelnen aufgeführt. Man glaubt, in Zukunft Anlagen mit Trennungsleistungen von 500 000 bis 2 500 000 kg/a ausbauen zu können; der Bedarf an Trennungsleistung wird bis 1980 auf 9×10^6 kg/a ansteigen (bei 60000 installierten MW) aufgrund des einschlägigen Schrifttums ist die Entwicklung der Ultrazentrifuge in den Niederlanden wahrscheinlich am weitesten fortgeschritten. Die Kennwerte der verschiedenen in Europa angewandten Anreicherungsverfahren werden miteinander verglichen.

407 ENSEIGNEMENTS TIRÉS DES ÉTUDES ET RÉALISATIONS FRANÇAISES RELATIVES A LA SÉPARATION DES ISOTOPES DE L'URANIUM.

Fréjacques, C., Galley, R.

Bull. Inform., Ass. tech. énerg. nucl., Fr. (1964), n° 50, 23-7.

En se basant sur l'expérience de Pierrelatte, on donne l'évaluation économique des différents paramètres du coût d'une usine de diffusion gazeuse produisant de l'U enrichi à 0,9% ou à 3% en fonction de sa taille et on la compare à une usine utilisant la centrifugation gazeuse. Intérêt économique.

408 ENSEIGNEMENTS TIRÉS DES ÉTUDES ET RÉALISATIONS FRANÇAISES RELATIVES A LA SÉPARATION DES ISOTOPES DE L'URANIUM.

Fréjacques, C., Galley, R.

In : « Proc. 3rd internation. Conf. peaceful Uses atom. Energy. Geneva, 1964, Dec. 3 ».

New York, United Nations, 1965. 28,5 × 22,5, 329-33.

Réalisations effectuées en séparation par diffusion gazeuse et par ultracentrifugation. Estimation économique. — Ibid., 485-96. — Discussion angl., fr., russe, esp. Sec 339, 342, 415.

409 CONSIDÉRATIONS RELATIVES A LA CONCEPTION ET A L'EXPLOITATION D'UNE INSTALLATION D'ENRICHISSEMENT PAR ULTRACENTRIFUGATION.

Bogaardt, M., Theyse, F.H.

Bull. Inform. ATEN, Fr. (1969), n° 75, 39-43, bibl. (2 réf.).

Stratégie de la réalisation en Europe d'une capacité de séparation de U utilisant l'ultracentrifugation basée sur un certain nombre de données parmi lesquelles figurent le taux des demandes, la capacité de l'usine projetée, la limitation du taux de croissance, le développement de l'ultracentrifugation et le coût d'une usine.

410 GASZENTRIFUGE FÜR DIE URANANREICHERUNG AUS BRITISCHER SICHT (CENTRIFUGEUSE A GAZ POUR L'ENRICHISSEMENT DE L'URANIUM DU POINT DE VUE BRITANNIQUE).

Atomwirtsch. Atomtech., Dtsch. (1969), 14, n° 2, S. 92-3.

Résumé des considérations économiques et techniques sur la centrifugation gazeuse exprimées par les participants anglais au Symposium du FAST à Milan le 13-12-1968.

411 PROBLEMAS RELATIVOS A LA SEPARACIÓN ISOTÓPICA DEL URANIA. SIMPOSIO CELEBRADO EN TURIN LOS DIAS 1-2 DE OCTUBRE DE 1968 (PROBLEMES RELATIFS A LA SEPARATION ISOTOPIQUE DE L'URANIUM. COLLOQUE DU TURIN, 1-2 OCTOBRE 1968).

Gispert Benach, M.

Energ. nucl., Esp. (1969), 13, n° 58, 119-30, bibl. (21 réf.).

Commentaires des mémoires présentés sur les procédés de diffusion gazeuse et de centrifugation et la méthode de la tuyère.

412 URANIUM ENRICHMENT STEPS INTO NUCLEAR SPOTLIGHT.

Chem. Engng. U.S.A. (1969), 76, n° 17, 40-2.

Possibilités d'exploitation, par organismes privés, des usines d'enrichissement de l'U aux États-Unis. Projet commun à l'Angleterre, la Hollande et l'Allemagne pour l'enrichissement par centrifugation. Travaux entrepris au Japon.

413 SYMPOSIUM D'UTRECHT SUR L'ENRICHISSEMENT DE L'URANIUM.

Renaudin, D.

Bull. Inform., ATEN, Fr. (1969), n° 77, 48-9.

Aspects techniques et économiques de l'enrichissement de l'U en Europe. L'ultracentrifugation, le procédé à tuyère du professeur Becker, une extension des usines américaines employant les barrières poreuses.

414 MATÉRIAUX NUCLÉAIRES. ASPECTS TECHNIQUES ET ÉCONOMIQUES DE L'ENRICHISSEMENT DE L'URANIUM EN EUROPE. JOURNÉES D'ÉTUDE ORGANISÉES PAR LE NEDERLANDS ATOOMFORUM A BUNNIK LE 30 MAI 1969.

Spilliaert, P.

Énerg. nucl., Fr. (1969), 11, n° 6, 377-8, bibl. (4 réf.).

Aspects techniques du procédé d'ultracentrifugation et son application. Nouvelles perspectives dans la diffusion gazeuse.

415 ENSEIGNEMENTS TIRÉS DES ÉTUDES ET RÉALISATIONS FRANÇAISES RELATIVES A LA SÉPARATION DES ISOTOPES DE L'URANIUM.

Fréjacques, C., Galley, R.

Rapp. CEA, Fr. (1964), n° 2648, 14 p., même art. angl., 13 p.

Estimation économique des différents paramètres intervenant dans les coûts de séparation des isotopes de l'U par diffusion gazeuse et ultracentrifugation. See **339, 342, 408.**

416 TRENNUNG DER URANISOTOPE. EIN VERGLEICH DER HEUTE ZUR DISKUSSION STEHENDEN VERFAHREN. (SÉPARATION DES ISOTOPES DE L'URANIUM. COMPARAISON DES PROCÉDÉS ACTUELLEMENT EN DISCUSSION.)

Becker, E.W. (Inst. Kernverfahrenstech., Univ. Karlsruhe).

In : **33.** „Physikertag. Karlsruhe, 1968". Stuttgart. Teubner, B.G., 1969. 20 × 14, S. 221-44, bibl., (17 réf.).

Procédés de la diffusion et de la centrifugation de gaz. Procédé (dû à l'auteur et coll.) de la tuyère de séparation; ce procédé, en cours de perfectionnement, peut déjà remplacer la technique de la diffusion de gaz.

417 FORTSCHRITTE AUF DEM GEBIET DER ISOTOPENTRENNUNG IM INDUSTRIELLEN MASSSTAB.

Villani, S. (Energia Nucleare, Suppl. 4, S. 187-95, 1957, ital.).

Die Herst. folgender Isotopen wird besprochen : ^{235}U, D bzw. D_2O, ^{15}N u. ^{10}B. ^{235}U wird als UF_6 in fl. Phase durch Thermodiffusion, in der Gasphase durch Membrantrennung, durch Zentrifugentrennung u. nach dem Trenndüsenverf. gewonnen. Die D-Herst. erfolgt durch Dest. von fl. H_2 oder durch Austauschrk. zwischen H_2 u. H_2O bei 100 u. 600° oder in fl. Phase mit Katalysatoren. Ferner werden der mit hohem Trenneffekt erfolgende D-Austausch zwischen HCl u. W. (industriell noch nicht angewendet) u. die Gegenstromtrennung zwischen W. u. D_2O erwähnt. Zur Anreicherung von ^{15}N werden 2 Verf. angegeben : Austausch zwischen NH_3 u. NH_4^+ u. zwischen NO u. HNO_3. Das letztere Verf. arbeitet bei optimaler 10 m HNO_3 Konz. mit einem Trennungsfaktor von 1,055. ^{10}B kann durch fraktionierte Dest. von BF_3 oder chem. Austauschrk. zwischen BF_3 u. therm. dissoziierbaren BF_3-Komplexen in fl. Phase in Form von Salzen oder als Metall hergestellt werden.

418 PHYSIKALISCH-TECHNISCHE GRUNDLAGEN DES REAKTORBAUES. HERSTELLUNG VON BRENNSTOFFELEMENTEN UNTER ANWENDUNG HYDRAULISCHER PRESSEN.

Pischel, H. (Industrieblatt 63, S. 465-70, 522-27, 1963. Stuttgart-Weilimdorf, VDI; dt.).

Es werden die allg. Grundlagen des Reaktorbaues besprochen u. dabei bes. auf U-Gewinnung, Isotopentrennung durch Gasdiffusions-, Gaszentrifugen- u. Trenndüsenverf.; künstliche Elemente, Reaktoren, Kernbrennstoffe, Moderatoren, Sicherheits- u. Regelstäbe, Kühlmittel, Abschirmung, Reaktortyp, wie Forschungs-, Leistungs-, heterogene u. homogene sowie therm. u. schnelle Reaktoren, eingegangen. Zur Herst. von Brennelementen werden feste Brennstoffe u. Hüllenwerkstoffe, Strangpressen, Schutzgas, Schutzsalz Co-extrusion von Pu, Sinterpressen behandelt.

4. CENTRIFUGE TECHNOLOGY

419 ÉCOULEMENT MONODIMENSIONNEL DE GAZ BINAIRES COMPRESSIBLES DANS LES CENTRIFUGEUSES.

Krause, E.

Deutsche Luft- und Raumfahrt, FB70-04 (2/70), 44 p., 16 fig., 2 tab., 7 réf. bibl. [Me.456-2].

Discussion des équations de mouvement et de leurs solutions pour un écoulement monodimensionnel de mélage gazeux binaire compressible mis en mouvement par deux cylindres coaxiaux infiniment longs dans une centrifugeuse servant à l'enrichissement des combustibles nucléaires. (SA).

Combustibles piles nucléaires. Écoulement compressible. Isotopes radioactifs. Centrifugeuses. Séparation isotopes. Écoulement unidimensionel. Mélanges gaz. Équations mouvement.

420 SEPARATION OF ISOTOPES WITH A COUNTERCURRENT GAS CENTRIFUGE. EFFECT OF THE PROFILE AND RATE OF THE GAS FLOW UPON THE SEPARATION EFFICIENCY.

Akira Kanagawa, Yoshitoshi Oyama, and Yoichi Takoshima.

Tokyo Kogyo Daigaku Gakuho 1962 (49), 151-65. (Eng.).

The sepn. efficiency of a countercurrent gas centrifuge is investigated as a function of the flow rate and flow profile in the rotor. From the equation for the diffusion rate an optimal gas concn. gradient was obtained, at which the centrifuge had its greatest sepn. efficiency. The flow coeff. K, which alone depends upon the countercurrent profile, proved to be a measure of the effect of the flow profile on the sepn. Sepn. factor and sepn. efficiency achieve a max. at the optimal rotation rate. The max. value of the sepn. efficiency increases with increasing flow rate. From CZ 1964 (29), abstr. No. 321.

421 SEPARATION OF ISOTOPES.

Cemil, B. Senvar (Ankara Univ.).

Turk. At. Energy Comm., Sci. Publ. Ser. B 6, 9 p. (1964). (Turk).

The sepn. of stable and radioactive isotopes is reviewed. The phys. and chem. principles involved in the electromagnetic, gaseous diffusion, distn., and ion-exchange methods are discussed, pointing out the fields of application of the individual methods. The other, less important methods, based on thermal diffusion, centrifugation, and electrolysis are also mentioned.

422 SEPARATION CENTRIFUGE FOR GASEOUS ISOTOPES.

Gerard E. Glud.

Fr. 1,421,429 (Cl. B 01d G 21), Dec. 17, 1965, Appl. Oct. 27, 1964, 6 p.

The rotating vessel of the sepn. centrifuge is subdivided into a set of concentric cylindrical compartments. The light isotopes conc. at the inner wall, and the heavy isotopes conc. at the outer wall of each compartment, where they can be pumped off sep. The compartments can be arranged for parallel or for cascade operation.

423 DEVICE FOR PRODUCING A ROTATION OF A GAS IN ORDER TO SEPARATE THE ISOTOPES.

Karl Steimel (Licentia Patent-Verwaltungs-GmbH).

Ger. 1,259,603 (Cl. G 01n), Jan. 25, 1968, Appl. Nov. 23, 1957, 4 p.

The static centrifuge drum consists of a rotating-sym. casing with an axial-sym. arranged elec. current of a gas discharge and a magnetic field at right angles with this current. In the magnetic field, the charged gas particles (of the gas discharge) moving with high rotational speed effect a rotation of the total gas by retransmitting their energy to uncharged particles, by shock. At least one electrode of the gas discharge must be split up in segments, either the cylinder jacket-shaped peripherical electrode or the ring-shaped target central electrode. One barrier resistance and/or one impedance coil must be arranged in the current supplies to each segment.

424 VORRICHTUNG ZUM TRENNEN VON GASGEMISCHEN, INSBESONDERE VON ISOTOPENGEMISCHEN IN DER GASPHASE, NACH DEM PRINZIP DER ISOTOPENSCHLEUSE (PROCÉDÉ DE SÉPARATION ISOTOPIQUE) (A PROCESS FOR ISOTOPE SEPARATION).

Schlottau, R.

Inv., Bagge, E.

Depot, Nov. 4, 1964. DADSch 36.054.

Publi., Aug. 22, 1968.

Brevet, DA I 275 517 (68/20/32) R.

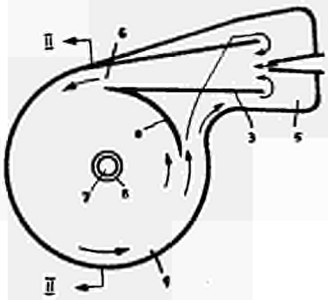
Procédé de séparation de mélanges gazeux, en particulier de mélanges d'isotopes en phase gazeuse, par application du principe de l'écluse à isotopes.

425 PROCÉDÉ ET APPAREIL DE CONCENTRATION OU DE SÉPARATION DES CONSTITUANTS D'UN MÉLANGE GAZEUX PARTICULIÈREMENT APPLICABLE AU CAS D'ISOTOPES.

Chalom, J.A. et Marchal, R.H.

(Société nationale d'étude et de construction de moteurs d'aviation).

BF. 1.375.154 (21 août 1963).



Un jet inducteur est introduit par la tuyère 2, qui entraîne, à travers l'ouverture 4 de la tubulure d'aspiration 3, le mélange gazeux contenu dans la chambre 1; la masse de fluide pénètre tangentiellement dans la chambre et acquiert un mouvement de rotation centripète et une vitesse tangentielle croissante jusqu'aux orifices d'aspiration 7 et 8 pratiqués dans les parois latérales de la chambre 1. Un mélange enrichi des éléments légers est recueilli au niveau de l'orifice 7; un mélange enrichi des éléments lourds est recueilli au niveau de l'orifice 8. Plusieurs variantes comportant plusieurs chambres de révolution sont décrites.

An apparatus for concentrating or separating the constituents of a gaseous mixture by means of an inductive jet, introduced through the nozzle 2, that carries, through the aperture 4 of the exhausting tube 3, the gaseous mixture contained within the chamber 1; the mass of the fluid enters the chamber tangentially and acquires a tangential speed that is increasing as it approaches the exhausting apertures 7 and 8 provided in the lateral walls of the chamber 1. A mixture enriched with the light elements of the mixture is collected at the level of the aperture 7; a mixture enriched with the heavy elements is collected at the level of the aperture 8. Other embodiments comprising several revolution chambers are described.

426 MÉTHODES PHYSIQUES RELATIVES A LA SÉPARATION DES ISOTOPES (PHYSICAL METHODS FOR ISOTOPE SEPARATION).

Kekeh, A. (Paris Univ., 75 France. Lab. de chimie minérale).

Revue de chimie minérale (F.), Vol. 5, N° 3, 1968, pp. 645-682.

On a essayé de classer les méthodes physiques relatives à la séparation des isotopes en fonction du traitement théorique dont elles font l'objet. Méthode de séparation électromagnétique et méthodes de séparation basées sur la diffusion de matière (diffusion gazeuse, diffusion thermique, électromigration, distillation moléculaire, centrifugation, chromatographie en phase gazeuse).

427 CENTRIFUGAL DEVICE.

Kanekawa Akira (Nippon Atomic Ind. Group Co., Ltd.).

Japanese Patent No. Showa 42-2753 (72C), Feb. 6, 1967 (Jan. 24, 1964). (d.).

In the centrifugal device proposed, especially of the parallel-flow type, for separating mixed gases, the efficiency can be increased, compared with the conventional one. It consists of a hollow cylinder rotated at a high speed; a plate closing the top of the cylinder, with the entrance for the mixed gases: a plate, closing the bottom. with the exit; and an upper and an lower disc, located below and above the top and bottom plates respectively, which are fixed (within and) to the cylinder so as to be rotatable with the latter; and a disc, fixed below and to the lower disc so as to form a room, with an exit concentric with, and within, the said other exit. Annular slits are cut in both the upper and the lower disc, one slit (at least) each on the outside and on the inside radially of the radial position γa of the "usual" single slit, which gives the highest separation efficiency.

428 VALVE.

Beams, J.W. (to U. S. Atomic Energy Commission).

U. S. Patent 2,521,891, Sept. 12, 1950.

This patent relates to a valve for a high speed centrifuge or other rotating device which may be opened or closed without regard to the speed of rotation of the device with which it is associated. The valve seat and valve plug are arranged coaxially to, and rotate with, the centrifuge.

429 SEPARATION OF STABLE ISOTOPES, p. 244-271 OF THE ROLE OF ENGINEERING IN NUCLEAR ENERGY DEVELOPMENT; THIRD ANNUAL OAK RIDGE SUMMER SYMPOSIUM; AUGUST 27 TO SEPTEMBER 7, 1951.

Manson Benedict (Massachusetts Inst. of Tech.).

Dec. 1951, pp. 244-271. (TID-5031).

A list of the isotopes of principal technical interest and the processes which have been used to separate the isotopes are given. The processes described are mass spectrometer, molecular distillation, electrolysis, gaseous diffusion, mass (or sweep) diffusion, thermal diffusion, chemical exchange, and gas centrifuge. Some of the novel characteristics of isotope separation plants are mentioned, with a few general conclusions regarding isotope separation.

430 (TID-5217) ELECTROMAGNETIC SEPARATION OF ISOTOPES IN COMMERCIAL QUANTITIES.

Wakerling, R.K., and Guthrie, A., eds. (California. Univ., Berkeley. Radiation Lab.).

June 1949. Decl. April 15, 1955, 434 p. Contract W-7405-eng-48.

Papers have been selected and compiled for the purpose of giving a complete picture of the history and development of electromagnetic isotope separation. Calutron considerations, space charge and beam plasma, magnetic shimming, electric focusing, accelerating electrode focusing, the isotron, the ionic centrifuge, radial magnetic separators, resonance separation, and grid-slit systems are discussed.

431 (A-3957) THE IONIC CENTRIFUGE.

Slepian, J. (California. Univ., Berkeley. Radiation Lab.)•

[Report for Period] Jan. 1, 1942 to Dec. 31, 1942. Decl. Dec. 8, 1955, 45 p. $7.80 (ph OTS); $3.30 (mf OTS).

Topics discussed include: an evaluation of the electromagnetic method of isotope separation; the production of ions at electrodes of a vacuum arc; the 1942 theory of the ionic centrifuge; the expected superiority of the ionic centrifuge over other electromagnetic devices; the experimental development of the arc ion source; experiments with the ionic centrifuge; isotope analyses made at Berkeley; results of thirty-three collection runs with the ionic centrifuge; and results from analyses of Berkeley samples made at Columbia.

432 (Y-748) MATHEMATICAL SURVEY OF A MAGNETIC CENTRIFUGE FOR ISOTOPE SEPARATION.

Dunn, P.F. (Oak Ridge National Lab., Tenn.).

Feb. 23, 1951. Decl. Jan. 6, 1956, 46 p. Contract W-7405-eng-26. Charge $7.80 (ph OTS); $3.30 (mf OTS).

It is suggested that, in a magnetic centrifuge, two different mass species should experience opposite directional effects, thus giving very high enrichments with few stages of processing. A complete mathematical analysis is given of the operation of such a centrifuge, which operates on the principle that if a magnetic field is applied antiparallel to the angular velocity of the centrifuge, ions of different weights will diffuse in different directions.

433 SEAL FOR HIGH SPEED CENTRIFUGE.

Skarstrom, C.W. (to U. S. Atomic Energy Commission).

U. S. Patent 2,816,704. Dec. 17, 1957.

A seal is described for a high speed centrifuge wherein the centrifugal force of rotation acts on the gasket to form a tight seal. The cylindrical rotating bowl of the centrifuge contains a closure member resting on a shoulder in the bowl wall having a lower surface containing bands of gasket material, parallel and adjacent to the cylinder wall. As the centrifuge speed increases, centrifugal force acts on the bands of gasket material forcing them in to a scaling contact against the cylinder wall. This arrangement forms a simple and effective seal for high speed centrifuges, replacing more costly methods such as welding a closure in place.

434 (AEC-tr-3170) CONVECTION PROCESSES IN THE GAS CENTRIFUGE THERMAL CONVECTION IN A STRONG GRAVITATIONAL FIELD.

Hans Martin.

Translated from Z. Elektrochem. 54, 120-9 (1950), 19 p.

A treatment is given of the efflux of a gas between 2 plane parallel heated plates for the case in which the gravitational field inducing the convection is extremely strong (the centrifugal field of an ultracentrifuge). The amount of gas discharging per second, the temperature process between the plates, and the velocity profile of flow are calculated. Except for very small plate distances, the flow conditions prove to be fundamentally different from those which exist when the acting gravitational field is that of the earth. The results, which predict peculiar thermal convection effects in rapidly rotating hollow bodies, are discussed. The case in which the gas is enclosed between unequally tempered walls is also discussed briefly. Reference is made to some of the relationships to problems that occur in the practice of gas ultracentrifuging. (Tr.-author)

435 (AEC-tr-3196) ISOTOPE CONCENTRATION IN ULTRA-CENTRIFUGES WITH HYDROGEN STABILIZATION.

Groth, W., and Harteck, P.

Translated from Z. Elektrochem., 54, 129-32 (1950), 5 p.

The enrichment of gaseous or vaporous isotopes of heavier elements with the aid of gas ultra-centrifuges was studied. The enrichment was found to take place in (1) single chamber centrifuges under discontinuous operation with concentration of the gas supplied to the centrifuge rotor resulting in an increase of the degree of enrichment, or according to (2) a multiplication process which in continuous operation with parallel connection of two centrifuges makes it possible to multiply simultaneously the enrichment of the light and heavy isotopes. (Author)

436 (A/CONF.15/P/723) TESTS OF THE THEORY OF ISOTOPE SEPARATION BY CENTRIFUGING.

Beams, J.W., Snoddy, L.B., and Kuhlthau, A.R. (Virginia. Univ., Charlottesville and Virginia. Univ., Charlottesville. Ordnance Research Lab.).

20 p. $0.50 (OTS).

Prepared for the Second U. N. International Conference on the Peaceful Uses of Atomic Energy, 1958.

Several experiments designed to test the theory for the separation of isotopes in a centrifuge are described. The separations were carried out primarily with the process material in the gaseous or vapor phase. Most of the separation experiments were made on the isotopes of chlorine in carbon tetrachloride and ethylchloride. The evaporative-centrifuge method and the concurrent centrifuge method were investigated. In each of the experiments the temperature of the centrifuge rotor was held uniform and constant. (Author)

437 INAPPLICABILITY OF CERTAIN HYDROMAGNETIC PRINCIPLES TO THE IONIC CENTRIFUGE.

Slepian, J.

Phys. Rev. Letters, 1, 287-8 (Oct. 15, 1958).

The inapplicability of the Chew, Goldberger, and Low paper on the Boltzmann equation and the one-fluid hydromagnetic equations in the absence of particle collisions in calculating the motion of isotope in the ionic centrifuge is discussed.

438 MEANS FOR DETERMINING CENTRIFUGE ALIGNMENT.

Smith, W.Q. (to U. S. Atomic Energy Commission).

U. S. Patent 2,848,817. Aug. 26, 1958.

An apparatus is presented for remotely determining the alignment of a centrifuge. The centrifuge shaft is provided with a shoulder, upon which two followers ride, one for detecting radial movements, and one upon the shoulder face for determining the axial motion. The followers are attached to separate liquid filled bellows, and a tube connects each bellows to its respective indicating gage at a remote location. Vibrations produced by misalignment of the centrifuge shaft are transmitted to the bellows, and thence through the tubing to the indicator gage. This apparatus is particularly useful for operation in a hot cell where the materials handled are dangerous to the operating personnel.

439 (A/CONF.15/P/801) NEW HORIZONS FOR STABLE ISOTOPES.

Ruderman, I.W. (Isomet Corp., Palisades Park, N. J.).
9 p. $0.50 (OTS).

Prepared for the Second U. N. International Conference on the Peaceful Uses of Atomic Energy, 1958.

Recent improvements in methods of stable isotope separation are summarized. Applications of nuclear magnetic resonance, ultra-centrifuge techniques, and emission spectroscopy for isotopic analysis are discussed. Recent applications of the stable isotopes of lithium, boron, carbon, nitrogen, and oxygen as tracers in studies in the fields of agronomy, biology, chemistry, medicine, physics, and nuclear engineering are summarized. 34 references.

440 ROTOR END CAP.

Rushing, F.C. (to U. S. Atomic Energy Commission).

U. S. Patent 2,872,105. Feb. 3, 1959.

An improved end cap is described for the cylindrical rotor or bowl of a high-speed centrifugal separator adapted to permit free and efficient continuous counter current flow of gas therethrough for isotope separation. The end cap design provides for securely mounting the same to the hollow central shaft and external wall of the centrifuge. Passageways are incorporated and so arranged as to provide for continuous counter current flow of the light and heavy portions of the gas fed to the centrifuge.

441 CENTRIFUGAL SEPARATORS.

Skarstrom, Ch. (to U. S. Atomic Energy Commission).

U. S. Patent 2,876,949. March 10, 1959.

A centrifugal separator is described for separating gaseous mixtures where the temperature gradients both longitudinally and radially of the centrifuge may be controlled effectively to produce a maximum separation of the process gases flowing through. The invention provides for the balancing of increases and decreases in temperature in various zones of the centrifuge chamber as the result of compression and expansion, respectively, of process gases and may be employed effectively both to neutralize harmful temperature gradients and to utilize beneficial temperature gradients within the centrifuge.

442 THE SEPARATION OF ISOTOPES IN THE ULTRA-CENTRIFUGE.

Anatol Selecki (Univ. of Warsaw).

Nukleonika 4, 13-33 (1959). (In Polish)

Basic problems underlying the use of high-speed centrifuges to separate isotopes are discussed. Particular consideration is given to recent advances in the design of ultra-centrifuges. A general theoretical analysis of the operation of isotope separation by ultra-centrifuging is outlined. Experimental results are reviewed. (Author) (Trans. 464)

443 (ORO-202) THE DEVELOPMENT OF SHORT BOWL ULTRA-CENTRIFUGES.

Gernot Zippe.

Virginia, Univ., Charlottesville. Ordnance Research Lab.

Progress Report. July 1, 1959. 19 p. Contract [AT(40-1)-2400]. (UVA/ORL-2400-59-PR-1). $3.30 (ph), $2.40 (mf) OTS.

Progress is reported on lifetime tests of rotors and determination of power loss of the scoop system. See 304

444 A METHOD AND APPARATUS FOR THE SEPARATION OF ISOTOPIC IONS.

Norbert Roger Beyrard-Benchemoul and Carel Jan Van Oss.

British Patent 823,283. Nov. 11, 1959.

A method and apparatus for separating isotopic ions by means of an opposed electric field and centrifugal force is described. The combined effect of centrifugal force and radial electric field can be adjusted to completely separate a heavier ion from a lighter one in one operation. Centrifugal accelerations of the order of 10^5 g are required and are obtained by causing the solution of ions to be separated and to be pumped at high linear speed through a spiral conduit. The spiral groove is lined with a conducting tape on which ions may be electrolytically deposited. Means for regulating flow rate and electric field strength are given.

445 (A-50) THEORY OF THE SIMPLE-PROCESS FLOW-THROUGH CENTRIFUGE.

Cohen, K.

Columbia Univ., New York. (194?). Decl. Feb. 1, 1960. 44 p. OTS.

The common principles underlying the theories of all types of isotope separation apparatus are discussed, and illustrated by existing theories of thermal diffusion columns and counter-current centrifuges. The method outlined is applied to the flow-through centrifuge, and a rigorous theory for this instrument is developed. An approximate theory is also found, compared with the exact theory, and corrected. It is then compared with experiment and found to be adequate. Working with the corrected approximate theory, the optimum operating conditions for a flow-through centrifuge, considered as one of a net-work of identical instruments, are determined. Three principal improvements in the design or use of flow-through centrifuges are shown to be the construction of a central core of a particular size, the operation of the centrifuge at a certain percent of its full equilibrium separation, and the use of larger-diameter rotors. (Author)

446 (A-51) THERMAL PHENOMENA IN CENTRIFUGATION.

Skarstrom, C., and Cohen, K.

Naval Research Lab., Washington, D. C. and Columbia Univ., New York. [nd]. Decl. Feb. 1, 1960. 10 p. OTS.

It is shown that the temperature gradients caused by the heating of an angularly accelerated gas due to compression and the converse cooling of the decelerated gas have appreciable effects on isotope separation factors as determined by centrifugation. These effects were found to be greater than would be indicated by the isothermal theory. The influence of these non-uniform temperatures on the performance of flow-through centrifuges is discussed.

447 (A-101) ABSOLUTE EFFICIENCIES OF ISOTOPE SEPARATION BY COUNTER-CURRENT CENTRIFUGES.

Cohen, C., and Kaplan, I.

Columbia Univ., New York. (Substitute Alloy Materials Lab.). A New Counter-Current Centrifuge. Jan. 28, 1942.

Decl. Feb. 1, 1960, 37 p. OTS.

The theory, the numerical estimates, and the advantages of counter-current centrifuges are presented. It was found that the fractional distilling centrifuge has an efficiency of 64%, which can be increased by appropriate baffles to 93%. A basic all-gas counter-current centrifuge is described which appears to have more chance of success. Its top efficiency is 81%. Complete and detailed numerical analyses of cascades of counter-current centrifuges are given. A brief comparison between flow-through and counter-current machines is made, and the advantages of the latter are shown.

448 (A-1911) LONG BOWL GAS SEPARATOR (OEMsr-415).

Rushing, F.C.

Westinghouse Electric and Mfg. Co., East Pittsburgh, Penna. April 6, 1944. Decl. Feb. 1, 1960, 29 p. Contract OEMsr-415. OTS.

The project called for development of the mechanics of a gas separator having a bowl 132 inches over-all length by 7.20 inches inside diameter with a rotating speed of 470 rps. Extruded 14ST aluminium alloy was selected for the bowl material. Special design consideration was given to the possible bowl vibration and the necessary damping to limit it. A full scale model was designed and built. After a few trials the bowl was rotated at 385 rps, above all its critical speeds; but on the way down at approximately 300 rps, excessive vibration occurred and the bowl, shafts, and part of the dampers were wrecked. From previous understanding of the design and from subsequent studies, it is believed that the vibration difficulty can be overcome and that this type of machine can be made to operate over the speed range up to 470 rps. As to the long-time operation of a quantity of the machines, the mechanical problems do not appear to be insurmountable. (Author)

449 (A-3113) SHORT BOWL GAS SEPARATOR.

Rushing, F.C.

Westinghouse Electric and Mfg. Co., East Pittsburgh, Penna.

Oct. 16, 1944. Decl. Feb. 1, 1960, 33 p. Contract OEMsr 489. (SR-239). OTS.

The design and operation of a gas separator having a 36-in. working length and 7.2-in. diameter bowl and a maximum speed of 470 rps are given.

450 (NYO-7347) DESIGN AND COST ESTIMATE FOR A FLEXIBLE PLANT WITH TEN LONG-BOWL GAS-CENTRIFUGES.

Barker, James J.

Kidde (Walter) Nuclear Labs., Inc., Garden City, N. Y.

May 18, 1956. Decl. Feb. 1, 1960, 40 p. Contract AT(30-1)-1374, Task VI. OTS.

The detailed description of a pilot plant for the centrifuge process of isotope separation is given. Included are a construction cost estimate, plant specifications, and plant performance with different gases.

451 PRODUCTION OF A SELF-CASCADING AXIAL FLOW IN A LONG ULTRA-CENTRIFUGE FOR ISOTOPE SEPARATION.

Steenbeck, M.

Kernenergie I, 921-8, (1958 Nov.). (In German)

The principle of the Clusius-Dickel column is described, and an improvement offered. The Clusius-Dickel column is a centrifuge with self-cascading circulation flow due to a thermal gradient. The improved column uses braking disks. In this column, not only is the gas pressed to the wall more at the bottom, but also the angular velocity at the bottom is greater. At the upper end is a small circular-shaped brake disk which does not rotate. The operation of the column is explained in some detail, and a mathematical treatment is given.

452 THE SEPARATION POTENTIAL OF THERMALLY CONTROLLED COUNTER-CURRENT GAS CENTRIFUGES. II. UNSYMMETRICAL SEPARATION PROCESS.

Bulang, W., Groth, W., Jordan, I., Kolbe, W., Nann, E., and Welge, K.H. (Universität, Bonn).

Z. physik. Chem. (Frankfurt) (N.S.) 24, 249-64 (May 1960). (In German)

In an earlier article (Z. Phys. Chem. 19, 1, 1959) the separation potential of thermally controlled counter-current centrifuges was reported for the case of symmetrical separation processes. The theory and the separation research was extended to the case of unsymmetrical separation processes. The results, significant for the practical purposes of isotope separation, show that the maximum separation potential is not attained at $\theta = 0.5$ (symmetrical separation process) but at $0.3 < \theta < 0.4$. At this extraction ratio the enrichment of the light fraction is considerably greater than in the symmetrical case (θ = molar current of light fraction: total molar current). (Tr-author) (Trans. 464)

453 METHOD OF CENTRIFUGE OPERATION.

Cohen, K. (to U. S. Atomic Energy Commission).

U. S. Patent 2,936,11. May 10, 1960.

A method of isotope separation is described in which two streams are flowed axially of, and countercurrently through, a cylindrical centrifuge bowl. Under the influence of a centrifugal field, the light fraction is concentrated in a stream flowing through the central portion of the bowl, whereas the heavy fraction is concentrated in a stream at the periphery thereof.

454 (JPRS-3694) SEPARATION OF ISOTOPES IN AN ULTRA-CENTRIFUGE.

Anatol Selecki.

Translated from Nukleonika 4, 13-33 (1959), 20 p. OTS.

Problems of separation of isotopes in an ultra-centrifuge are discussed. Basic design features of recent ultra-centrifuges are described. Essential elements of the theory of isotope separation in an ultra-centrifuge are outlined. Experimental results are reviewed. (Author) (Orig. 442)

455 (CF-60-8-127) EUROCHEMIC ASSISTANCE PROGRAM : INFORMATION FROM HAPO ON CENTRIFUGE DECONTAMINATION AND FUEL STORAGE CANAL WATER CLEAN-UP.

Hill, O.F.

Oak Ridge National Lab., Tenn. August 30, 1960, 3 p. OTS.

Information on decontamination of centrifuges used with highly radioactive solutions and criteria for fuel-storage-canal water clean-up are presented in the form of questions and answers.

456 CENTRIFUGE APPARATUS.

Skarstrom, H.C., Urey, C., and Cohen, K. (to U. S. Atomic Energy Commission).

U. S. Patent 2,947,472. August 2, 1960.

A high-speed centrifuge for the separation of gaseous isotopes is designed comprising a centrifugal pump mounted on the

outlet of a centrifuge bowl and arranged to pump the heavy and light fractions out of the centrifuge bowl in two separate streams.

457 CENTRIFUGES.

Beams, J.W., and Snoddy, L.B. (to U. S. Atomic Energy Commission).

U. S. Patent 2,948,572. August 9, 1960.

Damping bearings for use on the shafts of an ultra-centrifuge were designed which are capable of passing through critical angular speeds. The shaft extending from one end of the rotor is journaled in fixed-plain bearings mounted on annular resilient shock-absorbing elements to dampen small vibrations. The shaft at the other end of the rotor is journaled in two damper-bearing assemblies which are so spaced on the shaft that a vibration node can at no time exist at both bearing assemblies. These bearings are similar to the other bearings except that the bearing housings are slidably mounted on the supporting structure for movement transverse to the rotational axis of the rotor.

458 HOUSINGS AND MOUNTINGS FOR CENTRIFUGES.

Rushing, F.C. (to U. S. Atomic Energy Commission).

U. S. Patent 2,949,045. Aug. 16, 1960.

A protective housing for a gas centrifuge comprises a slidable connection between flanges and framework portions for absorbing rotational energy in case of bursting of the rotor and a sealing means for sealing the rotor chamber.

459 (A-52) THE INFLUENCE OF BAFFLES ON A COUNTER-CURRENT ULTRA-CENTRIFUGE.

Cohen, K.

Columbia Univ., New York. (194?). Decl. Sept. 23, 1960, 10 p. OTS.

An analysis of fractional distillation processes in a long empty ultra-centrifuge suggests that the use of appropriate baffles in the gas stream might improve the separations obtainable. The influence of ring-shaped baffles is discussed quantitatively by familiar theoretical methods. It is concluded that the introduction of baffles of certain dimensions will materially improve the concentration of isotopes in columns of the type discussed. (Author)

460 (A-119) THE EVAPORATIVE CENTRIFUGE METHOD.

Armistead, F.C., Williams, T.W., Johnston, W.C., Snoddy, L.B., and Beams, J.W. (Virginia, Univ., Charlottesville). (1942). Decl. Sept. 23, 1960. 10 p. Contract OEMsr-140. OTS.

Results are presented of tests to determine the efficiency of the evaporative centrifuge method for separation of isotopes. The separation theory is examined, and data are included which indicate that the separation to be expected may be calculated according to the theory.

461 (ORO-315) THE DEVELOPMENT OF SHORT BOWL ULTRA-CENTRIFUGES.

Gernot Zippe.

Virginia, Univ., Charlottesville. Research Labs. for Engineering Sciences. Final Report. June 15, 1960, 107 p.

Contract AT(40-1)-2400. (EP-4420-101-60U). OTS.

Experimental investigations of short-bowl gas centrifuges are described. The experiments include lifetime tests of rotors and bearings, auxiliary measurements on molecular pumps and internal gas handling systems using freon, and separation tests using ClF_6. Future prospects and economy considerations with respect to industrial applications are included. It is noted that final evaluation of the process is not possible at present.

462 (AEC-tr-4264) ON THE SEPARATION POTENTIAL OF THERMALLY DRIVEN COUNTER-CURRENT GAS CENTRIFUGES.

Groth, W., and Welge, K.H.

Translated by Quasebarth, K.H., from Z. physik. Chem. Frankfurt, N.S., 19, 1-20, (1959), 36 p. JCL.

Issued as Univ. of Virginia Report No. EP-4422-114-60U.

The theory of thermally driven countercurrent gas centrifuges is discussed, and the improvements in the construction of the centrifuge model ZG3 which were applied in experiments for the enrichment of isotopes of argon and xenon are described. Static enrichment factors and the dependence of the enrichment of the throughput at various pressures, of the peripheral velocity, and of the mean temperature of the rotor are reported as experimental results. From these the separation potential of the gas centrifuge can be calculated. A comparison with the maximum theoretical separation potentials shows that the countercurrent flow profile which is determined by the mass dependent pressure gradient strongly influences the experimentally attainable separation capacity of gas centrifuges. (Author)

463 (NP-tr-493) GAS CONVECTION IN ULTRA-CENTRIFUGES AND ITS SIGNIFICANCE IN THE DEVELOPMENT OF GAS CENTRIFUGATION.

Martin, H.

Translated by Kurt H., Quasebarth (Univ. of Virginia) from Chem.-Ingr.-Tech. 31, 73-9, (1959), 27 p.

Issued as Univ. of Virginia Research Laboratories for the Engineering Sciences Report No. EP-4422-111-60U.

The properties of radial axial, and turbulent convection in gas centrifuge rotors are reviewed and it is shown how the methods of gas centrifugation have been influenced in time by the increasing understanding of these kinds of flow. A report is given for the first time on a forerunner of the present counter-current centrifuge and on the results and course of the Institute's study in the field of gas centrifugation. (Author)

464 (AEC-tr-4349) ON THE SEPARATION POTENTIAL OF THERMALLY DRIVEN COUNTER-CURRENT GAS CENTRIFUGES. II. ASYMMETRICAL SEPARATION PROCESS.

Bulang, W., Groth, W., Jordan, I., Kolbe, W., Nann, E., and Welge, K.H.

Translated by Kurth H. Quasebarth from Z. physik. Chem., Frankfurt, N.S., 24, 249-64, (1960), p. 25 JCL.

Issued by the Univ. of Virginia. Research Labs. for Engineering Sciences as report EP-4422-117-60U.

This paper was previously abstracted from the original language and appears in NSA, Vol. 14, abstract No. 20512. (Orig. 452)

465 CUSHIONED BEARING.

Rushing, F.C. (to U. S. Atomic Energy Commission).

U. S. Patent 2,951,730. Sept. 6, 1960.

A vibration damping device effective to dampen vibrations occurring at the several critical speeds encountered in the operation of a high-speed centrifuge is described. A self-centering bearing mechanism is used to protect both the centrifuge shaft and the damping mechanism. The damping mechanism comprises spaced-apart, movable, and stationary sleeve members arranged concentrically of a rotating shaft with a fluid maintained between the members. The movable sleeve member is connected to the shaft for radial movement therewith.

466 CENTRIFUGE.

Rushing, F.C. (to U. S. Atomic Energy Commission).

U. S. Patent 2,951,731. Sept. 6, 1960.

A vibration damping mechanism for damping vibration forces occurring during the operation of a centrifuge is described. The vibration damping mechanism comprises a plurality of nested spaced cylindrical elements surrounding the rotating shaft of the centrifuge. Some of the elements are held substantially stationary while the others are held with respect to a pair of bearings spaced along the rotating shaft. A fluid is retained about the cylindrical elements.

467 (AEC-tr-4406) HIGH-SPEED GAS CENTRIFUGE.

Translated for Oak Ridge Gaseous Diffusion Plant from German Patent No. 1,071,593. Dec. 17, 1959, 14 p.

A description of a high-speed gas centrifuge for separation of gas mixtures, particularly isotopes, is presented. The centrifuge has a rotor, which is closed at the bottom, rotating around a perpendicular shaft and is contained in a fixed housing under reduced pressure. The rotor is provided with a circular top opening through which supply and removal pipes pass.

468 (AEC-tr-4431) NEW RESULTS IN THE ISOTOPE SEPARATION OF HEAVY GASES IN THE GAS ULTRA-CENTRIFUGE.

Hertz, G., and Nann, E.

Translated by Kurt H. Quasebarth from Z. Elektrochem., 58, 612-16, (1954), 14 p.

Issued by Univ. of Virginia Research Labs. for Engineering Sciences, as report EP-4422-120-61U.

Isotope separation experiments with xenon in the gas centrifuge gave the result that the fractions withdrawn from one rotor end are enriched in the heavy isotope, and fractions taken from the other end are enriched in the light isotope, regardless of whether the samples were taken from the axis or the edge. It has to be assumed as highly possible that the end at which the heavy gas occurs is warmer than the other. The cause of this phenomenon is assumed to be the occurrence of counter current circulation. The stability of the circulation is so great that it is possible to operate continuously and to reach separation effects of 4 to 5½ times the theoretical elementary separation. (Author)

469 (CEA-tr-A-795) DISPOSITIF DE SÉPARATION D'ISOTOPES A L'AIDE D'UNE TRAPPE A ISOTOPES FONCTIONNANT EN PHASE GAZEUSE (APPARATUS FOR SEPARATION OF ISOTOPES USING AN ISOTOPE TRAP OPERATING IN THE GAS PHASE).

Diebner, K.

Translated into French from German Patent 1,058,024. May 27, 1959, 9 p.

An isotope separator is described for gas-phase operation. A jet of the gaseous isotope mixture is directed radially outward from the center of a series of rotating and fixed screens. The first screens atomize the material. Then as

the particles move outward the lighter components move to the front and are chopped off in the second set of screens. Thus a discontinuous jet of enriched material is produced for condensation on the refrigerated outer collector, the heavier fraction being condensed at the second set of screens.

470 (DEG-Inf.Ser.-69) A NEW HIGH-SPEED CENTRIFUGE AND NEW LABORATORY CENTRIFUGE.

Wiedemann, E.

Translated by H.W. Curtis from Chem. Ingr. Tech., 28, 263-9, (1956). 18 p.

A description is given of the development and uses of a type of centrifuge, which was made possible by the construction of a new high-speed centrifuge and new laboratory centrifuges. The machines have in common exceptionally quiet running, high insensitivity to unequal loads, and a very good temperature constant at very high normal acceleration values, so that their field of application can be very much extended. (Author).

471 CENTRIFUGAL ISOTOPE SEPARATOR.

(to SNECMA).

Belgian Patent 597,350. Dec. 1, 1959. (In French)

The invention consists in adding to a gaseous isotopic mixture a sufficient volume of an auxiliary light gas to ensure a large dilution. The theory of aerodynamics can then be applied to the motion of these particles (molecules of isotopes) in a homogeneous medium (light gas). The apparatus described has no moving parts, is approximately cylindrical, and contains deflecting surfaces whose angle is chosen, taking into account the respective specific weights of the isotopes to be separated; because of this spinning flow only the heavier isotopes are extracted, the lighter ones remaining mixed with the diluting gas. (EURATOM)

472 (AEC-tr-4394) ISOTOPE SEPARATION.

Walcher, W.

Translated for Oak Ridge Gaseous Diffusion Plant from Ergeb. exakt. Naturw., 18, 155-6, 175-91, 206-13, 219-23, (1939), 60 p. (Includes original, 6 p.).

Selected parts of a review of isotope separation methods were translated. These parts include those dealing with diffusion, thermal diffusion, centrifuge, and a comparative evaluation of methods.

473 (AEC-tr-4766) DIFFUSION IN THE GAS CENTRIFUGE.

Janez Strnad.

Translated for Oak Ridge Gaseous Diffusion Plant from Glasnik mat. fiz. i Astrom., Ser. II, 14, 295-302, (1959), 11 p.

For the case of diffusion in the gas centrifuge, the diffusion equation was solved approximately for rigid rotation of the gas. It is shown that diffusion decreases with the circumferential speed of the centrifuge. Diffusion during starting and braking of the centrifuge is considered, and the application of the results to the counter-current centrifuge is discussed.

474 CENTRIFUGAL SEPARATORS.

(to United Kingdom Atomic Energy Authority).

British Patent 873,772. July 26, 1961.

A gas centrifuge of the continuous, flow-through type is designed with means for controlling temperature gradients in the gas and utilizing it to enhance the separation of gaseous mixtures.

475 METHOD FOR MANUFACTURING A CENTRIFUGE.

(to Reactor Centrum Nederland).

French Patent 1,210,792. Oct. 5, 1959.

A method is given for manufacturing tubular centrifuge bodies, comprising the impregnation of a cylindrical mat of glass fibers with a hardening liquid synthetic resin in a rotating mold. Pressure is exerted on the inner wall of the cylinder by means of an inflatable bag, and the mold is kept in rotation until the resin has set.

476 ULTRA-CENTRIFUGE FOR THE CONTINUOUS SEPARATION OF A GASEOUS MIXTURE INTO TWO COMPONENTS.

(to Reactor Centrum Nederland).

French Patent 1,224,098. Feb. 8, 1960.

A tubular ultra-centrifuge is described. The height is more than three times its diameter. It rotates and oscillates like a top. For that purpose the centrifuge is provided with a bottom pivot which rests on a flexibly mounted support. The centrifuge is held in its vertical position by means of an axial magnetic field generated between a first annular magnetic body which is fixed at the top of the centrifuge and a second annular magnetic body which is

flexibly mounted on the housing of the centrifuge. The centrifuge is brought into rotation by means of an electromagnetic motor, the rotor of which is fixed on the pivot. The centrifuge is provided at its top with axially mounted coaxial inlet and outlet tubes, while discharge openings for the heavy component are provided near the bottom.

477 (AEC-tr-4775) SEPARATION OF ISOTOPES IN A CIRCULAR STREAM.

Mürtz, H.J., and Nöller, H.G.

Translated for Oak Ridge Gaseous Diffusion Plant from Z. Naturforsch., 16a, 569-77 (1961), 16 p.

Centrifugal forces acting in a rotating gas are considered under conditions in which a gas mixture flows through a convergent nozzle at sound velocity tangentially into a pipe under low pressure. The dependence of the separation factor on the mass, the radius of the separating pipe, the diameter of the "peeling" pipe, and of the nozzle length are discussed. Maximum separation factors are given.

478 DAMPING MEANS FOR A VIBRATILE SHAFT, AND CENTRIFUGES AND LIKE ROTATING DEVICES INCORPORATING SUCH MEANS.

(to United Kingdom Atomic Energy Authority).

British Patent 876,364. August 30, 1961.

A centrifuge is designed for separating gaseous isotopes and is adapted for operation at speeds as high as 470 rps. The centrifuge has a damping mechanism to prevent severe vibrating forces from building up in the bearings and supporting structures at critical speeds. The damping mechanism comprises movable and stationary sleeve members spaced apart and surrounding the shaft, and a body of fluid is maintained between the sleeve members.

479 CENTRIFUGE DEVICE AND FLUID SEPARATION SYSTEMS EMPLOYING SUCH DEVICES.

(to United Kingdom Atomic Energy Authority).

British Patent 876,793. Sept. 6, 1961.

A centrifuge and pump construction is designed for use in a multi-stage gas separation system to induce forward and reflux circulation of the gases both through the system and the individual centrifuges. In this design, gas leakage is minimized by eliminating the glands, bearings, etc., that would be required if independent pumps were employed in conjunction with the individual centrifuges.

480 POWER DRIVEN CENTRIFUGES AND LIKE ROTATING DEVICES.

(to United Kingdom Atomic Energy Authority).

British Patent 876,910. Sept. 6, 1961.

A centrifuge is designed with a vibration damping structure. The damping structure comprises the bearings spaced apart axially at distances different from the spacing of the vibration nodes at critical speeds.

481 (AEC-tr-4822) ULTRA-CENTRIFUGE FOR THE SEPARATION OF A GAS MIXTURE INTO TWO COMPONENTS AND METHOD OF MANUFACTURE FOR SUCH A CENTRIFUGE.

Translated for Oak Ridge Gaseous Diffusion Plant, Tenn., from Dutch Patent No. 87,740, March 15, 1958, 8 p.

An invention is described for separating gas mixtures into two components by ultra-centrifugation. The apparatus consists of a cylindrical vessel with central spindles through which the conduits for feed and discharge extend. Methods for fabrication of the apparatus are given along with data on performance.

482 (AEC-tr-4823) CENTRIFUGE UTILIZING THERMODIFFUSION.

Masashi Hoyen.

Translated for Oak Ridge Gaseous Diffusion Plant, Tenn., from Japanese Patent No. 8867/57, Oct. 18, 1957, 6 p.

A centrifuge which can easily separate a large amount of isotope by the application of thermal diffusion in the centrifuge is described. The thermal diffusion field is maintained by keeping one side of the centrifuge at a higher temperature than the other side. Thus the outer circumference at lower temperature is compression-heated and the medium is passed through the inner circumference into a turbine where the medium is expansion-cooled to recover the energy of the medium. After this medium is passed through the outer circumference, it is circulated back to the compressor.

483 METHOD OF CENTRIFUGE OPERATION.

(to United Kingdom Atomic Energy Authority).

British Patent 879,118. Oct. 4, 1961.

A method of operating a centrifugal separator is described which produces more efficient separation of fluid mixtures, particularly gaseous isotopic mixtures, and is applicable to centrifuge cascades. The method comprises passing a first stream of the fluid in an axial direction through the central portion of a centrifuge rotor, passing a second stream through the peripheral portion of the rotor countercurrent to the first stream, and rotating the rotor to effect separa-

tion. Besides the advantage of more efficient separation, the method enables smaller centrifuges to be used and centrifuge cascades to be subdivided into independently controllable units.

484 (JPRS-11213(Pts.I and II)) THEORY OF ISOTOPE SEPARATION IN COLUMNS.

Adrian Mikhaylovich Rozen.

Translation of pp. 3-438 from "Teoriya Razdeleniya Izotopov v Kolonnakh" (A publication of the Publishing House of the State Committee of the Council of Ministers USSR on the Utilization of Atomic Energy, Moscow, 1960), 567 p.

A book is presented in which the basic methods of counter-current separation and the principles of separation in columns and column cascades are treated in detail. Distillation, isotope exchange, thermal diffusion, mass diffusion, and centrifugation are considered. A unified approach to various processes is used to facilitate understanding. Finally, applications of theory to engineering practice are discussed.

485 (CEA-tr-X-349) CENTRIFUGEUSE DE GAZ (GAS CENTRIFUGE).

Bergner, N.E.

Translated into French from Swedish Patent 124,732, Apr. 26, 1949, 30 p.

The design and properties of a gas centrifuge are described in which the gas is introduced into the external part of the separation chamber in such a manner as to produce a rotating movement around the central axis of the chamber, to cross the chamber by increasing its angular velocity, and to be diverted in the central part of the chamber. This central part is characterized by the presence of a turning helix in the form of an endless screw having one or several outlets to extract from the separation chamber the particles in suspension in the gas to be centrifuged. The helix turns in the same direction as the gas and has an angle of inclination less than 45°. The length of the helix is equal to or greater than its largest dimension and is greater than the dimension of the gas inlet. The turning velocity of the helix and its dimensions, the outlet dimensions, and inlet properties are given.

486 SEPARATION IN A CENTRIFUGE-MODEL.

Strnad, J. (Univ. of Ljubljana, Yugoslavia).

Appl. Sci. Research, 10A, 307-10 (1961). (In English).

The maximum peripheral velocity for a cylindrical centrifuge, where gas motion need not be considered, is analyzed mathematically.

487 ON THE ISOTOPE SEPARATION BY COUNTER-CURRENT GAS CENTRIFUGE. I. INFLUENCE OF A GAS FLOW PATTERN UPON SEPARATIVE POWER.

Akira Kanagawa and Yoshitoshi Oyama (Tokyo Inst. of Tech.).

J. At. Energy Soc. Japan, 3, 868-73 (Nov. 1961). (In Japanese).

The influence of a gas flow pattern in a rotor of a counter-current gas centrifuge upon the separation factor and the separative power is studied. The optimum gas concentration gradient, at which the centrifuge has maximum separative power, is obtained from the equation of the diffusion velocity. The equations with respect to the separation properties are derived in two regions of the rotor separately, one of which is an upper part above the feed point as a stripping section, the other a lower part as an enriching section. The effects of the radial concentration gradient on the performance of the centrifuge are considered by means of the flow pattern coefficient K, which depends only upon the flow pattern and approaches the maximum value, unity, as the neutral layer between the counter currents approaches the rotor wall. (Author) (Trans. 495).

488 GAS CENTRIFUGE FOR THE PURPOSE OF ISOTOPE ENRICHMENT.

(to Licentia Patent-Verwaltungs GmbH).

French Patent 1,215,694. Nov. 23, 1959.

In a cylindrical vessel of short axial length, a magnetic field is applied parallel to the axis and an arc discharge is maintained between the cylindrical wall and central electrodes near the end planes of the cylinder. If the pressure of the gas in the vessel is such that the collision frequency of the ions is more than twice the rotation frequency of the ions in the magnetic field, and the radius of the vessel is larger than the radius of the rotation circle of an ion, a rotation of gas will take place in the vessel. This causes isotope enrichment at the center and at the periphery of the vessel.

489 (AEC-tr-4984) HIGH-SPEED CENTRIFUGE FOR THE SEPARATION OF A GAS MIXTURE INTO TWO COMPONENTS IN A CONTINUOUS OPERATION.

Jaap Wind and Johannes Los.

Translated from German Patent 1,080, 931. Apr. 28, 1960, 9 p.

A high-speed centrifuge was developed for the separation of a mixture of gases into two components during continuous operation. It was provided with a tubular centrifugal drum rotatable around a vertical axis into which the ducts for the introduction of the gas mixture to be

separated and for the discharge of the components terminate. The centrifugal drum rotates around its axis on a single point located beneath its lower end similar to a top. It is kept in the vertical position by means of a magnetic field in the direction of the axis.

490 ON THE ISOTOPE SEPARATION BY COUNTER-CURRENT GAS CENTRIFUGE. II. RELATION BETWEEN FEED RATE AND SEPARATIVE POWER.

Akira Kanagawa and Yoshitoshi Oyama (Tokyo Inst. of Tech.).

Nippon Genshiryoku Gakkaishi, 3, 918-22 (Dec. 1961). (In Japanese).

The separative power of a counter-current gas centrifuge was studied in relation to the gas circulation rate in the rotor and the gas flow rates into or out of the rotor. It was found that the separative power evaluated from a peak value of N_p/N_w, $(N_p/N_w)^G{}_p$, at a certain feed rate increases toward the maximum, as the feed rate increases and accordingly $(N_p/N_w)^G{}_p$ decreases. The circulation rate at which $(N_p/N_w)^G{}_p$ is obtained increases with the feed rate. The separative power rapidly approaches the saturated value, as the increase of the separation factor by the longitudinal effect through the counter-current flow lowers. (Author) (Trans. 496)

491 PRINCIPLES OF CENTRIFUGAL SEPARATION. SOME FUNDAMENTAL PROBLEMS IN CENTRIFUGE DESIGN.

Kjellgren, O. (AB Separator, Stockholm).

Chim. e ind. (Milan), 43, 1128-34 (Oct. 1961). (In Italian).

After a short review of the principles controlling the processes of sedimentation and centrifugal separation, the main design features of a centrifugal separator are discussed. Directing criteria are: feed composition, chemical process in which the apparatus shall be used, and desired results. (Author)

492 IMPROVEMENTS IN OR RELATING TO CENTRIFUGES FOR THE SEPARATION OF ISOTOPES.

Konrad Beyerle and Karl Heinz Welge.

British Patent 893,647. April 11, 1962.

A gas centrifuge for isotope separation is designed in which the problems of gas removal and mixing of separated gas fractions are solved. The centrifuge comprises a casing, a rotatable drum with a clearance space between itself and the casing, an aperture in the drum for gas supply thereto, and outlet ports in the drum for passage of separated gas fractions into the clearance. Subsequent mixing of separated gas fractions in the clearance space is minimized by gaps of high flow resistance disposed between the parts of the space into which the fractions pass. A plurality of such drum units may be constructed within a casing for efficient isotope separation.

493 (AEC-tr-4150) NUKLEONIKA.

Translation of Nukleonika, 4, No. 1, 1-32, 35-45, 47-85, 87-100, 103-11 (1959), 88 p.

Twenty-two selected articles from Nukleonika, Vol. 4, No. 1, were translated from Polish. Topics covered include: isotope effect in the Van Slyke combustion of some ^{14}C-labeled aliphatic alcohols and acids, separation of isotopes in ultra-centrifuges, use of radiation in sterilization of food and medical supplies, survey of principle radioisotopes in biology and medicine, nuclear research in Brazil, extraction properties of TBP ester, 14-channel amplitude analyzer, electronic scalers and counters, external-moderator reactor, experimental reactor with high neutron flux, experimental fluidized plutonium reactor, natural uranium reactor with heavy water moderator and biphenyl coolant, fluidized salts power reactor, stannous fluoride a fuel carrier, damage to graphite during irradiation to 1 000 °C, effects of carbon dioxide on graphite in reactor conditions, and reactor siting criteria.

494 GAS CENTRIFUGE FOR THE CONCENTRATION OF ISOTOPES.

(to Licentia Patent-Verwaltungs-GmbH).

British Patent 896,126. May 9, 1962.

A gas centrifuge is designed which causes a gas to rotate in a stationary drum by means of a magnetic field and a gas discharge within the gas space of the drum. In this way, peripheral speeds many times that of the known gas centrifuges with a rotating drum can be obtained. Various designs of the centrifuge for improved isotope separation are discussed.

495 (AEC-tr-5135) ON ISOTOPE SEPARATION BY THE COUNTER-CURRENT GAS CENTRIFUGE. I. INFLUENCE OF A GAS FLOW PATTERN ON THE SEPARATIVE POWER.

Akira Kanagawa and Yoshitoshi Oyama.

Translated for Oak Ridge Gaseous Diffusion Plant, Tenn. from Nippon Genshiryoku Gakkaishi, 3, 868-73 (Nov. 1961), 15 p.

This paper was previously abstracted from the original language and appears in NSA, Vol. 16, abstract No. 5637. (Orig. 487)

496 (AEC-tr-5136) ON THE ISOTOPE SEPARATION BY THE COUNTER-CURRENT GAS CENTRIFUGE. II. RELATION BETWEEN FEED RATE AND SEPARATIVE POWER.

Akira Kanagawa and Yoshitoshi Oyama.

Translated for Oak Ridge Gaseous Diffusion Plant, Tenn. from Nippon Genshiryoku Gakkaishi, 3, 918-22 (Dec. 1961), 13 p.

This paper was previously abstracted from the original language and appears in NSA, Vol. 16, abstract No. 7819. (Orig. 490)

497 IMPROVEMENTS IN OR RELATING TO CENTRIFUGES.

Donald Arthur Boyland (to General Electric Co., Ltd.). British Patent 902,301. Aug. 1, 1961.

Centrifuges were designed consisting of rotors arranged for operation at high peripheral velocities and with an improved means of withdrawing the lighter fractions of centrifuged fluid from the rotor. The rotor is provided with at least one radial channel or section connected with the axial part of the main space within the rotor and to an external exhaust chamber so that, when the rotor is rotating, the light fraction of the fluid is evacuated by a centrifugal pumping action in the centrifuge in conjunction with such normal external pumping as may be necessary.

498 IMPROVEMENTS IN AND RELATING TO CENTRIFUGES.

Donald Arthur Boyland (to General Electric Co., Ltd.). British Patent 902,303. Aug. 1, 1962.

A method was developed for facilitating the withdrawal of fluid from the rotors of centrifuges. In this method the rotor has fixed to it a collecting chamber connected with the interior of the rotor, usually with the axial region, an injector jet arranged to extract fluid from the collecting chamber, an inlet passage for feeding an extracting fluid from an external source to the jet, and an outlet passage through which the mixture of fluid from the interior of the rotor and the extracting fluid can pass to the outside of the centrifuge. The extracting fluid should be readily separable from the lighter fraction from the rotor.

499 IMPROVEMENTS IN AND RELATING TO CENTRIFUGES.

Donald Arthur Boyland (to General Electric Co., Ltd.). British Patent 902,304. Aug. 1, 1962.

An improved means was developed for sealing the end plate to the body of a centrifuge rotor. The centrifuge has a hollow body and an end plate which is not integral with it. There is provided between annular surfaces on the end plate and body an annular sealing member of approximately U-shaped cross section. The outer surfaces of the flanges of the member are soldered or otherwise fixed to the annular surfaces on the end plate and body, respectively. The end plate can be detached, when required, by melting the solder, when this is used, or by cutting the sealing member. The sealing member is preferably of thin flexible material such as metal foil.

500 (K-1537) MACHINE CALCULATION OF CENTRIFUGE EFFICIENCIES.

Brooks, A.A. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

Sept. 21, 1962. Contract W-7405-Eng-26. 27 p.

An IBM-7090 computer program was written in Fortran to perform calculations necessary to the application of a recently developed centrifuge separation theory. Minimum instructions necessary to the use of the program and to the understanding of the program output are presented. In addition, a description of the Fortran program itself and a program listing are given. (Author)

501 (K-1536) A THEORY OF ISOTOPE SEPARATION IN A LONG COUNTER-CURRENT GAS CENTRIFUGE.

Berman, A.S. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

Nov. 2, 1962. Contract W-7405-eng-26. 47 p.

A separation theory is presented for use in interpreting the results obtained in experimental work on heavy isotope separation in a long counter-current gas centrifuge. The theory provides a detailed treatment of the radial concentration variations and is suitable for the description of centrifuge operation at high ratios of product to internal flow. Comparison is made between the predictions of the present theory and those provided by the Cohen theory for several special cases. The theory is also used for comparison with some early experimental observations of Groth and co-workers. (Author)

502 IMPROVEMENTS IN THE SEPARATION OF LIGHT AND HEAVY COMPONENTS OF A FLUID MIXTURE.

Reginald Jack Cross.

British Patent 907,657. Oct. 10, 1962.

A method and an apparatus are described for the improved separation of light and heavy components, especially isotopes, of a fluid by centrifugal force. In the apparatus, the fluid is caused to form an annulus whose radius increases along its axis, and temperature gradients are also used to improve the separation.

503 DEVELOPMENT DIRECTIONS IN THE PERFECTION OF METHODS FOR THE SEPARATION OF STABLE ISOTOPES.

Zavoronkov, N.M., and Sakodynskij, K.I. (Karpov Inst. of Physics and Chemistry, Moscow).

Kernenergie, 5, 211-19 (April-May 1962). (In German).

A survey of the most important developments of the last year in the area of stable isotope separation is given. Exchange distillation of complex compounds and azeotropic mixtures, the simultaneous enrichment of stable isotopes of several elements in one operation, low temperature distillation, centrifuge and separation nozzle methods, thermodiffusion in the liquid phase, the utilization of columns of tube bundles, and the calculation of optimum operation conditions for isotopic separation installations with the help of electronic computers were research projects emphasized for possible future study. (Tr.-author)

504 APPARATUS FOR SEPARATING MIXTURES.

(to Deutsche Gold- und Silber-Scheideanstalt vormals Roessler).

British Patent 909,235. Oct. 31, 1962.

An apparatus is described for separating gas mixtures or isotope mixtures in gaseous form by means of a centrifuge running "in vacuo".

505 (K-1535) A SIMPLIFIED MODEL FOR THE AXIAL FLOW IN A LONG COUNTER-CURRENT GAS CENTRIFUGE.

Berman, A.S. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

Jan. 25, 1963. Contract W-7405-eng-26. 23 p.

A model is proposed to describe the flow in a long counter-current gas centrifuge. The model provides for a central feed tube and a radial temperature gradient. Since the ends of the centrifuge and, hence, the actual driving forces for the internal flow are ignored, a term is included in the equations of motion to provide a driving force whenever a thermal gradient is present. The solutions to the simplified equations of motion and energy with the appropriate boundary conditions lead to a description of the radial variation of density, temperature, and axial velocity. (Author)

506 (TID-15764) FLOW AND SEPARATION IN A LONG COUNTER-CURRENT GAS CENTRIFUGE.

Berman, A.S. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

May 4, 1962. Contract [W-7405-eng-26]. 25 p.

A theory is developed for the separation of isotopes in a long counter-current gas centrifuge. With the selection of a suitably simplified hydrodynamic model, velocity profiles are obtained which permit the evaluation of the integrals arising in the separation theory. The treatment provides estimates of the axial variation of light component composition in each of the counter-current streams in the centrifuge. For a particular set of conditions, the present results are compared with those obtained from the theory previously presented by Cohen. Both theories yield virtually identical results for moderate peripheral velocities and low ratios of product to internal flow. At higher ratios of product to internal flow, the predictions of the present treatment depart from those of Cohen's theory. Enrichments predicted by the present theory are compared with some of Groth's experimental results. The agreement is satisfactory except at intermediate feed rates where the experimental results are significantly higher than those obtained from the theory. (Author) (See 544)

507 (UVA-279-63U) COUNTER-CURRENT FLOW IN A SEMI-INFINITE GAS CENTRIFUGE. PRELIMINARY RESULTS.

Hermon M. Parker and Thomas T. Mayo, IV (Virginia. Univ., Charlottesville. Research Labs. for Engineering Sciences).

Jan. 1963. Contract AT(40-1)-1779. 53 p. (EP-4422-279-63U).

Preliminary results on optimum and practical counter-current flow in gas ultra-centrifuges are presented. An internal flow problem for counter-current centrifuges was solved for a semi-infinite-length case. The lowest mode results indicate that at values of the speed parameter above about 2.5, decay lengths are higher than those calculated in an isothermal version of the problem.

508 (UVA-280-63U) COUNTER-CURRENT FLOW IN A SEMI-INFINITE GAS CENTRIFUGE: MIXED THERMAL BOUNDARY CONDITION.

Hermon (Herman) M. Parker (Virginia. Univ., Charlottesville. Research Labs. for Engineering Sciences).

Jan. 1963. Contract [AT(40-1)-1799]. 26 p. (EP-4422-280-63U).

Results of calculations are presented which provide an insight into the nature of the missing (two-stream) mode as apparent in an analysis of the previously reported insulated wall case. A mixed, thermal boundary condition is used which enables a continuous transition from the constant temperature wall case to the insulated wall case. It is found that the lowest constant temperature mode transforms smoothly, in the insulated wall limit, to a nondecaying ($\alpha \rightarrow 0$) mode which strongly violates any reasonable line-

arization criteria and which must be regarded as a non-physically realizable solution to the problem. The next higher constant temperature mode transforms smoothly into the three-stream insulated wall mode previously found.

509 IMPROVEMENTS IN AND RELATING TO ULTRA-CENTRIFUGES FOR THE SEPARATION OF GASES.

(to Reactor Centrum Nederland).

British Patent 921,350. Mar. 20, 1963. Priority date, Mar. 17, 1960, Netherlands.

An ultra-centrifuge is designed for the separation of gaseous isotopes. The ultra-centrifuge comprises a tubular rotor mounted for rotation in a casing, its interior forming a separation chamber. The rotor is open at one end and the separation chamber bounded at the open end by the casing, in order to induce a gas whirl transverse to the rotor rotation.

510 (UVA-198-62S) COUNTER-CURRENT FLOW IN A SEMI-INFINITE GAS CENTRIFUGE. AXIALLY SYMMETRIC SOLUTION IN THE LIMIT OF HIGH ANGULAR SPEED.

John Ging (Virginia. Univ., Charlottesville. Research Labs. for Engineering Sciences).

Jan. 1962. Contract AT(40-1)-1779. 14 p. (EP-4422-198-62S).

Equations for an approximate determination of the eigenmodes for the steady-state flow in a gas centrifuge operating at high angular speed and considering the effects of heat conduction are presented. The equations are written in cylindrical coordinates and the nonlinear parts of the inertial terms are neglected. It was convenient to use a system of coordinates that rotates with the angular velocity of the centrifuge. The asymptotic solutions derived from these equations are compared with results obtained from the digital computer with a close agreement being noted.

511 (WSEG-RM-20) CONTEMPORARY ULTRA-CENTRIFUGES AND ISOTOPIC SEPARATION.

An Appraisal.

Herbert O. Horn (Weapons Systems Evaluation Group. Inst. for Defense Analyses, Washington, D. C.).

Aug. 1, 1962, 38 p.

An appraisal of recent improvements in the construction and efficiency of ultra-centrifuges for the separation of isotopes is presented. The use of ultra-centrifugation from both a technical and economic standpoint not only for the United States and the smaller non-nuclear nations, but also in the light of current international discussions on disarmament is discussed. Three types of centrifuges, concurrent, evaporative, and counter-current, are described in detail and compared. The use of centrifuge for isotope separation is not economically possible at present; highly enriched material produced by this method would result in prices $\sim$ 75% higher than current U. S. prices. However, the centrifugation process might be attractive to smaller nations due to relatively low investment cost resulting from a short cascade length and the modular nature of construction. In light of recent German advances in ultra-centrifugation and the implications that follow from them, this process warrants detailed and continuing consideration.

512 A DIRECT METHOD OF CALCULATING THE OPTIMUM OPERATING CONDITIONS OF ISOTOPE SEPARATION COLUMNS.

Bock, I.E. (F.O.M. Laboratorium voor Massascheiding, Amsterdam).

Z. Naturforsch., 18a, 465-72 (April 1963). (In English).

The separative power of an infinitesimal counter-current element is expressed in terms of radial parameters. It is shown that the separative power is independent of the value of the radial product stream. Arbitrarily choosing this to be zero (i.e. "balanced diffusion") makes it possible to calculate the optimum radial isotope velocities and the axial profile directly from the diffusion and continuity equations. As an illustration of the method, the optimum axial flow profiles and maximum separative powers of gas centrifuges and thermal diffusion columns were calculated and compared with known results. In the case of the gas centrifuge, the effect that axial back diffusion has on the optimum profile and maximum separative power was calculated. The variation of the separative power with different axial profiles was determined for the thermal diffusion column. It appeared that the natural convection induced axial profile, which is used in thermal diffusion columns, gives a small fraction of the maximum separative power. Calculations indicated that a column with a static separative region (and boundary flows) will approach the maximum separative power and will be well suited for measurements of collision parameters. (Author)

513 ULTRA-CENTRIFUGES FOR THE SEPARATION OF A GAS MIXTURE IN TWO COMPONENTS.

Jaap Wind and Johannes Los (to Reactor Centrum Nederland).

Canadian Patent 665,505. June 25, 1963. Priority date Dec. 27, 1957, Netherlands.

A continuously operating ultra-centrifuge for the separation of gaseous isotopes is designed which avoids the difficulties usually encountered with centrifuges having axle bearings. The ultra-centrifuge comprises an oblong tubular

rotor drum supported at the bottom by a point bearing and at the top by magnetic forces. The magnetic forces are produced by a magnetic field and two rings of magnetic material, one of which is attached to the top of the drum, and roomy tubes for conducting gas into and from the drum are passed through the rings. Resilient and damping means are provided to permit the drum to attain supercritical speed easily.

514 IMPROVEMENTS IN ULTRA-CENTRIFUGES.

(to Reactor Centrum Nederland).

British Patent 947,892. Jan. 29, 1964. Priority date Mar. 22, 1960, Netherlands.

An ultra-centrifuge for the separation of gaseous mixtures is patented. The drum of the centrifuge is supported at its lower end for rotation about a vertical axis and is held in an upright position by magnetic suspension near the upper end. The drum is driven by an asynchronous rotary-field motor, the armature of which is a cylindrical sleeve of electrically conducting nonmagnetic material fixed to and coaxial with the drum. The armature extends into an annular gap formed by the stator, which is 2 concentric ferromagnetic members. The outer member of the stator carries windings for generating a rotary field, and the core member is made of a ferrite material with small hysteresis losses.

515 METHOD AND DEVICE FOR THE SEPARATION OF GAS MIXTURES BY THE ACTION OF CENTRIFUGAL FORCES.

Hans-Georg Nöller.

German Patent 1,154,793. Sept. 26, 1963. Filed Jan. 4, 1956.

The method described comprises the steps of injecting the gas tangentially into a vessel with a circular cross section, of choosing the jet velocity, the gas pressure within the vessel, and its length in such a way that a circular flow is established, and of extracting the mixture enriched in heavy molecules from the circumference and the mixture depleted from the center of the vessel. The vessel is rotated by the action of the injected gas. (Gmelin Inst.)

516 (UVA-325-64U) MODIFIED MINIMUM PRINCIPLE FOR STATIONARY FLOW IN A GAS CENTRIFUGE.

John L. Ging (Virginia. Univ., Charlottesville. Research Labs. for Engineering Sciences).

Mar. 1964. Contract AT(40-1)-1779. 8 p. (EP-3912-325-64U).

The Onsager Minimum Principle applies to stationary gas flow in a rotating system. The dissipative effects are discussed, particularly the Eckman layers. The removal of these layers from the equations is accomplished by replacing them with surface integrals. The resulting modified principle is given.

517 ISOTOPE SEPARATION BY CONCURRENT GAS CENTRIFUGE. (PART) I.

Akira Kanagawa and Yoichi Takashima (Tokyo Inst. of Tech.).

Nippon Genshiryoku Gakkaishi, 6, 20-8 (Jan. 1964). (In Japanese).

Both the separation factor and the separative power of a concurrent gas centrifuge were studied in relation to the gas feed rate and the effective length of the rotor. The differential equation of centrifugal separation through (n + 1) cylindrical thin concurrent streams was derived, and solved in the cases of n = 1 and 2. The relations of the gas feed rate per length of the rotor to both the separation factor and the separative power were compared with those in the case of counter-current flow, which vary with the ratio of length of rotor to the radius. It was found that the gas feed rates in the counter-current flows need much smaller values than the concurrent flow rates to get identical separative power, however, the gas circulating rates in the counter-current flow are comparable. From the analysis of three cylindrical thin concurrent streams, the influence of thickness of the streams upon the separation was evaluated. (Nucl. Sci. Abstracts of Japan, 3, No. 2, April 1964). (See 545)

518 (JPRS-23767) TRANSLATIONS OF COMMUNIST CHINA'S SCIENCE AND TECHNOLOGY No. 75.

Mar. 19, 1964, 82 p. (OTS-64-21840).

Translations are presented of ten selected articles which treat respectively a visit to Peking University, gas centrifugal separation of isotopes, pulse laser, ruby absorption spectrum, iodine heterocyclic compounds, decomposition, of boron phosphide, charged particle motion in dipole magnetic fields, survey of the Mount Everest region, material transport models, and Chinese medicine. Separate abstracts were prepared for two articles dealing with gas centrifugal separation and charged-particle motion in magnetic fields.

519 (ORNL-tr-265) ULTRA-CENTRIFUGE FOR THE SEPARATION OF GAS MIXTURES, FOR EXAMPLE, MIXTURES OF GASEOUS ISOTOPES.

Johannes Los and Fridjof Ernst Trangott Kelling.

Translated by A. Houtzeel (Oak Ridge National Lab., Tenn.), from Dutch Patent 103,433. Mar. 17, 1960, 6 p.

An ultra-centrifuge is designed in which the usual disadvantages encountered with the friction disk are avoided. In the ultra-centrifuge, the rotary tube takes the shape of a tube open at one end while the separation space at that side is limited by the friction disk. The stability of the rotor is improved, and the separation space is not shortened by the friction disk.

520 (A/CONF.28/P/637) THE SEPARATIVE POWER OF SHORT COUNTER-CURRENT CENTRIFUGES.

Ouwerkerk, C., and Los J. (Reactor Centrum Nederland, The Hague).

May 1964, 12 p.

In general counter-current centrifuges are operated as closed units, which are fed somewhere in the middle of the centrifuge, while at both ends the separated fractions are withdrawn. These centrifuges could be considered as the combination of a rectifying part and a stripping part. In a recent publication it was shown that a symmetrically operated counter-current centrifuge has an efficiency that amounts to 80% of the maximum separative work that can be performed. It was shown that the decrease of the separative power is due to the fact that no optimal radial concentration gradient can be maintained along the length of the centrifuge. At both ends the radial concentration gradient approaches the equilibrium concentration gradient, because the net desired material transport approaches zero. The influence of the feed on the separative power is considered. In most experiments the feed has to be introduced in the forward stream of the counter-current, thus giving rise to an asymmetry of the column parameters of the rectifying and the stripping part. This asymmetry can be corrected for only partially, by shifting the feedpoint upstream. It is shown that a further reduction of about 15% of the separative power results from this asymmetry. (Author) (See 546)

521 (A/CONF.28/P/440) ISOTOPE SEPARATION BY CONCURRENT GAS CENTRIFUGE.

Akira Kanagawa, M.E. Yoichi Takashima, and Yoshitoshi Oyama (Tokyo Inst. of Tech.).

May 1964, 12 p.

The relations between the separative power, the separation factor, the gas flow rate, the length of cylindrical rotor, the cuts and the radii to be extracted have generally been analyzed concerning isotope separation by the concurrent type of gas centrifuge and compared with those in the case of the counter-current type. The more generalized differential equation than that used by Cohen, which can be applied to centrifugal separation through (n + 1) cylindrical thin concurrent streams, has been obtained, and solved in the cases of n = 1 and n = 2. First of all, in the case of n = 1, already solved by Cohen, the relations of gas feed rate per length of the rotor to both the separation factor and the separative power have been calculated and compared with those in the case of counter-current flow using a parameter of Z/r_0 which is the ratio of the length of rotor to the radius. As a result, it has been shown quantitatively that as Z/r_0 increases, remarkably more flow rate should be required in the concurrent flow to get the same value of separative power as that in the counter-current flow, and the flow rate in the concurrent flow, however, is comparable with the circulation rate in the counter-current flow. In the case of n = 2, a higher maximum separative power is possible even if the inner two thin streams are mixed at the exit, than in the case of n = 1. The optimum condition in this case is as follows: $r_0/r_0 = 0.45$, $r_2/r_1 = 0.6$, $\theta_1 = 0.19$ and $\theta_2 = 0.31$, where r_1 and r_2 are the radii of the inner two streams and θ the cut. The maximum value of the separative power is 1.066 times that in the case of n = 1, and the optimum flow rate is 1.130 times. As a result of these analyses, it is suggested that the thickness of the flow path which should exist more or less in practice may bring better separation performance. (Author) (See 543)

522 (NP-14200) DE SCHEIDING VAN ZWARE ISOTOPEN IN EEN CENTRIFUGAAL VELD (THE SEPARATION OF HEAVY ISOTOPES IN A CENTRIFUGAL FIELD).

Los, J. (Leiden. Rijksuniversiteit).

1963, 100 p.

The separation of heavy isotopes by means of a centrifuge is studied. The experimental and theoretical work done on centrifuges is reviewed. The cascade theory as developed by Cohen is summarized, and the column theory is discussed. The theory of the counter-current centrifuge is then considered. Several profiles are treated to show how the discrepancy between the optimal and actual flow leads to severe losses of separative power. Some hydrodynamic aspects of the counter-current centrifuge are discussed. The experimental results of Groth and Zippe are briefly described.

523 ISOTOPE SEPARATION BY CONCURRENT GAS CENTRIFUGE. II. SEPARATIVE POWER OF THREE CONCURRENT STREAMS.

Akira Kanagawa and Yoichi Takashima (Tokyo Inst. of Tech.).

Nippon Genshiryoku Gakkaishi, 6, 511-16 (Sept. 1964). (In Japanese).

The separation performance was studied on a concurrent gas centrifuge with three thin streams. The radii of stream paths, the gas flow rates, and the cuts are the important factors for evaluation of the separative power. The calculated results showed that there existed some proper gas flow rate to get the maximum separative power for any set

of radii and cuts, and further the optimum set of radii and cuts under which condition the separative power could become largest was found. The case in which the inner two thin streams were mixed at the exit was also analyzed. As a result, it was confirmed that it was possible to obtain the larger separative power even in the latter case than that in the case of two thin streams. Therefore, it is suggested that the proper thickness of stream path may be rather favorable for the performance of separation. (Author)

524 METHODS OF SEPARATING THE STABLE ISOTOPES. II. METHODS BASED ON REVERSIBLE PROCESSES.

Vasaru, Gh.

Rev. Chim. (Bucharest), 14, 285-9, (May 1963). (In Romanian)

A description is given of different methods of separating the stable isotopes based on reversible processes (distillation, isotopic exchange, centrifugation). The separation coefficient is defined for each case emphasizing the possibilities of applying the methods described and their practical uses. (Author)

525 THE SEPARATION OF HEAVY ISOTOPES IN A CENTRIFUGAL FIELD.

Los, J.

Thesis, Leiden, Netherlands, Rijksuniversiteit te Leiden, 1963, 98 p. (In Dutch)

Experimental and theoretical work on centrifuges is reviewed along with centrifuge cascade theory. Theory of countercurrent centrifuges is examined and profiles of the countercurrent are presented to show the loss in separative power caused by discrepancies between optimal and actual flow patterns.

526 THE SEPARATION CASCADES IN DIFFUSION PROCESSES.

Dickel G., (Universitat, Munich).

Kerntechnik, 6, 561-5, (Dec. 1964). (In German)

For all separation methods based on diffusion processes the separation cascade with optimum efficiency can be obtained from a diagram. For the separation-tube method and the counter-current centrifuge the optima are given by a multitude of solutions containing two parameters. The cascades differ from each other only in their dimensions. (Author)

527 A CONTINUOUSLY WORKING INSTALLATION FOR THE SEPARATION OF ISOTOPES IN THE GAS PHASE.

Etterich, J. (Universitat, Kiel).

Kerntechnik, 6, 577-81, (Dec. 1964). (In German)

The plant described makes possible a continuous process for the separation of isotopes in the gas phase. One turbomolecular pump at a time is arranged at both sides of the separation zone. The density gradient effected by the turbines provides for removal of gases from separation zone. The enriched as well as the exhausted gas components are pumped to local separated catchers after the separating process is performed.

528 (MLM-1163(p.D-1-9)) OTHER ISOTOPE SEPARATION METHODS UNDER INVESTIGATION AT MOUND LABORATORY.

Foster, K.W. (Mound Lab., Miamisburg, Ohio).

Photochemical methods are inexpensive, relatively simple, and have moderately good enrichment. However, the total throughput capacity per unit is very low, being of the order of a few milligrams per day. As yet the method has been used successfully only on mercury, and extension to other elements is a formidable problem with no guarantee of solution. The mass filter is more expensive but has, in theory, excellent resolution and can be adapted to any light or medium weight element which can be ionized at reasonable potentials. The total throughput per unit can apparently be increased to the order of grams per week. Generally, there is an appreciable loss of source materials during the process so that recovery of a scarce source material would be a problem. Extension of the method to very heavy elements is not encouraging at present. Centrifuges have an inherently high capacity and possess definite advantages over other methods for the high mass elements. However, the separation per unit is quite low and a cascade system is required for significant isotope enrichments. (Author)

529 CENTRIFUGES, e.g. ULTRA-CENTRIFUGES FOR THE SEPARATION OF GASES.

Los, J., Kelling, Fridjof, E.T. (to Reactor Centrum Nederland).

Canadian Patent 710,184. May 25, 1965. Priority date March 17, 1960. Netherlands.

An ultra-centrifuge is described for separation of gas mixtures or gaseous mixtures of isotopes. The advantage lies in the simplicity of the production of a gas whirl tranversely directed to the axis of rotation.

530 ISOTOPE SEPARATION BY CONCURRENT GAS CENTRIFUGE.

Kanagawa Akira, Takashima Yoichi (Tokyo Inst. of Tech.). Bull. Tokyo Inst. Tech., No. 61, 43-50 (Dec. 1964).

The development of the gas centrifuge in Japan is described. Experiences suggested that the simplification of the centrifuge by using the concurrent type instead of the countercurrent type may be essential, as some mechanical and material problems still exist unsolved. The separation performance of the concurrent type consisting of more than two streams was calculated and the results showed that three streams can give a little better performance than two streams. (Author)

531 (AD-635643) ELEMENTARY INTRODUCTION TO ISOTOPE SEPARATION.

Holliday, D., Plesset Milton S. (RAND Corp., Santa Monica, Calif.).

June 1966. Contract AF49(638)-1700. 38 p. (RM-4938-PR). CFSTI $2.00 cy, $0.50 mn.

Six isotope separation processes are discussed: the separation nozzle; sweep diffusion; thermal diffusion; electromagnetic separation; gaseous diffusion; and centrifugation. The emphasis is on the physical principles involved in each process and on the use of these physical differences. Because five of the processes involve devices that give individually a very small separation, a cascade of these devices is required to effect large separations. The steady-state theory of such cascades is also discussed. (Author)

532 (K-Trans-20) ULTRA-CENTRIFUGE WITH MAGNETICALLY SUSPENDED ROTOR DRIVEN BY A MAGNETIC ROTATING FIELD.

Translated for Union Carbide Corp., Nuclear Div., Oak Ridge, Tenn., from German Patent 1,187,400. 10 p. Dep.

CFSTI. JCL $1.10 fs, $0.80 mf.

An ultra-centrifuge with a magnetically suspended rotor which is driven by a magnetic rotating field is described. The rotor without a solid shaft has an annular jacket consisting of ferromagnetic material which encloses a central cylindrical cuvette space. The top and bottom of the space consists of a transparent material. A camera for closed-circuit television may be installed above the cuvette. A hollow cylinder consisting of a ferromagnetic material with a dia slightly larger than the dia of the rotor is freely suspended on wires slightly below the rotor in an annulus filled with a damping fluid.

533 IMPROVEMENTS IN AND RELATING TO ULTRA-CENTRIFUGES.

Christ, M.

British Patent 1,119,420. July 10, 1968. Priority date Nov. 25, 1964, Germany.

A method is described for the operation of an ultra-centrifuge vessel to become horizontal while the motor is being operated at low power. The electrical circuits are described for the gradient density ultra-centrifuging operation.

534 IMPROVEMENTS IN AND RELATING TO CENTRIFUGES.

Salmon, B. (to Commissariat à l'Energie Atomique).

British Patent 1,161,465. August 13, 1969. Priority date Jan. 6, 1967, France.

An improved centrifuge is described that promotes increased mechanical strength of the rotary bowl by incorporating a lateral shell and two end plates designed so that each is assembled to the shell with an interposing seal between the end plate and the seal held by circumferentially spaced studs. Each end plate and shell is assembled in an interfitting relation along a contact surface which is inclined to the axis of the bowl and along a second surface which is perpendicular to the axis.

535 SEPARATION OF A BINARY GAS MIXTURE THROUGH CENTRIFUGATION : EXPLANATION OF THE AXIAL ENRICHMENT OBTAINED IN ULTRA-CENTRIFUGES.

Guilloud, J.C. (Univ., Grenoble, France).

Compt. Rend., Ser. A, 270, 963-6, (April 13, 1970). (In French)

One of the interesting points of the ultra-centrifuge in the field of isotopic separation is due to the fact that by creating an appropriate axial convection movement inside the rotor, the enrichment obtained between the two extremities is greater than radial enrichment. It is shown, by means of a simple diagram, why a transversal separation effect inside a mixture can be amplified axially by its mean movement. (Author) (France)

536 THEORETICAL AND EXPERIMENTAL STUDY OF CENTRIFUGATION WITHIN FIXED WALLS OF A GASEOUS BINARY MIXTURE.

Guilloud, J.C.

Entropie, Nos. 34-5, 23-35, (July-Oct. 1970). (In French)

A method of centrifugation in the gaseous state, is described; in contrast with ultra-centrifugation, it is the mixture to be separated which is rapidly rotated in a fixed device. The object of this study was to compare ultra-centrifugation and this possible method of isotopic separation. A physical explanation of the multiplying effect, which is the most interesting feature of ultra-centrifugation, and which does not occur in a turbulence tube, is given. Calculations on the magnitude of the differences in concentration likely

when centrifuging within fixed walls are given. The experimental loop in which the observed separation effects were less than those theoretically predicted, is described. The results obtained demonstrated the inferiority of this method in comparison with gaseous diffusion. (Author) (France)

537 (CONF-700557-4) NUMERICAL SOLUTION OF THE NAVIER-STOKES EQUATIONS TO CALCULATE INCOMPRESSIBLE CENTRIFUGE FLOWS.

Krause, E.

Translated from Strömungsmechanische Vorgänge in Gaszentrifugen, DFVLR-Kolloquium, om 14 Mai 1970, Porz, Wahn, Germany, 17 p. Dep. NTIS (U. S. Sales Only).

A new method is given for calculating the flow processes in gas centrifuges. The solution assumes that the flow can be described by a continuum concept. The non-steady-Nabier-Stokes equations and the energy equation form the starting point of this work. Using finite difference approximations the complete equations of motion are integrated in a cylindrical co-ordinate system. The axial symmetry of the problem is used to transform the original three-dimensional problem to a two-dimensional problem. Then a flow function can be introduced to satisfy the continuity equation. The tangential and radial velocities of the flow are determined as dependent on time. In a final calculation the Lagrange paths of the gas particles are determined. The throughput quantity and the width and arrangement of the throughput slits can be varied within definite limits. The method permits one to predict the effect of simple devices on the secondary flow. Previously, results for an incompressible centrifuge flow have been available. The results were for a closed pot-shaped centrifuge with a diameter/height ratio of 1 to 1. A slim tube was arranged concentric with the axis of rotation, turning with the same angular velocity as the centrifuge. Gas was fed in through a slit in the tube and removed through slits in the top and bottom of the centrifuge. The streamlines calculated give a detailed picture of the secondary flow in the centrifuge. (Author)

538 (CONF-700557-2) SLIP FLOW IN ONE-DIMENSIONAL GAS CENTRIFUGES.

Krause, E.

Translated from Strömungsmechanische Vorgänge in Gaszentrifugen, DFVLR-Kolloquium, om 14, Mai 1970, Porz, Wahn, Germany. 9 p. Dep. NTIS (U. S. Sales Only).

Approximate solutions are presented of equations of flow of compressible binary gas mixtures in one-dimensional gas centrifuges. The gas mixture is moved between two infinitely long coaxial cylinders. Assuming that the dependence of the transport coefficients on temperature and concentration can be neglected, the solutions are valid for continuum and slip ("Gleit") flow. Particular attention is given to the dependence of the separation factor on the peripheral velocity of the inner cylinder, the wall temperature and the Knudsen Number. (Author)

539 GAS SAMPLING DEVICE FOR ULTRA-CENTRIFUGES.

Le Manach, J. (to Commissariat à l'Énergie atomique).

French Patent 2,036,051. 14 Dec. 1970. Filed 3 March 1969. (In French)

A gas sampling device for ultra-centrifuges is presented. This device consists of a cylindrical bowl rotating about an axis, two parallel ends closing the bowl, and a feed pipe for the gas to be centrifuged, which is an extension of the axis. The bowl has a series of gas escape holes at one of its ends. The holes are distributed about the circumference of a circle whose diameter is slightly less than that of the bowl. (France)

540 GAS CENTRIFUGE AND A PROCESS FOR CONCENTRATING COMPONENTS OF A GAS MIXTURE.

Atomic Fuel Corp.

Inv., Oyama, Y., Takashima, Y.

Depot, March 21, 1967. USD 624.932.

Publi., March 17, 1970.

Brevet, U. S. 3,501,091 (70/19/31)R.

A gas centrifuge having a rotary chamber within an outer chamber, holes in each end of the rotary chamber for the draining of respectively enriched gas and poor gas and a means to flow a gas of relatively low molecular weight into the region between the outer chamber and the surface of the rotary chamber, thence to sweep toward the ends of the rotary chamber.

541 ISOTOPENTRENNUNG (SÉPARATION DES ISOTOPES).

Schindewolf, U. (Tech. Hochsch., Karlsruhe, Leopoldshafen).

Atomwirtschaft, Dtsch., (1964), 9, nº 11, 571-2.

Les installations de diffusion gazeuse de Pierrelatte ont suscité un grand intérêt. La séparation par centrifugation gazeuse se heurte encore à des difficultés. Les installations de production d'eau lourde se développent (Genève 1964).

542 STABLE ISOTOPE PREPARATION AND APPLICATIONS.

Baker, P.S.

Surv. Progr. Chem., U.S.A. (1968), 4, 69-125, bibl. (11 p.).

Méthodes de séparation des isotopes : processus électromagnétique, de diffusion, migration ionique, centrifugation en phase vapeur, distillation, échange chimique. Applic. des isotopes stables : cibles pour des mesures physiques nucléaires et non nucléaires, cibles pour la production de radioisotopes, traceurs, modérateur de neutrons, combustible nucléaire.

543 ISOTOPE SEPARATION BY CONCURRENT GAS CENTRIFUGE.

Takashima, Y., Kanagawa, A., Oyama, Y. (Tokyo Inst. Technol.).
In : "Proc. 3rd internation. Conf. peaceful Uses atom. Energy. Geneva, a964 Dec. 3." New York, United Nations, 1965. 28,5 × 22,5, 352-7.

Relations entre pouvoir séparateur, facteur de séparations, débit de gaz, longueur du rotor cylindrique, etc. Comparaison à la centrifugeuse à contrecourant. — Ibid., 485-96. — Discussion angl., fr., russe, esp. (See 521)

544 STRÖMUNG UND TRENNUNG IN EINER LANGEN GEGENSTROM-GASZENTRIFUGE.

Berman, A.S. (J. Chim. physique Physico-Chim. biol. 60, 217-23, 1963; Oak Ridge, Tenn., Gaseous Diffusion Plant; engl.).

Theoret. Untersuchung. (See 506)

545 ISOTOPENTRENNUNG MIT DER GLEICHSTROMGASZENTRIFUGE.

Akira Kanagawa und Yoichi Takashima (Japan atomie Energy Res. Inst., Chem. 1964, Nr. 29, 1-23, Tokyo Inst. of Technol., engl.).

Trennfaktor u. Trennleistung einer Gleichstromgaszentrifuge werden in Abhängigkeit von Gasgeschw. u. effektiver Rotorlänge rechner. untersucht. Für die Zentrifugaltrennung durch (n + 1) zylindr. dünne, in gleicher Richtung fließende Gasströme wird eine Differentialgleichung entwickelt u. für n = 1 u. 2 gelöst. Die Beziehungen werden mit Gegenstromexperimenten verglichen, wobei gefunden wurde, daß die Gaseintrittsgeschw. bei Gegenstromtrennung zur Erreichung gleicher Trennleistung wesentlich kleiner sein müssen als bei Gleichstromtrennung, obwohl die Gaszirkulationsgeschw. vergleichbar sind. (See 517)

546 TRENNLEISTUNG VON KURZEN GEGENSTROMZENTRIFUGEN.

Ouwerkerk, C., und Los, J. (Proc. third U. N. int. Conf. peaceful Uses atomic Energy, Geneva 1964, 12, 367-72, 1965, Amsterdam, RCN Labor., engl.).

Theoret. Betrachtung über die Zusammenhänge zwischen Trennfaktor, Trennleistung, Durchsatz, u. Art der Rohstoffzuführung bei Gegenstromzentrifugen zur Isotopentrennung. 2 Möglichkeiten der Errichtung eines Gegenstromes werden unterschieden : Zugabe des Rohstoffes an einer u. Abnahme des gesamten Prod. auf der Gegenseite; Zugabe des Rohstoffes in der Mitte u. Abnahme auf beiden Seiten bei innerem Gegenstrom. Letztere Variante läßt sich mit einer Kombination aus Dest. u. Stripper vergleichen mit Trennleistungen bis 80% der theoret. möglichen. Auf die Ursachen für den Wrkg.-Verlust (20%) wird eingegangen (Richtungsumkehr des inneren Gegenstroms, Asymmetrie des Rektifizier- u. Strippteiles). (See 520)

5. ELECTROMAGNETIC METHODS

547 HIGHLY ENRICHED ISOTOPES OF PLUTONIUM, THORIUM, AND OTHER ALPHA-ACTIVE ELEMENTS.

Chem. and Eng. News 40 (1962), 42, 48.

Highly enriched isotopes of plutonium, thorium, and other alpha-active elements are now being separated by Oak Ridge National Laboratory using electromagnetic separators. Originally, the eight electromagnetic separators were used only for separating ^{235}U. They have now been adapted to enrich the other isotopes for research purposes. They are part of an improved facility located in the Y-12 area and recently modified at a cost of $498,000. As part of the modification, they are housed in a doubly contained area. Gram amounts of the isotopes can be enriched to greater than 99.99% purity, according to ORNL. Isotopes of other elements are separated in 28 other electromagnetic separators.

548 ORNL ISOTOPES.

Chem. Ind. XV (1963), 3, 135, German.

A half million $ electromagnetic isotope production plant has been erected in the ORNL. The highly enriched isotopes of U, Pu, Th, etc., -α-active elements are produced for research work in a state of purity of more than 99.99%.

549 ENRICHMENT OF URANIUM (ENRICHISSEMENT DE L'URANIUM).

Nuclear Engineering, 13, No. 143 (4/68), pp. 335-340.

Description des méthodes d'enrichissement de l'uranium : diffusion thermique, diffusion gazeuse, et séparation électromagnétique. Problèmes techniques posés par la production de grandes quantités d'uranium.

550 ISOTOPIC SEPARATION BY ION RESONANCE.

Hermann, Peter, K. (Licentia Patent-Verwaltungs-GmbH).

Ger. 1,270,- 845 (Cl. C 01n), 20 June 1968, Appl. 28 July 1959, 6 pp.

Isotopes in a gas (e.g. UF_6) are sepd. by ionizing the gas in an elec. discharge tube and subjecting the ions to mutually perpendicular in-phase alternating elec. (E) and magnetic (H) fields. The relative amplitudes of E and H (at least 1,000 gauss) are so adjusted that the majority of isotope ions have orbits with the same frequency ($\sim$ 2,000 Hz.) as E and H (theoretical frequency is $2^cH/3\pi^2m$, where $^c/_m$ is the charge/mass ratio of an ion); these orbits are virtually immobilized by the combined effects of E, H, and ion-pumping. The minority isotope ions have open snakelike orbits with a net drift velocity, permitting their collection at a collector electrode placed at the end of the discharge tube on the axis perpendicular to both E and H.

551 ELECTRICAL ENGINEERING FOR ATOMIC ENERGY.

Cardwell, D.W.

AECD-2335, Sept. 10, 1948, Decl. Oct. 7, 1948, 20 p. Document for sale by AEC.

This paper surveys special problems in the field of electrical engineering which were presented by the atomic energy industry. The following topics are discussed: the electromagnetic process and gaseous diffusion processes for isotopes separation, nuclear reactors or piles, radiation detection instruments, high energy particle accelerators and applications of atomic energy (military weapons, isotopes, atomic power). 20 references.

552 REVIEWS OF UNCLASSIFIED LITERATURE.

Stevens, A.J., Feick, G., Pomeroy, J. H., Boyer, K., and Tittle, C.W.

MIT Nuclear Science and Engineering Appendix D, n.d., 18 p. (NP-164)

The following literature surveys are included: The fission of ^{235}U (the energy of neutrons from fission, gamma rays and gamma energy from fission, beta and neutrino energy, delayed neutron energy), fission of ^{238}U, fission of ^{232}Th. Electromagnetic methods of separating isotopes (theory of operation, advantages of the mass-spectrographic method, engineering difficulties, rate of production of separated isotopes, bibliography on the mass spectrometer. The number of secondary neutrons per fission and their energy distribution (number of secondary neutrons per fission of uranium, secondary neutrons from thorium energy spectrum of secondary neutrons.) References are given for each section.

553 THE PRODUCTION OF STABLE ISOTOPES AND THEIR USES IN RESEARCH.

Davis, W.C., Love, L.O., and Gilpatrick, L.O.

AECD-2436, Nov. 18, 1948. Decl. Nov. 24, 1948, 11 p. Document for sale by AEC.

In December, 1945, a program was undertaken at the Y-12 plant in Oak Ridge for the purpose of separating the naturally occurring isotopes. It was proposed to use the equipment and techniques developed for the electromagnetic concentration of ^{235}U for the separation of the isotopes of the entire

periodic table of the elements insofar as this should prove feasible. This program has been continued until at the present time some 37 elements have been successfully processed to give concentrates of all the isotopes of these elements. In the great majority of cases these isotope concentrates are available for distribution to qualified research organizations in quantities practical for most scientific purposes. The equipment used in the electromagnetic process is known as a "calutron". The calutron is a version of the mass spectrograph modified to favor the production of isotopes rather than their analysis, which has been the objective in the past. Present work, for example, on the production of the mercury isotope 204 is directed toward obtaining the highest possible degree of purity. The feed, or charge, material for the calutron can be solid, liquid, or gaseous, but it must fulfill certain conditions. It must supply sufficient vapor to maintain an arc within the working temperature range of the equipment; it must also be commercially available or easily synthesized from some commercially available compound; and it should be inexpensive if possible. The greatest field of usefulness is among those applications which depend upon the nuclear properties of the isotopes. There is, of course, a large field of application for stable isotopes in the measurement of fundamental nuclear properties such as capture cross section measurements for all types of bombardment but especially for neutron bombardment. Another use of isotope concentrates is in the identification of the complex activity produced by bombarding elements which are composed of many isotopes.

554 URANIUM AND ATOMIC ENERGY.

Dennis, W.H.

Mine and Quarry Engr. 15, 211-8, (July 1949).

The concentration methods used in obtaining U_3O_8, the preparation of the metal from its oxide, and the separation of ^{235}U and ^{238}U are described. The author discusses two methods for separating the isotopes of uranium; namely, gaseous diffusion and electro-magnetic. The formation of plutonium (239) is explained and since it is not an isotope, it can be extracted by chemical methods. The makeup of the nucleus is clearly presented along with the principle for transforming atomic mass into energy by nuclear bombardment ($E = MC^2$). A description of the first atomic energy machine employing a chain reaction is given. It was made up of grains of uranium embedded in graphite bricks. Later piles now operating at Clinton and Hanford in the U.S.A., and Great Britain are cubical in structure. Uranium is utilized in the form of long rods encased in aluminum containers which are slid into channels in the graphite pile. The containers protect the uranium from the cooling water. The reaction of the pile is controlled by inserting or removing cadmium rods from the lattice. The breeding principle, industrial utilization, radioactive isotopes and the military usage are also discussed. In conjunction with military usage, the author briefly discusses the critical size and states that the amount of uranium used in the atomic bomb is 135 pounds.

555 THE FUTURE OF ATOMIC ENERGY.

Dunning, J.R.

Am. Scientist 38, 60-85, (Jan. 1950).

The author describes, in nontechnical language, the fission process in ^{235}U. He then discusses the use of moderators and the problems involved in designing a satisfactory moderator system. Diffusion and electromagnetic separation methods are outlined, and the Oak Ridge and Hanford plants, for the production of ^{235}U and plutonium, respectively are briefly drescribed. Possible future applications of atomic energy are discussed in the last section. The author concludes that concentrated fuels are necessary for the practical production of atomic energy, and that these fuels will have to be produced by some sort of breeding process. Such a fuel could be utilized in a nuclear power plant similar in design to one suggested by the author.

556 ELECTROMAGNETICALLY ENRICHED ISOTOPES; INVENTORY JULY 31, 1951.

Keim, C.P., Normand, C.E., and Weaver, B.

Oak Ridge National Lab., Y-12 Area. July 1951, 65 p. (Y-790)

557 MASS-SPECTROGRAPHIC STUDIES OF IRRADIATED ^{235}U ENRICHED U SAMPLES.

Williams, D., and Yuster, P.

Los Alamos Scientific Lab. Jan. 24, 1945. Decl. July 12, 1951, 7 p. (AECD-3198; LADC-985)

A search was made for the possible presence of ^{236}U formed by neutron capture by ^{235}U. A graph is shown of the mass spectrum of UF^+_5 ions formed by electronic bombardment of UF_6, the U being enriched in ^{235}U. Peaks may be observed at mass numbers 333, 330, and 329 (corresponding to ^{238}U, ^{235}U, and ^{234}U), and a small "bump" appears at 331. Another graph shows the high-mass side of the ^{235}U peak under three different conditions of collector-slit width and source "tuning". The average ratios of ^{235}U to ^{238}U from measurements on two samples are, respectively, 1950 and 2500. It is possible but very unlikely that the 331 peaks are due to a fluorocarbon impurity. The estimated irradiation of the material was 3.5×10^{18} neutrons/cm^3. Using this value and the measured concentration of ^{236}U, the capture cross section of ^{235}U is computed as 128 barns.

558 CATALOG OF URANIUM, THORIUM, AND PLUTONIUM ISOTOPES.

Harmatz, B., McCurdy, H.C., and Case, F.N.

May 19, 1954, 6 p. Contract W-7405-eng-26. (ORNL-1724).

559 ION SOURCE.

Woodward, W.M., and Smith, L.G. (to U.S. Atomic Energy Commission).

U. S. Patent 2,677,060, April 27, 1954.

An apparatus and method for separating isotopes of metals such as, for examples, copper, cobalt, iron and uranium are reported. The invention provides an improved arc source of metal ions wherein a continuous ionization may be obtained as successive quantities of the metal are supplied during operation and wherein loss of the metal by reaction or in other ways may be reduced to a minimum.

560 VACUUM PROBLEMS AND TECHNIQUES.

Normand, C.E., Knox, F.A., Monk, G.W., Samuel, A.J., and Perret, W.R.

Clinton Engineer Works, Tennessee Eastman Corp.

Jan. 1950. Decl. June 18, 1954, 289 p. Contract W-7401-eng-23. (TID-5210; NNES-I-11)

Routine production of high vacuum in large systems on a scale never previously undertaken was required in the operation of the electromagnetic separation process for U isotopes and the information gained which is applicable to the solution of vacuum problems is presented. The original equipment used is described and its performance is evaluated. The most significant improvements in efficiency which resulted from changes in operating techniques are presented. The materials used, cold traps and refrigerants, instrumentation, vacuum testing and leak detection, and pump-down and outgassing are discussed.

561 (TID-5216) ELECTRICAL CIRCUITS FOR CALUTRONS.

Wakerling, R.K., and Guthrie, A., eds.

California, Univ., Berkeley. Radiation Lab. June 1949.

Decl. April 15, 1955. 287 p. Contract W-7405-eng-48. (NNES-1-3)

562 (TID-5218) SOURCES AND COLLECTORS FOR USE IN CALUTRONS.

Wakerling, R.K., and Guthrie, A., eds.

California, Univ., Berkeley. Radiation Lab. June 1949.

Decl. April 15, 1955, 280 p. Contract W-7405-eng-48. (NNES-I-0)

563 (TID-5217) ELECTROMAGNETIC SEPARATION OF ISOTOPES IN COMMERCIAL QUANTITIES.

Wakerling, R.K., and Guthrie, A., eds.

California, Univ., Berkeley. Radiation Lab. June 1949.

Decl. April 15, 1955, 434 p. Contract W-7405-eng-48.

Papers have been selected and compiled for the purpose of giving a complete picture of the history and development of electromagnetic isotope separation. Calutron considerations, space charge and beam plasma, magnetic shimming, electric focusing, accelerating electrode focusing, the isotron, the ionic centrifuge, radial magnetic separators, resonance separation, and grid-slit systems are discussed.

564 CALUTRON RECEIVER.

Barnes, S.W., and Brobeck, W.M. (to U. S. Atomic Energy Commission).

U. S. Patent 2,727,152. December 13, 1955.

A calutron receiver is described for receiving a plurality of non-interfering, intersecting, magnetically shimmed beams of singularly ionized uranium ions for separately collecting a portion of each beam enriched with respect to the ^{235}U isotope and impoverished with respect to the ^{238}U isotope. Provision is made for the ready adjustment of the spacing between the receivers and independent adjustment of each receiver in a direction along the general path of travel adjacent its region of focus of the beam to be received. Means are also provided for reducing contamination of the material collected from one beam by the scattered material from an adjacent beam after it strikes an adjacent receiver. (Author)

565 (A-3957) THE IONIC CENTRIFUGE.

Slepian, J.

California, Univ., Berkeley. Radiation Lab.

(Report for Period), Jan. 1, 1942 to Dec. 31, 1942. Decl. Dec. 8, 1955, 45 p. $7.80 (ph OTS); $3.30 (mf OTS).

Topics discussed include : an evaluation of the electromagnetic method of isotope separation; the production of ions at electrodes of a vacuum arc; the 1942 theory of the ionic centrifuge; the expected superiority of the ionic centrifuge over other electromagnetic devices; the experimental development of the arc ion source; experiments with the ionic centrifuge; isotope analyses made at Berkeley; results of thirty-three collection runs with the ionic centrifuge; and results from analyses of Berkeley samples made at Columbia.

566 (Y-660) ENRICHMENT OF ^{234}U.

Harmatz, B., and Livingston, R.S.

Oak Ridge National Lab., Y-12 Area, Tenn. Sept. 1, 1950.

Decl. Jan. 6, 1956, 39 p. Contract W-7405-eng-26. $6.30 (ph OTS); $3.00 (mf OTS).

Magnetic separation of U to achieve high purity ^{234}U is described. Innovations included multiple stage operation, processing of small quantities of feed, and control of the inhalation hazard from alpha-active ^{234}U. Starting with one per cent ^{234}U concentration, a two-stage separation program yielded 1.5 grams of U averaging 94 per cent ^{234}U. This result was obtained through a ^{234}U-^{235}U enrichment factor of 36 at a ^{234}U process efficiency of 9 per cent. (Author)

567 (BC-27) RECOVERY OF URANIUM FROM ALPHA-II CALUTRON EQUIPMENT.

Müller, M.E., [nd].

California, Univ., Berkeley. Radiation Lab. Paper No. 14.

Decl. Jan. 18, 1956, 49 p. $7.80 (ph OTS); $3.30 (mf OTS).

Recovery studies made with Alpha-II Calutron equipment and a study made of the Alpha-I/5 Liner at Berkeley are described. Mention is made of subsequent work done in the Alpha-II plant in the Y-12 area at Oak Ridge. It is shown that it is possible to account for 97.5 $\pm$ 1.2% of the U input in a series of 12 runs. The chemical recovery alone averaged 94.5%. The equipment consisted of one calutron tank. two sources, two liners, and two collectors. Descriptions of the equipment, the chemistry of the substances involved, and the methods employed for recovery are given in detail. The use of beta-count surveys for establishing the extent of the variation of the equipment and for accounting for a small amount of the total U is described, and a complete discussion of uncertainties and errors is included. (Author)

568 (AECD-4055) CRITICALITY IN GRAPHITE SYSTEMS.

Murray, R., and Schmidt, G.W.

(Tennessee Eastman Corp., Oak Ridge, Tenn.), (Jan. 1947). Decl. Jan. 17, 1956, 8 p. (A-7.390.21). $1.80 (ph OTS); $1.80 (mf OTS).

A modified thermal diffusion method is used to calculate critical conditions for ^{235}U-contaminated graphite collectors from the electromagnetic separation process.

569 (AECD-4185) THE PRODUCTION OF ^{234}U BY A MODIFIED CALUTRON.

McKinney, C.R. (Tennessee Eastman Corp., Oak Ridge, Tenn.).

May 21, 1946. Decl. Feb. 14, 1956. Includes appendix (photographs [D-4-250-30A]). 10 p. Contract W-7401-eng-23. (D-4-250-30). $1.80 (ph OTS); $1.80 (mf OTS).

Three and nine-tenths milligrams of ^{234}U were produced using a calutron. A Beta-size calutron was modified to produce complete resolution of the ^{234}U beam from the ^{235}U beam. With Beta charge the ^{234}U current was 4×10^{-6} amperes. The samples were collected upon flat pieces of graphite bent to fit the E curve. (Author)

570 (Y-697) THE SEPARATION AND COLLECTION OF ^{236}U BY THE ELECTROMAGNETIC PROCESS.

Savage, H.W., and Wilkinson, P.E. (Oak Ridge National Lab., Tenn.).

Nov. 30, 1950. Decl. Jan. 6, 1956, 136 p. Contract W-7405-eng-26. $0.65 (OTS).

Equipment is described which was used to separate and collect small, highly enriched samples of ^{236}U from a very small quantity of charge material using a special 12-in.-radius calutron. Appended are details of methods used for estimations of product purity, the preliminary experimental program, design of the calutron unit, handling equipment, ion source development, receiver development and beam studies, charge chemistry and recycle operation, the chemical purification of ^{236}U, operation of the calutron equipment, and health hazards.

571 (AECD-3997) THE CYCLORATOR: A DEVICE FOR THE SEPARATION OF ISOTOPES BY TIME-OF-FLIGHT IN A MAGNETIC FIELD.

Livingston, R.S., Martin, J.A., and Murray, R.L. (Oak Ridge National Lab., Y-12 Area, Tenn.).

Sept. 1951. Decl. with deletions Jan. 5, 1956, 45 p. Contract W-7405-eng-26. $0.30 (OTS).

When the time-of-flight principle is applied to isotope separation in a magnetic field, a separation-in-time is obtained which depends directly upon the difference in isotopic masses. Modulation of the ion beam is necessary for collection of separated isotopes. The relative merits of intensity, direction, and energy modulation are discussed. Separation of uranium isotopes, with low enrichment, was achieved by energy modulation. The cyclorator is found to have the same fundamental limitations as the calutron, the most significant being loss of resolution with increased throughput. (Author)

572 (ORNL-2141) CATALOG OF THE ISOTOPES OF THE HEAVY ELEMENTS.

Martin, J.A., Case, F.N., and Haynes, V.O. (Oak Ridge National Lab., Tenn.).

Sept. 20, 1956, 18 p. Contract W-7405-eng-26. $0.20 (OTS)

This catalog lists the available amounts and the purity of the isotopes of U, Th, and Pu which have been separated electromagnetically and ^{233}U and ^{241}Am which have been separated chemically from reactor-irradiated materials. (Author)

573 ISOTOPE ENRICHMENT PROCESS.

Carter, J.M., et al. (to U. S. Atomic Energy Commission).

U. S. Patent No. 2,758,006, Aug. 7, 1956.

An improved method is suggested for processing material enriched in a particular isotope by means of two stages of electromagnetic separation. The non-enriched material from the first stage calutron and the depleted material from the second stage calutron are combined and reworked as feed to the first stage. Likewise, the non-enriched material from the second stage and the enriched material from the first stage are combined and used as feed to the second stage. The enriched material from the second stage calutron is recovered as product. (Author)

574 AN ELECTROMAGNETIC ISOTOPE SEPARATOR.

Bernas, R. (Collège de France, Paris), and Cassignol, C. (Centre d'Études Nucléaires de Saclay, France).

L'Onde Électrique, 35, 1094-1100 (Nov. 1955). (In French).

The principles of electromagnetic separation of isotopes are reviewed, and detailed descriptions are given of the CEA electromagnetic separator.

575 ELECTROMAGNETICALLY ENRICHED ISOTOPES AND MASS SPECTROMETRY. PROCEEDINGS OF THE CONFERENCE HELD IN THE COCKCROFT HALL, HARWELL, 13-16 SEPTEMBER 1955.

Smith, M.L., ed.

London, Butterworths Scientific Publications, 1956, 272 p.

A summary is given of developments and future work in the field of electromagnetic isotope separation. The topics covered are ion sources, collector problems, chemical aspects and target preparation, utilization, isotopic abundance analysis, design of electromagnetic separators, and separation of active materials.

576 (Y-584) ELECTROMAGNETIC RESEARCH DIVISION PROGRESS REPORT (FOR) JANUARY 1, 1950 TO MARCH 31, 1950.

Livingston, R.S. (Oak Ridge National Lab., Y-12 Area, Tenn.).

Mar. 31, 1950. Decl. Mar. 5, 1957, 82 p. Contract W-7405-eng-26. $13.80 (ph OTS); $4.80 (mf OTS).

An increase in ion output, exceeding fivefold, resulting from the substitution of grid structures for the conventional ion acceleration system of the calutron has indicated the value of expanding research on this new principle. Investigation of proposed means of separating these high currents has been started. The magnet for the 86-in. cyclotron has been energized, just six months from ground-breaking. Most of the electrical supplies and control equipment has been built and tested on an electrical model of the dee-system. A material balance on the ^{234}U separation process shows that the 1.5 grams of 94% assay material was obtained with a dispersal of no more than 0.4% per cycle. First stage separation of irradiated uranium containing about 1% ^{236}U has yielded above 30% concentration. Procedures for the next purification stage have been worked out. A neutron flux of $1.2 \times 10^9/cm^2/sec$ has been reached with the D-D reaction spectrograph source. A preliminary mass measurement, using time-of-flight principle, gave the mass difference between ^{35}Cl and ^{37}Cl with an accuracy of $\pm$ 0.05 mass units. (Author)

577 (ORNL-1345(Del.) (ELECTROMAGNETIC RESEARCH DIVISION QUARTERLY PROGRESS REPORT, PART I, FOR PERIOD ENDING JUNE 30, 1952.

Howard, F.T., ed. (Oak Ridge National Lab., Tenn.).

Nov. 14, 1952. Decl. with deletions Mar. 1, 1957, 23 p.

Contract W-7405-eng-26. $4.80 (ph OTS); $2.70 (mf OTS). On the 86-inch cyclotron a 41-kw beam was calorimetered at a net ion loading efficiency of 40%; the average proton current was 1.85 ma at 22.5 MeV. Practical specific yields have been determined for (p, 2n) reactions on Zn and Bi. The investigation of products of proton-induced fission of U has been continued and new techniques are being used in measuring angular distribution of reaction products. The 63-inch heavy particle cyclotron is now in operation; N^{3+} particles have been accelerated to $\sim$ 25 MeV. In preliminary tests, induced activities have been detected in C, N_2, and O_2 targets. A hot-cathode type ion source is ready for test operation. The 22-inch cyclotron is being used in an investigation of the problems associated with the use of rf and de electrodes for the acceleration of protons from the ion source into the dees. Radiation-induced corrosion in Inconel tubing containing $\neq$ 21 eutectic was produced by proton irradiation in the 86-inch cyclotron; it is shown that the corrosion was not due to thermal effects. Approximately 150 g of highly purified ^{238}U ($<$ 5 ppm ^{235}U have been prepared, and two grams of ^{230}Th was enriched to 90.6%. (Author) (See 620, 622)

578 (TID-452) ELECTROMAGNETIC RESEARCH DIVISION MONTHLY INFORMATION MEETING, SEPTEMBER 15, 1950.

Livingston, R.S. [comp.] (Oak Ridge National Lab., Tenn.) Sept. 15, 1950. Decl. March 1, 1957, 35 p. Contract [W-7405-eng-26]. $6.30 (ph OTS); $3.00 (mf OTS).

The large alpha and beta magnets, 86-in. cyclotron, and 22-in. cyclotron at Y-12 lab in Oak Ridge are described. Some experiments with separation of U isotopes are briefly described.

579 (ORNL-2381) HIGH ENRICHMENT OF ^{235}U.

Harmatz, B., McCurdy, H.C., Case, F.N., and Livingston, R.S. (Oak Ridge National Lab., Tenn.).

Nov. 11, 1957, 26 p. Contract W-7405-eng-26. $0.75 (OTS).

This report summarizes the results from three programs for the production of highly enriched ^{235}U by the electromagnetic process. Products and enrichments obtained are: (1) 80 grams of 99.9% ^{235}U, (2) 1 100 grams of 99.7% ^{235}U, and (3) 8 grams of 99.994% ^{235}U. These materials have been made available for use on Atomic Energy Commission projects. An analysis of certain features of the process is made for its possible use in the separation of mass fractions 233 and 235 from 232, 234, and 235. (Author)

580 (Y-548) Y-12 RESEARCH LABORATORY PROGRESS REPORT (FOR) OCTOBER 1, 1949 TO DECEMBER 31, 1949. PART III. ELECTROMAGNETIC RESEARCH DIVISION.

(Carbide and Carbon Chemicals Div. Y-12 Plant, Oak Ridge, Tenn.).

Jan. 3, 1950. Decl. March 6, 1957, 78 p. Contract W-7405-eng-26. $12.30 (ph OTS); $4.50 (mf OTS).

During the last quarter of 1949 substantial progress is reported on the accelerator program. The small cyclotron was completed and used to obtain source performance and oscillator design information for the high current 86-in. cyclotron. The D-D neutron source was used to study the effect of neutron irradiation on germanium crystal rectifiers. The purification of ^{234}U to above 90% was achieved. Measurements showed that careful handling of the associated high level alpha activity prevented any above-tolerance health hazards. Successful separation of isotopes by the "time-of-flight" (cyclorator) principle was achieved. Fundamental studies of arcs and ion current limits were carried out and are reported in the latter portion of this report. (Author)

581 (Y-495) Y-12 RESEARCH LABORATORY PROGRESS REPORT (FOR) JULY 1, 1949 TO SEPTEMBER 30, 1949. PART III. ELECTROMAGNETIC RESEARCH DIVISION.

(Carbide and Carbon Chemicals Corp. Y-12 Plant, Oak Ridge, Tenn.).

Oct. 15, 1949. Decl. March 6, 1957, 66 p. Contract W-7405-eng-26. $10.80 (ph OTS); $3.90 (mf OTS).

Plans for, and construction of, a high current, 25-MeV proton cyclotron were begun. It is planned that this machine will be capable of developing more than 1 ma of beam current, and will be useful for nuclear research and for preparing radioactive isotopes in quantity. The smaller 2-MeV test cyclotron installed in a Beta calutron vacuum tank is nearing its initial test. Yields of almost 10^9 neutrons/sec have been obtained from a low-voltage neutron source, using the D-D reaction. Evidence has been found for the absorption of deuterium in ordinary metal targets in such amounts as to simulate a target actually coated with a deuteride. In the field of fundamental investigations of arc discharges, several facts have become more firmly established: the mass-dependence of Child's space charge law is reproduced in measurements of accelerated beams for elements of different masses; the electron energy distribution in an arc is apparently distorted from the expected Maxwell distribution; one of the important effects of an increase in magnetic field on an arc is increased linear uniformity of intensity and of output. Final calutron processing of high purity ^{235}U has been completed. Gram quantities of the isotope have been supplied to other research organizations. Preparation of highly concentrated ^{234}U is in the second and final stage. The small quantities processed and the control of hazards from the dispersal of alpha active material has necessitated the development of special equipment and techniques pending continuation of the program. Facilities and techniques for the concentration of ^{236}U have been prepared. Several proposed methods of isotope separation involving the use of electric and magnetic fields are under consideration. Of these, only the principle of separation-in-time (as applied in the cyclorator) has been subjected to experimental investigation. (Author)

582 ELECTROMAGNETIC ENRICHMENT OF STABLE ISOTOPES.

Smith, M.L.

Progr. Nuclear Phys., 6, 162-91 (1957).

An account of the limitations and advantages of the electromagnetic process is given. Discussions are included on the development of the large 180° separator, a general description of the present production machine, a detailed account of the separation process, chemical problems involved in processing isotopic concentrates, applications of electromagnetically enriched stable isotopes, and application of small laboratory electromagnetic separators to stable- and active-isotope enrichment, and the future of electromagnetic separation.

583 (AEC-tr-3160) A HIGH RESOLVING POWER ELECTROMAGNETIC ISOTOPE SEPARATOR FOR HEAVY ELEMENTS.

Artsimovich, L.A., Shchepkin, G.I., Zhukov, V.V., Makov, B.N., Maksimov, S.P., Malov, A.F., Nikulichev, A.A., Panin, B.V., and Brezhnev, B.G.

Translated from Atomnaya Energ., 3, 483-91 (1957), 14 p.

A description is given of the operating principles and basic parameters of an electromagnetic apparatus used in the separation of isotopes with a relative mass resolution of about 1/240. An axial symmetric magnetic field (focusing angle of 225°) is used in which the dispersion is proportional to the square of the focusing angle. A dispersion of the separating apparatus of 20 mm per 1% of the relative mass difference is obtained. The magnetic field of the apparatus is stabilized to 0.005% with the aid of an electron ray transmitter. Electron sources are produced with a vapor discharge of the operating and ballast substances for the separation of large and small amounts of the original isotope mixtures. Universal ion receptors have also been developed for the apparatus. Results of the separation of lead, uranium, and plutonium isotopes are given. The enrichment factor for the separation of lead isotopes is 300, while that of uranium and plutonium is $\sim$ 1 000. (Author) (Orig. 584)

584 ELECTROMAGNETIC ISOTOPE SEPARATING DEVICE FOR HEAVY ELEMENTS OF HIGH RESOLVING POWER.

Artsimovich, L.A., Shchepkin, G.Y., et al.

Atomnaya Energiya, 3, 483-91 (1957).

An apparatus which is able to separate isotopes with a relative mass difference of 1/240 is described. An axial-symmetrical field, the dispersion of which is proportional to the square of the focusing angle, was used as a magnetic field. The focusing angle is 225°. The measured dispersion of the apparatus is 20 mm at a relative mass difference of the masses to be separated of 1%. The magnetic field is stabilized at 0.005% with the aid of a valve scheme. The acceleration velocity for the ion source (up to 40 kV) is stabilized by a double cascade scheme up to 0.01%. The current in the discharge source of ions is also stabilized. The vacuum chamber is constructed from stainless steel in a C shape. A working vacuum of 4 to 6 $\times$ 10^{-6} mm Hg is maintained. A normal gas discharge ion source in which the material to be separated can be heated to 1 000 °C is used. Results obtained for the concentration of ^{208}Pb, ^{207}Pb, ^{238}U, ^{236}U, ^{239}Pu, ^{240}Pu, and ^{241}Pu are tabulated. (Trans. 583)

585 ELECTROMAGNETIC SEPARATION OF THE ISOTOPES OF THE HEAVY ELEMENTS.

Livingston, R.S., and Martin, J.A. (Oak Ridge National Lab., Tenn.).

Chapter 50 of Proc. Symposium on Isotope Separation, Amsterdam, 597-609 (1957).

Special high-resolution mass spectrographs have been developed for the preparation of highly enriched isotopes of the heavy elements. These special purpose isotope separators and the techniques used in handling alpha-active materials are described. (Author)

586 METHOD OF SEPARATING ISOTOPES OF URANIUM IN A CALUTRON.

Jenkins, F.A. (to U. S. Atomic Energy Commission).

U. S. Patent 2,833,927. May 6, 1958.

Mass separation devices of the calutron type and the use of uranium hexachloride as a charge material in the calutron ion source are described. The method for using this material in a mass separator includes heating the uranium hexachloride to a temperature in the range of 60 to 100 °C in a vacuum and thereby forming a vapor of the material. The vaporized uranium hexachloride is then ionized in a vapor ionizing device for subsequent mass separation processing.

587 (A/CONF.15/P/830) PRODUCTION AND DISTRIBUTION OF ELECTROMAGNETICALLY ENRICHED ISOTOPES.

Baker, P.S., Bell, W.A., Jr., Davis, W.C., Ketron, C.V., Love, L.O., Martin, J.A., Olszewski, E.B., Prater, W.K., and Spainhour, K.A. (Oak Ridge National Lab., Tenn.).

17 p. $0.50 (OTS).

Prepared for the Second U. N. International Conference on the Peaceful Uses of Atomic Energy, 1958.

The production and distribution of stable isotopes have been highlighted by the recent separation of dysprosium, erbium, and ytterbium isotopes for the first time. High-purity collections of ^{6}Li, ^{7}Li, ^{10}B, and ^{11}B have also been carried out using the large electromagnetic separators. The need for samples of ultra-high isotopic purity has led to the development of a high-resolution isotope separator (HRIS). In addition to being suitable for the further enhancement of small quantities of certain isotopes already enriched to 99.99% in the larger calutron facilities, the unit is capable of enriching ^{235}U from 0.7% in normal uranium to approximately 93% in a single pass. In typical runs, furthermore, the beam current has reached a peak of 4.8 ma, and has averaged 2 ma, with backgrounds of only 2 to 3 μa. The application of the HRIS to heavy element separations as well as to high-purity collections of small amounts of stable isotopes is considered, and the features of the unit responsible for its success is evaluated. (Author)

588 PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON ISOTOPE SEPARATION HELD IN AMSTERDAM, APRIL 23-27, 1957.

Kistemaker, J., Bigeleisen, J., and Nier, A.O.C., eds. Amsterdam, North-Holland Publishing Company, 1958 723 p.

Papers presented at the International Symposium on Isotope Separation held in Amsterdam, 1957, and the pertinent discussions are presented. Papers in English, French, and German are included in the fields of chemical engineering, molecular interactions, chemical exchange, electromigration, distillation, thermal diffusion, diffusion, electromagnetic separation, and the development of ultracentrifuges.

589 ELECTROMAGNETIC ISOTOPE SEPARATORS AND APPLICATIONS OF ELECTROMAGNETICALLY ENRICHED ISOTOPES.

Koch, J., ed., Dawton, R.H.V.M., Smith, M.L., and Walcher, W.

Amsterdam, North-Holland Publishing Company, 1958, 324 p.

The first two parts of the book are devoted to the technical description of isotope separators and the applications of enriched isotopes. In the third part of the book a general account is given of a number of fundamental physical problems, which are of importance in separator design and which have a special bearing on the future technological developments.

590 INAPPLICABILITY OF CERTAIN HYDROMAGNETIC PRINCIPLES TO THE IONIC CENTRIFUGE.

Slepian, J.

Phys. Rev. Letters 1, 287-8, (Oct. 15, 1958).

The inapplicability of the Chew, Goldberger, and Low paper on the Boltzmann equation and the one-fluid hydromagnetic equations in the absence of particle collisions in calculating the motion of isotopes in the ionic centrifuge is discussed.

591 PROCESS FOR SEPARATING URANIUM.

(to United Kingdom Atomic Energy Authority) (U.S.A.).

British Patent 794,490. Nuclear Eng. 3, 510, (Nov. 1958).

U. S. Patents Nos. 2,709,222, 2,758,006, and 2,771,340 refer to the production of uranium enriched with ^{235}U employing the "calutron" method for separating the constituent isotopes of an element in several stages. A final salvage treatment is important because an oxalate solution of relatively large volume is left which contains singly enriched uranium. The usual process, however, is difficult to operate on a large scale. In the new method, the solution is admitted to the anode compartment of a mercury cathode electrolytic cell whose cathode compartment contains a hydrochloric acid solution. The compartments are separated by an ion-permeable barrier of a ceramic insulating material which prevents mechanical passage of liquid. The uranium containing solution is then subjected to electrolysis in the cell causing transfer of uranium ions to the acidic solution in the cathode compartment. The metallic impurity is deposited in the mercury of the cathode.

U. S. Patent 2,709,222 see NSA-9-5565.

U. S. Patent 2,758,006 see 573.

U. S. Patent 2,771,340 see NSA-11-3244.

592 (A/CONF.15/P/2303) AN ION SOURCE FOR STABLE ISOTOPE SEPARATION.

Morozov, P.M., Makov, B.N., Ioffe, M.S., Brezhnev, B.G., and Fradkin, G.M., (U.S.S.R.), 11 p.

A universal ion source designed for stable isotope separation by electromagnetic means is described. A description is given of the investigations on the properties of a gas discharge occurring in UCl_4 vapors in a longitudinal magnetic field of the separation plant. The investigations show the dependence of the formation process of ions of different masses on the gas discharge parameters in the case of a complex molecule UCl_4. The practical results obtained with this source in the isotope separation of uranium and other elements are presented. For the uranium isotope separation the ion current (U^+) reached 0.3a and the separation factor (for uranium) amounted to 25 to 30%. Similar data on the separation of isotopes with intermediate masses are given. (Author).

593 INDUSTRIAL METHODS OF ^{235}U ENRICHMENT.

Kiss Istvan (State Research Inst., Dept. of Chemistry).

Energia es Atomtech. 11, 466-73, (1958). (In Hungarian)

Electromagnetic, centrifugal, gaseous diffusion, and gas jet separation methods of ^{235}U are described. (Trans. 613)

594 STABLE ISOTOPES : AID TO RESEARCH.

Baker, Ph.S., (Oak Ridge National Lab., Tenn.).

Chem. Eng. News 37, 60-5, (Feb. 2, 1959).

The electromagnetic separation and distribution of stable isotopes by Oak Ridge National Laboratory are discussed. The calutrons (Calif. Univ. Cyclotron) and their operation are described, and the chemical techniques, involving 55 elements, are discussed.

595 URANIUM ISOTOPE SEPARATION: A NEW INDUSTRY.

Geoghegan, G.R.H.

New Scientist 5, 408-72, (Feb. 26, 1959).

The gaseous diffusion separation process used in the British factory at Capenhurst is described, and consideration is given to the economic aspects of the plant. Information is also included on the basic principles of operation of the electromagnetic, gas-phase centrifuge, and jet processes.

596 THE CONCENTRATION OF ^{235}U: SURVEY OF MOST IMPORTANT METHODS AND PRINCIPLES.

Havlicek, F.I. (Institute J. Stefan, Ljubljana, Yugoslavia).

Energia nucleare, Milan, 6, 521-31, (Aug. 1959). (In Italian)

Diffusion, physical-chemistry, and electromagnetic methods for the separation of uranium isotopes are reviewed. An account is given of the principles on which each is based, a critical examination is made of the possibilities they offer, and a number of experimental devices are described. (Author) (Trans. 610)

597 A METHOD AND APPARATUS FOR THE SEPARATION OF ISOTOPIC IONS.

Beyrard-Benchemoul, N.R., and Van Oss, C.J.

British Patent 823,283. Nov. 11, 1959.

A method and apparatus for separating isotopic ions by means of an opposed electric field and centrifugal force is described. The combined effect of centrifugal force and radial electric field can be adjusted to completely separate a heavier ion from a lighter one in one operation. Centrifugal accelerations of the order of 10^5g are required and are obtained by causing the solution of ions to be separated and to be pumped at high linear speed through a spiral conduit. The spiral groove is lined with a conducting tape on which ions may be electrolytically deposited. Means for regulating flow rate and electric field strength are given.

598 (AERE-R-3043) THE ELECTROMAGNETIC SEPARATION OF PLUTONIUM ISOTOPES: OPERATIONAL EXPERIENCE IN 1957.

Freeman, J.H., Hill, K.J., and Smith, M.L.

United Kingdom Atomic Energy Authority. Research Group. Atomic Energy Research Establishment, Harwell, Berks, England. Aug. 1959, 61 p. BIS

A brief description of the 90° sector electromagnetic separator, Hermes, includes the actual machine, source unit, collectors and the associated electrical and other services. Separation experience up to February 1958 is given in considerable detail, first with preliminary runs on lead, cerium, thorium and uranium, and then, over a period of 9 months, with plutonium containing 6% ^{240}Pu. Experiments on a range of pocket designs are described and resolution, outputs, efficiencies, etc., discussed. An analysis of machine and service failures is included, and Appendix VII sets out the operational checks and procedures, and provides an indication of the operator training problems involved in the project. The report concludes with a brief discussion on the relative merits of sealed room and other possible modes of working on projects of this type. A list of the plutonium isotopic samples provided for various applications is given. (Author)

599 METHOD OF OPERATING A CALUTRON.

Davidson, P.H. (to U. S. Atomic Energy Commission).

U. S. Patent 2,921,199. Jan. 12, 1960.

A method of operating an electromagnetic isotope separator of the calutron class is reported whereby uranium tetrachloride is produced at a controlled rate within the source rather than being introduced therein as was formerly practiced. This is accomplished by placing a uranium-bearing material, such as uranium metal, uranium trichloride, or uranium carbide in the charge receptacle of the calutron, heating this material to about 500 °C, and reacting the heated material with chlorine gas to produce uranium tetrachloride vapor at a rate controlled by the chlorine gas flow into the source. The vapor is subsequently ionized by an electric arc and mass separated by conventional calutron methods.

600 CONTROL SYSTEM FOR ISOTOPE SEPARATING APPARATUS.

Barnes, S.W. (to U. S. Atomic Energy Commission).

U. S. Patent 2,922,882. Jan. 26, 1960.

A method is described for controlling the position of the ion beams in a calutron used for isotope separation. The ^{238}U beam is centered over the ^{235}U receiving pocket, the operator monitoring the beam until a maximum reading is achieved on the meter connected to that pocket. Then both beams are simultaneously shifted by a preselected amount to move the ^{235}U beam over the ^{235}U pocket. A slotted door is placed over the entrance to that pocket during the ^{238}U beam centering to reduce the contamination to the pocket, while allowing enough beam to pass for monitoring purposes.

601 PROCESSES OF PRODUCING AND RECOVERING URANIUM ENRICHED WITH ^{235}U.

(to United Kingdom Atomic Energy Authority).

British Patent 836,771. June 9, 1960.

A process is described for the recovery of U from a calutron source region. The parts of the calutron source are washed with hot water. The hot water is passed through a sieve and the solid impurities are discarded. The wash water from the sieve is passed into an oxidizing zone containing

H_2O_2. The resulting oxidized solution is treated with NH_3 to precipitate ammonium diuranate and ferric and chromium hydroxides.

602 PROCESSES OF PRODUCING URANIUM ENRICHED WITH ^{235}U.

(to United Kingdom Atomic Energy Authority).

British Patent 841,311. July 13, 1960.

A calutron process is described for the production of U enriched in ^{235}U. Also included are processes for reclaiming U from the calutron and purifying the recovered U.

603 "ION SOURCES".

(to United Kingdom Atomic Energy Authority).

British Patent 841,821. July 20, 1960.

An apparatus is described for producing ions of uranium and uranium halides for use in separating isotopes of these metals.

604 IMPROVEMENTS IN OR RELATING TO CALUTRONS.

Lawrence, Ernest Orlando.

British Patent 845,881. August 24, 1960.

An improved calutron of the arc-multiple ion-beam type was invented in which the arc blocks of the arc source are insulated from each other and the individual ion beams are focused on a single receiver. Complete details of the design are given. This calutron is particularly suitable for separating uranium isotopes using UCl_4.

605 CALUTRON RECEIVERS.

(to United Kingdom Atomic Energy Authority).

British Patent 839,358. June 29, 1960.

A calutron receiver is described in detail for isotope separation, particularly ^{235}U, and comprises a collecting pocket having an opening for admitting one beam component and a deionizing electrode for intercepting a second-beam component.

606 ION SOURCES.

(to United Kingdom Atomic Energy Authority).

British Patent 847,604. Sept. 7, 1960.

An ion source of the arc type is designed which furnishes high ion currents on the order of 10 ma, enough for calutron separation of uranium isotopes. It comprises an evacuated chamber, a thermionically emissive cathode, and a tungsten anode so shaped that the amount of uranium supported by it is small enough to prevent appreciable conversion of the tungsten into an alloy with consequent anode melting.

607 (TID-5232) CHEMICAL PROCESSING EQUIPMENT: ELECTROMAGNETIC SEPARATION PROCESS.

Akin, G.A., Kackenmaster, H.P., Schrader, R.J., Strohecker, J.W., and Tate, R.E., eds. (Tennessee Eastman Corp., Oak Ridge, Tenn.).

April 1947. Decl. Nov. 23, 1959, 510 p. (NNES-1-12).

608 ISOTOPE SEPARATOR WITH DOUBLE MAGNETIC DEFLECTION FOR THE PRODUCTION OF VERY HIGH PURITY ISOTOPES.

Bernas, R., Sarrouy, J.L., and Camplan, J. (Faculté des Sciences, Paris).

J. phys. radium, 21, 191A-203A (Nov. 1960). (In French)

The electromagnetic separator of the Nuclear Physics Laboratory of Orsay is made up of a 60° sector homogeneous magnetic field analyzer followed by a semi-circular inhomogeneous field analyzer of the Svartholm-Siegbahn type. The enrichment factors reached are from 10 to 100 times higher than those obtained with the other types of separators while the ion beam intensity remains in the neighborhood of 1 ma. A description of the instrument is given as well as the first results obtained in the separation of the isotopes of a few elements: Cr, Sr, Yb, Hg, and U. (Author)

609 (ORNL-1169(Del.)) ENRICHMENT OF ^{236}U.

Harmatz, B., McCurdy, H.C., Case, F.N., and Livingston, R.S. (Oak Ridge National Lab., Tenn.).

Dec. 1951. Decl. with deletions Jan. 4, 1960, 47 p. Contract W-7405-eng-26.

Neutron-irradiated uranium was electromagnetically separated to provide enrichment of the isotope of mass 236. The final isotopic abundance of ^{236}U was determined to be 95% in 1 800 milligrams of uranium. Useful by-products of the program were 22 grams of 25% ^{236}U and 1 100 grams of 99.7% ^{235}U. These enriched materials were made available for use on Atomic Energy Commission projects.

Possible application of this separation process to recovery of the fuel from the MTR reactor is described. (Author) (See 619)

610 (AEC-tr-4753) CONCENTRATION OF ^{235}U: REVIEW OF SOME OF THE MOST IMPORTANT METHODS AND PRINCIPLES.

Havlicek, F.I.

Translated for Oak Ridge Gaseous Diffusion Plant from Energia nucleare (Milan), 6, 521-31 (1959), 38 p.

This paper was previously abstracted from the original language and appears in NSA, Vol. 13, abstract No. 20000. (Orig. 596)

611 (MLM-1115) MOUND LABORATORY MONTHLY PROGRESS REPORT FOR MAY 1961 (ON PLASTICS, RADIOELEMENTS, ISOTOPE SEPARATION, AND REACTOR FUELS).

Eichelberger, J.F. (Mound Lab., Miamisburg, Ohio).

May 30, 1961. Contract AT-33-1-GEN-53. 18 p.

Formulation of 13 new epoxy-modified polyurethane systems were cast and cured. Results of chemical tests on an epoxy curing exudate are included. Comparison of solvent effects on retention of radioelements by stainless steel was started and data are tabulated for ^{227}Ac, ^{227}Th, and ^{223}Ra. Work on protactinium was resumed after suspension of this project in 1960. Methods for preparation of small quantities of highly enriched U isotopes are being examined. Included in the survey are chemical exchange, electromagnetic separation, gaseous and liquid thermal diffusion, gas centrifugation, and photochemical techniques. Continued investigation of viscosities of La and Pr for use in Pu alloys is reported. Phase studies of Au-Pt systems were continued along with studies of Pu bearing glass fibers.

612 (NP-tr-817) SOME METHODS OF PRODUCING ENRICHED ^{235}U.

Ho Ping.

Translated from K'o Hsueh T'ung Pao, No. 2, 36-41 (Jan. 26, 1959), 10 p.

Methods for producing uranium are described as gaseous diffusion, supersonic jet pump, super-centrifuge, magneto-ionic expansion, ionic migration, and electromagnetic separation. A comparative table on the methods is included for rate of production, separation factor, cost scale, material, problems, and present progress.

613 (CEA-tr-X-397) MÉTHODES INDUSTRIELLES POUR L'ENRICHISSEMENT DE ^{235}U (INDUSTRIAL METHODS FOR ENRICHMENT OF ^{235}U).

Istvan, E.K.

Translated into French from Energia es Atomtech., 11, 466-73 (1958), 32 p. (Includes original, 8 p.).

In the selection of an industrial method for the enrichment of ^{235}U, the enrichment factor, the chemical and physical characteristics of the materials participating in the enrichment process, the engineering possibilities of the method, and the economics of the method must be considered. The gaseous diffusion process and the centrifugation process for heavy isotopic enrichment are discussed, and the enrichment factors are calculated theoretically. Cascade parameters and equilibrium times are calculated for the two processes. The energy requirement for a gaseous diffusion cascade and the engineering problems of such a plant are reviewed. (Orig. 593)

614 ELECTROMAGNETIC SEPARATION OF RADIOISOTOPES OF THE HEAVY ELEMENTS AT THE OAK RIDGE NATIONAL LABORATORY.

Love, L.O., Banic, G.M., Bell, W.A., and Prater, W.K. (Oak Ridge National Lab., Tenn.).

pp. 141-54 of "E.M. Separation of Radioactive Isotopes. Proceedings of the International Symposium, Vienna, May 1960". Vienna, Springer-Verlag, 1961. (In English).

Discussion is given on an ion source designed for use in plutonium separation, but which was sufficiently versatile to be used in uranium and stable isotope separation. Also discussed is a receiver concept which appears desirable in single isotope collections; included are typical results from the various separations programs.

615 ELECTROMAGNETIC SEPARATION OF RADIOACTIVE ISOTOPES. PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM HELD IN VIENNA, MAY 23-25, 1960.

Higatsberger, M.J., and Viehboeck, F.P., eds.

Vienna, Springer-Verlag, 1961, 326 p. $13.50.

Thirty-four papers are presented; separate abstracts are prepared for 29 papers, 4 were previously abstracted, and one was not abstracted in NSA. The 4 papers previously abstracted are The Relative Enhancement Factor in Electromagnetic Isotope Separation, Electromagnetic Separation of Radioisotopes of the Heavy Elements at Oak Ridge National Lab., Ion Sources with High Efficiency and Intensity, and Protective Measures in Connection with Electromagnetic Separations of Radioactive Isotopes at Oak Ridge National Lab. The paper not abstracted is Sputtering at High Energy.

616 CONTRIBUTION TO THE STUDY OF ISOTOPIC CONTAMINATION WITH A DOUBLE MAGNETIC DEFLECTION ISOTOPE SEPARATOR.

Bernas, R., Camplan, J., van Ments, M., and Sarrouy, J.L.

(Université, Paris, Laboratoire de Physique Nucléaire, Orsay, France).

pp. 68-80 of "Electromagnetic Separation of Radioactive Isotopes". Vienna, Springer-Verlag, 1961.

The second magnetic stage of an electromagnetic isotope separator was used for the analysis of the isotopic composition of the ion beam which enters the collector. This gives an accurate indication of the nature of contamination in these instruments. Although the contribution of fast neutral particles produced by change of charge is important, it can easily be eliminated and does not constitute a limiting factor to isotopic purity. This limit is due to scattered ions and, for a small part, to ions that were slowed down or that did not receive the full accelerating voltage. The contribution of neutrals is obtained from the difference between the isotopic composition of a deposit made on the first stage collector and that of the corresponding ion beam analyzed by the second stage. The experiments were carried out on Sr, Yb, and U. The results confirm the preferential contamination by neighboring isotopes of heavier mass. The origin of this asymmetry is discussed. The consequences of these various processes on the limiting performances of magnetic cascades were studied. (Author)

617 DOUBLE MAGNETIC DEFLEXION ISOTOPE SEPARATOR FOR THE PRODUCTION OF VERY HIGH PURITY ISOTOPES.

Bernas, R., Sarrouy, J.L., and Camplan, J. (Université, Paris, Laboratoire de Physique Nucléaire, Orsay, France).

pp. 121-40 of "Electromagnetic Separation of Radioactive Isotopes". Vienna, Springer-Verlag, 1961.

The electromagnetic separator is made up of a 60° sector homogeneous magnetic field analyzer followed by a semicircular inhomogeneous field analyzer of the Svartholm Siegbahn type. The enrichment factors reached are from ten to a hundred times higher than those obtained with other separator types while the ion beam intensity remains in the neighborhood of 1 ma. A description of the instrument is given as well as the first results obtained in the separation of isotopes of a few elements: Cr, Sr, Yb, Hg, U, and Eu. (Author)

618 GÉNIE ATOMIQUE. TOME QUATRE. LES MATÉRIAUX NUCLÉAIRES. VOLUMES UN ET DEUX (ATOMIC ENGINEERING. TOME IV. NUCLEAR MATERIALS. VOLUMES 1 AND 2).

Saclay, France, Institut National des Sciences et Techniques Nucléaires and Paris, Presses Universitaires de France, 1961. 1848 p.

A review is given of the extraction, physical properties, mechanical properties, physical metallurgy, and relations to properties of solids in general of U, Pu, and Th metals. Nuclear structural materials are reviewed, including Al, Mg, Be, Zr, alloys of these metals, and steels. Refractory materials are surveyed, including UO_2, uranium carbides, and BeO. The production and properties of graphite are outlined. An investigation is made of fuel elements for heterogeneous reactors and of control elements. Radiation effects on nuclear materials are surveyed, with particular attention to fast neutron effects on graphite, physical-chemical behavior of light and heavy water in reactors, interactions between graphite and cooling liquids, and organic liquid coolant behavior. Corrosion problems in water-, gas-, and liquid-metal-cooled reactors are reviewed. Isotope separation techniques are summarized, emphasizing isotopic exchange reactions, electromagnetic separation, U-isotope separation, and heavy water production. Processing procedures for irradiated fuels are detailed. The preparation and industrial and medical uses of artificial radionuclides are reviewed. Methods for measuring radioactivity are examined.

619 (ORNL-1169) ENRICHMENT OF ^{236}U.

Harmatz, B., McCurdy, H.C., Case, F.N., and Livingston, R.S. (Oak Ridge National Lab., Tenn.).

Dec. 1951. Contract W-7405-eng-26. 46 p.

Neutron irradiated uranium was electromagnetically separated to provide enrichment of ^{236}U. The final isotopic abundance was determined to be 95% in 1 800 milligrams of uranium. Useful by-products of the program were 22 grams of 25% ^{236}U and 1 100 grams of 99.7% ^{235}U. Possible application of this separation process to recovery of the fuel from the MTR reactor is described. (Author) (See 609)

620 (ORNL-1269) ELECTROMAGNETIC RESEARCH DIVISION QUARTERLY PROGRESS REPORT, PART I FOR PERIOD ENDING DECEMBER 31, 1951.

Howard, F.T. (Oak Ridge National Lab., Y-12 Area, Tenn.).

May 19, 1952. Contract W-7405-eng-26). 47 p.

Operation of the 86-in. cyclotron was continuous except for a three-day interruption caused by a water leak inside the vacuum chamber; monthly output averaged over 210 000 μa-hr; the average continuous (168-hour week) beam power was approximately 5.5 kW; and the energy of the beam was determined to be $\sim$ 19.4 MeV. No changes because of radiation damage were detected in Inconel tubes containing UF_4-NaF-KF eutectic which were irradiated in the 86-in. cyclotron with power inputs up to $\sim$ 415 w/cc. The major components of the 63-in. cyclotron were fabricated and tested as the machine was being assembled. On the 22-in. cyclotron a radius-wise examination of the fine structure of the proton beam revealed definite proton orbits. Several grams of very pure ^{235}U were prepared;

the chemical recovery for first-stage separation of ^{236}U was established as 97%; and facilities for laboratory-scale separation of Pu isotopes were being prepared. (Author) (See 577, 622).

621 (Y-676) ELECTROMAGNETIC RESEARCH DIVISION PROGRESS REPORT JULY 1, 1950 TO OCTOBER 1, 1950.

Livingston, R.S. (Oak Ridge National Lab., Y-12 Area, Tenn.).

Oct. 12, 1950. Contract W-7405-eng-26. 72 p.

With the installation of the dee assembly and the shielding, the 86-in. cyclotron is structurally complete. The resonant system is being adjusted to improve oscillator performance. The 22-in. cyclotron is being operated as a test instrument for the study of beam efficiencies and beam deflection methods. Expressions for the "horizontal" and the "vertical" motions of ions in a fixed frequency cyclotron were formulated. The separation of intermediate-level ^{236}U is nearing completion, and preliminary tests were made for the separation of thorium, bismuth, and plutonium isotopes. The 90° focus of a beam obtained from a flat-grid ion source was too broad to permit isotope separation; conditions which may account for beam spread are being investigated. Equipment for measuring low reaction cross sections is being tested. Studies of radiation damage and target design were initiated. (Author)

622 (ORNL-1345) ELECTROMAGNETIC RESEARCH DIVISION QUARTERLY PROGRESS REPORT, PART I FOR PERIOD ENDING JUNE 30, 1962.

Howard, F.T., ed. (Oak Ridge National Lab., Y-12 Area, Tenn.).

Nov. 14, 1952. Contract W-7405-eng-26. 23 p.

On the 86-inch cyclotron a 41-kW beam was calorimetered at a net ion loading efficiency of 40%; the average proton current was 1.85 ma at 22.5 MeV. Practical specific yields were determined for (p,2n) reactions on zinc and bismuth. The investigation of products of proton-induced fission of uranium was continued and new techniques are being used in measuring angular distribution of reaction products. The 63-inch heavy particle cyclotron is now in operation; N^{3+} particles were accelerated to $\sim$ 25 MeV. In preliminary tests, induced activities were detected in carbon, nitrogen, and oxygen targets. A hot-cathode type ion source is ready for test operation. The 22-inch cyclotron is being used in an investigation of the problems associated with the use of r-f and d-c electrodes for the acceleration of protons from the ion source into the dees. Radio-induced corrosion in Inconel tubing containing No. 21 eutectic was produced by proton irradiation in the 86-inch cyclotron; it is shown that the corrosion was not due to thermal effects. Approximately 150 grams of highly purified ^{238}U ($<$ 5 ppm ^{235}U) were prepared, and two grams of ^{230}Th was enriched to 90.6%. (Author) (See 577, 620)

623 (ORNL-TM-658) ISOTOPIC SEPARATIONS.

Progress Report, April-June 1963.

Love, L.O., comp. (Oak Ridge National Lab., Tenn.).

Nov. 14, 1963. Contract W-7405-eng-26. 45 p.

Progress is reported on inhomogeneous field separator development; magnetic field studies, ion source studies, ion receiver studies, spectrographic studies of calutron ion beams, beryllium separation studies, chemical aspects of isotope separation, electromagnetic separations, heavy element separations, and thermal diffusion.

624 SEPARATION OF URANIUM ISOTOPES.

Pecqueur, M.

Ann. Mines, 11-30 (Nov. 1963). (In French).

Descriptions are given of electromagnetic separation, heat diffusion, centrifugation and expansion in nozzles as means of enriching ^{6}UF gas or liquid to obtain ^{235}U and ^{238}U. Parameters and techniques for the gas diffusion enrichment process, including equipment, pressure, gas concentration, charge quantity, and barrier pore size were determined. (Rev. Metal Lit., 21, No. 2, Feb. 1964).

625 (ORNL-3606) REVIEW OF ORNL ELECTROMAGNETIC SEPARATIONS PROGRAM, JANUARY-DECEMBER 1963.

Love, L.O., and Bell, W.A. (Oak Ridge National Lab., Tenn.).

May 1964. Contract W-7405-eng-26. 53 p.

Developments and activities of the Electromagnetic Isotope Separations Department for 1963 in areas of magnetic fields, ion sources, ion receivers, charge evaluation, contamination, system modifications, quality control, and chemistry are reviewed. Both stable isotope separations and special heavy element separations are included. (Author)

626 (ORNL-TM-879) ISOTOPES DEVELOPMENT CENTER, ISOTOPIC SEPARATIONS PROGRESS REPORT, JANUARY-MARCH 1964.

Love, L.O., comp. (Oak Ridge National Lab., Tenn.).

July 1964. Contract W-7405-eng-26. 22 p.

The focusing of ions in the 255° calutron under two-arc operation was studied; source geometry and beam position-

ing factors are discussed. Separations of tungsten, sulfur, and magnesium isotopes are reported in progress. Calutron ion sources and receivers are discussed: an internally valved ion source feed system is described and its performance is shown for mercury, tungsten, and sulfur ions; a receiver (collector) specially for implanting impurities in single crystals is described and its performance is shown for ^{31}P deposition of p-type silicon. Sample contamination in the calutron is considered. A summary is given of current electromagnetic isotope separation for stable isotopes of Ba, Ca, Ni, Mg, S, Si, and W. Enriched isotope recovery for plutonium series "a" is reported; results are given for $^{239,240,241,242}Pu$. Uranium-233 separation series are discussed; preliminary results are given. Electrodeposition of ^{241}Am, ^{237}Np, and ^{240}Pu is reported. A mathematical study was made of the concentration gradients in a mixture of many isotopes at equilibrium in a thermal diffusion column. Neon-21, ^{38}Ar, ^{13}C, and ^{86}Kr concentrations in columns are reported.

627 METHOD OF DOUBLE SIMULTANEOUS CENTRIFUGATION, MEANS EMPLOYED AND PRODUCTS THUS OBTAINED.

Rabissow, G.A.

French Patent 1,330,152. May 13, 1963. Filed Feb. 15, 1962.

The construction of an apparatus in which material to be separated is simultaneously subjected to two different centrifugal forces is described. The apparatus consists of a container that rotates on two different axis. During centrifugation the material can be ionized and the ionized particles subjected to a magnetic field. The apparatus is particularly useful for separating H and U isotopes.

628 PRODUCTION OF NUCLEAR FUELS. PART 2. ENRICHED URANIUM.

Ploeger, F., Vietzke, H. (Nuklear-Chemie und -Metallurgie GmbH, Wolfgang, Ger.).

Chem.-Ingr.-Tech., 37, 692-9, (July 1965). (In German)

The ^{235}U isotope can be concentrated in the form of gaseous uranium hexafluoride either by the Calutron process, by the diffusion method with Al_2O_3 membranes, or by means of gas-centrifuges and separating nozzles. The hexafluoride is then converted either to uranium dioxide or the metal for use in nuclear reactors. (Author)

629 GÉNIE ATOMIQUE. TOME V. ÉLABORATION DES MATÉRIAUX NUCLÉAIRES DE BASE. ÉLABORATION ET UTILISATION DES ÉLÉMENTS ARTIFICIELS (ATOMIC ENGINEERING. VOLUME V. PRODUCTION OF BASIC NUCLEAR MATERIALS. PRODUCTION AND UTILIZATION OF ARTIFICIAL ELEMENTS.

Deuxième Édition revue et augmentée de partie du Tome IV. Second Edition Review and Addenda to part of Volume IV.

Saclay, France, Institut National des Sciences et Techniques Nucléaires. Paris, Presses Universitaires, 1965, 596 p.

A series of monographs on the production and use of basic nuclear materials and artificial elements was compiled. The topics considered are the preparation of uranium from the ore to the ingot, the preparation of thorium from the ore to the metal, the formation and properties of transuranium elements and fission products, chemical properties of plutonium, chemical processing of irradiated fuel elements, the physical and chemical properties of isotopes, separation of isotopes, production of heavy water, separation of uranium isotopes, electromagnetic separation of isotopes, isotopic analysis and determination of heavy water and uranium, production of graphite for nuclear purposes, preparation of radioisotopes, industrial uses of radioisotopes biological tracers, and the chemical uses of radiation. Each section contains its own bibliography and there is an index for the entire volume.

PIERRELATTE — USINE DE SÉPARATION DES ISOTOPES DE L'URANIUM (PIERRELATTE—PLANT FOR SEPARATION OF URANIUM ISOTOPES).

Paris, Commissariat à l'Énergie Atomique, 1964, 38 p.

The design and development of the Pierrelatte Isotope Separation Plant is described. The isotopic enrichment processes used are electromagnetic separation, thermal diffusion, centrifugation, expansion in a shock tube, and gaseous diffusion. The principle of each of these methods is described briefly. The characteristics of the plant are given.

631 ELECTROMAGNETIC ISOTOPE SEPARATORS AND THEIR APPLICATIONS.

Koch, J., Nielsen, K.O., eds.

Proceedings of the International Conference, Aarhus, Denmark, June 14-18, 1965. Nucl. Instrum. Methods, 38, 1-325, 1965. (CONF-650627).

Sixty-eight papers and four abstracts of papers are included. Separate abstracts were prepared for sixty-five papers: two papers were previously abstracted in NSA, see 19, 39370 and 42017. The paper not abstracted is a brief statement on scattering in double-focusing separators.

632 ORNL CALUTRON PROCESSING OF ALPHA,GAMMA MATERIALS AND STUDIES ON NEW SEPARATORS ADAPTABLE TO THIS PURPOSE.

Love, L.O., Prater, W.K., Scheitlin, F.M., Whitehead, T.W. Jr., Dagenhart, W.K., Tracy, J.G., Johnson, R.L., Banic, G.M. (Oak Ridge National Lab., Tenn.).

Nucl. Instrum. Methods, 38, 148-51, (1965).

Special equipment was designed at the Oak Ridge National Laboratory (ORNL) for the calutron processing of moderate quantities of α,γ-emitting materials. A 73-h run having an average ion output of 2.9 mamp provided 71 mg of 20.4% ^{242m}Am from an americium sample containing $\sim$ 1% of the nuclide. Other elements that have been separated in the special electromagnetic containment facility at ORNL include plutonium, thorium and uranium. Some separations were made to reduce the unwanted isotope to the ppM- or ppB-level. (Author)

633 (ORNL-4006) REVIEW OF ORNL ELECTROMAGNETIC SEPARATIONS PROGRAM, 1965.

Love, L.O., Bell, W.A. (Oak Ridge National Lab., Tenn.).

Aug. 1966. Contract W-7405-eng-26. 37 p. Dep. mn. CFSTI $2.00 cy, $0.50 mn.

The effort in the electromagnetic separations program was divided between separating materials for requirements and developing techniques and equipment needed for the separations program to keep pace with stated or anticipated requirements in quantity and isotopic purity of product samples. In > 50% of the separations completed this year, operations improved in one or more of the parameters used in judging separation performance. The first major electromagnetic separation of beta-gamma material was completed in the heavy-element section of the program. Ion sources, isotope receivers, ion implantation, contamination studies, vacuum improvement, developments incorporated into scheduled separations, 180° sector separator development, heavy-element separations, and stable isotope separations are discussed.

634 AEC, INDUSTRY, UTILITIES EXPLORE PRIVATE ENRICHMENT POSSIBILITIES.

Grant, J.

Nucleonics, 25, No. 2, 54-7, 84, (Feb. 1967).

Views of the AEC, private industry, and public utilities on the possibility of private uranium enrichment are discussed. Some questions considered are: the urgency of private participation in enrichment; availability of classified information; prospects for methods of enrichment other than gaseous diffusion; would a monopoly be created which would damage competition; and would private enrichment bring cheaper fuel costs and if so would savings be passed on to public utilities. A short history of uranium enrichment in the U. S. is given. Other methods of enrichment such as thermal diffusion, electromagnetic, gas centrifuging, and chemical separation are summarized.

635 CALUTRON EXPERIMENTS WITH MILLIGRAM QUANTITIES OF CHARGE MATERIAL.

Underwood, J.N., Love, L.O., Prater, W.K., Scheitlin, F.M. (Oak Ridge National Lab., Tenn.).

Contract W-7405-eng-26. Nucl. Instrum. Methods, 57, 17-21 (Dec. 1967). (ORNL-P-3134).

An ORNL electromagnetic isotope separator (calutron) has been operated with milligram amounts of uranium charge material. A series of nine experimental runs using 1 to 50 mg of charge (material) achieved process efficiencies ranging from 1 to 13 %. In one of the experimental runs, ^{235}U was enriched from 0.72 (normal abundance) to 94.3% in a single pass. (Author)

636 SEPARATION OF U ISOTOPES IN FRANCE AND IN THE WORLD.

Pecqueur, M. (CEA, Paris).

Énerg. Nucl., Paris, 9, 480-8, (Dec. 1967). (In French)

The development of the Pierrelatte installation and the history of the isotopic separation of U in France and in the world are outlined. The civil and military reasons for the separation of U isotopes are given. The U isotope separation developments of the United States, England, Russia, China, and France are briefly reviewed. The principal separation procedures — electromagnetic separation, thermal diffusion, the Becker method, and centrifugation — are described in principle. The gaseous diffusion procedure is described in slightly more detail. The Pierrelatte installation based on the gaseous diffusion procedure is described. Technological difficulties in the design and construction of this installation were connected with the properties of uranium hexafluoride, the barrier, and the compressor and its tightness The solutions used in each of these areas are indicated. (Trans. 638)

637 (ORNL-4271) REVIEW OF ORNL ELECTROMAGNETIC SEPARATIONS PROGRAM, 1966-67.

Love, L.O., Bell., W.A. (Oak Ridge National Lab., Tenn.).

July 1968. Contract W-7405-eng-26. 78 p. Dep. CFSTI.

Research progress is reported under the following headings: stable isotopes separated, separations typifying progress in methods, isotope usage, calutron feed advancements, isotope

receiver improvements, ion source development, radioactive gas separation, ion implantation, natural element contamination and problems of retention of low-abundance isotopes, sector separator, inhomogeneous-field 255° separator, and heavy-element separations.

638 (K-Trans-45, pp.7-28) URANIUM ISOTOPE SEPARATION IN FRANCE AND IN THE WORLD.

Pecqueur, M.

Translated from Energ. Nucl., Paris, 8, 481-9, (Dec. 1967).

An abstract of this paper, prepared from the original language, appeared as NSA 22, 23230. (Orig. 636)

639 (ORNL-TM-2889) ISOTOPE PROGRAM (5000) PROGRESS REPORT FOR QUARTER ENDING DECEMBER 31, 1969.

Gillette, J.H. (Oak Ridge National Lab., Tenn.).

March 1970. Contract W-7405-eng-26. 16 p. Dep. CFSTI.

Progress is summarized on target fabrication and development, isotopic separations, radioisotopic separations, sector isotope separator operation, chemistry of processing, and isotope sales.

640 (ORNL-TM-2985) ISOTOPE PROGRAM (5000) PROGRESS REPORT FOR QUARTER ENDING MARCH 31, 1970.

Gillette, J.H. (Oak Ridge National Lab., Tenn.).

May 1970. Contract W-7405-eng-26, 18 p. Dep. CFSTI.

Research progress is reported on target fabrication and development, stable isotope separations, radioisotope separations, sector isotope separator experiments, processing chemistry, and isotope preparation and sales.

641 URANIUM ENRICHMENT INDUSTRY.

Avery, D.G., Kehoe, R.B. (United Kingdom Atomic Energy Authority, Risley, Eng.).

Atom, London, 164, 120-30, (June 1970).

A survey of the historical background of isotope separation and uranium enrichment is given. Four processes of uranium enrichment are discussed; the centrifuge method, the electromagnetic (calutron) method, the thermal diffusion method, the gas diffusion process. The capacity of the present day gas diffusion plants in U.S.A., U.K., France, Russia and China are considered. A simplified treatment of the diffusion process is given which enables the main design and optimization characteristics to be identified. Membrane development is reviewed and the difficulties of plant design when dealing with UF_6 considered. The nozzle process and the centrifuge method are examined and their economics discussed. The growing demand for uranium enrichment in Europe is considered in the light of the tripartite agreement.

642 (CEA-R-4043) STUDY OF THE ISOTOPIC CONTAMINATION WITH THE TWO-STAGE GRENOBLE MAGNETIC SEPARATOR.

Boge, M. (Commissariat à l'Énergie Atomique, Grenoble, France. Centre d'Études Nucléaires).

Aug. 1970, 93 p. (In French) Dep. CFSTI (U. S. Sales Only).

Thesis. Submitted to Univ. of Grenoble, Faculte des Sciences, France.

In order to know the limits of enrichment of the Grenoble electromagnetic isotope separator, the principal contaminations caused by ion scattering on the residual gas and by chromatism were studied. A second magnet was used with neodymium to analyze the ions ($Nd^+ \approx 500\,\mu A$, $NdO^+ \approx 120\,\mu A$, $Nd^{2+} \approx 70\,\mu A$) which passed through the first stage slit. Therefore, the scattering with and without charge exchange of Nd^+ and the dissociation of NdO^+ were measured. The chromatism was studied by means of an electrostatic analyzer used as a third stage. The limits of enrichment were obtained for argon, uranium, and neodymium. (Author) (France)

643 (BMBW-FBK-70-28, pp.381-93) ISOTOPIC CONTAMINATION IN THE GRENOBLE ISOTOPE SEPARATOR.

Boge, M., Bouriant, M., Chantereau, E., Dousson, S., Bouchez, R., (Commissariat à l'Énergie Atomique, Grenoble France. Centre d'Études Nucléaires. Grenoble Univ., France. Institut des Sciences Nucléaires).

From seventh international conference on electromagnetic isotope separators and the technique of their applications, Marburg, Germany, (Sept. 7, 1970).

In Proceedings of the international conference on electromagnetic isotope separators and the techniques of their applications (1970).

Results of studies show that the contamination factor C after the first magnet is relatively low ($\approx 10^{-3}$ to 10^{-4}) and the neutral contamination is then dominant. After the second magnet, the contamination factor is still smaller (10^{-5} to 10^{-6}). This residual effect is related to the chromatism. With a third electrostatic stage high-purity separation could be obtained; however, unfavorable conditions

became evident, i.e., vacuum contamination, surface effects, and external contamination. However it, is believed that the method is useful for isotope collections of low natural abundance such as ^{204}Pb (1.37%) and ^{235}U (0.6%). (Author)

644 ENGINEERING FEATURES OF THE ATOMIC BOMB PLANTS.

Klein, A.C.

April 1946, 23 p. Price: Microfilm $1.00; Photostat $2.00.

The author, engineering manager of Stone and Webster Engineering Corporation, Boston, Mass., and one of the first engineers to be associated with the Manhattan Project, describes the engineering accomplishments in procuring uranium ore and in designing and constructing plants. The Boston engineers concentrated principally on the plant which utilizes the electromagnetic or mass spectroscope method for the separation of fissionable isotope ^{235}U from natural uranium, but work was also carried on on the design and construction of the first catalytic heavy water plant, design and construction of a Plutonium pilot plant, and the construction of the town of Oak Ridge. Although many of the most important engineering features of the electromagnetic process are still closely guarded secrets, a few interesting features are divulged herein. Photographs of the electromagnetic plant are appended.

645 ARRICCHIMENTO DELL'URANIO — ALCUNI METODI ED IMPIANTI.

5 ref.

Notiziario 14, (1968), n. 6, p. 49-56.

Metodi di separazione — separazione elettromagnetica — diffusione termica — jet gassoso — centrifugazione gassosa — diffusione gassosa — alcuni impianti di diffusione — Capenhurst (G.B.) — Pierrelatte (Francia) — Oak Ridge (U.S.A.) — Paducah (U.S.A.) — Portsmouth (U.S.A.).

646 BASIC STUDIES ON THE PRODUCTION OF ENRICHED ^{237}U AND THE MEASUREMENT OF ITS SPECIFIC ACTIVITY.

Hashimoto, T., Sakanoue, M. (Dept. Chem., Fac. Sci., Kanazawa Univ.).

Sci. Rep. Kanazawa Univ., Jap. (1966), 11, n° 1, 49-71, bibl., (46 réf.).

Méthodes de production : réaction (n, 2n) par irradiation dans un réacteur, par un cyclotron et par générateur de neutrons; réaction (γ, n). Purification chimique de U de la cible irradiée. Mesure de l'activité spécifique. Expériences d'irradiation de la cible d'U. L'emploi de composé organométallique est avantageux pour obtenir un facteur d'enrichissement élevé.

6. CHEMICAL METHODS

647 METHODE DE SEPARATION ISOTOPIQUE. III: SEPARATION DES ISOTOPES DE L'URANIUM A L'AIDE D'ECHANGEURS D'IONS.

CIRIC, (Milan).

Energie Nucléaire, 10, 6, 10/68, pp. 316-380, 4 fig., 10 réf. bibl.

Les effets de séparation des isotopes pour les systèmes constitués par des solutions aqueuses de sels d'uranyle et un échangeur de cations du type Dowex 50 ont été étudiés. La phase échangeur s'enrichit en isotope léger U^{235}. Le facteur de séparation déterminé par la méthode d'analyse frontale varie de 1,0000 à 1,0006. L'analyse isotopique est faite au spectromètre de masse par ionisation de surface.

648 SEPARATION OF ISOTOPES.

Robieux, J., and Auclair, J.M. (Compagnie Générale d'Electricité).

Fr. 1,391,738 (Cl. B 01^d, C 22^b, G 21), March 12, 1965, Appl. Oct. 21, 1963; 4 pp.

^{235}U and ^{238}U were sepd. by selective ionization of their UF_6 compds. The lowest energy level (V_0) and the ionization energy (V_3) are the same for both, but the energy levels of the excited states differ slightly (V1 for ^{235}U and V_2 for ^{238}U). The UF_6 gases were passed through a cell provided with a gas inlet tube and 2 outlet tubes (one opposite the inlet tube and the other at 90° from it) and 2 windows on opposite sides. They were irradiated with a narrow beam of essentially monochromatic light sufficient to excite ^{235}U but not the ^{238}U (i.e. $> V_1 - V_0$ but $< V_2 - V_0$). Through the window on the opposite side was passed a beam with sufficient energy to ionize the activated mols. of ^{235}U, but not the unactivated ^{238}U fluoride mols. (i.e. $> V_3 - V_1$ but $< V_3 - V_0$). The cell was in an elec. field so that the ionized mols. were deflected through the outlet tube at right angles while the unionized gas passed directly through the opposite tube. The energy needed for the excitation is in the order of ir, which is in the laser region. The laser can give the desired monochromaticity (10^{-3}). For the 2nd radiation, uv light was used. The radiation can be continuous or pulsed. This is a purification process only, but a series of cells can be interconnected according to the methods of fractional purification. (See 657)

649 SEPARATION OF LITHIUM ISOTOPES BY COUNTERCURRENT EXCHANGE ELECTROLYSIS.

Arkenbout, G.J., Smit, W.M., (Fys. Chem. Inst., T.N. O., Delft, Neth.) and Boerboom, A.J.H.

TNO Nieuws 20, 10, 723-9, (1965). (Dutch)

The sepn. of Li isotopes by countercurrent exchange electrolysis was investigated. The expts. are based on an exchange between Li amalgam and a soln. of a Li salt (e.g. 0.4^M LiCl in $HCONMe_2$), transported in countercurrent through a column. It is possible to obtain a satisfactory countercurrent transport in a column packed with sand of a particle size between 0.35 and 0.55 mm. The reflux at the bottom of the column, where Li is transported from the amalgam to the electrolyte soln. (anodic reflux) is realized in two stages by continuous exchange electrolysis in a concd. soln. of alkali or alk. earth halides. The cathodic reflux is obtained by evapg. the solvent $HCONMe_2$, transferring the LiCl into water, and electrolyzing this soln. By use of a high c.d. (7 amp./cm^2), a high LiCl concn. ($> 2^M$), and a small contact time of the amalgam and the LiCl soln., a current efficiency of 95% is achieved. Expts., carried out in an exchange column with a length of 1-2 m and a diam. of 2.5 cm, during 20 to 40 hrs., resulted in an increase of Li^6 content from 7.5 to 13% at the bottom of the column and a decrease from 7.5 to 5.3% at the top of the column. The velocities of both phases in the column were $\sim$ 0.2 ml/min. cm^2. This method should give sepd. isotopes of, e.g., Li, Ca, and U at very low costs.

650 SEPARATION OF URANIUM ISOTOPES ON CATION-EXCHANGE RESINS.

Ciric, M.M., and Zmbov, K.F. (Boris Kidrich Inst. Nucl. Sci., Belgrade, Yugoslavia).

Abhandl. Deut. Akad. Wiss. Berlin, Kl. Chem., Geol. Biol., 1964, 7, 223-7. (Eng.).

Isotope sepn. factors of 1.00004-1.0007 were obtained with various uranyl salt solns. in columns with Amberlite IR-120 (0.1-0.2 mm particle size, 2 m × 0.5 cm^3 column) and Dowex 50-X8 (100-200 mesh, 1 m × 1.5 cm^3 column). ^{238}U was concd. in the resin phase. The isotope compn. was detd. by mass spectrometer. From CZ 1965, (51), Abstr. No. 502.

651 ISOTOPE ENRICHMENT BY ELECTROMIGRATION IN ION-EXCHANGE RESINS.

Asahi Chemical Industry Co., Ltd., Hidetake Kakihana, and Atomic Fuel Corp. Fr. 1,403,198 (Cl. B 01^d, G 21), June 18, 1965; Japan. Appl. June 21, 1963; 10 pp.; cf. U. S. 2,989,457.

Preferably it applies to the sepn. of U, B, N, Cl, C, and K isotopes as anions or cations through anionic or cationic exchange resins in the form of membranes, columns, tubes, etc., of at least two large dimensions. At both ends of the membrane a d.c. is applied and at least two different solns. are successively supplied to one electrode at known intervals of time to produce alternate migration bands that are sepd. continuously at the other electrode. Isotopes in the form of anions and cations can be sepd. simultaneously with alternate anionic and cationic exchange membranes with intermediate compartments for isotope sepn. Likewise, more than two isotopes of an element can be sepd. Multiple

alternate membranes can be assembled for cascade enrichment of low-concn. solns. Cationic exchange resins are selected among those with sulfonic, carboxylic, phosphoric, or hydroxy groups and anionic with amino or quaternary ammonium groups. The matrix can be vinyl or divinyl polymers such as styrene and divinylbenzene. For example, to a 0.2-mm-thick, 20-cm-wide, 80-cm-long cationic exchange membrane was applied a 30-ma, d.c. at 1005 v. along its length through a Ni-cathode and a Ta-Pt anode immersed in the electrode compartments. A 0.1M NaCl soln. was flowing through the cathode. Every 68 hours, 0.05*M* UO_2Cl_2 and 0.05*M* NH_4Cl solns. were supplied successively to the anode compartment to form two alternate different bands of 8 cm along the membrane. After 679 hours the first U band reached the cathode and was divided in two fractions by the flowing cathodic solns. The two U fractions, 4510 and 4545 g, resp., were sepd. and recovered for a 34-hour period each. The first NH_4Cl band was recovered for a 64-hour period. In the first fraction 0.7185% ^{235}U was enriched to 0.7280% and depleted to 0.7089% in the second, i.e. 1.32% enrichment for ^{235}U and ^{238}U was obtained. Other examples are given for the enrichment of Li, Cl, and U isotopes. Elec. consumption is low and the procedure can be applied on a continuous and economic basis in industry. (See 659)

652 SEPARATION OF ISOTOPES.

Blanc, C., Chanh Trung Huynh, and Espagno, L. (Société Nationale des Pétroles d'Aquitaine).

Fr. 1,490,724 (Cl. B 01^d), Aug. 4, 1967, Appl. June 23, 1966, 3 pp.

A gaseous absorption method, similar to that used for the sepn. of mixts. in gas chromatography, is applied to the sepn. of isotopes. A natural mixt. of Xe isotopes was introduced periodically and in small quantity into a current of pure CO which was passed over a 5-A. mol. sieve at 20°. The CO carrier was enriched in Xe_{129} and was removed periodically to conc. the isotope. Sepn. was improved at high carrier gas pressures (15-100 bars), high mol. wt. of the carrier gas, and low differential in diffusion coeff. between carrier and gas confg. the desired isotope. The method is also applicable to the sepn. of ^{235}U in $^{238}UF_6$.

653 ISOTOPIC ENRICHMENT.

Inchauspe, N. (Société Nationale des Pétroles d'Aquitaine).

S. African 68 00,180 01. Aug. 1968, Fr. Appl. 17 Jan. 1967-7 Aug. 1967; 44 pp.

A process is described in which a gaseous mixt. contg. different isotopes of an element is enriched in 1 of its isotopes. The gaseous mixt. is introduced into a chamber previously filled with a sorbing agent and a buffering gas, which is inert to the gaseous mixt. and the sorbing agent. This is continued until at least 1 fraction (head fraction) is collected at the outlet. The injection of the gaseous mixt. is stopped when the fraction has been collected. Then the buffering gas is introduced, and the different fractions of the gaseous mixt. are collected sep. at the outlet of the chamber. Three fractions of the isotopic mixt. are collected independently at the chamber outlet, viz., a head fraction enriched in 1 of the isotopes, an intermediate heart fraction in which the isotope ratio is substantially equal to the initial isotopic ratio, and a tail fraction stripped of the isotope which is concd. in the head fraction. The head fraction undergoes a further enrichment cycle in an app.-element situated downstream, the heart fraction is recycled to the inlet of the chamber which has served for the fractionation, and the tail fraction is refluxed into a chamber situated upstream from the chamber which has served for the fractionation. This is referred to as cascade enrichment. The app. comprises a series of columns filled with sorbing agent arranged in cascade formation. The outlet of each column is connected to a conduit system. At least 1 conduit is intended to collect a fraction enriched in 1 of the isotopic forms. The isotopes of B and U ($^{10,11}B$ and $^{235,238}U$) have been sepd. by this method.

654 ENRICHMENT OF ISOTOPIC MIXTURES BY ISOTOPIC EXCHANGE USING AN ION EXCHANGER IN A FIXED BED.

Charlot, G., Didier, A., Rat, G., Spilliaert, P. (Ugine Kuhlmann and Echangeurs d'Ions Mineraux "E.D.I.M.").

S. African 69 06, 549, 3 April 1970, Fr. Appl. 9 Oct. 1968, 26 pp.

Isotope exchange between ions of the same element, but in 2 different valence forms, takes place on an ion exchanger, which selectively adsorbs only one valence form. In an example, the ion exchange resin Dowex 50W-X8 is used to obtain uranium enriched in the ^{235}U isotope. This is accomplished because ^{235}U has the tendency to conc. in the hexavalent state, and in this system only the tetravalent uranium is adsorbed.

655 INCREASING MAXIMUM ENRICHMENT PROCESSING CAPABILITY THROUGH CRITICALITY CALCULATIONS.

Dunaway, D.L., Miller, G.P., Johnson, W.A. (Nat. Lead Co. of Ohio, Cincinnati, Ohio).

Nucl. Appl. Technol., 1970, 8,(6), 482-7, (Eng).

A study was initiated to det. the highest ^{235}U enrichment that could be processed safely in a facility originally designed for refining natural U ores and concs. The equipment used in converting uranyl nitrate to UO_3 was the limiting factor. Calcns. of n multiplication throughout the denitration cycle were made by using data from the anal. of process material. ^{235}U enrichment could be safely increased to 2.0% from the previous limit of 1.25% ^{235}U. Processing at the higher enrichment required slight changes in equipment to ensure against moderation of the material. (See 726)

656 EFFECT OF SUPERPOSITION OF ALTERNATING ELECTRIC CURRENT FOR ISOTOPE SEPARATION BY ION EXCHANGE ELECTROMIGRATION METHOD.

Kishimoto, M., Satô, A., Suzuki, S., and Gotô, H.

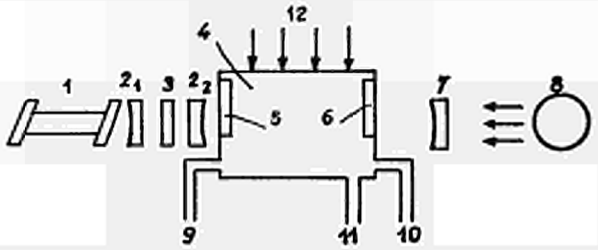
Sci. Rep. Res. Insts Tohoku, Univ. A, Japan, Vol. 18, 315-20, (1966).

The investigations on the enrichments of nitrogen-15 and of ^{235}U were carried out by the ion exchange electromigration method with the superposition of alternating electric current on direct electric current. It was found that the heavier isotope proceeded more quickly to the cathodic compartment, while the lighter isotope remained in the anodic compartment, and the results obtained were better than those by the conventional ion exchange electromigration method.

657 PROCÉDÉ DE SÉPARATION ISOTOPIQUE.

Robieux, J., et Auclair, J.M.

Compagnie Générale d'Electricité (BF. 1.391.738, 21 Oct. 1963).



Procédé pour séparer l'U^{235} de l'U^{238} par exposition, dans la cuve 4, du mélange isotopique à un premier rayonnement (source I, focalisateur 21, 23) d'énergie correspondant à la transition V_0/V_1 (V_1 : niveau d'excitation de ^{235}U), puis à un second rayonnement (source 8, focalisateur 7) d'énergie telle que seules les molécules de ^{235}U atteignent le niveau d'ionisation V_3 et sont déviées par le champ électrique vers la conduite II.

A process for separating ^{235}U from ^{238}U by subjecting, in the vessel 4, the isotopic mixture to a first radiation (source, 1 focusing device 21, 23) having an energy corresponding to the transition V_0/V_1 (V_1 : excitation level of ^{235}U), then to a second radiation (source 8, focusing device 7) with such an energy that only the molecules of ^{235}U reach the ionization level V_3 and are deflected by the electric field towards the conduit 11. (See 648)

658 PERFECTIONNEMENTS APPORTES AUX PROCEDES POUR LA SEPARATION D'ISOTOPES.

Asahi Kasei Kogyo Kabushiki Kaisha et M. Hidetake Kakihana,

Japon, 2 août 1963, (BF. 1.402.626, 30 juillet 1964).

Procédé pour séparer en continu et économiquement des isotopes de U, Li, Ca, B, D, N, Cl et C à l'aide d'un appareil d'électrodialyse comportant, entre anode et cathode, des membranes sélectives de cations C_1, C_2 ... alternant avec des membranes sélectives d'anions a_1, a_2 ... pour former des compartiments de désionisation A_1, A_2 ... et de concentration B_1, B_2 ... susceptibles d'être reliés par des canalisations X et Y selon la nature de la solution à traiter.

A process for separating continuously and economically isotopes of U, Li, Ca, B, D, N, Cl and C by means of an electrodialysis apparatus comprising, between the cathode and anode, cation selective membranes C_1, C_2 ... alternating with anion selective membranes a_1, a_2 ... constituting deionization compartments A_1, A_2 ... and concentration compartments B_1, B_2 ... liable to be connected by means of pipes X and Y according to the nature of the solution to be treated. (See 717)

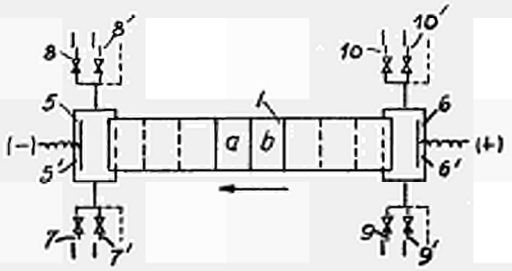
659 PROCEDE POUR SEPARER ET ENRICHIR DES ISOTOPES.

Asahi Kasei Kogyo Kabushiki Kaisha, M. Hidetake Kakihana, et Atomic Fuel Corporation.

(BF. 1.403.198, 19 juin 1964).

Procédé pour séparer ou concentrer des isotopes consistant à utiliser au moins un ruban I en résine échangeuse d'ions appropriée, disposé entre au moins un compartiment cathodique 5 et un compartiment anodique 6, à introduire au moins deux solutions contenant les ions à séparer ou concentrer, soit dans le compartiment anodique (cations), soit dans le compartiment cathodique (anions) à intervalles répétés tels que des bandes de migration alternées a, b (deux solutions) se forment dans le ruban, les bandes étant recueillies par fractions d'ions légers et lourds.

A process for separating or enriching isotopes consists of using at least one tape (1) made of an appropriate ion



exchange resin and mounted between at least one cathode compartment (5) and one anode compartment (6), in introducing

at least two solutions containing the ions to be separated or enriched, either in the anode compartment (cations) or in the cathode compartment (anions) at repeated intervals in such a manner that alternated migration bands a, b (two solutions) are formed in the tape, the bands being collected in fractions of light and heavy ions. (See 659)

660 PROCEDE DE SEPARATION DES ISOTOPES DE L'URANIUM AU MOYEN D'ECHANGE D'IONS.

Japan Atomic Energy Research Institute, Japon, 30 juillet 1964. (BF. 1.480.129, 28 juillet 1965-3 avril 1967).

Procédé de séparation des isotopes de U, p. ex. pour accroître la concentration de ^{235}U dans une solution de U (VI), consistant à mettre en contact — dans une colonne d'échange — ladite solution avec une charge mobile de résine échangeuse de cations ayant absorbé des ions U (IV) par contact préalable avec la solution issue d'une colonne d'oxydation-réduction (contenant un amalgame de Zn avec HCl) par l'intermédiaire de laquelle est recyclée la solution issue de la colonne d'échange. La concentration en ions H et le débit de la solution, celui de résine sont choisis pour un équilibre d'échange isotopique dans la colonne d'échange.

A process for separating U isotopes, e.g. for increasing the concentration of ^{235}U in a solution of U (VI), consists of putting in contact—within an exchange-column—said solution with a moving charge of cation-exchange resin having absorbed ions U (IV) by previously contacting the solution issuing from an oxidation-reduction column (containing a Zn amalgam with HCl) through which is recycled the solution issuing from the exchange column. The concentration of the H ions and the flow rate of the solution, the flow rate of the resin are chosen for establishing an isotopic exchange equilibrium in the exchange column. (See 721)

661 CALCUL DES FRONTS EN CHROMATOGRAPHIE D'ECHANGE D'IONS, DEVELOPPEMENT PAR DEPLACEMENT (FRONT CALCULATIONS IN ION-EXCHANGE CHROMATOGRAPHY, DISPLACEMENT TECHNIQUE).

Persoz, J.

Ecole supérieure de physique et chimie industrielles, 75, Paris, France. Lab. de chimie analytique.

Bulletin de la Société Chimique de France, N° 2, Février 1968, pp. 848-853. Rapport CEA-TP-6549.

Nous exposons une méthode de calcul numérique du front de développement par déplacement de bandes comportant deux constituants. Dans le cas où la constante d'échange est élevée, la bande atteint un état stationnaire pour lequel les deux zones contenant chaque constituant pur sont séparées par un front symétrique bilogarithmique. Dans le cas d'une constante d'échange très faible, K = 1,001 par exemple pour les isotopes de l'uranium, la bande atteint un état stationnaire très différent du précédent. Des indications sont données pour la production par développement par déplacement. (See 662)

662 CALCUL DES FRONTS EN CHROMATOGRAPHIE D'ECHANGE D'IONS (FRONT CALCULATIONS IN ION-EXCHANGE CHROMATOGRAPHY).

Persoz, J.

Paris Univ., 75, France. Faculté des Sciences.

Thèse Sciences physiques, Faculté des Sciences de Paris. Sans lieu ni date, 89 feuillets, figures et tableaux.

La méthode de calcul numérique des fronts permet de prévoir les phénomènes en chromatographie, dans des cas où les équations mathématiques sont insolubles. Dans le cas des séparations isotopiques. Charlot, G., a prévu par des calculs littéraux le front stationnaire en développement par déplacement. Les calculs numériques, dans le cas des isotopes de l'uranium et de ceux du bore, ont permis de confirmer ces résultats, et de connaître l'évolution du front avant l'état stationnaire. Le front d'analyse frontale ne tend pas vers un état stationnaire. Les fronts calculs à la machine ont pu être comparés aux fronts expérimentaux, dans le cas d'analyse frontale avec les isotopes du bore. La HPTE relative à l'échange 8-10 8-11 sur résines anioniques a pu être déterminée. Lorsque les constantes d'échange sont plus élevées, le calcul numérique a confirmé les équations des fronts stationnaires de permutation d'ions, d'analyse frontale et de développement par déplacement, établies par trémillon. Il renseigne en outre sur l'évolution du front avant l'état stationnaire, et permet de déterminer la HPTE dans ce cas, ce qui évite des manipulations très longues. Quelques exemples d'application sont donnés, par l'étude de l'échange de cations alcalins et divalents sur les résines Dowex M-50, Dowex A-1 et Duolite C-63. La méthode de calcul permet de tenir compte de la variation des constantes apparentes d'échange. La méthode peut s'appliquer à d'autres types de chromatographie, chromatographie de partage liquide-liquide, liquide-solide ou chromatographie en phase gazeuse, à condition de modifier le calcul des équilibres dans les plateaux en fonction du problème étudié. (See 661)

663 SEPARATION OF ISOTOPES BY ELECTROLYTIC MIGRATION OF IONS.

Klemm, A.

J. chim. phys. 49, C18-C24, (June 1952). (In French)

Numerous published experiments on the isotopic enrichment in various systems by ionic migration are summarized, the apparatus being sketched for most of the examples. An empirical expression for the mass effect is derived.

664 (A-750) INVESTIGATION OF THE PHOTOCHEMICAL METHOD FOR URANIUM ISOTOPE SEPARATION.

Urey, H.C.

Columbia Univ., New York. Div. of War Research.

July 10, 1943. Decl. Dec. 8, 1955, 97 p. (2CR-135). $15.30 (ph OTS); $5.40 (mf OTS).

665 CONCENTRATION OF URANIUM ISOTOPES BY MOLECULAR DISTILLATION OF URANIUM POLY-ALKOXIDES.

Brewer, A.K., Madorsky, S.L., and Taylor, T.I. (to U. S. Atomic Energy Commission).

U. S. Patent 2,727,000. December 13, 1955.

A method of partial separation concentrating isotopes of ^{238}U and ^{235}U in a molecular still is reported. Either uranium pentaethoxide or uranium penta normal propoxide may be used although the former is preferred as having greater thermal stability. The distillation is performed under a vacuum of between 10^{-7} and 10^{-3} mm of mercury. For uranium pentaethoxide a temperature of between 85 and 20°C., ^{235}U and ^{234}U are separated by molecular countercurrent distillation from ^{238}U, the latter being the enhanced residue. Uranium penta normal propoxide requires a temperature of between 100 and 210°C., again concentrating ^{238}U in the residue and ^{235}U with ^{234}U in the distillate. (Author)

666 (AEC-tr-2393) PERUVIAN CHEMIST SEPARATES ^{238}U FROM ^{235}U.

Report of work of Angel Grayson Fossa.

Translated from La Cronica, (Aug. 25-26, 1955), 5 p.

Uranium isotopes ^{235}U have been separated from ^{238}U by flotation techniques utilizing mass differences, molecular forces, and osmotic pressures. The uranium solutions were converted to uranoso uranic oxides, which were subsequently reduced to metallic U by reaction with Zn at high temperature. (News report)

667 (AECD-4107) ANALYTICAL METHODS AND RESULTS.

Thomas, H.C., and Bither, T.A. [nd]. (Yale Univ., New Haven).

Decl. Jan. 30, 1956, 9 p. (100XR-991). $1.80 (ph OTS); $1.80 (mf OTS).

Enrichment of U isotopes by electrolytic methods is evaluated. Detailed descriptions of the techniques employed in sample purification, preparation, and counting are given. Results of the analysis indicate an isotopes enrichment less than 3.0%.

668 (Y-257) THE SEPARATION OF URANIUM ISOTOPES BY CHEMICAL EXCHANGE.

(Progress Report for the Month of September 1948).

Woodard, R.W. (Carbide and Carbon Chemicals Corp. Y-12 Plant, Oak Ridge, Tenn.).

Oct. 5, 1948. Decl. Jan. 16, 1956, 6 p. Contract W-7405-eng-26. $1.80 (ph OTS); $1.80 (mf OTS).

669 (CF-54-9-171) URANIUM ISOTOPE FRACTIONATION FACTOR IN BATCH EQUILIBRATION BETWEEN RESIN AND VERSENE SOLUTION.

Drury, J.S., and Rutenberg, A.C. (Oak Ridge National Lab., Tenn.).

Sept. 29, 1954. Decl. Feb. 14, 1957, 9 p. Contract W-7405-eng-26. $1.80 (ph OTS); $1.80 (mf OTS).

The isotopic fractionation factor for the reaction of aqueous uranyl ion (in the presence of diammonium versenate ion) with the uranyl form of Dowex-50 resin was estimated to be 1.00006 for the following reaction: $^{238}UO^{2+}_2$ (aqueous versenate) + $^{235}UO_2R_2$ — $^{235}UO^{2+}_2$ (aqueous versenate) + $^{238}UO_2R_2$, where R is the resin.

670 (CF-54-11-162) FRACTIONATION OF URANIUM ISOTOPES BY ION EXCHANGE.

Drury, J.S., and Rutenberg, A.C. (Oak Ridge National Lab., Tenn.).

Nov. 23, 1954. Decl. Feb. 14, 1957, 6 p. Contract W-7405-eng-26. $1.80 (ph OTS); $1.80 (mf OTS).

An experiment was performed to determine the isotope fractionation obtained by passing a band of U through an ion exchange column. The conditions of the experiment were similar to those existing in the experiment described in ISC-475, except that an 11-in. band of U was passed through 64-in. of Cu resin. Very little enrichment resulted. (Author) (ISC-475, see 680)

671 (ORNL-1874) CHEMICAL SEPARATION OF ISOTOPES SECTION SEMIANNUAL PROGRESS REPORT FOR PERIOD ENDING DECEMBER 31, 1954.

(Oak Ridge National Lab., Tenn.).

May 20, 1955. Decl. March 2, 1957, 32 p. Contract W-7405-eng-26. $1.80 (ph OTS); $2.70 (mf OTS).

New systems involving the exchange of B between boron trifluoride and boron trifluoride addition compounds have been explored. These systems have large separation factors and potentially simple reflux mechanisms. A precise determination of the separation factor for the anisole-boron trifluoride system gave the value $\alpha(90\ \%\ \text{C. L.}) = 1.0291 \pm 0.0009$. B exchange was found to occur between BF_3 and BCl_3. Several homogeneous catalysts have been found which activate the hydrogen-water exchange, but none are adaptable to the production of deuterium because of the slow exchange rate. Pt of platinum oxide may be usable as a heterogeneous catalyst with proper support or dispersion techniques. The high-pressure solubility of H in several amalgams was investigated in connection with a unique countercurrent exchange system. A proposed system involving isotopic exchange between lithium dipivaloylmethane in diethyl ether and lithium hydroxide in aqueous solution was shown to give little or no isotopic separation. Column studies of the carbonate system exchange reaction were concluded with a 40°C run. Slightly higher enrichment of N^{15} was obtained than at 30°C. The temperature dependence of α_{eff} in this system was measured between 15 and 45°C. The factor increases with temperature, showing a tendency toward a maximum near 45 °C. Isotopic exchange was found to occur between ammonia gas and aqueous carbamate ion. The exchange appears to be complete in less than 3 min. A qualitative examination was made of the carbonate system waste reflux reaction in laboratory equipment. No insurmountable difficulties are anticipated in connection with this reaction. The critical product-reflux reaction is being studied in pilot-scale equipment. Preliminary data are encouraging. Additional N exchange reactions have been studied to provide a broader basis for selecting a system for large-scale production of enriched N isotopes. A proposed system for enriching K isotopes was found to have a single-stage separation factor of $\alpha(90\ \%\ \text{C. L.}) = 1.006 \pm 0.002$. The single-stage fractionation factor between uranyl ion on Dowex 50 resin and on aqueous solution of uranyl ion in the presence of Versene was found to be approximately 1.00006. Very little enrichment resulted from passing a band of uranyl ion down an ion exchange column. (Author)

672 ISOTOPE EXCHANGE PROCESS.

Woodard, R.W. (to U.S. Atomic Energy Commission).

U.S. Patent 2,787,587. April 2, 1957.

A method is given for obtaining the isotopic concentration of U by effecting isotopic exchange between ionic uranium maintained in different valence states. Aqueous solutions of uranous and uranyl ion in the form of strong mineral acid salts are maintained at a pH of approximately 2.0. The heavier isotope concentrates in the lower valent state and the lighter isotope in the higher valent state. The single stage enrichment factor is sufficiently great to make feasible isolation of a single isotope by a multistage operation. (Author)

673 (A-49(Del.)) COMPARISON OF DIFFERENT METHODS APPLICABLE TO THE SEPARATION OF THE URANIUM ISOTOPES.

Urey, H.C. (Columbia Univ., New York. Div. of War Research).

[1942 ?]. Decl. with deletions Feb. 12, 1957, 22 p. $4.80 (ph OTS); $2.70 (mf OTS).

The effectiveness of thermal diffusion, Hertz diffusion, Maier diffusion, distillation, and chemical exchange methods for the separation of uranium isotopes is discussed.

674 (A-3227) THE U ISOTOPE EFFECT AND OTHER FEATURES IN THE ABSORPTION AND FLUORESCENCE SPECTRA OF URANYL COMPOUNDS.

Final Report.

Dieke, G.H. (Johns Hopkins Univ., Baltimore).

March 23, 1945. Decl. Feb. 12, 1957, 174 p. Contract W-7405-eng-50. Subcontract No. 36. $27.30 (ph OTS); $8.10 (mf OTS).

Work was undertaken in order to find the differences in the absorption spectra of uranium compounds when ^{238}U is replaced by ^{235}U, and utilizing this for a photochemical separation of the isotopes. Two substances, $CsUO_2(NO_3)_3$ and $Cs_2UO_2Cl_4$, as representatives of two types of compounds, were studied extensively. All results obtained during the project relating directly to the U isotope effect are presented. In addition work was done to clear up the structure of these and other uranium compounds and their spectra. (Author)

675 (MonT-210) ION EXCHANGE RESINS IN SEPARATIONS INVOLVING URANIUM.

Period [Covered] June 1, 1945-Sept. 15, 1946. Problem Assignment Number TX5-11.

Monet, G.P. (Clinton Labs., Oak Ridge, Tenn.).

Nov. 25, 1946. Decl. March 7, 1957. 53 p. Contract W-7405-eng-39. $9.30 (ph OTS); $3.60 (mf OTS).

Unit operations involved in the separations processes with ion exchange resins have been discussed. These operations have been applied to the development of separations processes for the decontamination and purification of U from the homogeneous pile, the heterogeneous pile, the separation of U from Th (233 purification and UX_1 preparation) and the separation of U isotopes. (Author)

676 (Y-41) SIMPLE PROCESS SEPARATION FACTORS FOR THE SEPARATION OF URANIUM ISOTOPES BY CHEMICAL EXCHANGE.

Clewett, G.H., and Schaap, W.B. (Carbide and Carbon Chemicals Corp. Y-12 Plant, Oak Ridge, Tenn.).

Oct. 16, 1947. Decl. March 6, 1957. 31 p. Contract W-7405-eng-26. $6.30 (ph OTS); $3.00 (mf OTS).

677 ELECTROLYTIC SEPARATION OF METALLIC ISOTOPES.

Andrews, J.H., Ceresna, I., Rohrman, F.A., and Utlaut, W.F. (Univ. of Colorado, Boulder).

Chem. Eng. Progr., 52, Symposium Ser., No. 19, 49-52 (1956).

By use of ^{63}Ni as a radioactive tracer it was found possible with electrochemical techniques to enrich the concentration of this Ni in the cathodic deposit. Nickel 63 apparently behaves more like a noble metal than do the ordinary Ni isotopes. Attempts to enrich Cd, Ag, and U by similar electrolytic means have not been successful up to this time. Counting techniques were employed to follow the Ni, Cd, and Ag electrolyses, and the mass spectrometer was used for the U isotopes. (Author)

678 (Y-185(Del.)) CHEMICAL SEPARATION OF THE ISOTOPES OF URANIUM.

Woodard, R.W., Twichell, L.P., Lee, D.A., Petretzky, P.B., Drury, J.S., Williams, R.D., Tilson, F.V., Waldrop, F.B., and Clewett, G.H. (Carbide and Carbon Chemicals Corp. Y-12 Plant, Oak Ridge, Tenn.).

Aug. 1948. Decl. with deletions March 6, 1957. 111 p.

Contract W-7405-eng-26. $13.80 (ph OTS); $4.80 (mf OTS).

The enrichment of the isotopes of uranium has been successfully accomplished using chemical exchange reactions. Two such reactions have been utilized: the first involves a two phase liquid-liquid system in which a chloroform solution of an organic complex of uranium is contacted with an aqueous solution of tetravalent uranium ions, after the system has reached isotopic equilibrium, the phases are separated and the uranium recovered: the second is a single phase system, in water, wherein the separation of uranium is accomplished by an exchange reaction involving the exchange of uranium between U^{+4} and UO^{2+}_2 ionic species. The separation effects obtained from these two reactions (each has a factor of about 1.001) are disappointingly low when considered from the possibility of adaptation to large scale processing, but the most significant feature of the work presented is the fact that measurable separation of the isotopes has been attained. Extensive efforts were made to utilize the liquid-liquid system in continuous column operation. These efforts were unsuccessful primarily because of the fact that the organic complexing agent, cupferron, was subject to oxidation, and the oxidation products prevented the smooth operation of the column. Considerable effort was made to find a more satisfactory organic compound which would be suitable for complexing the uranium and still not have the disadvantages associated with cupferron. Complete success was not attained, although the list of materials tested was large. Future work designed to increase this separation effect is outlined. (Author)

679 (Y-488(Rev.)) THE CONCENTRATION OF ^{235}U BY CHEMICAL EXCHANGE IN COMBINATION WITH COUNTERCURRENT ELECTROMIGRATION.

Twichell, L.P., Williams, R.D., and Clark, A. (Carbide and Carbon Chemicals Corp. Y-12 Plant, Oak Ridge, Tenn.).

Aug. 22, 1949. Decl. Sept. 4, 1957. 44 p. Contract W-7405-eng-26. $0.45 (OTS).

It has been previously shown that ^{235}U concentrates to a slight extent as $UO^{2}_{2}+$ in the U^{4+}-$UO^{2}_{2}+$ aqueous system. In this report a method is described for a continuous chemical process in which the ^{235}U isotope has been successfully concentrated by a chemical exchange reaction. In this method U^{4+} and $UO^{2}_{2}+$ move countercurrently to each other by the countercurrent electromigration principle which was developed to concentrate certain isotopes of potassium, chlorine, and copper. When this method is applied to the U^{4+}-$UO^{2}_{2}+$ system, the U^{4+} moves countercurrently to $UO^{2}_{2}+$, and the concentration of ^{235}U should increase in the $UO^{2}_{2}+$; correspondingly, the concentration of ^{238}U should increase in the U^{4+}. It was found that $UO^{2}_{2}+$ could be washed from cathode to anode by a stream of electrolyte which flowed countercurrently to the U^{4+} migrating to the cathode. One cell was operated for 1 400 hours to increase the concentration of ^{235}U from 0.7111 to 0.7171%. Details of the method and the difficulties encountered in its operation are described. (Author)

680 (ISC-475(Del.)) THE SEPARATION OF ISOTOPES BY ION-EXCHANGE. PROGRESS REPORT ON THE SEPARATION OF ISOTOPES ON ION-EXCHANGE COLUMNS.

Spedding, F.H., Powell, J.E., Svec, H.J., Evans, J.L., and Harrington, R.E. (Ames Lab., Ames, Iowa).

Spedding, F.H., and Powell, J.E. (Ames Lab., Ames, Iowa).

April 7, 1957. Decl. with deletions Feb. 25, 1957. 15 p. Contract W-7405-eng-82. $3.30 (ph OTS); $2.40 (mf OTS).

Progress of the work on the separation of isotopes on ion exchange columns is reported. Results indicate that isotopes can be separated in high purity, fairly rapidly, and with relatively inexpensive equipment by ion exchange methods. (See 670)

681 ISOTOPIC FRACTIONATION PROCESS OF URANIUM.

Clark, A. (to U. S. Atomic Energy Commission).

U. S. Patent 2,813,064. Nov. 12, 1957.

A method for isotopic enrichment of uranium is presented. In electrolyzing an aqueous solution containing a mixture of U^{4+} and $UO^2{}_2{}^+$ ions, the lighter, more positively charged U^{4+} ions migrate towards the cathode faster than the $UO^2{}_2{}^+$ ions. If during the electrolysis, the electrolyte is flowed as a stream from the cathode to the anode at a velocity between the migration velocities of the two ions, the uranyl ions will be slowly washed downstreams towards the anode, while the uranous ions will make headway towards cathode. It has unexpectedly been found that in the course of this process, the lighter isotope of uranium will concentrate in the UO_2^{2+} ions near the anode, while the heavier isotope will concentrate in the uranyl ions near the cathode.

682 (ORNL-2477) A SUMMARY OF THE SEPARATION OPERATIONS.

Whatley, M.E. (Oak Ridge National Lab., Tenn.).

April 11, 1958, 102 p. Contract W-7405-eng-26. $2.75 (OTS).

The subjects discussed are: chemical engineering systems, common concepts used in separation operation, distillation, gaseous diffusion, solvent extraction, and ion exchange.

683 (TID-5224) CHEMICAL SEPARATION OF THE URANIUM ISOTOPES.

Hutchison, Jr. C.A., Murphy, G.M., ed. 1952. (Columbia Univ., New York).

Decl. with deletions Feb. 27, 1957. 178 p. Contract W-7405-eng-50. $4.75 (OTS).

This is a deleted version of NNES-III-3.

This volume describes studies made to find a two-phase system suitable for counter-current fractionation of the U isotopes. Systems studied included gas-liquid systems, liquid-liquid systems, gas-solid systems, and liquid-solid systems. No system was found that possessed sufficient chemical stability, a sufficiently rapid exchange of U, and a appreciable separative effect. The design, development, and fabrication of standard vacuum or other system equipment from fluorinated plastics which enabled the handling of fluorides in transparent and nonreactive systems are also described. Methods for the preparation of samples for mass spectrometric analysis are given.

684 ISOTOPE FRACTIONATION PROCESS.

Clewett, G.H., and Lee, DeW.A. (to U. S. Atomic Energy Commission).

U. S. Patent 2,835, 687. May 20, 1958.

A new method is described for isotopic enrichment of uranium. It has been found that when an aqueous acidic solution of ionic tetravalent uranium is contacted with chelate complexed tetravalent uranium, the ^{238}U preferentially concentrates in the complexed phase while ^{235}U concentrates in the ionic phase. The effect is enhanced when the chelate compound is water insoluble and is dissolved in a water-immiscible organic solvent. Cupferron is one of a number of suitable complexing agents, and chloroform is a suitable organic solvent.

685 PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON ISOTOPE SEPARATION HELD IN AMSTERDAM, APRIL 23-27, 1957.

Kistemaker, J., Bigeleisen, J., and Nier, A.O.C., eds.

Amsterdam, North-Holland Publishing Company, 1958. 723 p.

Papers presented at the International Symposium on Isotope Separation held in Amsterdam, 1957, and the pertinent discussions are presented. Papers in English, French, and German are included in the fields of chemical engineering, molecular interactions, chemical exchange, electromigration, distillation, thermal diffusion, diffusion, electromagnetic separation, and the development of ultracentrifuges.

686 (K-1247) SEPARATION OF URANIUM ISOTOPES BY ELECTROMIGRATION IN FUSED URANIUM TETRACHLORIDE.

Grisard, J.W., and Kirslis, S.S. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

Aug. 28, 1958. Decl. Sept. 18, 1958. 13 p. Contract W-7405-eng-26. $3.30 (ph OTS); $2.40 (mf OTS).

Separation of uranium isotopes by countercurrent electromigration in fused uranium tetrachloride has been demonstrated on a laboratory scale. A separation factor of 1.005 ± 0.001 was obtained between cathode and anode samples with an average current of 0.13 amperes for 116 hours; this value corresponds to an electromigration separation coefficient of 1.00036 ± 0.00007. (Author)

687 THE CONCENTRATION OF ^{235}U: SURVEY OF MOST IMPORTANT METHODS AND PRINCIPLES.

Havliček, F.I. (Institute J. Stefan, Ljubljana, Yugoslavia).

Energia nucleare (Milan), 6, 521-31 (Aug. 1959). (In Italian).

Diffusion, physical-chemistry, and electromagnetic methods for the separation of uranium isotopes are reviewed. An

account is given of the principles on which each is based, a critical examination is made of the possibilities they offer, and a number of experimental devices are described. (Author) (Trans. 693)

688 (HW-40810) THE SEPARATION OF URANIUM AND PLUTONIUM ISOTOPES IN CHEMICAL EXCHANGE SYSTEMS.

Hahn, H.T. (General Electric Co. Hanford Atomic Products Operation, Richland, Wash.).

May 16, 1955. Decl. Nov. 23, 1959. 18 p. OTS.

The theory and results of chemical exchange experiments for separation of Pu and U isotopes are presented. Solvent extraction systems were studied in both aqueous and organic media. Chemical exchange systems are proposed which could yield high separation factors.

689 ON THE EVAPORATION OF UF_6 FROM CHLOROFLUOROBUTANES.

Havliček, F.I., Modesto, M., and Strle, J. (Institut J. Stefan, Ljubljana, Yugoslavia).

Energia nucleare (Milan), 7, 53 (Jan. 1960). (In English).

Experiments on evaporation of UF_6 from a 1 : 1 mixture of $C_4Cl_2F_8$ and $C_4Cl_9F_7$ at 35 °C are briefly reported which show a ^{238}U-^{235}U separation factor of 1.0001.

690 ISOTOPE SEPARATION BY REVERSIBLE CHEMICAL PROCESSES.

Glückauf, E.

Endeavour, 20, No. 77, 42-50 (Jan. 1961).

A survey of the field of chemical isotope separation is presented. The various methods described and discussed include distillation, exchange distillation, chemical exchange (gas-liquid), chemical exchange (liquid-liquid), dual-temperature chemical exchange, and chromatographic.

691 CONCENTRATION OF URANIUM ISOTOPES BY MOLECULAR DISTILLATION OF URANIUM POLY ALKOXIDES.

(to United Kingdom Atomic Energy Authority).

British Patent 863,259. Mar. 22, 1961.

A process is given for separating uranium isotopes, e.g., ^{235}U and ^{236}U, by molecular fractional distillation. In this process, uranium pentaethoxide or penta-n-propoxide is distilled under a vacuum of 10^{-3} to 10^{-7} mm Hg at a temperature between 100 and 210 °C. An apparatus for this process is described.

692 (IA/588-tr) PHASE EQUILIBRIA AND ISOTOPE SEPARATION.

Istvan Kiss.

Translated by A. Szoke and H. Szoke from Fiz. Szemle, 10, No. 10, 230-? (1960), 17 p.

Isotope effects appearing at phase equilibrium which may serve as the basis for isotope separation are discussed. The strength of the isotope effect is measured by the enrichment or separation factor. The enrichment factors for several light elements on distillation are given. The temperature dependence of these factors and attempts to explain the inverse effect observed for some are discussed. Experimental methods for the determination of isotope pressure differences are described. Recent studies of isotope separation in liquid-liquid and liquid-solid phase equilibria are summarized.

693 (AEC-tr-4753) CONCENTRATION OF ^{235}U: REVIEW OF SOME OF THE MOST IMPORTANT METHODS AND PRINCIPLES.

Havliček, F.I.

Translated for Oak Ridge Gaseous Diffusion Plant from Energia nucleare (Milan), 6, 521-31 (1959). 38 p.

This paper was previously abstracted from the original language and appears in NSA, Vol. 13, abstract No. 20000. (Orig. 687).

694 IMPROVEMENTS IN OR RELATING TO PRODUCTION OF URANIUM AND ITS COMPOUNDS.

Mann, J.E., Worthington, R.E., and Johnson, K.D.B. (to United Kingdom Atomic Energy Authority).

British Patent 874,904. Aug. 16, 1961.

A process is outlined for producing U or its compounds enriched in ^{235}U with less production of UF_6 than in previous processes and avoidance of UF_6 conversion to UF_4. The process comprises reacting enriched UF_6 with UF_6 in a fluidized bed to form enriched UF_5, heating the UF_5 to $\sim$ 400 °C to cause disproportionation to UF_6 and enriched UF_4, and recycling the UF_6 for re-enrichment. The enriched UF_4 may be treated for conversion to metal. Flowsheets are presented for the process.

695 (MLM-1115) MOUND LABORATORY MONTHLY PROGRESS REPORT FOR MAY 1961 (ON PLASTICS, RADIOELEMENTS, ISOTOPE SEPARATION, AND REACTOR FUELS).

Eichelberger, J.F. (Mound Lab., Miamisburg, Ohio).

May 30, 1961. Contract AT-33-1-GEN-53. 18 p.

Formulation of 13 new epoxy-modified polyurethane systems were cast and cured. Results of chemical tests on an epoxy curing exudate are included. Comparison of solvent effects on retention of radioelements by stainless steel was started and data is tabulated for ^{227}Ac, ^{227}Th, and ^{223}Ra. Work on protactinium was resumed after suspension of this project in 1960. Methods for preparation of small quantities of highly enriched U isotopes are being examined. Included in the survey are chemical exchange, electromagnetic separation, gaseous and liquid thermal diffusion, gas centrifugation, and photochemical techniques. Continued investigation of viscosities of La and Pr for use in Pu alloys is reported. Phase studies of Au-Pt systems were continued along with studies of Pu bearing glass fibres.

696 ENRICHMENT OF ^{237}U BY SZILARD-CHALMERS METHOD USING URANYL DIBENZOYLMETHANE.

Martynov, N.P., Bochkarev, V.A., and Lbov, A.A.

Radiokhimiya, 3: 508-9 (1961). (In Russian).

^{237}U enrichment by the Szilard-Chalmers method using uranyl dibenzoylmethane is described. The enrichment factor is $\sim 10^3$.

697 (NP-tr-817) SOME METHODS OF PRODUCING ENRICHED ^{235}U.

Ho Ping.

Translated from K'o Hsueh T'ung Pao, No. 2, 36-41 (Jan. 26, 1959), 10 p.

Methods for producing uranium are described as gaseous diffusion, supersonic jet pump, super-centrifuge, magneto-ionic expansion, ionic migration, and electromagnetic separation. A comparative table on the methods is included for rate of production, separation factor, cost scale, material, problems, and present progress.

698 (AEC-tr-4993) METHOD OF SEPARATION OF URANIUM ISOTOPES.

Shiraishi, Y.

Translated for Oak Ridge Gaseous Diffusion Plant, Tenn., from Japanese Patent 8,479/1960. July 4, 1960, 6 p.

A method is presented for separating uranium isotopes. The metallic uranium is dissolved in metals such as Hg, Sn, W, Zn, Cr, Fe, Mo, Ni, Al, Pb, etc., then the solution is heated to a high temperature to vaporize the uranium with the metal. The vapors are then condensed to concentrate ^{235}U.

699 FUNDAMENTAL STUDIES ON THE ION EXCHANGE SEPARATION OF ISOTOPES. V. SEPARATION FACTOR OF URANIUM ISOTOPES USING ION EXCHANGER.

Kakihana, H. (Tokyo Inst. of Tech.), Mori, Y. Sato, H. and Kanzaki, T.

Nippon Genshiryoku Gakkaishi, 4, 857-60 (Dec. 1962). (In Japanese).

Breakthrough experiments are done through a cation exchange resin column of 100 cm height and 1 cm diameter with 0.6 N and 2 N hydrochloric acid solutions containing greater part of uranous ions together with smaller uranyl ions. For each experiment the largest depletion of ^{235}U is found at the front of uranous breakthrough, while minor depletion is also observed at the front of uranyl fraction. An equation giving the approximate value for the separation factor $^{235}_{238}$S from the breakthrough results is derived. Where D is total depletion of ^{235}U in eluates, Q is total amount of uranium adsorbed on the column, and R_0 is the mole fraction of ^{235}U in the original sample solution. The values 1.00028 $\sim$ 1.00048 are obtained for $^{235}_{238}$S. (Author) (Trans. 732)

700 A FUNDAMENTAL STUDY ON THE ION EXCHANGE SEPARATION OF LITHIUM, NITROGEN AND URANIUM ISOTOPES.

Kakihana, H. (Tokyo Inst. of Tech.).

J. Chim. Phys., 60, 81-8 (Jan.-Feb. 1963). (In English).

Fundamental equations for the ion exchange separation factor of the isotopes A and B were derived:

a) for the system having the molecules or ion associations $\ln S_A^B = \ln K_{A+}^{B+} + \ln {}_A^B K_X - \ln {}_A^{\overline{B}} K_Y - \ln \{1 + [{}_A^B K_X - 1/1 + (AX)/(A^+)]\} + \ln \{1 + [{}_A^{\overline{B}} K_Y - 1/1 + (AY)/(A^+)]\}$; b) for the system having stepwise series of complexes $\ln S_A^B = \ln {}_A^B K_z + \ln \prod_{z+1}^{n} K_n - \ln \prod_{1}^{s} \overline{K}_s - \ln [\sum_{n=0}^{n} (AX_n)]^{-1} [(A) \prod_{1}^{n} K_n + (AX) \prod_{2}^{n} K_n + \cdots + (AX_z) \prod_{z+1}^{n} K_n + \cdots + (AX_n)] + \ln [\sum_{s=0}^{s} (\overline{AX_zY_s})]^{-1} [(\overline{AX_z}) \prod_{1}^{s} \overline{K}_s + (\overline{AX_zY}) \prod_{2}^{s} \overline{K}_s + \cdots + (\overline{AX_zY_s})]$.

According to the prediction based on these fundamental equations, some experimental works were done to obtain larger separation factors for the isotopes Li, N, and U. The results are as follows: Separation factors of 1.005 to 1.008 for Li; 1.027 to 1.029 for N, and 1.00028 to 1.00040 for U. (Author)

701 FUNDAMENTAL STUDIES ON THE ION EXCHANGE SEPARATION OF ISOTOPES. VI. THEORETICAL CONSIDERATION FOR ION EXCHANGE SEPARATION FACTORS OF ISOTOPES.

Kakihana, H. and Kurisu, K. (Tokyo Inst. of Tech.).

Nippon Genshiryoku Gakkaishi, 5, 292-9 (April 1963). (In Japanese).

Ion exchange separation factors for the quaternary valence isotopes (A) forming stepwise complexes (AX_n) in external solutions were theoretically evaluated. Two forms of the limits for the separation factors were found both for the anion exchanger and the cation exchanger systems.

For the anion exchanger, (1) $\lim \Delta = \lim (\ln S^A_B - \ln {}^A_B K_5) = -(\prod_{m+1}^{5} K_n - 1)$, (2) $\lim \Delta = -\varepsilon/6$, $\lim \Delta = -(\varepsilon - \prod_{m+1}^{5} K_n + 1)/5$, $\lim \Delta = -\{\varepsilon - (\prod_{m+1}^{5} K_n - 1) - (\prod_{q+1}^{5} K_n - 1)\}/4$. For the cation exchanger, (1) $\lim \Delta = -(\prod_{i}^{m} K - 1)$, (2) $\lim \Delta - \varepsilon/6$, $\lim \Delta = -(\varepsilon - \prod_{i}^{m} K_n + 1)/5$, $\lim \Delta = -\{\varepsilon - (\prod_{i}^{m} K - 1) - (\prod_{i}^{q} K - 1)\}/4$.

On the anion exchanger system, in the case of only AX_5 being adsorbed on and the very large excess of A existing in the external solution, the effect by five times as large as the ratio of the stability constants of one step complex formation is expected on the separation factor. On the cation exchanger, the highest effect is expected when only A is adsorbed on and the very large excess of AX_6 exists in the external solution. The value for the effect is approximately six times as large as the ratio of the stability constants of one step complex formation. (Author)

702 A THEORY OF ISOTOPE SEPARATION BY TWO PHASE DISTRIBUTION.

Kakihana, H. and Kurisu, K. (Tokyo Inst. of Tech.).

Nippon Kagaku Zasshi, 84, 470-3 (1963). (In Japanese).

The separation factor for systems involving a series of complexes, AX_n, in the first phase was examined theoretically, to find the best chemical isotope fractionation process between two phases. The separation factor of isotopes A and B between two phases S^B, is divided into two terms: $\ln S^B_A = \ln {}^B_A K_z + \Delta$, where ${}^B_A K_z$ is the equilibrium coefficient for isotopic exchange reaction of AX_z and BX_z between two phases which is nearly constant, and Δ is a variable. Δ was evaluated for 4 possible cases. (1) Systems in which only one species, AX_z, is extractable by the second phase: $\Delta_{z,p}$. (2) Systems in which a species, AX_z, and lower species AX_{z-p}, are extractable by the second phase: Δ_{z+q}. (3) Systems in which a species, Ax_z, and higher species, AX_{z+q}, are extractable by the second phase: $\Delta_{z,q}$. (4) Systems in which AX_{z-q}, AX_z and ZX_{z+q}, are extractable by the second phase: Δ. The following relations were obtained:

$$\Delta_{z,p} > \Delta_z, \Delta > {}_{z,q}\Delta_{z,p}, \Delta_{z,q} > \Delta_z, \Delta.$$

It was shown that the larger absolute value of $\Delta_{z,p}$ is obtained, the smaller the concentrations of the lower species AX_{z-p} in the first phase of a system. (Author)

703 FUNDAMENTAL STUDIES ON THE ION EXCHANGE SEPARATION OF ISOTOPES. VIII. SEPARATION FACTOR OF URANIUM ISOTOPES. PART 2.

Kakihana, H. Gonda, K. Sato, H. and Mori, Y.(Tokyo Refinery. Atomic Fuel Corp. and Tokyo Inst. of Tech.).

Nippon Genshiryoku Gakkaishi, 5, 990-3 (Dec. 1963). (In Japanese).

Breakthrough experiments on U(IV) and U(VI) were done using an anion exchange resin column of 100 cm height and 1.2 cm diameter with 8N hydrochloric acid. Uranous ions gave better separation factor (0.9993) than uranyl ions (1.0000). Mixed solutions of uranous and uranyl ions gave good separation factors (0.9992 ~ 0.9986), which can be explained by effective contribution of the isotope effect of the electron-exchange reaction: $^{235}U(VI) + {}^{238}U(IV) \overset{ke}{\rightleftarrows} {}^{238}U(VI) + {}^{235}U(IV)$. The results agree with the theoretical values derived from the following fundamental equation by assuming ke = 1.002. $\ln S^{235}_{238}(U) = \ln S_2 + \ln\{1 + (S_1 ke S_2^{-1} - 1/-1 + \bar{p})\} + \ln\{1 + (ke^{-1} - 1)/1 + p)\}$, where S_1 is the separation factor with the system containing only uranous ions, S_2 is for uranyl; p and $\bar{p}$ are the ratios of uranyl ions to uranous ions in the solution and in the exchanger resin, respectively. (Author) (See 734)

704 A THEORY OF URANIUM ISOTOPE SEPARATION BY TWO PHASE DISTRIBUTION INVOLVING ELECTRON EXCHANGE REACTION.

Kakihana, H. Kurisu, K. and Hosoe, M. (Tokyo Inst. of Tech.).

Nippon Kagaku Zasshi, 84, 784-7 (Oct. 1963). (In Japanese).

In a theoretical attempt to find the best separation factor of uranium isotopes, the isotopic effect of electron exchange

was considered and a fundamental equation $\ln S = \ln S_2 + \ln\{1 + (S_1 k_e S^{1-}{}_2 - 1/1 + \bar{p})\} + \ln s\{1 + (k_e^{-1} - 1/1 + P)\}$ was obtained where S_1 and S_2 are separation factors for systems having only U(IV) and only U(VI), respectively, k_e is the equilibrium coefficient for the electron exchange reaction between ^{235}U and ^{238}U in aqueous solution, p is the ratio of the concentration of U(VI) and U(IV), and $\bar{p}$ represents the second phase. Limiting values for ideal cases are given. Using the values of p and $\bar{p}$ obtained for systems consisting of hydrochloric acid solution and ion exchange resin, practically attainable separation factors were estimated for cation exchange resin with 2^N HCl solution of uranium ($p = 4 \sim 9$) and for anion exchange resin with 8^N HCl solution of uranium ($p = 0.11 \sim 0.25$).

705 SEPARATION OF ISOTOPES BY UF_6 SUBLIMATION.

French Patent 1,335,830. Aug. 23, 1963. Filed Oct. 9, 1962.

706 (A/CONF.28/P/439) SOME JAPANESE WORKS ON CHEMICAL SEPARATION OF URANIUM ISOTOPES.

Kakihana, H. (Tokyo Inst. of Tech.).

May 1964. 15 p.

The theoretical studies have proved that the mixture of U(IV) and U(VI) should be a favorable system, if the electron exchange reaction between the isotope could be catalyzed. Cation and anion exchange resins were ascertained as very promising catalyzers. For example: rate of electron exchange in cation exchange resin/rate of electron exchange in solution = 10^3-10^4. Better separation factors were observed for U(IV) (1.0007) than U(VI) (1.0000). Much higher separation factors (1.0014) were obtained for the mixed systems of U(IV) and U(VI), which could be explained by the effective contribution of the isotopic effect in electron exchange reaction between U(IV) and U(VI). At the front of the U-band in an ion exchange membrane an appreciable enrichment of ^{235}U was observed just as in the case of Li isotope. By superimposing a-c similar favorable effects to N isotopes were observed on U isotope fractionation. An apparatus based on the idea of combining two processes, ion exchange elution and ionic migration, was devised to aim the synergetic effect of them as well as the continuous operation. Through this apparatus the continuous flow of enriched ^6Li (e.g., $^7Li/^6Li = 11.61$) was obtained at the cathode side, with the depleted ^6Li (e.g., 12.81) at the anode side. Similarly the enrichment of ^{235}U was observed in the flow of the cathode side. (Author) (See 736)

707 (A/CONF.28/P/61) RESEARCH ON PROCESSES FOR THE CONVERSION OF URANIUM COMPOUNDS WITH HIGH ISOTOPE ENRICHMENT—DESIGN AND CONSTRUCTION OF A TREATMENT PLANT.

Nollet, P., and Sarrat, P. (Commissariat à l'Energie Atomique, Paris, France).

May 1964, 14 p.

The enriched uranium workshops in Cadarache have a double purpose: to convert uranium hexafluoride into metal or oxide, and to recover the uranium in scrap materials. The principles adopted for the design and safety of these workshops are reported. The uranium hexafluoride of high isotopic enrichment is converted either by injection of the gas into ammonia or by direct hydrogen reduction to uranium tetrafluoride. (Author)

708 ION EXCHANGE AND OTHER METHODS FOR ISOTOPE SEPARATION.

Roth, E.

Bull. Inform. Sci. Tech. (Paris), No. 85, 97-100 (July-Aug. 1964). (In French).

The chemical and physical methods used for the isotopic separation of rare gases, ^3He, ^6Li, Cl, ^{18}O, ^{34}S, ^{15}N, ^{13}C, ^{10}B, Hg, D, and ^{235}U are tabulated.

709 THE SEPARATION OF ISOTOPES BY MEANS OF ION EXCHANGE RESINS.

Rosset, R., Tremillon, B., and Fould, H. (Ecole de Physique et de Chimie, Paris).

Bull. Inform. Sci. Tech. (Paris), No. 85, 101-13 (July-Aug. 1964). (In French).

The characteristics of the ion exchange method, which favour its use in some cases of isotope separation, are reviewed. Isotopic separation coefficients were derived. The results obtained for nitrogen, lithium, boron, carbon, oxygen, sodium, sulfur, chlorine, calcium, iron, copper, and uranium are summarized.

710 ISOTOPE SEPARATION BY DISTILLATION AND CHEMICAL EXCHANGE.

Murrenhoff, A.P. (Kernforschungsanlage, Julich, Germany).

Kerntechnik, 6, 554-7 (Dec. 1964). (In German).

The principles of isotope separation by distillation and chemical exchange are reviewed, together with important applications to the separation of light element isotopes (except the H/D-separation). (Author)

711 METHOD FOR THE ENRICHMENT OF URANIUM COMPOUNDS.

Hecht, F., Antal, P., and Korkisch, H. (to Österreichische Studiengesellschaft für Atomenergie Gesellschaft mbH).

German Patent 1,186,842. Feb. 11, 1965. Priority date May 6, 1959, Austria.

Uranium compounds are enriched from mineral acid solutions by adsorption in anion exchangers. In order to build up complexes a solution of mineral acid in a primary aliphatic alcohol, in a ketone, preferably an acetone, an ether, or an ester, preferably an ethyl acetate, is used. (Gmelin Inst.)

712 REVIEWS OF ISOTOPE SEPARATION RESEARCHES IN JAPAN. ACTIVITIES OF THE SPECIAL COMMITTEE ON ISOTOPE SEPARATION.

Nippon Genshiryoku Gakkaishi, 7, 429-37 (Aug. 1965).

(In Japanese).

The Special Committee on Isotope Separation of the Atomic Energy Society of Japan was established in April 1963 and ended in March 1965. Studies were made on the separation of natural isotopes. The isotopes separated included D, ^{6}Li, ^{7}Li, ^{10}B, ^{13}C, ^{15}N, ^{18}O, ^{39}K, ^{40}Ar, and ^{235}U. The methods of separation adopted included gaseous diffusion, ultracentrifuge, thermal diffusion, molecular distillation, chemical exchange and electrophoresis. (Author)

713 PIERRELATTE — USINE DE SEPARATION DES ISOTOPES DE L'URANIUM (PIERRELATTE—PLANT FOR SEPARATION OF URANIUM ISOTOPES).

Paris, Commissariat à l'Energie Atomique, 1964, 38 p.

The design and development of the Pierrelatte Isotope Separation Plant is described. The isotopic enrichment processes used are electromagnetic separation, thermal diffusion, centrifugation, expansion in a shock tube, and gaseous diffusion. The principle of each of these methods is described briefly. The characteristics of the plant are given.

714 PHOTOCHEMICAL SEPARATION OF ISOTOPES.

Rozenberg, J. (Centre d'Etudes Nucléaires, Saclay, France).

Isotop. Radiat. Technol., 3, 200-5. (Spring 1966).

A literature review on photochemical separation of mercury isotopes indicated this to be a promising technique. Good separation requires that the isotope bands in the absorption spectrum of the element be widely separated and that the product enriched by photoselective reaction not be contaminated by secondary reactions. Separation of mercury isotopes is a well-developed procedure and is about to become industrial. Lithium isotopes should theoretically be separable by such a technique, but handling of molten lithium is difficult. The failure of the first attempts to separate chlorine and uranium isotopes is considered probably due to misjudgement of the primary mechanisms and the use of too simple techniques. Hydrogen isotopes may be separated with light sources with H (or D) α Lyman sources, but yields are too low for large-scale use. (Author)

715 METHOD FOR SEPARATING ^{235}U BY MOLECULAR DISTILLATION OF URANIUM HEXAETHOXIDE.

Nakane Ryohei, Oyama Toshiyuli.

Japanese Patent 1966-8280. Feb. 8, 1966. Filed Oct. 20, 1962.

A proposed method for separating ^{235}U by molecular distillation of uranium hexaethoxide, which largely eliminates the drawbacks of the pentaethoxide-distillation method, is capable of effecting separations comparable with the gaseous diffusion method.

716 AEC, INDUSTRY, UTILITIES EXPLORE PRIVATE ENRICHMENT POSSIBILITIES.

Grant, J.

Nucleonics, 25, No. 2, 54-7, 84, (Feb. 1967).

Views of the AEC, private industry, and public utilities on the possibility of private uranium enrichment are discussed. Some questions considered are: the urgency of private participation in enrichment; availability of classified information; prospects for methods of enrichment other than gaseous diffusion; would a monopoly be created which would damage competition; and would private enrichment bring cheaper fuel costs and if so would savings be passed on to public utilities. A short history of uranium enrichment in the U. S. is given. Other methods of enrichment such as thermal diffusion, electromagnetic, gas centrifuging, and chemical separation are summarized.

717 SEPARATING ISOTOPES BY ELECTRODIALYSIS.

Kakihana, H. (to Asahi Kasei Kogyo Kabushiki Kaisha).

British Patent 1,067,567. May 3, 1967. Priority date Aug. 2, 1963, Japan.

A process is described for separating isotopes except those of rare gas elements, especially isotopes of U, Li, Ca, B, H, N, Cl, and C, by utilizing multi-cell electrodialysis apparatus. The apparatus comprises alternating resalting and concentrating compartments arranged between a cathode and an anode. Each desalting compartment has an anion

exchange membrane on its anode side and a cathode exchange membrane on its cathode side, and each concentrating compartment has the membranes reversed. The solution to be separated is fed into an input desalting compartment, and a direct electric current is passed across the apparatus between the electrodes so that isotopic anions and cations of smaller mass migrate more rapidly through the anion exchange membranes and cation exchange membranes respectively to the adjacent concentrating compartments than the isotopic ions of larger mass. The isotopic ions of smaller mass are obtained from a compartment spaced from the input desalting compartment in the direction of electromigration of the isotopic ions, and the ions of larger mass are obtained from a compartment spaced from the input compartment in the opposite direction of electromigration of the isotopic ions. (See 658)

718 ISOTOPIC TREATMENT PROCESS.

(to Compagnie Generale d'Electricité).

British Patent 1,074,710. July 5, 1967. Priority date Oct. 21, 1963, France.

Equipment and procedures used in separating gaseous mixtures containing two isotopic compounds are described. One of the compounds must have a first excitation potential which is lower than the excitation potential of the second compound. The mixture is subjected to radiation with a spectrum showing a line narrow enough for exciting only one compound while molecules of the other compound remain at ground state. A second radiation with a shorter wavelength is used to excite the molecules in the second compound. The first radiation may be in the infra-red band and the second in the ultra-violet band. This separation method may be used in the separation of ^{235}U and ^{238}U from gaseous UF_6.

719 FUNDAMENTAL STUDIES ON THE ION EXCHANGE SEPARATION OF ISOTOPES. IX. SEPARATION FACTOR OF URANIUM ISOTOPES. PART 3.

Gonda Kozo (Atomic Fuel Corp., Tokyo), Kawashima, Nobuyoshi; Kakihana Hidetake.

Nippon Genshiryoku Gakkaishi, 9, 376-81 (July 1967). (In Japanese).

Breakthrough experiments were carried out to study ion-exchange separation of uranium isotopes. Four kinds of solutions containing natural uranium (mole fraction of ^{235}U $0.720_0 \times 10^{-2}$, (1) 0.05M TnOA/benzene solution saturated with U(IV)-chloro complex, (2) mixture of 0.05M TnOA/benzene solution saturated with U(IV)-chloro complex and 0.05M TnOA/benzene solution saturated with U(VI)-chloro complex, (3) 0.05M TBP/benzene solution with U(IV)-chloro complex, and (4) mixture of 0.05M TBP/benzene solution saturated with U(IV)-chloro complex and 0.05M TBP/benzene solution saturated with U(VI)-chloro complex, were passed through 100 cm long, 1.3 cm diameter anion exchange resin columns until the composition of the effluents became equal to that of the feed solutions. Near the front of the breakthrough of solution (4) above, the ^{235}U was found enriched to $0.732_4 \times 10^{-2}$ (enrichment factor 1.017), while for solution (2), ^{235}U was depleted to $0.710_7 \times 10^{-2}$ (enrichment factor 0.987). From the total amounts of ^{235}U enriched or depleted by these breakthrough experiments, single-process ion-exchange separation factors of uranium isotopes were estimated to be 1.000000 for solution (1), 1.00033 for solution (2), 0.99989 for solution (3), and 0.99988 for solution (4). Based on these data, the apparent equilibrium coefficients of the electron exchange reaction, $^{235}U(VI) + {}^{238}U(IV) \leftrightharpoons {}^{238}U(VI) + {}^{235}U(IV)$ were estimated to be 1.0010 and 1.0013 for TnOA/benzene and TBP/benzene systems, respectively. These values are smaller than the value of 1.0020 previously obtained for 8 M hydrochloric acid. The apparent equilibrium coefficient of the electron exchange reaction in the anion exchange resin (Dowex 21 K) was estimated to be 1.0010 to 1.0013. (Author) (Trans. 724)

720 CONCENTRATION OF URANYL IONS BY AN ION EXCHANGE MEMBRANE PROCESS.

Davis, T.A.

Columbia, S. C., Univ. of South Carolina, 1967. 97 p.

Thesis.

The counter-diffusion of uranyl and hydrogen ions through the AMF C-103 cation exchange membrane was investigated in order to develop a continuous process for concentrating uranyl nitrate. In the proposed two-stage process, uranyl ions are transferred from a feed solution with an initial concentration of 0.01 molar to a product concentration of 0.25 molar uranyl nitrate. The driving force for this Donnan dialysis process is the Donnan potential induced by the excess of hydrogen ions in the nitric acid stripping solution. The uranyl ion flux is proportional to the uranyl nitrate concentration on the feed side of the membrane. The membrane acts as a barrier to the passage of anions and solvent but allows free passage of cations. Since the membrane is not perfectly semi permeable, osmosis and anion leakage which increase with increased stripper concentration tend to limit the effectiveness of the process. By using a more dilute stripper solution and concentrating the uranyl ions in two stages, the adverse effects of anion leakage and osmosis can be reduced, allowing higher concentrations of the product to be achieved. (Disser. Abstr.)

721 METHOD FOR ENRICHING URANIUM ISOTOPES BY MEANS OF ION EXCHANGE.

(to Japan Atomic Energy Research Inst.).

British Patent 1,120,208. July 17, 1968. Priority date July 30, 1964, Japan.

A solution containing ^{235}U or ^{238}U or a mixture of the two can be enriched by contacting the solution containing U in the hexavalent state in countercurrent flow in an exchange

column or tower with particles of an acidic cation exchange resin on which tetravalent U has been absorbed. The contacting solution should be 1 ^{N} or less in acidity. The process may be carried out in a succession of at least three columns of moving resin. The acidic exchange resin particles are moved from the upper end to the lower end of the column, and the hexavalent U solution is moved toward the upper end of the column against the resin movement. (See 660)

722 ENRICHMENT OF LITHIUM, POTASSIUM, COPPER, AND URANIUM ISOTOPES BY ELECTROMIGRATION IN A CATION EXCHANGE MEMBRANE.

Kakihana, H., Okamoto, M., Fujii, Y. (Tokyo Inst. of Tech.).

Isotopenpraxis, 4, 232-4 (June 1968).

An apparatus used is shown. From the anode solution the cationic isotopic ions move into the cation exchange membrane on application of suitable voltage between the anode and cathode. Experimental conditions are described for Li, K, Cu, and U isotopes.

723 ISOTOPE EFFECT AND ISOTOPE SEPARATION.

Kakihana, H. (Tokyo Inst. of Tech.).

Nippon Kagaku Zasshi, 89, 734-45 (Aug. 1968). (In Japanese).

The values of the reduced partition function ratios for isotopic molecules are calculated from the spectroscopic data on molecular vibrations, based on the statistical mechanics with small quantum corrections. Equilibrium constants for isotopic exchange reactions derived from the results may serve as a basis for further comparative discussion of isotope separation. Theoretical considerations are made on the contribution of chemical reactions to isotope separation, when isotopic substances are distributed in two phases. The resulting fundamental equations can be used to find the most effective system for isotope separation and to estimate isotope effects for each chemical reaction. Interpretations within the framework of the present theory were carried out on the experimental results for the isotope separation of Li, N, Cu, and U with the use of an ion exchanger. (Trans. 733)

724 (NSJ-tr-144) FUNDAMENTAL STUDIES ON THE ION EXCHANGE SEPARATION OF ISOTOPES. IX. SEPARATION FACTOR OF URANIUM ISOTOPES. PART 3.

Gonda, Kozo; Kawashima, Nobuyoshi; and Kakihana, Hidetake.

Translated from Nippon Genshiryoku Gakkaishi, 9, 376-81 (July 1967), 12 p. Dep.

An abstract of this paper, prepared from the original language, appeared as NSA 21, 40982. (Orig. 719)

725 STUDY OF THE POSSIBLE CONTROL OF ^{234}U AND ^{238}U ATOM SEPARATION BY THE WAY OF AN EXTERNAL OXIDATION OF URANIUM CONTAINED IN NATURAL COMPOUNDS.

Chalov, P.I., Merkulova, K.I. (Inst. of Physics and Mathematics, Frunze, USSR).

Geokhimiya, No. 2, 225-8 (Feb. 1969). (In Russian).

The isotopes ^{234}U and ^{238}U may be partially separated by isolating the valence fractions resulting from the difference in oxidation rates of these isotopes contained in natural uranium compounds. An attempt was made to increase the degree of separation by subjecting the uranium in minerals to an external oxidation process. Experiments included the determination of $^{234}U/^{238}U$ ratio $= \gamma$, in activity units, in tetravalent and hexavalent uranium, designated as γ_4 and γ_6, respectively, and in material leached from the rock, γ_1. The spectrometrically determined γ values indicated that the pitchblende specimen had a total uranium content of 37.9%, with U^{6+}/U^{4+} ratio of 0.17 before oxidation with oxygen. The isotopic ratio of uranium had the equilibrium value, $\gamma_E = 1$, but in the hexavalent and tetravalent factions it differed strongly: $\gamma_6/\gamma_4 = 1.11$. It was concluded that the degree of separation of the two isotopes may be strongly affected by separating the uranium into fractions with different valence states. The maximum possible separation depends on the differential oxidation rates of ^{234}U and ^{238} U.

726 INCREASING MAXIMUM ENRICHMENT PROCESSING CAPABILITY THROUGH CRITICALITY CALCULATIONS.

Dunaway, D.L. (National Lead Co. of Ohio, Cincinnati), Johnson, W.A.

Trans. Amer. Nucl. Soc., 12, 339 (June 1969).

From 15th Annual Meeting of the American Nuclear Society, Seattle, Wash. (See CONF-690609) (See 655)

727 CHEMICAL FRACTIONATION OF URANIUM ISOTOPES.

Rutenberg, A.C., Drury, J.S. (Oak Ridge National Lab., Tenn.).

J. Inorg. Nucl. Chem., 31, 2289-95 (Aug. 1969).

Precise measurements were made of the chemical fractionation of ^{235}U and ^{238}U between several forms of U(IV) and

U(VI) salts. The observed separation factors were very much smaller than previously supposed. It is shown that the chemical exchange method of isotope separation is unlikely to be economically or technically useful. (Author)

728 SEPARATION OF URANIUM ISOTOPES BY CHEMICAL EXCHANGE.

Shimokawa, J., Kobayashi, F. (Japan Atomic Energy Research Inst., Ibaraki).

Isotopenpraxis, 6, 170-6 (May-June 1970).

The isotope separation effect between U(1V) complex and U(VI) ions was investigated in a mixed system of uranyl solution and cation exchange resin containing uranous ions. The columns were filled with the water slurry of the U(1V)-form resin particles. From the variation of the isotope abundance ratio $^{235}U/^{238}U$ of U(VI) in the effluent, it was found that: the apparent process of the isotope exchange under study is represented as $[U^{(5)}\ (1V)\ complex]_{resin} + [U^{(6)}\ (V1)O^{+2}_2]_{sol} \rightleftharpoons^{K} [U^{(6)}\ (1V)\ complex]_{resin} + [U^{(5)}\ (V1)O_2^{+2}]_{sol}$; the heavy uranium isotopes are concentrated preferentially in the U(1V) complex ions; the equilibrium constant, K, is about 1.0005, independently of the experimental conditions; and the rate of isotope exchange is extremely sensitive to temperature. (Author)

729 PROCESS AND APPARATUS FOR THE ENRICHMENT OF ISOTOPIC MIXTURES.

(to Société Nationale des Pétroles d'Aquitaine).

British Patent 1,211,104. Nov. 4, 1970. Priority date Jan. 17, 1967, France.

In a process for enriching a mixture of isotopic constitutents in one isotope a stream of the isotopic mixture in gaseous form is introduced into a chamber filled with a sorbing agent that was previously filled with a different gas (a buffering gas) that is inert with respect to the gaseous mixture and the sorbing agent. The gaseous mixture is introduced until at least one fraction (head fraction) has been collected at an outlet from the chamber, and the introduction of gaseous mixture is stopped when the head fraction has been collected. Then the buffering gas is reintroduced and the different fractions of the gaseous effluent displaced by the buffering gas are collected separately at the outlet. The method is particularly applicable to the enrichment of isotopes of B, C, U, or rare gases. The apparatus for carrying out the process is described in detail.

730 ION EXCHANGE METHOD FOR SEPARATING URANIUM ISOTOPES.

Shimokawa Junichi, Nishio Gunji, Kobayashi Fumiaki.

U. S. Patent 3,511,620. May 12, 1970. Priority date July 30, Japan.

A cation exchange resin carrying adsorbed cations of U(1V) is contacted with an acid solution of U(V1) cations having an acidity not substantially above 1 N. Shortly thereafter, a higher proportion of ^{235}U is found in the dissolved U than in the adsorbed U, the ratio being 1.0007 : 1 at isotope equilibrium. Natural U is thus separated into fractions respectively enriched with, and depleted of, ^{235}U by countercurrent flow of resin and solution in multiple stages. (Offic. Gaz.)

731 ELUTION REQUIREMENTS FOR ION-EXCHANGE SEPARATION OF URANIUM ISOTOPES.

Gonda, K., Ohnishi, A., Narita, D., and Murase, T. (Power Reactor and Nuclear Fuel Development Corp., Tokai).

J. Chromatogr., 55, 395-401 (March 3, 1971).

The necessary flow rate and the effective bed length for the ion-exchange separation of uranium isotopes were calculated using Rosen's theory. The applicability of Rosen's theory was verified using the isotope exchange of ^{235}U-^{238}U between the anion-exchange resin bed and 8.4 M hydrochloric acid. The effective feed rate and the estimated column bed length were 8.6×10^{-3} cm/sec and 3.4×10^{2} cm, respectively, for the linear isotherm system of U(1V) using 8.4 M hydrochloric acid and the anion-exchange resin, Diaion SA10. (Author)

732 (ORNL-tr-2507) FUNDAMENTAL STUDIES ON THE ION EXCHANGE SEPARATION OF ISOTOPES. V. SEPARATION FACTOR OF URANIUM ISOTOPES USING ION EXCHANGER.

Kakihana, H., Yoshihiro, M., and K. Tadao.

Translated for Oak Ridge National Lab., Tenn., from Nippon Genshiryoku Gakkaishi, 4, 857-60 (1962). 7 p. Dep. NTIS.

An abstract of this paper, prepared from the original language, appeared as NSA 17, 12578. (Orig. 699)

733 (ORNL-tr-2512) ISOTOPE EFFECT AND ISOTOPE SEPARATION.

Kakihana, H.

Translated for Oak Ridge National Lab., Tenn., from Nippon Kagaku Zasshi, 89, 743-5 (1968). 37 p. Dep. NTIS.

An abstract of this paper, prepared from the original language, appeared as NSA 22, 51058. (Orig. 723)

734 IONENAUSTAUSCHTRENNUNG VON ISOTOPEN. 8. MITT. TRENNFAKTOREN VON URANISOTOPEN (TEIL 2).

Hidetake Kakihana, Kozo Gonda, Hitoshi Sato und Yoshihiro Mori (Japan Atomic Energy Res. Inst., Chem.).

1964, Nr. 28, 1-12, Tokyo, Tokyo Inst. of Technol. (In English).

Bei der Ionenaustauschchromatographie von U-Lsg. am Anionenaustauscher in 8 n HCl wurde festgestellt, daß die Trennfaktoren $^{235}U/^{238}U$ in der Reihenfolge U(VI) < U(IV) < U(VI)/U(IV) zunehmen (1,0000, 0,9993, 0,9986-0,9992), was durch den Einfl. eines Isotopeneffekts auf die Elektronenaustauschrk. $^{235}U(VI) + {}^{238}U(IV) \rightleftharpoons {}^{238}U(VI) + {}^{235}U(IV)$ (Gleichgew.-Koeff. $k_e \sim 1{,}002$) erklärt wird. Unter der Annahme dieses Wertes für k_e werden theoret. Trennfaktoren berechnet, die mit den experimentellen Werten in guter Übereinstimmung stehen. (See 703)

735 TRENNUNG DES GEMISCHES VON HEXAFLUORIDEN DER U-ISOTOPEN.

Tröbs, H. Freiberg.

(Tschech. P. 115177 vom 24.8. 1962, ausg. 15.6. 1965.)

UF_6 wird in fein dispergierter krist. Form im Verdampfer, bes. unter 50-200 Torr, bei < 60° verdampft. Im Verdampfer bestehen feste u. fl. Phase nebeneinander, wobei die feste in fein dispergiertem krist. Zustande gehalten u. das Phasensyst. ununterbrochenen Pulsationen (Expansion u. Kompression) bei kontinuierlichem oder unterbrochenem Abziehen der Dämpfe ausgesetzt wird. Die einzelnen Dampffraktionen werden kondensiert u. zur weiteren Anreicherung bzw. Herabsetzung des Isotopengeh. in den Verdampfer zurückgeleitet. — Zeichnungen.

736 JAPANISCHE ARBEITEN ÜBER CHEMISCHE ABTRENNUNG VON URANISOTOPEN.

Kakihana, H., Hoshino, T., Sato, H., Gonda, K., Mori, Y., Kurisu, K., Kanzaki, T., Shimokawa, J., Nishio, G., Goto, H., Suzuki, S., Sato, A. und Kishimoto, M.

(Proc. third U.N. int. Conf. peaceful Uses atomic Energy, Geneva 1964, 12, 342-51, 1965; Tokyo, Japan, Atomic Fuel Corp.). (In English).

In Übereinstimmung mit theoret. Berechnungen konnte für U(IV)-U(VI)-Gemische gezeigt werden, daß die für den Elektronenaustausch zwischen den Isotopen notwendige Rk. durch kation. oder anion. Harzaustauscher katalysiert werden kann. Mit Membranen von Ionenaustauscherharzen können bei Anlegen von Gleichstromspannungen (0,2 V) mit u. ohne Überlagerung von Wechselstrom (4,0 V) durch die verschiedene schnelle Ionenwanderung leichte Isotope, wie ^{14}N, ^{6}Li, ^{235}U im Anodenraum angereichert u. so von den schweren Isotopen ^{15}N, ^{7}Li, ^{238}U kontinuierlich abgetrennt werden. (See 706)

7. NOZZLES

737 GAS-PHASE ISOTOPE SEPARATION.

Becker, E.W. (Gesellschaft für Kernforschung mbH).

Ger. 1,198,328 (Cl. B 01d), Aug. 12, 1965, Appl. March 9, 1963, 5 p.

A device is described to sep. isotopes with at. wt. > 200 in the gas phase. The isotopes to be sepd. are mixed with a carrier gas with an at. wt. much less than the isotopes at. wt. The gas mixt. is passed through a small aperture and then moves along a semicylindrical wall. The lighter components are deflected more than the heavier ones. There is one pipe to convey the lighter part and one for the heavier. Several sepn. units are put together. E.g., the gas mixt. was 95 mole% He and 5 mole% $^{235}UF_6$–$^{238}UF_6$. The aperture diam. was 0.23 mm and the semi-cylindrical wall diam. was 1.5 mm. The gas inlet pressure was 80 torr and the outlet pressures were 8 and 10 torr, resp. Cf. CA 56, 1120f.

738 SEPARATION OF URANIUM ISOTOPES.

Becker, E.W. (Univ. Karlsruhe, Karlsruhe, Ger.).

Umschau 1969, 69 (20), 656-7 (Ger.).

The production of enriched U by gaseous diffusion or centrifugation or by nozzle sepn. processes is considered.

739 PREPARING ENRICHED URANIUM FOR NUCLEAR FUELS.

Jelinek-Fink, P. (Nukl.-Chem. und -Met. GmbH, Wolfgang/Hanau, Ger.).

Haus Tech., Essen, Vortragsveröff. 1969, 214, 15-28 (Ger.).

For the enrichment of ^{235}U from 0.71% (natural content) to 2-4% (for light-water reactors) or to > 90% (for high-temp. reactors), gas diffusion, ultracentrifuge, and sepg. jet methods have been developed which are all based on the small wt. difference between $^{235}UF_6$ and $^{238}UF_6$. Only gas-diffusion cascade processes, however, are used in a tech. scale at present. It appears that the ultracentrifuge process when appropriately improved might compete with the gas diffusion process; the sepg. jet process presumably would be too expensive.

740 URANIUM ENRICHMENT PROCESS.

Aochi, Tetsuo (Japan).

Kagaku Kogyo 1970, 21 (10), 1375-80 (Japan).

A review is given on U enrichment by gas diffusion, centrifugal sepn., and nozzle sepn. 3 refs.

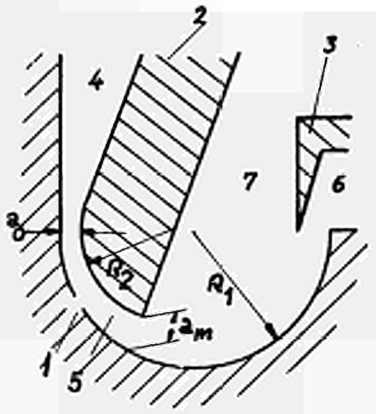
741 VORRICHTUNG ZUM TRENNEN VON GAS- ODER DAMPFFORMIGEN STOFFEN, INSBESONDERE ISOTOPEN NACH DEM PRINZIP DER TRENNDÜSE (PROCÉDÉ DE SÉPARATION ISOTOPIQUE METTANT EN APPLICATION LE PRINCIPE DE LA TUYERE A JET SUPERSONIQUE) (A PROCESS FOR ISOTOPIC USING A SUPERSONIC JET TUYER).

Bier, K., Bier, W. (Gesellschaft für Kernforschung mbH).

Brevet, DA 1 279 653 (68/24/25) R.

Dépôt, 14 juin 1966, DAD G47.154.

Publi., 10 oct. 1968.



Résumé : Utilisation, type tuyère-laval et application à la séparation des isotopes de l'uranium.

742 TEN STAGE CASCADE NOZZLE ENRICHMENT.

Becker, E.W., Frey, G., Schuette, R., and Seidel, D.

Nuclear Eng., Vol. 13, No. 148 (Sept. 1968), pp. 770-1.

Method of ^{235}U concentration, based on partial gravity separation by curved supersonic flow has been developed in Germany; method is known as jet separation and eliminates both fine-pore barriers of diffusion method and mechanical heavy-duty parts of centrifuges; as in other methods, separating effect must be multiplied by making use of cascade; gas-dynamic stability and control of such cascade must be fully understood for evaluating economic prospects of method; team at Karlsruhe accordingly designed 10-stage pilot jet separation plant for U-isotope separation.

743 CENTRIFUGE ENRICHMENT FOR EUROPE.

Lawes, G.

New Scient., 41, (641), 640-41 (March 20, 1969).

It is now virtually certain that Britain, W. Germany and Holland will build a pair of ultra-centrifuge, U enrichment plants. Major technical problems have been overcome and initial technological collaboration will be minimal. Capacity

in kg/yr, investment in $/kg/yr, electricity consumption in kWh/kg of SW, kWh price in mills/kWh, and separation cost in $/kg of SW are compared for: gaseous diffusion, nozzle separation, and ultra-centrifuging.

744 GERMANY CONTINUES TO GROOM A NEW "NOZZLE SEPARATION" PROCESS FOR URANIUM ENRICHMENT.

Anon.

Chem. Engng, 76, (1), 21 (Jan. 13, 1969).

The Gesellschaft für Kernforschung is building a full-size, single enrichment stage using cascade nozzle-separation. This avoids the membrane of conventional gaseous diffusion and the high mechanical loading of gas centrifugation. A gas feed of He-diluted UF_6 is directed supersonically by a nozzle into a jet comprising a semi-circular deflection wall surrounding an eccentrically placed solid cylinder, where the heavier material stays closer to the concave wall. Power needed is $>$ in diffusion but investment is $\ll$.

745 TECHNICAL AND ECONOMIC ASPECTS OF URANIUM ENRICHMENT IN EUROPE.

Anon.

Nucl. Engng int., 14, (158), 580-583 (July 1969).

A report of the one day international symposium organised by the Netherlands Atoomforum at Utrecht in May which covered: predicting future enrichment capacity needs; comparing the cost of separation by ultracentrifuge and gas diffusion; developing nozzle separation for U enrichment; centrifuge theory; comment on the Foratom Report on Economic Aspects of Uranium Enrichment in Europe; and proposals by the European Commission on enrichment facilities.

746 (AEC-tr-2415) THE SEPARATING NOZZLE. A NEW APPARATUS FOR THE SEPARATION OF GASES AND ISOTOPES.

Becker, E.W., Bier, K., and Burghoff, H.

Translated from Z. Naturforsch., 10a, 565-72 (1955).

Available from Lawyers & Merchants Translation Bureau, New York.

Upon the flow of a mixture of gases or isotopes out of a nozzle, there occurs, under suitable pressure conditions, a partial spatial separation of the components which can be utilized for the recovery of the components by the provision of a skimming diaphragm. The properties of the combination of nozzle and skimming diaphragm, which is given the name "skimming nozzle" are determined with various mixtures of gases and isotopes and discussed with respect to the separation of isotopes in practical work. The separation factors which can be obtained between the gas streams agree approximately with those of a Hertz porous-barrier unit. The replacement of the fine pore barriers by separating nozzles leads however to considerably greater dependability in operation and permits a substantially higher flow of gas with the same expenditure for the separating elements. (Author)

747 (AEC-tr-2660) THE SEPARATION OF URANIUM ISOTOPES WITH THE SEPARATION NOZZLE.

Becker, E.W., and Schütte, R.

Translated from Z. Naturforsch., 11a, 679 (1956), 3 p.

A technique for the separation of U isotopes is described which depends upon the partial spatial separation of gases of different mass in a nozzle flow. Results are reported from experiments with UF_6.

748 NEW RESEARCH DEVELOPMENTS FOR INDUSTRIAL SCALE ISOTOPE SEPARATION.

Villani, S.

Energia nucleare (Milan), 4, 187-95 (June 1957). (In Italian).

Separation methods for ^{235}U, ^{2}H, ^{15}N, and ^{10}B are discussed.

749 (IGRL-T/CA-59) THE SEPARATION OF ^{235}U.

Caldirola, P.

Translated by E.G. Peters from Energia nucleare (Milan), 3, Suppl. 74-81 (1956), 10 p.

A brief description is presented of the principles on which the centrifugal separation and the "Trenndüse" processes for ^{235}U separation are based. A more detailed description of the gaseous diffusion process for ^{235}U separation is included. (Author)

750 ISOTOPE SEPARATION.

Klemm, A.

Atomwirtschaft, 3, 341-2 (Aug.-Sept. 1958). (In German).

Processes developed in the German Federal Republic for the separation of isotopes are described. These include distillation of liquid hydrogen and dual-temperature exchange for the production of heavy water, gas centrifugation and separation nozzle for uranium enrichment, and other methods for the enrichment of magnesium, lithium, and ^{14}C. (Trans. 765)

751 (A/CONF.15/P/1002) SEPARATION OF THE URANIUM ISOTOPES BY THE NOZZLE PROCESS.

Becker, E.W., Bier, K., Burghoff, H., Hagena, O., Lohse, P., Schütte, R., Turowski, P., and Zigan, F. (Univ. of Marburg, Ger.).

15 p.

Preliminary results on the separation of uranium isotopes by the nozzle process, which is based on the pressure diffusion in a free expanding jet stream, are reported. A description is given of the apparatus used, and the optimum operating conditions are determined.

752 INDUSTRIAL METHODS OF ^{235}U ENRICHMENT.

Istvan, K. (State Research Inst., Dept. of Chemistry).

Energia es Atomtech., 11, 466-73 (1958). (In Hungarian).

Electromagnetic, centrifugal, gaseous diffusion, and gas jet separation methods of ^{235}U are described. (Trans. 768)

753 URANIUM ISOTOPE SEPARATION: A NEW INDUSTRY.

Geoghegan, G.R.H.

New Scientist, 5, 468-72 (Feb. 26, 1959).

The gaseous diffusion separation process used in the British factory at Capenhurst is described, and consideration is given to the economic aspects of the plant. Information is also included on the basic principles of operation of the electromagnetic, gas-phase centrifuge, and jet processes.

754 PROCESS FOR SEPARATING GASEOUS OR VAPOROUS SUBSTANCES, MORE ESPECIALLY ISOTOPES.

(Deutsche Gold- und Silber-Scheideanstalt vorm. Roessler, Germany).

British Patent 803, 689. Nuclear Eng., 4, 284 (June 1959).

Reference is made to B.P. 794,834 which describes a process of separating gaseous or vaporous substances of different molecular weight and/or molecular diameter, in particular isotopes. The separating system consists of a nozzle and an apertured diaphragm which is placed in the path of the jet, formed by the mixture when passing through the nozzle, and dividing the jet into a core stream and a peripheral stream, the heavier and lighter components of the mixture thus being concentrated in the respective component streams. In order to obtain good quality separation, it is important to maintain a specific ratio of the pressure of the gas entering the nozzle to the pressure of the gas leaving the nozzle, this ratio varying from 100 : 1 to 1 000 : 1. In the previously described form of the process, suitably designed pumps were employed for maintaining these pressure ratios with delivery of the streams of vapor or gas. Where the method is employed in the form of a multistage process, a plurality of pumps with high capacities is required making the equipment expensive. In the present patent a revised version of the method is described, eliminating the use of pumps for this purpose. Instead, the transport of the gases and vapors through the separating system is effected by successive vaporization and condensation steps, resulting from periodical addition and withdrawal of heat. The process being carried out in the sub-atmospheric pressure range can also be used for subliming substances, e.g., for the concentration of uranium isotopes from uranium hexafluoride.

755 (AEC-tr-3839) THE SEPARATION NOZZLE. II. THE PHYSICAL BASES AND THE SPECIFIC MAGNITUDES OF THE EXPENDITURES OF THE PROCESS.

Becker, E.W., Beyrich, W., Bier, K., Burghoff, H., and Zigan, F.

Translated by E. Von Halle from Z. Naturforsch., 12a, 609-21 (1957), 31 p. $6.30 (ph), $3.00 (mf) JCL.

A gas and isotope separation process based on the partial spatial separation of heavy gases in an expanding supersonic stream were investigated. The influence of the nozzle shape and gas pressure on the stream expansion, and on the magnitude and spatial character of the separation was determined. It is shown that the characteristics of the separation effect may be explained by certain aspects of diffusion. A systematic analysis of the specific magnitudes of process expenditures was used to determine the most favourable operating conditions of a separation nozzle cascade.

756 PROCESS FOR THE SEPARATION OF GASEOUS OR VAPOROUS SUBSTANCES, MORE ESPECIALLY ISOTOPES.

Becker, E.W.A.

British Patent 825,798. Dec. 23, 1959.

An improvement of the expanding jet isotope separation process of patent No. 794,834 is offered. It was found that pressure ratios before nozzle/after diaphragm and before nozzle/after nozzle can be reduced to 1/2 or 1/3 to increase separation if a light gas (H_2 or He) is added. (B.P. 794,834, see NSA 13-3458)

757 GERMAN PROCESSES FOR URANIUM ISOTOPE ENRICHMENT.

Groth, W. (Universität, Bonn).

Chem. Ing. Tech., 31, 310-18 (May 1959). (In German).

The gas-diffusion and jet separation processes and the gas centrifuge treatment are described and their economic prospects are compared. For gas centrifuging theoretical and technical details and experimental results with the isotopes of xenon and argon are reported. (Author) (Trans. 761)

758 URANIUM ISOTOPE SEPARATION BY NOZZLES.

Myron Levoy (Thiokol Chem. Corp., Denville, N. J.).

Nucleonics, 18, No. 4, 68-70 (April 1960).

The concepts of a method for the enrichment of uranium in UF_6 which makes use of nozzles are presented. This method is considered capable of competing alternatively with the gaseous diffusion method. Experiments with UF_6 have shown that the separation effect per stage is the same order of magnitude as in the conventional process. Process and nozzle parameters are given relative to pressure diffusion created by radial pressure gradients in the jet. The basic theory concerning nozzle separation process is discussed.

759 THE SEPARATION NOZZLE METHOD. III. SEPARATION OF URANIUM ISOTOPES.

Becker, E.W., and Schütte, R. (Kernforschungszentrum, Karlsruhe, Ger.).

Z. Naturforsch., 15a, 336-47 (April 1960). (In German).

With a single-stage separating nozzle apparatus, the separation of the uranium isotopes in UF_6 was determined in dependence on the intake pressure, the front and rear back pressures, the intake temperature, and the geometry of the separating system. With the experimental results the optimum operating conditions and the specific input magnitudes of the separating nozzle method were determined for the case of uranium isotopes. It is shown that the specific ideal isothermal compression work in the separating nozzle method is in the same order of magnitude as in the diffusion method. The weakest point of the separating nozzle method is shown to be the large specific intake volume which means relatively high investments for the compressors and tube power. (Tr.-author)

760 SEPARATION OF ISOTOPE MIXTURE BY NOZZLE PROCESS.

Hisashi Mikami, and Yoshitoshi Oyama (Tokyo Inst. of Tech.).

J. Atomic Energy Soc. Japan, 2, 291-5 (May 1960). (In Japanese).

It was recently discovered by E.W. Becker et al. that an isotope gas mixture could be separated in a supersonic flow of jet. The separation may be due to pressure diffusion caused by a radial pressure gradient in the vicinity of the nozzle opening when the Knudsen number K_n is much smaller than 10^{-1}. On the other hand, when $K_n \gg 10^{-1}$, it may be explained in terms of free molecular effusion of the gas mixture at the nozzle opening, but in an intermediate regime, $K_n \sim 10^{-1}$, theoretical treatment is difficult. The correlation of separation effect ε_A, and cut η was derived from the kinetic theory of gases on the assumption that the gas mixture effuses as free molecular flow at the nozzle opening. The calculated values were found to be in fairly good agreement with experimental data obtained by Becker et al. when the nozzle inlet pressure was maintained at 30 torr. (Author) (Trans. 769)

761 (GAT-Z-5016) GERMAN PROCEDURES FOR THE ENRICHMENT OF THE URANIUM ISOTOPE.

Groth, W.

Translated by J.R. Arndt from Chem. Ingr. Tech., 31, No. 5, 310-18 (1959), 15 p.

This paper was previously abstracted from the original language and appears in NSA, Vol. 14, abstract No. 7670. (Orig. 757)

762 URANIUM CONCENTRATION.

Yoshitoshi Oyama (Tokyo Inst. of Tech.).

Genshiryoku Hatsuden, 4, No. 3-4, 23-8 (1960). (In Japanese).

A brief survey of the historical background and of the present status of the enrichment methods is given. Gaseous diffusion, centrifugal, and nozzle separation are considered of interest for application in Japan. The ideal and the squared-off cascade concepts are discussed for arriving at an economic evaluation of the ^{235}U plant design. On the basis of cost calculations published by USAEC and the Saclay Nuclear Study Center, the economic bases of the gaseous diffusion method are given, including the estimation of the required capital investment and operating costs for plants installed in France and in Japan, comparing the estimated production costs with the U. S. data. Results indicate that the costs exceed the U. S. values by 50 to 90%. Groth and Zippe's data for UF_6 separation are included in a survey of the centrifuge method for isotope separation, comparing the power and capital costs with those required for the gaseous separation method, without drawing definite conclusions for lack of data. Leroy's survey on the nozzle separation method is expanded by including 20 additional references. Treatment of the jet stream and Becker's experimental data for UF_6 separation is discussed.

763 ACTUAL METHODS FOR THE ENRICHMENT OF ^{235}U.

Martensson, M.

Tek. Tidskr., 89, 487-93 (1959). (In Swedish).

A review of methods for the enrichment of ^{235}U is presented. The separation processes discussed are gaseous diffusion, effusion through a nozzle, and gas centrifugation. Equipment diagrams and principles of operation are included.

764 (AEC-tr-4751) METHOD FOR THE SEPARATION OF GASES AND MIXTURES OF ISOTOPES.

Christiansen, J. and Leisinger, K-F.

Translated for Oak Ridge Gaseous Diffusion Plant from German Patent No. 1,055,508, April 23, 1959, 4 p.

A method for the separation of gases and mixtures of isotopes by pressure reduction of the mixture through a nozzle into an evacuated vessel is described. The method is characterized by the fact that the greater part of the vessel wall is held at a temperature which is so low that most of the molecules from the inflowing gas striking the wall are precipitated. Several cooling baffles concentrically arranged around the beam are utilized.

765 (AEC-tr-4779) ISOTOPE SEPARATION.

Klemm, A.

Translated by Kurt H. Quasebarth for Univ. of Virginia from excerpt of Atomwirtschaft, 3, 341-2 (1958), 5 p. (EP-4422-506-61U).

This paper was previously abstracted from the original language and appears in NSA, Vol. 12, abstract No. 16546. (Orig. 750)

766 PROCESS AND APPARATUS FOR SEPARATION OF GASEOUS SUBSTANCES.

Becker, E.W.

Canadian Patent 624,264. July 25, 1961.

A process for separating gaseous isotopes is described in which the mixture is caused to issue from a nozzle in the form of an expanding supersonic jet and separated into its components by an apertured diaphragm. The heavy component is generally concentrated in the core portion. Unit apparatus and multi-unit configurations for carrying out the process are described.

767 (NP-tr-817) SOME METHODS OF PRODUCING ENRICHED ^{235}U.

Ho Ping.

Translated from K'o Hsueh T'ung Pao, No. 2, 36-41 (Jan. 26, 1959), 10 p.

Methods for producing uranium are described as gaseous diffusion, supersonic jet pump, super-centrifuge, magneto-ionic expansion, ionic migration, and electromagnetic separation. A comparative table on the methods is included for rate of production, separation factor, cost scale, material, problems, and present progress.

768 (CEA-tr-X-397) METHODES INDUSTRIELLES POUR L'ENRICHISSEMENT DE ^{235}U (INDUSTRIAL METHODS FOR ENRICHMENT OF ^{235}U).

Istvan, (E.) Kiss.

Translated into French from Energia es Atomtech., 11, 466-73 (1958), 32 p. (Includes original, 8 p.).

In the selection of an industrial method for the enrichment of ^{235}U, the enrichment factor, the chemical and physical characteristics of the materials participating in the enrichment process, the engineering possibilities of the method, and the economics of the method must be considered. The gaseous diffusion process and the centrifugation process for heavy isotope enrichment are discussed, and the enrichment factors are calculated theoretically. Cascade parameters and equilibrium times are calculated for the two processes. The energy requirements for a gaseous diffusion cascade and the engineering problems of such a plant are reviewed. (Orig. 752)

769 (AEC-tr-5069) SEPARATION OF ISOTOPE MIXTURE BY NOZZLE PROCESS.

Hisashi Mikami and Yoshitoshi Oyama.

Translated from Nippon Genshiryoku Gakkaishi, 2, 291-5 (1960), 9 p.

This paper was previously abstracted from the original language and appears in NSA, Vol. 14, abstract No. 18085. (Orig. 760)

770 SEPARATION NOZZLE DISSOCIATION IN DEFLECTED GAS JETS.

Becker, E.W., Burghoff, H., and Gspann, J. (Technische Hochschule, Karlsruhe, Ger.).

Z. Naturforsch., 16a, 955-60 (Oct. 1961). (KFK-78). (In German).

In the separation nozzle effect there exists a relationship between the deflection of the flow lines of the supersonic beam and the dissociation. In the free expansion of a given gas, the deflection of the flow lines can be affected only by the expansion behaviour. Since the possible expansion behaviour is limited in a practical utilization of the method on economic grounds, the effect of a mechanical deflection of the jet in the space between the nozzle and the separation plate on the spatial behaviour of the dissociation and on the specific expenditures was investigated. (Tr.-author)

771 SEPARATION NOZZLE DISSOCIATION OF URANIUM ISOTOPES BY USE OF LIGHT ADMIXED GASES.

Becker, E.W., Bier, K., Bier, W., and Schütte, R. (Technische Hochschule, Karlsruhe, Ger.).

Z. Naturforsch., 18a, 246-50 (Feb. 1963). (In German).

For the separation of uranium isotopes, in a working slit-formed separation nozzle arrangement with free expansion by an addition of 400 mol% He to UF_6 the specific adsorption volume could be lowered 1/4 and the specific slit length 1/2 compared with optimum values achieved with pure UF_6. At the same time the specific compression work increased to 4 times the earlier optimum value. On the other hand for a separation nozzle system in which the jet was mechanically turned 180°, with a mixture of 5 mol% UF_6 and 95 mol% He, the same decrease of specific adsorption volume and a decrease of the specific slit length to 1/30 were attained while the specific compression work at the same time climbed only about 20%. By means of the strong decrease achieved by the bent system the controlling specific expenditure for investment cost improved the economic situation of the separation nozzle process considerably. Nevertheless the separation nozzle process in the present condition of development may show advantages over the diffusion process only at high enrichments of ^{235}U, at which the lower number of stages, the omission of fine-pored membranes, and the expected smaller adjustment time are important. (Tr.-author)

772 THE NOZZLE SEPARATION PROCESS.

Becker, E.W., Bier, K., Bier, W., and Schütte, R. (Kernforschungszentrum, Karlsruhe, Ger. and Technische Hochschule, Karlsruhe, Ger.).

J. Chim. Phys., 60, 212-16 (Jan.-Feb. 1963). (In German).

In the nozzle separation process the addition of a light gas increases the density of the pressure diffusion current of a heavy isotope mixture which gives rise to a higher separation factor. It is shown experimentally that in a mixture of 10 mole% argon and 90 mole% helium the elementary separation effect of the argon isotopes is higher by a factor of 1.7 as compared with pure argon under the same throughput and cut of the isotopic mixture. The economy of the separation process is also improved by the addition of a light gas although it too has to be processed in the separation cascade. In case of the argon isotopes the addition of 400 mole% helium reduces the specific suction volume to 1/3, the specific slit length to 1/5, and the specific compression energy to 3/4 of the values for pure argon. Preliminary experiments with UF_6/He-mixtures show that also in the separation of the uranium isotopes economic advantages are to be expected from the addition of a lighter gas. (Author)

773 (AEC-tr-5986) ISOTOPE SEPARATION AND ENRICHMENT.

Bier, K., Fischer, W., and Dickel, G.

Translated by L.L. Smith (Savannah River Lab., Aiken, S.C.) from Chem.-Ing.-Tech., 34, 580 (1962), 8 p.

The enrichment of ^{235}U by the partition diffusion method and the problems involved are discussed. The state of the art of uranium isotope separation by the gas centrifuge and partition jet methods is described briefly. The use of ion migration in the pre-enrichment of ^{46}Ca in ^{47}Ca prior to calutron enrichment is considered, and the migration model for explaining the measured mass effects is discussed. The problem of deriving a useful theory of thermal diffusion separations is considered; the invariant theory of the separative tube cascade was developed which uses separation work rather than separation efficiency. The results of centrifugal separation of argon isotopes in a vortex tube are given which were used to derive the separation mechanism.

774 SEPARATION OF URANIUM ISOTOPES.

Pecqueur, M.

Ann. Mines, 11-30 (Nov. 1963). (In French).

Descriptions are given of electromagnetic separation, heat diffusion, centrifugation and expansion in nozzles as means of enriching UF^6 gas or liquid to obtain ^{235}U and ^{238}U. Parameters and techniques for the gas diffusion enrichment process, including equipment, pressure, gas concentration, charge quantity, and barrier pore size were determined. (Rev. Metal Lit., 21, No. 2, Feb. 1964)

775 PRODUCTION OF NUCLEAR FUELS. PART 2. ENRICHED URANIUM.

Ploeger, F., Vietzke, H. (Nuklear-Chemie und -Metallurgie GmbH, Wolfgang, Ger.).

Chem.-Ingr.-Tech., 37, 692-9 (July 1965). (In German).

The uranium 235 isotope can be concentrated in the form of gaseous uranium hexafluoride either by the Calutron process, by the diffusion method with Al_2O_3 membranes,

or by means of gas-centrifuges and separating nozzles. The hexafluoride is then converted either to uranium dioxide or to metal for use in nuclear reactors. (Author)

776 SEPARATION OF URANIUM ISOTOPES ACCORDING TO THE SEPARATION JET PROCESS.

Becker, E.W., Bier, K., Bier, W. (Technische Hochschule, Karlsruhe, Ger. Kernforschungszentrum, Karlsruhe, Ger.).

Chem.-Ing.-Tech., 39, No. 1, 1-7 (Jan. 1967). (In German).

A separation-jet process, based on the partial spatial demixing of components of different mass in an expanding ultrasonic jet stream, is reported. It is of interest for the separation of uranium isotopes. The economic aspect of the process was considerably improved by increasing the mach number, by mixing the uranium hexafluoride with a light gas, and by increasing the angle of deflection of the flow planes with a bent deflection plate. Optimum process conditions are reported and the minimum specific costs achieved are compared with those of the diffusion process. (Author)

777 SEPARATION OF THE ISOTOPES OF URANIUM BY THE SEPARATION NOZZLE PROCESS.

Becker, E.W., Bier, K., Bier, W., Schütte, R., Seidel, D. (Technische Hochschule, Karlsruhe, Ger.).

Angew. Chem. Int. Ed. Engl., 6, 507-18 (June 1967).

The separation nozzle process is based on the partial spatial separation of components of different mass in an expanding supersonic jet stream. The process is of special interest for the separation of uranium isotopes. Details of a systematic experimental determination of the most favorable operating conditions for such a separation are given and the construction and testing of a closed circulation system, the basic unit of a ten membered pilot cascade separator for uranium isotope separation, is described. The optimum values of the specific cost factors obtained experimentally for the separation nozzle process are compared with the corresponding values estimated for the gaseous diffusion process. (Author)

778 SEPARATION OF U ISOTOPES IN FRANCE AND IN THE WORLD.

Pecqueur, M. (CEA, Paris).

Énerg. Nucl. (Paris), 9, 480-8 (Dec. 1967). (In French).

The development of the Pierrelatte installation and the history of the isotopic separation of U in France and in the world are outlined. The civil and military reasons for the separation of U isotopes are given. The U isotope separation developments of the United States, England, Russia, China, and France are briefly reviewed. The principal separation procedures—electromagnetic separation, thermal diffusion, the Becker method, and centrifugation—are described in principle. The gaseous diffusion procedure is described in slightly more detail. The Pierrelatte installation based on the gaseous diffusion procedure is described. Technological difficulties in the design and construction of this installation were connected with the properties of uranium hexafluoride, the barrier, and the compressor and its tightness. The solutions used in each of these areas are indicated. (Trans. 781)

779 (KFK-702) PLANUNG UND BAU EINER 10-STUFIGEN PILOTANLAGE FÜR DAS TRENNDÜSENVERFAHREN (PLANNING AND CONSTRUCTION OF A 10-STAGE PILOT PLANT FOR THE NOZZLE SEPARATION METHOD).

Becker, E.W., Frey, G., Schütte, R. (Kernforschungszentrum, Karlsruhe, West Germany. Institut für Kernverfahrenstechnik).

Feb. 1968, 46 p. (In German). Dep.

Thesis. Submitted by G. Frey to Technische Hochschule, Karlsruhe, Ger.

The nozzle separation method uses the partial spatial separation of various components of a gas mixture in an expanding ultrasonic beam for isotope separation. The planning and construction of a 10-stage pilot plant for separation of uranium isotopes is described in detail. The nozzle separation cascade, the UF_6 separation installation, the vacuum system, and the antiresonant power supply of the condenser are each discussed. The present status of the planning and construction is outlined. (See 809)

780 SEPARATION OF URANIUM ISOTOPES IN A 10-STAGE SEPARATION NOZZLE PILOT PLANT.

Becker, E.W., Frey, G., Schütte, R., Seidel, D. (Univ., Karlsruhe, Ger. Kernforschungszentrum, Karlsruhe, Ger.).

Atomwirt., Atomtech., 13, 359-62 (July 1968). (In German).

A process was developed for enrichment of ^{235}U that depends on the partial spatial separation of various heavy components in a supersonic flow over curved paths. The method, known as the separation nozzle process, avoids the microporous membranes of the diffusion process and the mechanically highly stressed parts of the centrifugal process. The elementary separation effect must be reinforced by use of a series of separation elements connected in cascade. A precise knowledge of the stability of gas dynamics and control characteristics of such a cascade is required in order to assess the industrial prospects of the process. For this purpose a 10-stage separation nozzle experimental plant for separation of uranium isotopes was built. Its construction and commissioning are described. A mixture of UF_6 and helium is fed through a curved Laval nozzle. It consists of a deflecting partition and a full cylinder which is mounted eccentrically to it. The gas mixture expands in the nozzle.

A knife edge, know as the "peeler", is mounted at the place where the gas stream leaves the deflecting partition. The flow is split up by the peeler into light and heavy fractions. The 10 stages of the separation nozzle cascade were installed together with the compressors in a single room. From the beginning it has worked in a stable manner. Experiments carried out indicate that no serious control problems are likely to arise with a technical realization of the separation nozzle process. (Author)

781 (K-Trans-45, pp.7-28) URANIUM ISOTOPE SEPARATION IN FRANCE AND IN THE WORLD.

Pecqueur, M.

Translated from Énerg. Nucl. (Paris), 9, 481-8 (Dec. 1967).

An abstract of this paper, prepared from the original language, appeared as NSA 22, 23230. (Orig. 778)

782 (KFK-859) SEPARATION OF THE URANIUM ISOTOPES: A COMPARISON OF THE PROCEDURES UNDER DISCUSSION TODAY.

Becker, E.W. (Kernforschungszentrum, Karlsruhe, West Germany. Institut für Kernverfahrenstechnik).

Oct. 1968, 24 p. (In German). Dep.

The general construction of uranium isotope separation installations is described. The concepts of value function and separative work used for the characterization of their efficiency were explained. The technical details of the gaseous diffusion method, the gas centrifuge method, and the separating nozzle method, as far as they are known from the open literature, are reported. The economic aspects of the three methods are compared. (See 814)

783 WHICH SEPARATION METHOD FOR URANIUM ENRICHMENT ?

Dreissigacker, H.-L., Schmidt-Keuster, W.-J.

Atomwirt., Atomtech., 14, 71-2 (Feb. 1969). (In German).

In studies on methods to assure that the European needs for enriched uranium are fulfilled, the gas diffusion method is of primary importance since it has been tested to the fullest. The progress made in the development of two other separation methods, the gas centrifuge and the separation nozzle methods, is however so encouraging that the decision on the construction of large installation should be deferred until the advantages of the various methods are sufficiently compared. (Tr.-author)

784 (KFK-853) PRINCIPLES AND ECONOMIC ASPECTS OF THE SEPARATION NOZZLE PROCESS.

Becker, E.W., Bier, W., Schütte, R. (Kernforschungszentrum, Karlsruhe, West Germany. Institut für Kernverfahrenstechnik).

Oct. 1968, 13 p. (CONF-681015-2). Dep.

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy.

A process for enriching ^{235}U, based on pressure diffusion in supersonic jets, is described. A mixture of 5 mole% UF_6 and 95 mole% He is expanded through a slit-shaped nozzle. Deflection of the jet by curved walls results in a partial spatial separation of the components; the gas moving close to the deflecting wall becoming enriched in ^{238}U, while ^{235}U accumulates in the remaining fraction. Economic aspects of the process are considered.

785 (KFK-854) OPERATION OF A 10-STAGE SEPARATION NOZZLE PILOT PLANT.

Becker, E.W., Frey, G., Schütte, R., Seidel, D. (Kernforschungszentrum, Karlsruhe, West Germany. Institut für Kernverfahrenstechnik).

Oct. 1968, 13 p. (CONF-681015-3). Dep.

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy.

A computer analysis of the steady-state and transient behaviour of a small separation nozzle cascade indicated that the system was inherently stable. Therefore, the pilot plant was constructed without any automatic control installations. Equipment design and arrangement for the plant are discussed. Plant operation was stable with an overall enrichment factor of 1.082.

786 EUROPEAN ENRICHMENT PLANT.

Nucl. Eng. Int., 14, 343-5 (April 1969).

Future uranium requirements were assessed and the size of plant needed thus estimated. The economics of the three separation methods, diffusion, the nozzle process, and the gas ultracentrifuge, were studied, and their relative merits observed. The centrifuge process appeared to offer the best prospects.

787 SEPARATION DEMONSTRATION PLANTS FOR URANIUM ENRICHMENT.

Becker, E.W., Bier, W., Frey, G., Schütte, R. (Kernforschungszentrum, Karlsruhe, Ger.).

Atomwirt., Atomtech., 14, 249-51 (May 1969). (In German).

In order to make more accurate economic evaluations of the separation nozzle method, development and design studies were undertaken for a pilot plant with a separation output of 600 000 kg U/yr. The plant would supply light water reactors with a total capacity of 6 000 MW(e) continuously with fuel. It would cost approximately 300 million DM and consume about 10% of the current produced. It was calculated that the investment costs and the current consumption could be reduced significantly by additional development work. A prototype of the nozzle stages proposed for the pilot plant is under construction. (Tr.-author) (Trans. 793)

788 COMPARISON OF THREE SEPARATION METHODS.

Becker, E.W. (Karlsruhe Univ., Ger.).

Nucl. News, 12, No. 7, 46-51 (July 1969).

With the advent of additional nuclear reactors in the next ten years, the requirements of uranium-235 will increase to such that existing separation plants will be unable to produce sufficient fuels. The gas diffusion and gas centrifuge processes are now operating. Another method of enriching uranium-235 has been developed which is based on the partial spatial demixing of components of different weights in a gas flowing along curved tracks. Known as the separation nozzle method, it avoids the fine porous membranes of the diffusion method and the mechanically highly stressed components of the centrifuge. The 3 methods are described, and compared economically and technically.

789 (KFK-1002) SEPARATION NOZZLE PROCESS FOR URANIUM ENRICHMENT.

Becker, E.W. (Kernforschungszentrum, Karlsruhe, West Germany. Institut für Kernverfahrenstechnik).

June 1969, 13 p. (CONF-690530-1). Dep. CFSTI (U. S. Sales Only).

From Atomforum Conference, Utrecht, Netherlands.

In the separation nozzle process, a mixture of about 5 mole% UF_6 and 95 mole% He is expanded through a slit-shaped nozzle. Operation of a 10-stage pilot plant for this process is described. A method for inexpensive mass production of separation nozzle systems was developed. Economic aspects are discussed.

790 SEPARATION OF ISOTOPE MIXTURE IN A TWO-DIMENSIONAL SUPERSONIC JET.

Mikami Hisashi (Tokyo Inst. of Tech.).

J. Nucl. Sci. Technol. (Tokyo), 6, 452-7 (Aug. 1969).

A numerical analysis is presented on the separation of UF_6 isotope mixture in a supersonic jet from a two-dimensional sonic nozzle, based on the kinetic theory of gas in the continuum region. The results of calculation for the diffusion flux are found to be in fairly good agreement at low Knudson numbers with the results of experiment given by Becker et al. (Author)

791 URANIUM ENRICHMENT.

Avery, D.G. (United Kingdom Atomic Energy Authority, Risley, Eng.).

Phys. Bull. (London), 21, 17-21 (Jan. 1970).

The principal technical features of the gaseous diffusion technique, the gas centrifuge method, and the separation nozzle process used for enrichment of the fissile ^{235}U content of natural uranium and the problems that have to be solved in bringing these techniques to the stage of economic industrial exploitation are discussed.

792 PLANNING FOR FUTURE ENRICHMENT PLANTS.

Allday, C., Avery, D.G., Kehoe, R.B.

pp. 167-79 of Utilizzazione del Combustibile Nucleare. Roma, Comitato Nazionale Energia Nucleare (1969).

From 10th International Nuclear Energy Conference, Milan, Italy. See CONF-681219.

The United Kingdom and European requirements for enrichment and the plans for meeting them are summarized. A number of factors which arise in optimizing the installation of plant and its subsequent operation are discussed. The problems arising in considering the diffusion nozzle and centrifuge separation processes are considered. (Author) (See 807)

793 (NP-tr-1884) SEPARATION NOZZLE DEMONSTRATION PLANT FOR URANIUM ENRICHMENT.

Becker, E.W., Bier, W., Frey, G., Schütte, R.

Translated by G.H. Wheelhouse (Australian Atomic Energy Commission Research Establishment, Lucas Heights), from Atomwirt., Atomtech., 14, 249-51 (May 1969), 8 p. Dep. CFSTI (U. S. Sales Only).

An abstract of this article, prepared from the original, appeared as NSA 23, 33336. (Author) (Australia) (Orig. 787)

794 SEPARATION NOZZLE PROCESS FOR URANIUM ENRICHMENT.

Becker, E.W.

Atoomenergie Haar Toepass., 11, 272-6 (Nov. 1969).

The separation nozzle process for uranium enrichment is described. The process is based on pressure diffusion in a gaseous mixture of UF_6 and an additional light gas flowing at high speed along curved walls. The principles involved in the separation nozzle process along with results obtained are presented. A cost estimate of a separation nozzle plant is given in which the cost of a separative work unit is $35.00. This is 35% more than the guaranteed U.S. price. However, since the separation nozzle process is comparatively new, it is believed that a program of basic and developmental research will result in a better understanding of the separation mechanism and will result in further economic improvements.

795 URANIUM ENRICHMENT INDUSTRY.

Avery, D.G., Kehoe, R.B. (United Kingdom Atomic Energy Authority, Risley, Eng.).

Atom (London), 164, 120-30 (June 1970).

A survey of the historical background of isotope separation and uranium enrichment is given. Four processes of uranium enrichment are discussed; the centrifuge method, the electromagnetic (calutron) method, the thermal diffusion method, the gas diffusion process. The capacity of the present day gas diffusion plants in USA, UK, France, Russia and China are considered. A simplified treatment of the diffusion process is given which enables the main design and optimization characteristics to be identified. Membrane development is reviewed and the difficulties of plant design when dealing with UF_6 considered. The nozzle process and the centrifuge method are examined and their economics discussed. The growing demand for uranium enrichment in Europe is considered in the light of the tripartite agreement.

796 URANIUM ENRICHMENT INDUSTRY.

Avery, D.G., Kehoe, R.B. (United Kingdom Atomic Energy Authority, Risley, Eng.).

J. Brit. Nucl. Energy Soc., 9, 163-9 (July 1970).

An outline is given of the historical development of U isotope separation and of the principles involved. The quantity known as separative work, i.e., the amount of separation an enrichment plant can achieve, is explained. Descriptions of the diffusion process and the nozzle processes are followed by a detailed description of the technology of the centrifuge method. International collaboration in centrifuge development for uranium enrichment is described.

797 ISOTOPE SEPARATION BY NOZZLE METHOD.

Droscha, H.

Industriekurier, 23, No. 81, 17 (1970). (In German).

Brief description is given of principles of the gaseous diffusion method, gas centrifuge method, and nozzle method for enrichment of ^{235}U using UF_6.

798 URANIUM ENRICHMENT IN EUROPE. COMPARISON BETWEEN THE REPORTS OF THE EURATOM AND FORATOM STUDY GROUPS.

Scuricini, G.B.

Com. Naz. Energ. Nucl., Notiz., 16, No. 3, 33-7 (March 1970). (In Italian).

The Euratom and Foratom reports on the economic future of uranium enrichment in Europe are in essential accord; the basic disagreements occur because of the different times at which the two reports were made. The Foratom report was begun in January 1967 and the Euratom report in March 1968. The cost evaluations for the design and construction of enrichment installations are compared. The economic aspects of the gaseous diffusion process, the ultracentrifuge, and the separation nozzle method are considered. It is concluded that the work of the Foratom group be continued in order to prepare work schedules for continuously evaluating the evolution of the cost and market situation.

799 CREATION OF AN INSTALLATION FOR THE ENRICHMENT OF URANIUM IN THE EUROPEAN COMMUNITY.

Baruffa, A.

Neue Tech., B, 10, 237-41 (1968). (In French).

The creation in the European Community of a facility for uranium enrichment involves an examination of commercial, political, and technical problems of considerable difficulty. These considerations include: the enrichment requirements and capabilities of the western world, particularly those of the Community and the availability of enriched uranium supplies from the UK or USA; the technical and industrial aspects; economic aspects; and a comparison of currently used enrichment processes, i.e., gaseous diffusion, ultracentrifugation, and the gas nozzle process.

800 (CONF-700557-3) EXPECTED DEVELOPMENT OF METHODS FOR ENRICHING URANIUM IN EUROPE.

Dreissigacker, H.L.

Translated from Strömungsmechanische Vorgänge in Gaszentrifugen, DFVLR-Kolloquium, om 14. Mai 1970, Porz, Wahn, Germany. 6 p. Dep. NTIS (U. S. Sales Only).

The present technical and economic states of the gaseous diffusion, gas centrifuge, and separation nozzle methods for U enrichment are described, and their potentials for development in Europe are re-assessed from the present-day point of view. The prospects of the three methods are qualitatively assessed and compared, particularly in view of the hoped-for European collaboration in the production of enriched uranium. (Author)

801 ENRICHMENT OF ^{235}U BY THE NOZZLE PROCESS.

Becker, E.W. (Kernforschungszentrum, Karlsruhe, Ger.).

pp. E.1-6 of Séparation Isotopique de l'Uranium et son Économie. Rueil-Malmaison, France; Société de Chimie Industrielle (1971).

From Meeting on the uranium isotope separation and the corresponding economics, Paris, France (Nov. 27, 1970). See CONF-701133.

A separation nozzle process was developed at the nuclear research centre of Karlsruhe. In order to demonstrate the gas-dynamic stability of a separation nozzle cascade, a 10-stage pilot plant was built. A systematic test series allowed the behaviour of the plant to be investigated. Three methods for inexpensive mass-production of separation nozzle systems with optimum inlet pressures between 400 and 600 mm mercury were developed in cooperation with industry. In March 1970, Gesellschaft für Kernforschung, Karlsruhe, and STEAG (Essen) signed a contract on co-operation in the separation nozzle process, the purpose of this co-operation being to provide further development, industrialization, and application of the process. The construction of a plant with a net output of 500 000 to 1 000 000 SWU/year will be studied. (Author) (France)

802 ARRICCHIMENTO DELL'URANIO — ALCUNI METODI ED IMPIANTI.

5 ref.

Notiziario, 14 (1968), No. 6, pp. 49-56.

Metodi di separazione — separazione elettromagnetica — diffusione termica — jet gassoso — centrifugazione gassosa — diffusione gassosa — alcuni impianti di diffusione — Capenhurst (GB) — Pierrelatte (Francia) — Oak Ridge (USA) — Paducah (USA) — Portsmouth (USA).

803 IL SIMPOSIO DI TORINO SULLA SEPARAZIONE ISOTOPICA DELL'URANIO.

Notiziario, 14 (1968), No. 12, pp. 55-64.

Diffusione gassosa — teoria delle barriere ed esperienze relative — teoria delle cascate e loro ottimizzazione — sistema Trenndüse — ultracentrifughe.

804 DIE VORBEREITUNGEN FÜR DEN BAU EUROPÄISCHER URANANREICHERUNGSANLAGEN MÜSSEN DRINGEND AN DIE HAND GENOMMEN WERDEN.

Atom Pressedienst, (1969), Nr. 1, S. 3.

Internationale Expertengruppe unter der Leitung von Ständerat Choisy, Genf, veröffentlicht aufsehenerregende Empfehlungen — sowohl die Zentrifuge als auch das Trenndüsenverfahren auch bei kleineren Einheitsgrößen relativ wirtschaftlich —, dies ist bei der Diffusion nicht der Fall: hier sind nur Großanlagen, welche Milliarden-Investitionen erfordern, wirtschaftlich.

805 FORATOM URGES EUROPEAN ENRICHMENT PLANT COMMITMENT BY 1972.

Nucl. Ind., 16 (1969), No. 2, pp. 25-29.

Foratom recommends pushing ahead with process development at a pace that will permit making a construction commitment by 1972 — centrifuge economics — nozzle enrichment plant costs — potential advantages of the two alternative processes.

806 ALTERNATE ENRICHMENT METHODS.

Nucl. Ind., 15 (1968), No. 11/12, pp. 69-72.

Economical jet nozzle uranium enrichment process, as a promising alternative to gaseous diffusion, particularly under European conditions — estimated total investment for the demonstration plant — high power consumption — centrifuge plant feasibility.

807 PLANNING FOR FUTURE ENRICHMENT PLANTS.

Allday, C., Avery, D.G., and Kehoe, R.B.

Atom, (1969), No. 148, pp. 36-42.

Estimated UK requirements for separative work — European enrichment requirements — planning the production of enrichment — fuel cycle integration — diffusion plant considerations — ultra-centrifuge process — nozzle-jet separation plant — idea of a European enrichment plant complex. (Sec 792)

808 ERPROBUNG DES TRENNDÜSENVERFAHRENS IN EINEM GESCHLOSSENEN VERFAHRENSKREISLAUF.

Schütte, R. und Seidel, D.

Chemie-Ing.-Techn., 39 (1967) 2, 80/84.

Ein in den letzten Jahren entwickeltes Verfahren zur Trennung der Uranisotope ^{235}U und ^{238}U vermeidet die beim Diffusionsverfahren empfindlichen Membranen sowie die bei Zentrifugenverfahren mechanisch hochbelasteten Teile. Das neue Trenndüsenverfahren kombiniert die Trennwirkung eines expandierenden Überschallstrahls mit der mechanischen Umlenkung des Strahls an einer festen Wand. Im expandierenden Überschallstrahl reichert sich in der Kernzone die schwerere und in der Mantelzone die leichtere Komponente an. Die Mach-Zahl wurde durch Zusatz eines leichten Gases (Helium) zu dem zu trennenden Isotopengemisch (Uranhexafluorid) erhöht. Die mechanische Strahlumlenkung ruft eine Zentrifugalkraft hervor und läßt die schwerere Komponente sich an der Umlenkwand anreichern, wo sie von einer messerförmigen Schneide abgeschält wird.

Die Düse besteht aus einer gekrümmten Laval-Düse, deren eine Wand 1,5 mm Krümmungsradius besitzt und deren andere Wand von einem exzentrisch angeordneten Vollzylinder mit 1,8 mm Ø gebildet wird. Der engste Düsenquerschnitt beträgt 0,4 mm, der Spalt zwischen äußerer Wand und Abschälschneide 0,2 mm. In der vorliegenden Arbeit wird die Ausführung des Trennelements eingehend beschrieben. Zur Erzielung eines guten Trenneffekts müssen mehrere Trenndüsen hintereinandergeschaltet werden.

Zur Verdichtung des Ausgangsgases wurde in Zusammenarbeit mit der Firma E. Leybold's Nachf., Köln-Bayental, ein aus der Baureihe „Ruvac E 126" speziell entwickeltes Roots-Gebläse verwendet, dessen besondere Konstruktionsmerkmale sowie Kennlinien ausführlich mitgeteilt werden.

Ein Schema der Versuchsanlage wird dargestellt und erläutert. Dauerversuche zur Erprobung des Trenndüsensystems wurden mit einem Gemisch aus 5 Mol% UF_6 und 95 Mol% He bei konstantem Düsenvordruck von 48 Torr unter Variation des Expansionsverhältnisses durchgeführt. Diagramme zeigen u.a. den Verlauf der „spezifischen Aufwandsgrößen": die spez. Kompressionsarbeit, das spez. Ansaugvolumen und die spez. Schlitzlänge als Funktion des Expansionsverhältnisses. Diese Größen sind ein Maß für die Investierungskosten, deren Kenntnis für die Aufstellung einer Wirtschaftlichkeitsrechnung unerläßlich ist. (6 Abb., 8 Qu.)

809 PLANUNG UND BAU EINER 10-STUFIGEN PILOTANLAGE FÜR DAS TRENNDÜSENVERFAHREN.

Frey, G.

Diss. TH Karlsruhe (1967), 45 S.

S. Verfahrenstechn. Ber. 6832/25, DK 621.039.341.4.

(14 Abb., 2 Tab.)
(See 779)

810 DIE VERFAHREN ZUR TRENNUNG DER URANISOTOPE.

Becker, E.W. (Univ. Karlsruhe).

Kerntechn., 11, (1969) 3, 129/139.

Da das in der Natur vorkommende Uran nur zu 0,7 % aus dem spaltbaren Isotop ^{235}U besteht, ist zur Erhöhung der Leistungsdichte in Kernreaktoren eine Anreicherung dieses Isotops notwendig. Auch beim Betrieb schneller Brutreaktoren mit Plutonium wird man u. U. auf ^{235}U angewiesen sein, das in der westlichen Welt hauptsächlich in den drei Gasdiffusionsanlagen der USA erzeugt wird. Neben diesem Verfahren wurde bisher dem Gaszentrifugenverfahren stärkere Beachtung gewidmet. Die dritte Möglichkeit besteht in der Auftrennung der Isotope $^{235}/^{238}U$ nach dem Trenndüsenverfahren. Durch Einführung der Begriffe „Wertfunktion" und „Trennarbeit" lassen sich die wirtschaftlichen Aspekte miteinander vergleichen. Für kleine Trennanlagen bietet das Gaszentrifugenverfahren Vorteile, da für die Produktion von 3 %igem Material, wie es für Leichtwasserreaktoren benötigt wird, nur 10 bis 20 Gegenstromzentrifugen hintereinander geschaltet zu werden brauchen; jedoch müssen wegen des geringen Durchsatzes viele Einheiten parallel geschaltet werden, was bei den beiden anderen Verfahren nicht notwendig ist.

Trenndüsenanlage und Diffusionsanlage sind „proliferationssicher," da die bei der Genehmigung vorgeschriebene Produktkonzentration nicht durch Umschalten von Trennelementen wesentlich erhöht werden kann. (10 Abb., 2 Tab., 16 Qu.)

811 DIE ANWENDUNG DER ULTRAZENTRIFUGE ZUR URANANREICHERUNG IN EUROPA (DE TOEPASSING VAN DE ULTRACENTRIFUGE VOOR DE VERRIJKING VAN URANIUM IN EUROPA).

Ingenieur (holl.), 81, (1969) 16, A 243/A 245.

Zur Urananreicherung werden in Europa drei Verfahren angewandt: die Gasdiffusion, das Trennungsventil und die Ultrazentrifuge. Die Merkmale der Verfahren werden erörtert.

Die Ultrazentrifuge besteht aus einer sich schnell drehenden (50 000 bis 100 000 U/min) Trommel, in der die schwereren Isotopen stärker als die leichteren nach außen geschleudert werden. Das Verfahren ist gekennzeichnet durch sehr große Trommelanzahl, niedrige Stromkosten und eine spezifische Investierung, die bei weiterer Entwicklung viel niedriger als für andere Verfahren werden kann. Bei Annahme einer Trennungsarbeit (a, in kg je kg angereichertes Uran) von 2 bis 6 kg/a je Trommel werden 1975 $\approx$ 2, 1980 $\approx$ 5 Millionen Trommeln erforderlich sein. Die für die Entwicklung der Ultrazentrifuge (deren Leistung der 4. Potenz der Umfangsgeschwindigkeit und der Länge proportional ist) maßgebenden Punkte (Trommelbau, Trommelschnelldrehung, Zusammenbau der Trommeln zu einer „Kaskade") werden im einzelnen aufgeführt. Man glaubt, in Zukunft Anlagen mit Trennungsleistungen von 500 000 bis 2 500 000 kg/a ausbauen zu können; der Bedarf an Trennungsleistung wird bis 1980 auf 9×10^6 kg/a ansteigen (bei 60 000 installierten MW) aufgrund des einschlägigen Schrifttums ist die Entwicklung der Ultrazentrifuge in den Niederlanden wahrscheinlich am weitesten fortgeschritten. Die Kennwerte der verschiedenen, in Europa angewandten Anreicherungsverfahren werden miteinander verglichen.

812 PROBLEMAS RELATIVOS A LA SEPARACION ISOTOPICA DEL URANIO. SIMPOSIO CELEBRADO EN TURIN LOS DIAS 1-2 DE OCTUBRE DE 1968 (PROBLEMES RELATIFS A LA SEPARATION ISOTOPIQUE DE L'URANIUM. COLLOQUE DU TURIN, 1-2 OCTOBRE 1968).

Benach, G.M.

Energ. nucl., Esp. (1969), 13, N° 58, 119-30, bibl. (21 réf.).

Commentaires des mémoires, présentés sur les procédés de diffusion gazeuse et de centrifugation et la méthode de la tuyère.

813 SYMPOSIUM D'UTRECHT SUR L'ENRICHISSEMENT DE L'URANIUM.

Renaudin, D.

Bull. Inform. ATEN, Fr. (1969), N° 77, 48-9.

Aspects techniques et économiques de l'enrichissement de l'U en Europe. L'ultracentrifugation, le procédé à tuyère du Pr. Becker, une extension des usines américaines employant les barrières poreuses.

814 TRENNUNG DER URANISOTOPE. EIN VERGLEICH DER HEUTE ZUR DISKUSSION STEHENDEN VERFAHREN (SÉPARATION DES ISOTOPES DE L'URANIUM. COMPARAISON DES PROCÉDÉS ACTUELLEMENT EN DISCUSSION).

Becker, E.W. (Inst. Kernverfahrenstech., Univ. Karlsruhe).

In: "33. Physikertag. Karlsruhe, 1968". Stuttgart. B.G. Teubner, 1969. 20 × 14, 221-44, bibl. (17 réf.).

Procédés de la diffusion et de la centrifugation de gaz. Procédé (dû à l'auteur et coll.) de la tuyère de séparation; ce procédé, en cours de perfectionnement, peut déjà remplacer la technique de la diffusion de gaz. (See 782)

815 FORTSCHRITTE AUF DEM GEBIET DER ISOTOPENTRENNUNG IM INDUSTRIELLEN MASSSTAB.

Villani, S.

Energia Nucleare, Suppl. 4, 187-95, 1957, ital.

Die Herst. folgender Isotopen wird besprochen: ^{235}U, D bzw. D_2O, ^{15}N u. ^{10}B. ^{235}U wird als UF_6 in fl. Phase durch Thermodiffusion, in der Gasphase durch Membrantrennung, durch Zentrifugentrennung u. nach dem Trenndüsenverf. gewonnen. Die D-Herst. erfolgt durch Dest. von fl. H_2 oder durch Austauschrk. zwischen H_2 u. H_2O bei 100 u. 600° oder in fl. Phase mit Katalysatoren. Ferner werden der mit hohem Trenneffekt erfolgende D-Austausch zwischen HCl u. W. (industriell noch nicht angewendet) u. die Gegenstromtrennung zwischen W. u. D_2O erwähnt. Zur Anreicherung von ^{15}N werden 2 Verf. angegeben: Austausch zwischen NH_3 u. NH_4^+ u. zwischen NO u. HNO_3. Das letztere Verf. arbeitet bei optimaler 10m HNO_3 Konz. mit einem Trennungsfaktor von 1,055. ^{10}B kann durch fraktionierte Dest. von BF_3 oder chem. Austauschrk. zwischen BF_3 u. therm. dissoziierbaren BF_3-Komplexen in fl. Phase in Form von Salzen oder als Metall hergestellt werden.

816 PHYSIKALISCH-TECHNISCHE GRUNDLAGEN DES REAKTORBAUES. HERSTELLUNG VON BRENNSTOFFELEMENTEN UNTER ANWENDUNG HYDRAULISCHER PRESSEN.

Pischel, H.

Industrieblatt, 63, 465-70, 522-27, 1963, Stuttgart-Weilimdorf, VDI, dt.

Es werden die allg. Grundlagen des Reaktorbaus besprochen u. dabei bes. auf U-Gewinnung, Isotopentrennung durch Gasdiffusions-, Gaszentrifugen- u. Trenndüsenverf.; künstliche Elemente, Reaktoren, Kernbrennstoffe, Moderatoren, Sicherheits- u. Regelstäbe, Kühlmittel, Abschirmung, Reaktortyp, wie Forschungs-, Leistungs-, heterogene u. homogene sowie therm. u. schnelle Reaktoren, eingegangen. Zur Herst. von Brennelementen werden feste Brennstoffe u. Hüllenwerkstoffe, Strangpressen, Schutzgas, Schutzsalz, Coextrusion von Pu, Sinterpressen behandelt.

8. THERMAL DIFFUSION

817 ENRICHMENT OF URANIUM (ENRICHISSEMENT DE L'URANIUM).

Nuclear Engineering, 13, No. 143 (4/68), pp. 335-40.

Description des méthodes d'enrichissement de l'uranium : diffusion thermique, diffusion gazeuse et séparation électromagnétique. Problèmes techniques posés par la production de grandes quantités d'uranium.

818 METHOD AND APPARATUS FOR SEPARATING FLUIDS BY THERMAL DIFFUSION.

Beams, J.W. (to U.S. Atomic Energy Commission).

U.S. Patent 2,521,112. Sept. 5, 1950.

This patent covers a method and apparatus for separating fluid mixtures by thermal diffusion. Two thermally conducting parallel tapes are moved in opposite directions to conduct lighter and heavier components counter current to each other. The separation fractions produced are drawn off at the end of their respective courses.

819 SEPARATION OF BINARY MIXTURES.

Klemm, A.

Naturforsch., 7a, 417-21 (June 1952). (In German).

The nonlinear differential equations for separation of a binary mixture in an infinitely long thermal-diffusion column (trennrohr), closed at one end, have been solved with the help of a transformation given by Majumdar (Phys. Rev., 81, 844 (1951), NSA 5-2210). The time dependence of the separation factor at the end of the diffusion column is presented graphically for various mixture ratios, and compared, for the extreme ratios 0 and ∞, with that of a diffusion column of finite length.

820 (A-531) THEORETICAL CONSIDERATIONS ON LIQUID THERMAL DIFFUSION EXPERIMENTS.

Cohen, K. (Columbia Univ., New York. Div. of War Research).

Feb. 5, 1943. Decl. Feb. 12, 1957. 22 p. Contract OEMsr-412. (4-R-21). $4.80 (ph OTS).

821 (A-41) THE DETERMINATION OF THE COEFFICIENT OF THERMAL DIFFUSION OF URANIUM HEXAFLUORIDE.

Nier, A.O. (Minnesota. Univ., Minneapolis).

May, 28, 1941. Decl. Jan. 30, 1957. 9 p. $1.80 (ph OTS); $1.80 (mf OTS).

By means of a Clusius type thermal diffusion column, an attempt has been made to evaluate the coefficient of thermal diffusion of UF_6 in the temperature range between 65 and 480 °C. As no appreciable separation was observed, it is concluded that this coefficient is so small that the method could not be used in this range for the separation of quantities of ^{235}U. (Author)

822 (A-49(Del.)) COMPARISON OF DIFFERENT METHODS APPLICABLE TO THE SEPARATION OF THE URANIUM ISOTOPES.

Urey, H.C. (Columbia Univ., New York. Div. of War Research).

[1942?]. Decl. with deletions Feb. 12, 1957. 22 p. $4.80 (ph OTS); $2.70 (mf OTS).

The effectiveness of thermal diffusion, Hertz diffusion, Maier diffusion, distillation, and chemical exchange methods for the separation of uranium isotopes is discussed.

823 NEW RESEARCH DEVELOPMENTS FOR INDUSTRIAL SCALE ISOTOPE SEPARATION.

Villani, S.

Energia nucleare (Milan), 4, 187-95 (June 1957). (In Italian).

Separation methods for ^{235}U, ^{2}H, ^{15}N, and ^{10}B are discussed.

824 (A-781) DESIGN OF CASCADES OF THERMAL DIFFUSION COLUMNS FROM EXPERIMENTAL DATA: A NOMOGRAPH OF RAPID CALCULATIONS.

Cohen, K. (Columbia Univ., New York. Div. of War Research).

Aug. 13, 1943. Decl. Jan. 31, 1957. (4-R-95).

Includes Attachments:

MEMORANDUM ON THE THERMAL DIFFUSION METHOD AS CARRIED OUT BY THE NAVAL RESEARCH LABORATORY. Urey, H.C. Feb. 19, 1943. (100M-79); [Letter to Lewis, W.K., Re: NAVAL RESEARCH LABORATORY METHOD.] Urey, H.C. Sept. 4, 1943. (100U-L-260); [Letter to Briggs, L.J., Re: THERMAL DIFFUSION METHOD.] Urey, H.C. Jan. 28, 1943. (100L-39); [Letter to Conant, J.B., Re: LIQUID THERMAL DIFFUSION PROCESS.] Briggs, L.J., Urey, H.C., Murphree, E.V., and Lewis, W.K. Sept. 8, 1943; and [Letter to Conant, J.B., Re: LIQUID THERMAL DIFFUSION PROCESS AS AN ALTERNATE TO THE DIFFUSION SCREEN PROCESS.] Briggs, L.J. Jan. 30, 1943. 15 p. Project SAM. Contract W-7405-eng-50. $3.30 (ph OTS); $2.40 (mf OTS).

Some considerations preliminary to the design of cascades for thermal diffusion separation of U isotopes are given.

825 (HW-39477) INTERIM REPORT ON THE SEPARATION OF ISOTOPES BY LIQUID THERMAL DIFFUSION.

Hahn, H.T. (General Electric Co. Hanford Atomic Products Operation, Richland, Wash.

Oct. 21, 1955. Decl. Feb. 26, 1957. 18 p. Contract W-31-109-eng-52. $3.30 (ph OTS); $2.40 (mf OTS).

Experiments in the separation of U isotopes by liquid thermal diffusion in $UO_2(NO_3)_2$-TBP complex and in aqueous and molten $UO_2(NO_3)_2$ are described.

826 PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON ISOTOPE SEPARATION HELD IN AMSTERDAM, APRIL 23-27, 1957.

Kistemaker, J., Bigeleisen, J., and Nier, A.O.C., eds.

Amsterdam, North-Holland Publishing Company, 1958, 723 p.

Papers presented at the International Symposium on Isotope Separation held in Amsterdam, 1957, and the pertinent discussions are presented. Papers in English, French, and German are included in the field of chemical engineering, molecular interactions, chemical exchange, electromigration, distillation, thermal diffusion, diffusion, electromagnetic separation, and the development of ultracentrifuges.

827 (CF-60-3-37) AN INVESTIGATION OF THERMAL DIFFUSION SEPARATION OF ^{232}U-^{233}U AS AN ALTERNATE TO REMOTE PROCESSING.

Jury, S.H. (Oak Ridge National Lab., Tenn.).

March 10, 1960, 7 p. Contract W-7405-eng-26. OTS.

Liquid phase thermal diffusion separation of ^{232}U-^{233}U was investigated. The calculations were based on a horizontal type thermal diffusion column operating 24 hours/day on spent thorium fuel. The irradiation level is such that 8 tons contains $\sim$ 80 000 g of ^{233}U with about 500 ppm ^{232}U in the ^{233}U at the time of processing. For a column with a practical channel cross section and a temperature differential of 100 °K across the barrier it was found that the enriching section at total reflux was 5.46×10^7 ft in length, and the strip section was 2.82×10^7 ft in length. Since these lengths must be even greater during product withdrawal, the use of thermal diffusion in this application was considered impractical due to excessive channel length, hold-up, and radiation shielding requirements. (Author)

828 ISOTOPE SEPARATION BY LIQUID-PHASE THERMODIFFUSION.

Alexander, K.F. (Zentralinstitut für Kernphysik, Rossendorf, Ger.).

Fortschr. Physik, 8, 1-41 (1960). (In German).

The use of gas-phase thermodiffusion for isotope separation in preference to liquid-phase is based on groundless prejudice. Experimental data are given to support this viewpoint, with particular attention being given to thermodynamic effects and optimal dimensions in liquid-separation tubes. The thermodiffusion principle and theory are treated first, followed by consideration of the separation tube with constant cross section. A transport equation is set up and solved for this case, and factors and coefficients are determined. The ideal separation apparatus is then studied, the separation tube with variable cross section. The application of the principle in separation of U isotopes in liquid UF_6 is discussed, and numerical examples given to compare with the gaseous diffusion process.

829 ISOTOPE SEPARATION BY THERMAL DIFFUSION IN LIQUID PHASE.

Alexander, K.F. (Zentralinstitut für Kernphysik, Dresden) and Krecker, U. (Deutsche Akademie der Wissenschaften, Berlin).

Kernenergie, 1, 437-9 (June 1958). (In German).

Using the Clusius and Dickel separation-tube process, the isotope effect in thermal diffusion in liquid butyl chloride and in liquid bromobenzene was studied. The thermal diffusion factors found in this study as well as those produced in other work are noticeably larger than those thermal diffusion factors expected in the gaseous phase. A comparison of the liquid and gas separation with respect to energy requirements and apparatus requirements leads to a general preference for the liquid process. (Tr.-author)

830 (AEC-tr-4394) ISOTOPE SEPARATION.

Walcher, W.

Translated for Oak Ridge Gaseous Diffusion Plant from Ergeb. exakt. Naturw., 18, 155-6, 175-91, 206-13, 219-23 (1939), 60 p. (Includes original, 6 p.).

Selected parts of a review of isotope separation methods were translated. These parts include those dealing with diffusion, thermal diffusion, centrifuge, and a comparative evaluation of methods.

831 (MLM-1115) MOUND LABORATORY MONTHLY PROGRESS REPORT FOR MAY 1961 (ON PLASTICS, RADIOELEMENTS, ISOTOPE SEPARATION, AND REACTOR FUELS.)

Eichelberger, J.F. (Mound Lab., Miamisburg, Ohio).

May 30, 1961. Contract AT-33-1-GEN-53. 18 p.

Formulation of 13 new epoxy-modified polyurethane systems were cast and cured. Results of chemical tests on an epoxy curing exudate are included. Comparison of solvent

effects on retention of radioelements by stainless steel was started and data are tabulated for ^{227}Ac, ^{227}Th, and ^{223}Ra. Work on protactinium was resumed after suspension of this project in 1960. Methods for preparation of small quantities of highly enriched U isotopes are being examined. Included in the survey are chemical exchange, electromagnetic separation, gaseous and liquid thermal diffusion, gas centrifugation, and photochemical techniques. Continued investigation of viscosities of La and Pr for use in Pu alloys is reported. Phase studies of Au-Pt systems were continued along with studies of Pu bearing glass fibres.

832 (MLM-1140) MOUND LABORATORY PROGRESS REPORT FOR AUGUST 1962.

Grove, G.R., Jones, L.V., and Eichelberger, J.F. (Mound Lab., Miamisburg, Ohio).

Aug. 30, 1962. Contract AT(33-1)-gen-53. 25 p.

The need for more shock resistant thermosetting plastics led to the development of glass-filled diallyl phthalate as a molding powder. The glass-filled formulation has a greater shock resistance than the asbestos-filled plastic. The molding characteristics of the glass-filled material were very good, but a new technique for inspection is required, since bright spots on the X-ray films from the orientation of the glass fibers appeared as high density inclusions. The effect of the initial curve temperature on Oxiron adhesives is being studied. By properly controlling the initial curve temperature, increased tensile strength at 160 °F can be obtained without imparing the flexibility of the material. When the ratio of anhydride to epoxy is too small for a satisfactory cure, increased initial cure temperatures do not cause an increase in tensile strength at 160 °F. A system to determine the thermomolecular correction for He^3 vapor pressure data is being assembled. This research is directed toward establishing an international temperature scale between 0.3 and 3.2 °K. The isotopes of B may be separated by thermal diffusion if BF_3 is used as the feed gas. Thermodynamic studies revealed that most conventional materials of construction are stable in BF_3 up to 1 000 °K. Methane is being evaluated as a feed gas to separate C^{13} by thermal diffusion. A hot-wire thermal diffusion column separates the heavy impurities in CH_4 prior to enrichment of the C^{13}. Low temperature distillation is also being evaluated as a technique to separate the impurities from CH_4. Studies on the conversion of CO to CH_4 with the activated Ni catalyst are being continued. Alternate methods to separate U isotopes are being evaluated. The reaction of UF_6 at elevated temperatures with various materials is being studied. Thermodynamic calculations indicate that Au is the only material which is stable in UF_6 at elevated temperatures. This material may be used in the design of a thermal diffusion column to separate research quantities of the U isotopes. The separation of ^{234}U from aged ^{238}Pu was demonstrated. Preliminary calculations indicate that Pu elution is not always quantitative. An agglomeration and degradation of the resin from alpha bombardment may contribute to poor eluation. Although the total capacity of the experimental resin was greatly reduced, no accurate figures are available.

833 SEPARATION OF URANIUM ISOTOPES.

Pecqueur, M.

Ann. Mines, 11-30 (Nov. 1963). (In French).

Descriptions are given of electromagnetic separation, heat diffusion, centrifugation and expansion in nozzles as means of enriching UF^6 gas or liquid to obtain ^{235}U and ^{238}U. Parameters and techniques for the gas diffusion enrichment process, including equipment, pressure, gas concentration, charge quantity, and barrier pore size were determined. (Rev. Metal Lit., 21, No. 2, Feb. 1964)

834 MEASUREMENT OF THERMAL DIFFUSION AND DETERMINATION OF THE INTERMOLECULAR POTENTIAL OF GASEOUS URANIUM HEXAFLUORIDE.

Kirch, P., and Schütte, R. (Technische Hochschule, Karlsruhe, Ger., and Kernforschungszentrums, Karlsruhe, Ger.).

J. Chem. Phys., 42, 3729-30 (May 15, 1965).

Experiments on the thermal diffusion of gaseous UF_6 were carried out at various temperatures and gas pressures in a 3-m-long thermal diffusion column made of concentric nickel tubes having a distance of 4 mm between the hot and the cold wall. The separation effects given by $q - 1 = [n_t(1 - n_b)/n_b(1 - n_t)] - 1$ (n_t, n_b are the mole fractions of $^{235}UF_6$ at the top and the bottom of the column, respectively) were found to be in the range of 5×10^{-4} to 4×10^{-3} and were measured with a relative accuracy of about $\pm$ 5%. The experimental values for the thermal diffusion factor α of gaseous UF_6 are plotted vs the absolute temperature T. For the completely specified intermolecular potential all transport coefficients and the second virial coefficient of gaseous UF_6 were calculated as functions of temperature. Within the available experimental data given by others, the results show complete agreement between theoretical and measured values of viscosity, thermal conductivity, self-diffusion, and also with experimental values of the non-ideality parameter of gaseous UF_6.

835 REVIEWS OF ISOTOPE SEPARATION RESEARCHES IN JAPAN. ACTIVITIES OF THE SPECIAL COMMITTEE ON ISOTOPE SEPARATION.

Nippon Genshiryoku Gakkaishi, 7, 429-37 (Aug. 1965).

(In Japanese).

The Special Committee on Isotope Separation of the Atomic Energy Society of Japan was established in April 1963 and ended in March 1965. Studies were made on the separation of natural isotopes. The isotopes separated included D, ^6Li, ^7Li, ^{10}B, ^{13}C, ^{15}N, ^{18}O, ^{39}K, ^{40}Ar, and ^{235}U. The methods of separation adopted included gaseous diffusion, ultracentrifuge, thermal diffusion, molecular distillation, chemical exchange and electrophoresis. (Author)

836 PIERRELATTE — USINE DE SEPARATION DES ISOTOPES DE L'URANIUM (PIERRELATTE—PLANT FOR SEPARATION OF URANIUM ISOTOPES).

(Commissariat à l'Energie Atomique, Paris).

1964, 38 p.

The design and development of the Pierrelatte Isotope Separation Plant is described. The isotopic enrichment processes used are electromagnetic separation, thermal diffusion, centrifugation, expansion in a shock tube, and gaseous diffusion. The principle of each of these methods is described briefly. The characteristics of the plant are given.

837 AEC, INDUSTRY, UTILITIES EXPLORE PRIVATE ENRICHMENT POSSIBILITIES.

Grant, J.

Nucleonics, 25, No. 2, 54-7, 84 (Feb. 1967).

Views of the AEC, private industry, and public utilities on the possibility of private uranium enrichment are discussed. Some questions considered are: the urgency of private participation in enrichment; availability of classified information; prospects for methods of enrichment other than gaseous diffusion; would a monopoly be created which would damage competition; and would private enrichment bring cheaper fuel costs and if so would savings be passed on to public utilities. A short history of uranium enrichment in the U. S. is given. Other methods of enrichment such as thermal diffusion, electromagnetic, gas centrifuging, and chemical separation are summarized.

838 MEASUREMENT OF THE THERMAL DIFFUSION FACTORS AND DETERMINATION OF THE MOLECULAR INTERACTION POTENTIALS OF GASEOUS URANIUM HEXAFLUORIDE.

Kirch, P., Schütte, R. (Technische Hochschule, Karlsruhe, Ger. Kernforschungszentrum, Karlsruhe, Ger.).

Z. Naturforsch., 22a, 1532-7 (Oct. 1967). (In German).

Measurements of the thermal diffusion of gaseous U hexafluoride in a thermal diffusion tube of concentric Ni tubes showed that the thermal diffusion factor α between 328 and 452 °K is negative and at 384 °K reaches an extreme value of -2.9×10^{-5}. Below 328 °K and over 452 °K α possesses a positive sign. The measured temperature dependence of the thermal diffusion factor of UF_6 can be quantitatively described by assumption of an interaction law of the modified Buckingham potential type, when the values $^{s} = 14.75$ and $\varepsilon^*/k = 582$ °K were used for the potential parameter. By use of an experimental viscosity value, the third potential parameter $r_m = 5.44$ Å was determined. With the molecular interaction potential thus established the absolute value and the temperature dependences of all transport coefficients and of the second virial coefficient could be theoretically described in agreement with the latest measurement values. (Tr.-author)

839 SEPARATION OF U ISOTOPES IN FRANCE AND IN THE WORLD.

Pecqueur, M. (CEA, Paris).

Energ. Nucl. (Paris), 9, 480-8 (Dec. 1967). (In French).

The development of the Pierrelatte installation and the history of the isotopic separation of U in France and in the world are outlined. The civil and military reasons for the separation of U isotopes are given. The U isotope separation developments of the United States, England, Russia, China, and France are briefly reviewed. The principal separation procedures—electromagnetic separation, thermal diffusion, the Becker method, and centrifugation—are described in principle. The gaseous diffusion procedure is described in slightly more detail. The Pierrelatte installation based on the gaseous diffusion procedure is described. Technological difficulties in the design and construction of this installation were connected with the properties of uranium hexafluoride, the barrier, and the compressor and its tightness. The solutions used in each of these areas are indicated (Trans. 840)

840 (K-Trans-45, pp.7-28) URANIUM ISOTOPE SEPARATION IN FRANCE AND IN THE WORLD.

Pecqueur, M.

Translated from Energ. Nucl. (Paris), 9, 481-8 (Dec. 1967).

An abstract of this paper, prepared from the original language, appeared as NSA 22, 23230. (Orig. 839)

841 (NP-18173) ENRICHMENT OF URANIUM BY THERMAL DIFFUSION.

Cruz, Concepcion Morales (Universidad Nacional Autonoma de Mexico, Mexico City. Facultad de Quimica).

61 p. (1969). (In Spanish). Dep. CFSTI (U. S. Sales Only).

A design for the enrichment of uranium by thermal diffusion is proposed. The design indicates the most convenient equipment and the subsequent operational problems for the enrichment of natural uranium (0.7% of ^{235}U) up to 2.1% ^{235}U. The theoretical results indicate that the operation in principle is simple, and the equipment requirements are very simple and can be easily fabricated in any institution or laboratory of limited resources. The installation is easy and does not require much horizontal space, only a space with sufficient height. For the thermal diffusion design, the temperatures, wire, and the tube were 298 °K for the primary and 1 073 °K for the secondary loops. The

electrical power necessary is 1.675 kW. The calculated cost was \$8.55/g of UO_2. Construction of the thermal columns derived from the theory is under way.

842 URANIUM ENRICHMENT INDUSTRY.

Avery, D.G., Kehoe, R.B. (United Kingdom Atomic Energy Authority, Risley, Eng.).

Atom (London), 164, 120-30 (June 1970).

A survey of the historical background of isotope separation and uranium enrichment is given. Four processes of uranium enrichment are discussed; the centrifuge method, the electromagnetic (calutron) method, the thermal diffusion method, the gas diffusion process. The capacity of the present day gas diffusion plants in USA, UK, France, Russia and China are considered. A simplified treatment of the diffusion process is given which enables the main design and optimization characteristics to be identified. Membrane development is reviewed and the difficulties of plant design when dealing with UF_6 considered. The nozzle process and the centrifuge method are examined and their economics discussed. The growing demand for uranium enrichment in Europe is considered in the light of the tripartite agreement.

843 ARRICCHIMENTO DELL'URANIO — ALCUNI METODI ED IMPIANTI.

5 ref.

Notiziario, 14 (1968), n. 6, pp. 49-56.

Metodi di separazione — separazione elettromagnetica — diffusione termica — jet gassoso — centrifugazione gassosa — diffusione gassosa — alcuni impianti di diffusione — Capenhurst (GB) — Pierrelatte (Francia) — Oak Ridge (USA) — Paducah (USA) — Portsmouth (USA).

844 FORTSCHRITTE AUF DEM GEBIET DER ISOTOPENTRENNUNG IM INDUSTRIELLEN MASSSTAB.

Villani, S.

Energia Nucleare, Suppl. 4, 187-95, 1957, ital.

Die Herst. folgender Isotopen wird besprochen: ^{235}U, D bzw. D_2O, ^{15}N u. ^{10}B. ^{235}U wird als UF_6 in fl. Phase durch Thermodiffusion, in der Gasphase durch Membrantrennung, durch Zentrifugentrennung u. nach dem Trenndüsenverf. gewonnen. Die D-Herst. erfolgt durch Dest. von fl. H_2 oder durch Austauschrk. zwischen H_2 u. H_2O bei 100 u. 600° oder in fl. Phase mit Katalysatoren. Ferner werden der mit hohem Trenneffekt erfolgende D-Austausch zwischen HCl u. W. (industriell noch nicht angewendet) u. die Gegenstromtrennung zwischen W. u. D_2O erwähnt. Zur Anreicherung von ^{15}N werden 2 Verf. angegeben: Austausch zwischen NH_3 u. NH_4^+ u. zwischen NO u. HNO_3. Das letztere Verf. arbeitet bei optimaler 10m HNO_3 Konz. mit einem Trennungsfaktor von 1,055. ^{10}B kann durch fraktionierte Dest. von BF_3 oder chem. Austauschrk. zwischen BF_3 u. therm. dissoziierbaren BF_3-Komplexen in fl. Phase in Form von Salzen oder als Metall hergestellt werden.

9. MISCELLANEOUS METHODS

845 ISOTOPE SEPARATION WITH A MOLECULAR PUMP.

Böttger, O., and Pingel, M.

Vak. Tech., 12, (1963) 2, 33-37, 8 fig., 1 tab., 4 ref. (In German).

Separating factor and separative power of a molecular pump with simple geometry were calculated. Moreover calculations were made for a pump with two pump-slits: one of them is used for enriching the light component of a binary gas-mixture, and the other for enriching the heavy component. The pump works in such a manner that the input is divided in the two components without rest. The separation of UF_6 is discussed as a numeric example of isotope separation.

846 THE ELECTROCHEMICAL INDUSTRIES, ELECTROMETALLURGY AND NUCLEAR ENERGY.

Anon. (from de Vitry, R.).

Journ. Four Elect. & des Indust. Electrochim., 7, (1962) 226, 1 ref. (In French).

New sources of energy. Application of electrochemical and metallurgical techniques to the development of nuclear industry: f.i. extraction of U and preparation of its compounds (F6 U), separation of Pu. Isotopic separation of ^{235}U. Direct transformation of nuclear energy into electric energy.

847 CONGRÈS DE TURIN SUR LA SÉPARATION DE ^{235}U.

Brigoli, B., and Villani, S.

Energia Nucleare, 15, (12) (12/68), 8 fig., réf. bibl., pp. 787-97.

Résumé des articles présentés au symposium qui s'est tenu à Turin les 1 et 2 octobre 1968.

848 CONTROVERSES AUTOUR DU PIERRE-LATTE EUROPÉEN.

Malleroy, A.

Atomes 24, No. 261 (1/69), pp. 55-57, 1 fig.

Nécessité de la création d'une usine européenne d'enrichissement de l'uranium. Valeur des trois procédés de séparation isotopique. (LT).

849 SEPARATION OF A MIXTURE OF GASES BY DIFFUSION THROUGH A MOVING WALL AND EQUIPMENT FOR THIS METHOD.

(Centre National de la Recherche Scientifique).

Neth. Appl. 6,402,685 (Cl. B 01^d), Sept. 15, 1964; Fr. Appl. March 14, 1963; 19 p.

A stream of mols. of different masses in thermodynamic equil. impinges on a moving wall and is sepd. into 2 fractions, one contg. mols. with velocities larger than the mean velocity and one contg. mols. with smaller velocities. The sepn. is based on the difference of the velocity components parallel to the moving surface relative to the velocity of the surface itself. By detg. the angle between the gas stream and the moving surface, the mixt. is sepd. into two streams, the upstream one contg. more light mols. than the original stream, and the downstream one contg. more heavy mols. The equipment consists of a rotating disc with a linear velocity of the same order of magnitude as the mol. velocities in a vacuum chamber, and 3 tubes, one for delivery and 2 for collecting the sepd. streams. The distances between the tubes and the disk are between 0.01 and a few tenths of a mm. More than one assembly can be fixed in one chamber with one disk, and a no. of chambers may be connected in order to build a countercurrent continuous system. Enrichment coeffs. are claimed to be much larger than those of the diffusion process. The equipment is especially suited for the sepn. of isotopes of Hg and UF_6.

850 NUCLEAR FUELS.

Ryo Amanuma (At. Fuel Corp., Ibaraki, Japan).

Genshiryoku Kogyo, 11 (4), 27-32 (1966) (Japan).

U ore, the smelting of U, ceramic fuels, enrichment in ^{235}U, and the reprocessing of spent fuels in Japan in the last decade are reviewed. The domestic U ore is leached with H_2SO_4 and the leached soln. treated by solvent-extn. and ion-exchange methods to form a U concentrate (yellow cake). U fluoride is prepd. from the chloride soln. by a wet method, the latter being prepd. from a HCl soln. of the conc. by using ion exchange and electrolytic redn. Metallic U is prepd. from U fluoride by Mg redn. As ceramic fuels, UO_2 was esp. studied. Research and future programs on enrichment in ^{235}U and the reprocessing of spent fuels are also discussed.

851 FUEL SUPPLY PARAMETERS OF REACTORS AND REACTOR SYSTEMS.

Grumm, H. (Inst. Reaktortech. Österreichischen Studienges. Atomenergie, GmbH, Vienna).

Atomkernenergie, 12, (1-2), 1-4 (1967) (Ger.).

Fuel supply parameters of reactors and reactor systems are defined including U supply, fueling, fuel cycle, U sepn., and reprocessing plants.

852 NUCLEAR REACTORS : ISOTOPE SEPARATION.

Drury, J.S. (Oak Ridge National Lab., Oak Ridge, Tenn.)

Kirk-Othmer Encycl. Chem. Technol., 2nd Ed., 14, 85-7 (1967) (Eng.).

A review on the sepn. of ^{235}U, ^{10}B, and ^{7}Li. 10 references.

853 ISOTOPIC SEPARATION BY ION RESONANCE.

Hermann, P.K. (Licentia Patent-Verwaltungs-GmbH).

Ger. 1,270,845 (Cl. C 01n), June 20, 1968, Appl. July 28, 1959, 6 p.

Isotopes in a gas (e.g. UF_6) are sepd. by ionizing the gas in an elec. discharge tube and subjecting the ions to mutually perpendicular in-phase alternating elec. (E) and magnetic (H) fields. The relative amplitudes of E and H (at least 1 000 gauss) are so adjusted that the majority of isotope ions have orbits with the same frequency ($\sim$ 2 000 Hz.) as E and H (theoretical frequency is $2\ eH/3\ \pi^2 m$, where e/m is the charge/mass ratio of an ion); these orbits are virtually immobilized by the combined effects of E, H, and ion-pumping. The minority isotope ions have open snake-like orbits with a net drift velocity, permitting their collection at a collector electrode placed at the end of the discharge tube on the axis perpendicular to both E and H.

854 ISOTOPE ENRICHMENT.

Dewez, D.

Ger. Offen. I,964,783 (Cl. B 01^d), July 23, 1970, Lux. Appl. Dec. 31, 1968; 11 p.

A process is described for isotope enrichment by diminishing the enthalpy of a gaseous compd. of the element to be enriched with partial solidification using an inert auxiliary gas and sepn. of the solidified from the non-solidified part. ^{235}U enrichment via the expansion of a UF_6-He gas mixt. is reported.

855 POSSIBILITIES AND CONDITIONS OF SUPPLYING FUEL FOR NUCLEAR POWER PLANT.

Mojovic, Lj.

Elektroprivreda (Yugoslavia), Vol. 23, Nos 3-4, pp. 117-25 (March 1970). (In Croatian).

A number of specialized industries participate in the supply of nuclear fuel. In the paper an analysis is made of the possibilities of ensuring the supply of concentrated nuclear fuel, uranium enrichment, fuel element manufacture, decayed fuel reprocessing and other steps in the combustion cycle. A survey of the actual state on the world market and of future trends is made. The possibility of ensuring the individual phases of the combustion cycle from the country's resources are analized in consideration of Yugoslavia's estimated needs. A comparison is made between the natural and enriched uranium cycle from the point of view of the rational use of the raw materials and autonomy of supply. (15 refs.)

856 RÉPERTOIRE DES INSTALLATIONS NUCLÉAIRES DE LA COMMUNAUTÉ EUROPÉENNE DE L'ÉNERGIE ATOMIQUE (QUATRIÈME ÉDITION) (NUCLEAR INSTALLATIONS IN THE COUNTRIES OF THE EUROPEAN ATOMIC ENERGY COMMUNITY (FOURTH EDITION).

EUK 3568 f (1967) FS 120 p., BFrs 165 (2)

Ce répertoire fait état de l'ensemble des installations spécifiquement nucléaires existantes, en construction, dont la construction a été décidée ou qui sont projetés dans les pays membres de l'Euratom. Il comporte, pour chaque installation, une brève description, limitée aux principales caractéristiques, et la mention des principales entreprises connues comme ayant participé à la réalisation des installations.

This survey features all the specially nuclear installations which already exist, which are under construction, the construction of which has been decided, or which are being planned in the member countries of Euratom. It comprises, for each installation, a short description limited to its main characteristics; it also mentions the more important enterprises which are known to have participated in the building of these installations. (See 880)

857 MAXWELL'S DEMON HAS COME TO THE AID OF THE NUCLEAR POWER INDUSTRY.

Anon.

Chem. Engng, 74, (18), 53 (Aug. 28, 1967).

The process could provide a simple way to enrich uranium, at a fraction of AEC's cost. In the process, invented by Sarasota Research and Development Corp., a vortex or Schleinen-tube separates molecules of gas according to their kinetic energy; in this case UF_6 molecules are separated into streams richer and poorer in U-235. Feed for the new process will also be cheaper if supplied by a new UF_6 plant that UKAEA are building, claimed to cut the cost of producing the gas by more than half.

858 URANIUM ENRICHMENT IN EUROPE.

Scuricini, G.B. (Comitato Nazionale per l'Energia Nucleare, Rome, Italy).

Com. Naz. Energ. Nucl., Notiz.

In the evaluation of some figures the two reports differ sometimes substantially. The strict classification of information and the uncertainties existing do not allow presently a comparison between the conclusions reached; moreover a certain degree of difference exists in the opinions of experts.

The author believes that the Foratom activities aiming at the preparation of conclusive steps to be undertaken and the evaluation of the situation, should be continued.

859 OPTIMUM STEP COMPOSITIONS FOR STRIPPING AND ENRICHMENT SQUARED-OFF CASCADES.

Oliveri, E. (Palermo Univ., Italy. Istituto di Applicazioni e Impianti Nucleari).

In this paper the results are given of a calculation concerning the optimization of squared-off cascades for uranium enrichment. Such calculation is based on a method previously proposed by the same Author.

860 FRANKREICH, PARTNER AUF ALLEN GEBIETEN DES BRENNSTOFFKREISLAUFS (LA FRANCE, PARTENAIRE DANS TOUS LES SECTEURS DES CYCLES DE COMBUSTIBLES) (FRANCE, PARTNER IN ALL SECTIONS OF FUEL CYCLES).

Mabile, J. (Commissariat à l'Energie Atomique, 75 - Paris, France).

Atomwirtschaft-Atomtechnik (C), Vol. 14, No. 6, juin 1965, pp. 251-93. Rapport CEA-TP-7508.

La France dispose dans tous les secteurs des cycles de combustibles de connaissances et de capacités sur la base desquelles elle peut faire des offres attirantes aux autres pays européens pour assurer une industrie européenne efficace et compétitive, l'uranium, le retraitement et la séparation des isotopes étant les acquis dont dispose la France.

861 FUNDAMENTALS OF ISOTOPE SEPARATION.

Cohen, K.

United States Naval Medical Bulletin. March-April 1948 Suppl., pp. 6-16; Nucleonics, 2, pp. 3-9, June 1948. (See also MDDC-1138).

Isotope separation is usually accomplished by repeated application of an elementary process which by itself changes the concentrations only slightly. The importance of proper design of such cascades of separated elements became vital with the increasing scale and difficulty of isotope separation. The phenomenon of relaxation time makes proper cascading essential even for laboratory equipment. One may solve the cascade design problem for binary mixtures in a quite general way, and it will be valid for almost all separation processes. The solution is found by determining the smallest possible cascades for producing a given amount of product of given purity. This minimal cascade is called an "ideal cascade". The size of an ideal cascade is the ratio of two functions: the value function, which represents the relative difficulty of obtaining material of any concentration from a fiducial concentration, and a separative power function. The separative power depends only on parameters of the particular process, such as the elementary separation factor and the flow per unit. The design of a separation unit thus reduces to maximizing the separative power. A general procedure for determining the separative power of any type element is outlined and illustrated by examples.

862 PAPERS PRESENTED AT THE CONFERENCE ON ATOMIC ENERGY EDUCATION (HELD) AT THE UNIVERSITY OF NEW MEXICO (ON) OCTOBER 17 AND 18, 1952. (AECU-2537).

Garrett, G.A. (Los Alamos Scientific Lab.).

Papers presented at the Conference on Atomic Energy Education at the Univ. of N. Mex. on the following subjects are reproduced: Possible Uses of Nuclear Power; Atomic Blast Effects on Buildings and Structural Dynamics; Uranium Exploration; Separation of U Isotopes; Industrial Power from Nuclear Energy; Radioisotopes for Industrial Research and Application.

863 BRITAIN'S ATOMIC FACTORIES; THE STORY OF ATOMIC ENERGY PRODUCTION IN BRITAIN.

Jay, K.E.B.

London, Her Majesty's Stationery Office, 1954, 100 p.

The production of fissionable materials in Britain is described, including the design of the factories, the separation processes used, the health safeguards, and the organization of the British Division of Atomic Energy Production.

864 (AERE-Lib/Trans-690) PROBLEMS AND METHOD OF TRACE ENRICHMENT.

Specker, H., and Hartkamp, H.

Translated by R.J. Richardson from Angew. Chem., 67, 173-8 (1955), 15 p.

865 ATOMIC POWER FOR PEACE. VOLUME 1. URANIUM.

Vogt, W.J.

Johannesburg, Union of South Africa, Atomic Power Review, 1956, 28 p.

A general history of U is given. The methods of separating ^{235}U from ^{238}U are described briefly. A flowsheet of the

uranium extraction and sulfuric acid plant in the Union of South Africa is presented. The extraction of U from ores and the production of U metal in the Union of South Africa are described.

866 (K-1369) MEASUREMENT OF THE ISOTOPIC ENRICHMENT OF URANIUM BY A DIRECT COMPARISON MASS SPECTROMETER METHOD

Warren, V.L., and Smith, L.A. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

June 24, 1958, 18 p. Contract W-7405-eng-26. $0.75 (OTS).

A direct comparison mass spectrometer method of measuring the separation of uranium isotopes is described. Data are given to show that for separation factors less than 1.06, the accuracy and precision are equivalent to those of the commonly used hexafluoride dilution method. The technique is useful for other separation factor ranges and is particularly adaptable to automatic instruments which should give even better results. (Author)

867 ^{235}U AND PLUTONIUM-CADENCE AND ACCOMPLISHMENT.

Baumgartner, R.

pp. 187-91 of "Journées d'Information sur l'Énergie Nucléaire, 14-15-16 janvier 1957". Documents, Suppl. to No. 114. Commissariat Général à la Productivité, France, 1957, 203 p. (In French).

The development of nuclear power in France will fall into two phases, the use of natural or slightly enriched uranium for reactor fuel and the use of plutonium for reactor fuel. The first period, which will extend to about 1965, has the program of constructing nuclear power stations, research and prototype reactors, an isotope separation plant for uranium, prototypes for marine reactors, and finally reactors for exportation. In the second period, plutonium will be used as fuel, but the energy needs after 1965 are too uncertain for definite plans to be made.

868 URANIUM PRODUCTION TECHNOLOGY.

Harrington, C.D., and Ruehle, A.E., eds.

Princeton, N.J., D. Van Nostrand Company, Inc., 1959, 588 p. $17.50.

This volume attempts to present the essential features of uranium production technology. Five chapters are general and deal with basic chemistry and metallurgy and with consideration of health and safety in protecting against new hazards. The other chapters discuss past, present, and possible future production methods, with emphasis on current practices.

869 (AEC. TID-8522) METHODS OF CALCULATING ^{235}U OUTPUTS AND CHARGES BY USE OF IDEAL CASCADE THEORY.

Snyder, A.J. (Office of Operations Analysis and Forecasting,

Feb. 1960, 43 p. OTS.

A brief technical discussion of general theoretical considerations and calculation methods involving ideal cascades for isotope separation is given. A discussion of AEC schedules of charges is included, and problems such as estimating the reduction of cascade top product output as a result of intermediate withdrawals, calculating charges for ^{235}U burn-up in reactors, and determining the effects of blending uranium of different assays are examined.

870 SEPARATION OF ISOTOPES.

London, H., ed.

London, George Newnes Limited, 1961, 500 p., 80 s.

The various isotope separation methods are described and are brought into a common perspective in order that a selection may be easily made for each particular isotope separation problem. The separation theory of statistical processes is presented. The photochemical and electromagnetic methods, reversible statistical processes, and irreversible statistical processes are covered.

871 GÉNIE ATOMIQUE. TOME QUATRE. LES MATÉRIAUX NUCLÉAIRES. VOLUMES UN ET DEUX (ATOMIC ENGINEERING. TOME IV. NUCLEAR MATERIALS. VOLUMES 1 AND 2).

Institut National des Sciences et Techniques Nucléaires, Saclay, France, Paris, and Presses Universitaires de France, 1961. 1848 p.

A review is given of the extraction, physical properties, mechanical properties, physical metallurgy, and relations to properties of solids in general of U, Pu, and Th metals. Nuclear structural materials are reviewed, including Al, Mg, Be, Zr, alloys of these metals, and steels. Refractory materials are surveyed, including UO_2, uranium carbides, and BeO. The production and properties of graphite are outlined. An investigation is made of fuel elements for heterogeneous reactors and of control elements. Radiation effects on nuclear materials are surveyed, with particular attention to fast neutron effects on graphite, physical-chemical behaviour of light and heavy water in reactors, interactions between graphite and cooling liquids, and organic liquid coolant behaviour. Corrosion problems in water-, gas-, and liquid-metal-cooled reactors are reviewed. Isotope separation techniques are summarized, emphasizing isotopic exchange reactions, electromagnetic separation, U-isotope separation, and heavy water production. Processing procedures for irradiated fuels are detailed. The

preparation and industrial and medical uses of artificial radio-nuclides are reviewed. Methods for measuring radioactivity are examined.

872 ENRICHED URANIUM HEXAFLUORIDE.

Eschnauer, H.

Atomwirtschaft, 7, 357-60 (July 1962). (In German).

Technical data on the procurement of nuclear fuels from the USA are given. The physical and chemical properties of UF_6 are described, and the preparation of the enriched fluoride is discussed. The different principles used for the isotopic separation are reviewed. Conversion of UF_6 in both aqueous and nonaqueous media is briefly described. The specifications of the enriched UF_6 supplied by the USA are given in tabular form.

873 (MLM-1140) MOUND LABORATORY PROGRESS REPORT FOR AUGUST 1962.

Grove, G.R., Jones, L.V., and Eichelberger, J.F. (Mound Lab., Miamisburg, Ohio).

Aug. 30, 1962. Contract AT(33-1)-Gen-53. 25 p.

The need for more shock resistant thermosetting plastics led to the development of glass-filled diallyl phthalate as a moulding powder. The glass-filled formulation has a greater shock resistance than the asbestos-filled plastic. The moulding characteristics of the glass-filled material were very good, but a new technique for inspection is required, since bright spots on the X-ray films from the orientation of the glass fibers appeared as high density inclusions. The effect of the initial curve temperature on Oxiron adhesives is being studied. By properly controlling the initial curve temperature, increased tensile strength at 160 °F can be obtained without imparing the flexibility of the material. When the ratio of anhydride to epoxy is too small for a satisfactory cure, increased initial cure temperatures do not cause an increase in tensile strength at 160 °F. A system to determine the thermomolecular correction for He^3 vapour pressure data is being assembled. This research is directed toward establishing an international temperature scale between 0.3 and 3.2 °K. The isotopes of B may be separated by thermal diffusion if BF_3 is used as the feed gas. Thermodynamic studies revealed that most conventional materials of construction are stable in BF_3 up to 1 000 °K. Methane is being evaluated as a feed gas to separate C^{13} by thermal diffusion. A hot-wire thermal diffusion column separates the heavy impurities in CH_4 prior to enrichment of the C^{13}. Low temperature distillation is also being evaluated as a technique to separate the impurities from CH_4. Studies on the conversion of CO to CH_4 with the activated Ni catalyst are being continued. Alternate methods to separate U isotopes are being evaluated. The reaction of UF_6 at elevated temperatures with various materials is being studied. Thermodynamic calculations indicate that Au is the only material which is stable in UF_6 at elevated temperatures. This material may be used in the design of a thermal diffusion column to separate research quantities of the U isotopes. The separation of ^{234}U from aged ^{238}Pu was demonstrated. Preliminary calculations indicate that Pu elution is not always quantitative. An agglomeration and degradation of the resin from alpha bombardment may contribute to poor eluation. Although the total capacity of the experimental resin was greatly reduced, no accurate figures are available.

874 GAS SEPARATION WITH THE MOLECULAR PUMP. I. SEPARATION FACTOR AND SEPARATION POTENTIAL OF A MOLECULAR PUMP WITH POSITION-INDEPENDENT SLIT HEIGHT.

Bœttger, O., and Pingel, H. (AEG-Forschungsinstitut, Frankfurt am Main).

Z. Angew. Phys., 15, 320-5 (April 1963). (In German).

The separation factor and separation potential of a molecular pump with constant groove height were calculated for a two-component gas mixture. Knudsen streaming was assumed. Numerical values for the separation factor and separation potential for uranium hexafluoride are given. (Tr.-author)

875 GAS SEPARATION WITH THE MOLECULAR PUMP. III. SEPARATION FACTOR AND SEPARATION POTENTIAL OF A MOLECULAR PUMP WITH SIMULTANEOUS ENRICHMENT AND IMPOVERISHMENT OF THE GAS MIXTURE INTRODUCED.

Bœttger, O., and Pingel, H. (AEG-Forschungsinstitut, Frankfurt am Main).

Z. Angew. Phys., 16, 55-8 (1963). (In German).

The separation factor and separation potential were calculated for a molecular pump in which at one slit a part of the gas mixture introduced was enriched and at the second slit the other part was impoverished. Dimensions of the pump were selected so that, in the stationary state, the composition of the gas mixture introduced was not altered at the input; it is then complementary. Since the equilibrium system appearing in the calculation cannot be explicitly resolved, only numerical solutions for UF_6 in the technically interesting range were given, in opposition to both previous works. (Tr.-author)

876 EFFICIENCY FOR AN ISOTOPE SEPARATION ELEMENT AND CORRELATION BETWEEN CHANGE IN MIXING ENTROPY AND SEPARATION POTENTIAL.

Bœttger, O., and Pingel, H. (AEG-Forschungsinstitut, Frankfurt am Main).

Atomkernenergie, 9, 107-12 (March-April 1964). (In German).

To compare various elements for isotope separation of two-component mixtures, the variation of mixing entropy caused by the separation element can be used. For isothermal processes the separation power δA_m readily follows from the variation of mixing entropy per unit time in the separating device. If in the first approximation the separation power is divided by the product of the mole fraction N and the thermal energy $\bar{R}T$ per mole; the separation power δU of the separation element is obtained. The separation power δU becomes a maximum for a maximum variation of mixing entropy. The efficiency of a separation element is given by the quotient of the separation power δA_m and the total Power δA, which the element uses for operation. Some numerical examples were calculated for the separation of uranium hexafluoride; the efficiency in these cases is of the order of 10^{-7} to 10^{-6}. When using separation elements as parts of a cascade, the power consumption of a separation element is independent of the mole fraction N and the stage of the cascade, whereas the change of value described by the variation of mixing entropy depends on the concentration N. (Author)

877 CHEMICAL PROCESSING IN THE ATOMIC ENERGY INDUSTRY.

Cooper, A.R.

London, Iliffe Books Ltd., 1964, 169 p., 38s 6d.

Techniques for processing reactor materials are reviewed; and the extraction and properties of Pu, U, Th, Zr, Be, Nb, and graphite are described individually. Methods for reprocessing several kinds of fuels are also considered, together with isotope separation techniques and techniques for production of D_2O and enriched U.

878 ION EXCHANGE AND OTHER METHODS FOR ISOTOPE SEPARATION.

Roth, E.

Bull. Inform. Sci. Tech. (Paris), No. 85, 97-100 (July-Aug. 1964). (In French).

The chemical and physical methods used for the isotopic separation of rare gases, ^{3}He, ^{6}Li, Cl, ^{18}O, ^{34}S, ^{15}N, ^{13}C, ^{10}B, Hg, D, and ^{235}U are tabulated.

879 ISOTOPE SEPARATION, THE FINAL STEP IN RAW MATERIAL PRODUCTION FOR NUCLEAR TECHNOLOGY.

Murrenhoff, A.P. (Kernforschungsanlage, Julich, Ger.).

Kerntechnik, 6, 553-4 (Dec. 1964). (In German).

The function of isotope separation in the nuclear technology and general points regarding the suitability of isotope separation processes for different separation problems are discussed. (Author)

880 (EUR-2271.f) RÉPERTOIRE DES INSTALLATIONS NUCLÉAIRES DE LA COMMUNAUTÉ EUROPÉENNE DE L'ÉNERGIE ATOMIQUE. TROISIÈME ÉDITION (NUCLEAR INSTALLATIONS IN THE COUNTRIES OF THE EUROPEAN ATOMIC ENERGY COMMUNITY. THIRD EDITION).

(European Atomic Energy Community).

Jan. 1, 1965, 102 p. Dep. (mn).

A survey is given of nuclear installations which already exist, which are under construction, whose construction has been decided, or which are being planned in the member countries of Euratom. For each installation, a short description of its main characteristics is presented, and the more important enterprises known to have participated in the building of these installations are mentioned. (Author) (See 856)

881 URANIUM RESERVES AND FUEL ELEMENTS. REPORTS OF SECTIONS 1A AND 1B OF THE FORATOM CONGRESS.

Beisswenger, H. (Kernforschungszentrum, Karlsruhe, Ger.).

Atomwirtschaft, 10, 662-4 (Dec. 1965). (In German).

No acute lack of nuclear fuel materials is expected, however, West Europe is dependent on imports so long as no improved fuel element utilization and breeding with plutonium is developed. Increases in the capacity of processing installations are considered. (Tr.-author)

882 SECOND FORATOM CONGRESS. FUEL ELEMENTS.

Boettcher, A. (Établissement de Recherche Nucléaire, Jülich, Ger.).

Bull. Inform. ATEN (Ass. Tech. Énerg. Nucl.), No. 57, 17-28 (Jan.-Feb. 1966). (In French).

The effects of the American purposes concerning private ownership and toll enrichment are reviewed. The capacities of existing installations and those under construction for the transformation of fissile material into fuel elements are summarized. A survey is made of the retreatment capacity for irradiated fuels in installations in operation or under design. The effects of fuel cycle factors are discussed.

883 PIERRELATTE — USINE DE SÉPARATION DES ISOTOPES DE L'URANIUM (PIERRELATTE—PLANT FOR SEPARATION OF URANIUM ISOTOPES).

Commissariat à l'Energie Atomique, Paris, 1964, 38 p.

The design and development of the Pierrelatte Isotope Separation Plant is described. The isotopic enrichment processes used are electromagnetic separation, thermal diffusion, centrifugation, expansion in a shock tube, and gaseous diffusion. The principle of each of these methods is described briefly. The characteristics of the plant are given.

884 (K-Trans-17) REVIEW OF ISOTOPE SEPARATION RESEARCH IN JAPAN.

Report of the Special Committee on Isotope Separation.

Translated for Oak Ridge Gaseous Diffusion Plant, Tenn., from Nippon Genshiryoku Gakkaishi, 7, 429-37 (1965), 24 p. Dep. mn. JCL $2.60 (fs), $0.92 (mf).

Research on isotope separation in Japan is reported. Summaries are given for studies on: methods for isotope separation; heavy hydrogen separation with Pd membrane; concentration of ^{13}C by thermal diffusion of methane; separation of lithium isotopes by molecular distillation of lithium metal; theory of isotope separation; electrophoretic separations; effects of a-c on separation of nitrogen and uranium isotopes; separation and concentration of isotopes by electrophoresis of fused salts; isotopic exchange equilibrium constant for ammonia-ammonium ion system; relation between isotopic ratio and chemical form of antimony during neutron irradiation; and separation of K, Ar, N, B, U isotopes.

885 ATOMIC ENERGY DEVELOPMENTS AND FUTURE URANIUM REQUIREMENTS AS ENVISAGED AT THE THIRD INTERNATIONAL UNITED NATIONS CONFERENCE ON THE PEACEFUL USES OF ATOMIC ENERGY, GENEVA, SEPTEMBER 1964.

Roscoe, S.M.

Ottawa, Queen's Printer, 1965, 17 p. $0.35.

Expansion of the demand for uranium to fuel new thermal power plants is expected not only to restore a rapid rate of extraction of Canada's large known uranium ore reserves within ten years but to present opportunities to exploit deposits as yet not discovered or deposits considered below ore grade at current uranium price levels. Demand for uranium as reactor fuel in projected power plants for the rest of the 20th century is surveyed in detail along with other applications of atomic energy. Other matters incidental to the nuclear industry such as isotope separation and safety are discussed.

886 ENRICHMENT TESTER FOR 0.15 TO 3.0 WEIGHT PERCENT ^{235}U URANIUM FUEL.

Jackson, C.N.Jr. (Battelle-Northwest, Richland, Wash.).

Contract AT(45-1)-1830. Mater. Eval., 24, 431-5 (Aug. 1966).

A combination single channel analyzer and gamma scintillation system was developed to measure enrichment of ^{235}U in metallic U. The technique uses a unique characteristic of the gamma decay of ^{235}U and ^{238}U to obtain a net activity proportional to the concentration of ^{235}U. This technique is independent of daughter equilibrium buildup products in U that is older than 60 days from the date of the last chemical separation. The tester is routinely used at Hanford to perform a rapid, non-destructive identification of reactor fuels with 0.72, 0.95, 1.25, 1.6 and 1.95 wt% enrichments. The capability of the tester was demonstrated for a range from 0.15 to 3.0 wt% enrichment. It has an approximate accuracy of a 0.1% in equivalent enrichment level using a two-min counting period. Laboratory investigations of specimen geometry, cladding thickness, and other factors were conducted to obtain design data for developing the tester. The use, calibration, and performance of the tester for routine enrichment measurement are described. (Author)

887 CHEMICAL RESEARCH AT THE SWEDISH ATOMIC ENERGY COMPANY.

Svenke, E. (Aktiebolaget Atomenergi, Stockholm).

Svensk Kem. Tidskr., 79, No. 2, 89-93 (1967). (In Swedish).

A survey is given of facilities and research in nuclear sciences in the company. Development of equipment, facilities, methods, and procedures for research in radioactive environments, processing techniques and radiation sources, rare construction materials for nuclear applications, and transportation equipment for radioactive materials was continued. Research on activation analysis, corrosion, fuel reprocessing, heavy water production, isotope production and technology, prospecting of uranium deposits, radiation chemistry, transuranium chemistry, uranium production and enrichment, and waste handling was the basic activity.

888 ISOTOPE SEPARATION.

Holmberg, K.E. (Aktiebolaget Atomenergi, Stockholm).

Svensk Kem. Tidskr., 79, No. 2, 131-5 (1967). (In Swedish).

A survey of research and development on hydrogen and uranium isotope separation supported and achieved by the Swedish Atomic Energy Company is given. Exchange distillation was used for separation of boron isotopes. Different separation processes and isotopic systems were investigated. Research on separation effects for hydrogen isotopes, on formation of vapor or ice from salt solutions, and solubility of salts in heavy water are continued.

889 (NP-16984) ESTUDIO DE PREINVERSION: CENTRAL NUCLEAR PARA LA ZONA DEL GRAN BUENOS AIRES-LITORAL. IV. ANEXOS AL CAPITULO 5. ANEXO 5B. POSIBLE CONTRIBUCION DE LA INDUSTRIA NACIONAL A LA CONSTRUCCION Y OPERACION DE LA CENTRAL NUCLEAR BUENOS AIRES. ANEXO 5C. RECURSOS Y PRODUCCION DE URANIO. ANEXO 5D. URANIO ENRIQUECIDO. ANEXO 5E. PRODUCCION DE GRAFITO Y AGUA PESADA EN LA REPUBLICA ARGENTINA. ANEXO 5F. SEGURIDAD DE REACTORES DE POTENCIA (PRELIMINARY INVESTMENT STUDIES: NUCLEAR POWER PLANTS OF THE BUENOS AIRES REGION AND COASTAL ZONE. IV. APPENDIX TO CHAPTER 5. 5B. POSSIBLE CONTRIBUTION OF THE NATIONAL INDUSTRY IN CONSTRUCTION AND OPERATION OF BUENOS AIRES POWER PLANTS. 5C. URANIUM PRODUCTION RESOURCES. 5D. ENRICHMENT OF URANIUM. 5E. PRODUCTION OF GRAPHITE AND HEAVY WATER IN THE REPUBLIC OF ARGENTINA. 5F. REACTOR POWER AND PROTECTION).

(Comision Nacional de Energia Atomica, Buenos Aires, Argentina).

1965, 165 p. (In Spanish). Dep.

The possible contribution of Argentine industry to the design, construction, and manufacture of electromechanical components, construction of turbo-alternator, and production of fuel elements and control rods is analyzed. U resources and production in Argentina are considered. The capacity for the preparation of U concentrates and refined products is evaluated. The production costs are estimated. The procuring of enriched U, both from domestic and foreign sources, is discussed. The capacity for the production of graphite of nuclear purity and heavy water in Argentina is evaluated.

890 (CEA-N-616, pp.86-96) TRAITEMENT DE L'URANIUM (PROCESSING URANIUM).

(Commissariat à l'Énergie Atomique, Fontenay-aux-Roses, France. Centre d'Études Nucléaires).

(In French).

Developments are reported for studies on: processing uranium minerals; processing enriched uranium; new methods for processing uranium; and prototypes of apparatus and ensembles of chemical engineering for uranium processing.

891 (CEA-N-816, pp.80-9) TRAITEMENT DE L'URANIUM (PROCESSING URANIUM).

(Commissariat à l'Énergie Atomique, Fontenay-aux-Roses, France. Centre d'Études Nucléaires).

(In French).

Developments are reported for studies on: use of bacteria for treating ores; treatment of enriched uranium; and new techniques for treatment of uranium.

892 URANIUM ENRICHMENT: METHODS AND PLANTS.

Casa, A.F.

Com. Naz. Energ. Nucl., Notiz., 14, No. 6, 49-56 (June 1968). (In Italian).

A comprehensive review is presented of the principal methods used and major plants for uranium enrichment in operation or planned. (Author)

893 URANIUM: THE WAY TO PRIVATE ENRICHMENT.

Edelson, E.

New Sci., 39, 380-1 (Aug. 22, 1968).

The one function in the US nuclear power industry that has not yet been handed over to private enterprise is the enrichment of uranium. There is now a strong demand for such a move. (Author)

894 THE NUCLEAR INDUSTRY.

Washington, D.C.

Atomic Energy Commission, 1968, 267 p. GPO $2.00.

Progress in the peaceful applications of nuclear energy during 1968 is summarized. The nuclear industry highlights which are discussed include: civilian nuclear power; private ownership of nuclear material; enrichment; safeguards; radioisotopes; Plow-share; spin-off; licensing and regulation; legal aspects; and international activities. Extensive charts and tables are included.

895 USE OF FUELS IN UKAEA FOR NUCLEAR ENERGY.

Manning, R.B.

Elektrotech. Maschinenbau, 85, 252-4 (May 1968). (In German).

Uranium enrichment and preparation in the UKAEA are discussed. Fuel element production is described.

896 A REPORT OF THE SURVEY ON SPECIAL ELEMENTS.

Kagaku Gijutsu-cho Shigen Chosa-kai Hokoku, No. 44, 122-5, 153-67, 256-63 (Jan. 1968). (In Japanese).

A survey of special elements including thorium, titanium, and uranium is described. Domestic nuclear fuels and other materials are also described. For the former, the survey indicates minerals, producing areas, consumption, exports, imports, and Japanese production uses, enterprises, and customs duty. Also included in the survey are uranium fuels, nuclear fuel cycles, uranium enrichment, fuel fabrication, research and development on power reactor fuels, uses of domestic fuels, fabrication of cladding, and fuel reprocessing.

897 LONG RANGE PLANS FOR URANIUM ENRICHMENT.

Com. Naz. Energ. Nucl., Notiz., 15, 89-99 (May 1969). (In Italian).

The full text of the Euratom Report on Uranium Enrichment in Europe is given. (Author)

898 MATERIALE NUCLEARE (NUCLEAR MATERIAL).

Maxim, I.V.

Bucuresti, Editura Academiei Republicii Socialiste Romania, 1969, 443 p. 30 lei.

Detailed data are given on the management, disposal, and processing of radioactive waste. Practices in the treatment of low- and intermediate-level radioactive waste, fuel processing, ground storage of high-level radioactive waste, solidification, and disposal into the sea are discussed. Tables of materials are given considering uranium mineral concentration and enrichment of uranium in ^{235}U. Preparation, properties, and structure of thorium, plutonium, beryllium, and zirconium are described. The structure and properties of liquid fuels, moderator and coolant materials, ceramics, and shielding materials are evaluated.

899 (NP-17955) NATIONAL COMMISSION ON NUCLEAR ENERGY.

Tacar, Pulat (Atomic Energy Commission, Ankara, Turkey). 1969, 134 p. (In Turkish). Dep.

After a brief introduction to production and enrichment processes for uranium and plutonium, the subject of control is introduced by discussing methods of sealing, inspection, tracing and sampling. The control system instituted by the International Atomic Energy Agency is discussed in detail. The items to be controlled are clarified, and the points at which control starts and ends are spelled out. The selection, appointment, and dispatching of inspectors are discussed. Control of nuclear materials by the European Nuclear Energy Agency (ENEA) is discussed in a separate section. The methods of inspection and legal implications are considered. Documents for the IAEA control system (Information Circ/66/1) are appended. Copies of the IAEA inspector's report, and a Turkish deposition on the subject of nuclear energy control are also presented.

900 ATOMIC ENERGY WHITE PAPER, THE 1969 EDITION.

Genshiryoku Hakusho, No. 13, 205 p. (Aug. 1969). (In Japanese).

Atomic energy activities in Japan during 1968 are described. Topics described include: development of power reactors, the start of construction of the first nuclear-powered ship "Mutsu", advances in the fields of uranium enrichment, food irradiation, nuclear fusion, and the advanced international co-operation, especially between the U.S., U.K., and Japan.

901 FUELS.

Gauthron, M.

pp. 1-26 of Génie Atomique, Tome II. Institut National des Sciences et Techniques Nucléaires, Saclay, France.

Presses Universitaires de France, Paris, 1968. (In French).

The uranium-thorium fuel cycle is briefly outlined. The three primary steps in the processing of nuclear fuels in this cycle are the extraction of uranium from the ore, processing of the irradiated fuel and the extraction of Pu, and the isotopic separation of ^{235}U. Each of these is described. The physical and chemical properties of U, Pu, and Th and the behaviour of these metals and their most important alloys and compounds in a reactor are described.

902 WORKING CONCEPT OF ISOTOPIC SEPARATION (ACCORDING TO THE AMERICAN REPORT ORO-658).

Blum, J.M.

Bull. Inform. ATEN (Ass. Tech. Énerg. Nucl.), No. 76, 26-9 (March-April 1969). (In French).

The quantity of natural uranium necessary to give a given enrichment and the separation work necessary are calculated and the results are tabulated.

903 VALUE FUNCTION FOR MULTICOMPONENT ISOTOPE SEPARATION.

Lehrer-Ilamed, Y. (Israel Atomic Energy Commission, Tel-Aviv).

pp. 39-54 of Problemi della Separazione Isotopica dell'Uranio. Comitato Nazionale Energia Nucleare, Roma, 1968.

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy. See CONF-681015.

A method is described for calculating an infinite set of linearly independent solutions of the equation $\Omega\vec{V}(\vec{N}) = H$ where $\vec{V}(\vec{N})$ denotes the value of one mole of material composition and $H = \delta u/L$ = constant where δu is the separative power and L denotes the flow of L moles per second. Ω is the operator.

904 THEORY OF ISOTOPE SEPARATION ON A THERMODYNAMIC BASIS.

Basso, G. (CNEN, Rome).

pp. 55-72 of Problemi della Separazione Isotopica dell'Uranio. Comitato Nazionale Energia Nucleare, Roma, 1968. (In Italian).

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy. See CONF-681015.

A new thermodynamic-based theory of isotope separation was developed which responds to the following criteria. It is valid both for gases and liquids, as well as for gas liquid mixtures, it takes into consideration the irreversibility of the phase transformation due to the internal friction of the fluids, and the final formula does not contain correction factors of an empirical nature. Initial studies showed that in order to interpret the motion of a fluid it is necessary to take into consideration the integral characteristics of the system, both geometric and thermodynamic. The theory developed gives the solution as a function of the thermodynamic irreversibility of the outflow.

905 THE FUEL CYCLE: PLANNING AND PROGRAMMING BY THE CNEN.

Salvetti, Carlo (CNEN, Rome).

Com. Naz. Energ. Nucl., Notiz., 15, No. 1, 21-6 (Jan. 1969). (In Italian).

The individual components of the production of fuel elements by the CNEN are briefly described. These steps include procurement of the uranium, conversion of the ores into uranium, isotopic enrichment, design and fabrication of fuel elements, and reprocessing of the spent fuel.

906 NUCLEAR MATERIALS MANAGEMENT: WHERE DO WE STAND.

Ramey, J.T. (Atomic Energy Commission, Washington, D.C.).

pp. 215-30 of Proceedings of the Tenth Annual Meeting of the Institute of Nuclear Materials Management, Las Vegas, Nevada, April 28-30, 1969. Columbus, Ohio, Institute of Nuclear Materials Management, 1969. See CONF-690411.

The status of methods and safeguards used in nuclear materials management in the US is discussed briefly with emphasis on the roles of government and industry in nuclear materials management, growing uses of nuclear materials, and special problems involving uranium enrichment.

907 FUEL SERVICES FOR MEDIUM SIZED REACTORS.

Spencer, P.H. (United Kingdom Atomic Energy Authority, Risley, Eng.).

pp. 8.1-8.9 of Proceedings of Symposium on Medium Sized (200-450 MW) Nuclear Power Stations, Belfast, Oct. 2-4, 1968. Belfast, The Queen's University of Belfast [1969]. See CONF-681075.

The fuel services of the UKAEA are described in terms of the fuel cycle. The stages considered are purification and conversion of uranium ore to hexafluoride, enrichment, conversion to UO_2 and fabrication into fuel, provision of fuel designs, management schemes and guarantees, reprocessing, utilization or sale of recovered plutonium, transportation, and optimization work.

908 FUEL CYCLE.

Nucl. News, 13, 38-42 (Jan. 1970).

The production, conversion capacity, and enrichment of U are discussed. The enrichment plants in the US will remain a government monopoly for the present. A complete industry capability exists to produce all types of fuel elements that have been used or are being considered. Enriched U was sent to foreign countries in the form of UF_6, but it is expected that soon all enriched U will be fabricated abroad. Utilities are expected to plan the recycle, sale, or storage of their plutonium. The utility actions transacted during 1969 were discussed concerning spent fuel reprocessing. Development of waste handling and management undertaken by nuclear companies is also discussed.

909 PRESENT STATE OF URANIUM ENRICHMENT.

Kawamo Keishiro (Science and Tech. Agency, Tokyo).

Shin Kinzoku Kogyo, 14, 333-5 (Dec. 1969). (In Japanese).

The state of uranium enrichment is described. The background for the emergence of the problem of uranium enrichment, the promising future of atomic power generation, increase in the demand of enriched uranium, the transfer of enrichment service to private firms in the U S, trend in European countries, and atomic power generation in Japan are considered. Significance of research and development

on uranium enrichment, the future demand of enriched uranium, and the necessity for the research and development on uranium enrichment are discussed.

910 DIFFICULTIES IN INTERNATIONAL CO-OPERATION ON URANIUM ISOTOPIC SEPARATION.

Com. Naz. Energ. Nucl., Notiz., 16, No. 5, 78-85 (May 1970). (In Italian).

The full text of an article outlining the history of the attempts made, from the earliest days of the nuclear era to the present, in the area of international co-operation on the isotopic separation of uranium is presented. (Author)

911 (CONF-700903-15) DEMAND OF URANIUM ENRICHMENT SERVICES FOR SWEDEN'S NUCLEAR POWER PROGRAM, 1975-1985.

Almgren, B. (Oskarshamnsverkets Kraftgrupp A.B., Stockholm, Sweden); Edman, R. (Statens Vattenfallsverk, Stockholm, Sweden).

May 1970, 3 p. Dep. NTIS (U. S. Sales Only).

From 4. Foratom Congress on industrial aspects of the nuclear fuel cycle in Europe; Stockholm, Sweden (Sept. 21, 1970).

The Swedish nuclear power program is briefly described. The separative work demand is estimated to be 600 000 kg in 1975, 1 300 000 kg in 1980, and 2 200 000 kg in 1985. It is stated that this demand for enrichment services is far too small for a diffusion plant of economic size in Sweden. A centrifuge plant could possibly be built in 1980's. (Sweden)

912 URANIUM ENRICHMENT ACTIVITIES IN ITALY.

Com. Naz. Energ. Nucl., Notiz., 16, No. 10, 60-2 (Oct. 1970). (In Italian). (CONF-700903-9).

From fourth Foratom Congress on Industrial Aspects of the Nuclear Fuel Cycle in Europe, Stockholm, Sweden (Sept. 21, 1970).

The enrichment activities by the CNEN and industry in Italy are briefly summarized.

913 CHEMICAL ENGINEERING ASPECTS OF NUCLEAR POWER.

Benedict, M., Pigford, T.H. (Nuclear Chemical Engineering). New York: McGraw-Hill (1957), S. 1-19, 14 Fig., 2 Tab.

Im Einführungskapitel dieses Buches wird eine kurze Übersicht über die als Kernbrennstoff, Moderator, Kühlmittel etc. im Reaktor verwandten Materialien gegeben. Die Spaltbarkeit gewisser Kerne durch langsame Neutronen wird am Beispiel des U-235 erläutert. Die Aufarbeitung und Gewinnung der verschiedenen Arten von Kernbrennstoffen wird an mehreren schematischen Fließbildern gezeigt. Eine genauere Beschreibung der Trennungs- und Anreicherungsverfahren erfolgt jedoch erst in den folgenden Kapiteln.

914 SIMPOSIO SUI PROBLEMI CONCERNENTI LA SEPARAZIONE ISOTOPICA DELL'URANIO.

Rostagni, A.

Ing. Nucl., 9 (1968), No. 5, pp. 5-9.

Torino 1-2 ottobre 1968 — corso di 4 sessioni affidate al Prof. P. Caldirola, al Dr. C. Frejacques, al Dr. M. Bogaard't e al Dr. Manson Benedict — Vari aspetti del problema e le indicazioni tecniche sui vari sistemi di separazione isotopica applicati o in via di sperimentazione.

915 LES PERSPECTIVES DE DÉVELOPPEMENT DES CENTRALES NUCLÉAIRES EN FRANCE.

Én. Nucl., 11 (1969), No. 1, pp. 7-16.

Éléments de décision concernant le cinquième plan — le développement de la filière à eau ordinaire — le développement de la filière uranium naturel — graphite — gaz — la technique AGR — le développement de la filière — eau lourde — l'enrichissement de l'uranium — l'acquisition des connaissances et l'amélioration des techniques.

916 PNC RESEARCH AND DEVELOPMENT.

Inouye, G.

Nucl. Engng. Int., 14 (1969), No. 156, pp. 406-410.

Fast breeder reactors — advanced thermal reactors — construction of research facilities — fuel development — enrichment of uranium — fuel inspection technology — manufacture of uranium metal — plutonium fuel — reprocessing of spent fuel — prospect and development of uranium resources.

917 NUCLEAR FUEL CYCLE FOR JAPAN.

Imai, R.

Nucl. Engng. Int., 14 (1969), No. 156, pp. 410-13.

Uranium resources — enrichment — BWR fuel assembly for JPDR — fuel fabrication — loading of JPDR assembly —

irradiated fuel — Mihama No. 1 PWR fuel assembly being manufactured by Mapi Omiya fuel shop — plutonium utilization.

918 THE ATOMIC INDUSTRY.

Astashenkov, P.T. (Naval Intelligence Command, Washington, D.C. Translation Div.).

July 22, 1968, 227 p. Rep. No. NIC-Trans-2653.

Trans of mono Atomnaya Promyshlennost, Moscow, 1956, 237 p.

Descriptors: (*Nuclear energy, Textbooks), Nuclear industrial applications, Fission, Thermonuclear reactions, Uranium, Isotope separation, USSR, Industries.

Identifiers: Translations.

In the USSR a leading atomic industry has been created and is developing successfully. This branch of production also exists in other countries of the world. In this book an attempt has been made using the materials which have been published in the Soviet and foreign press and on the basis of the achievements of Soviet and foreign technology to give an account in popular form of the most important aspects of the production picture of a modern atomic industry. (Author)
AD-674 339.

919 REMARQUES PRÉSENTÉES AU DEUXIÈME CONGRÈS DE FORATOM SUR LE CYCLE EUROPÉEN DES COMBUSTIBLES NUCLÉAIRES EN 1980.

Mabile, M.J. (CEA, Paris).

Bull. Inform. ATEN, Fr., No. 56, 5-7 (1965).

Étude de la politique des combustibles nucléaires à long terme. Choix des filières de réacteurs. Problèmes de l'enrichissement de l'U et du traitement des combustibles irradiés.

920 ENRICHISSEMENT EN URANIUM DANS LES PROBLEMES DE COMBUSTIBLE.

Oyama, Y.
J. atom. Energy Soc. Jap., 9, No. 3, 146-9 (1967). (En japonais).

921 DÉVELOPPEMENT DE LA TECHNOLOGIE D'ENRICHISSEMENT DE L'URANIUM AU JAPON.

Yoshimura, K.

J. atom. Energy Soc. Jap., 9, No. 3, 152-5 (1967). (En japonais).

922 TORONTO CONVENTION. A REPORT ON THE JOINT ANNUAL MEETINGS OF THE CANADIAN NUCLEAR ASSOCIATION AND THE AMERICAN NUCLEAR SOCIETY HELD IN TORONTO FROM 9-13 JUNE.

Nucl. Engng, G.B., 13, No. 147, 672-5 (1968).

Situation de l'U. Position du Pu. Enrichissement de l'U. Th dans les réacteurs rapides. Politique canadienne de la science nucléaire. Projet d'un AGR en Amérique.

923 LE RAPPORT PÉON. LES PERSPECTIVES DE DÉVELOPPEMENT DES CENTRALES NUCLÉAIRES EN FRANCE.

Rev. fr. Energ., 20, No. 206, 111-21 (1968).

Rapport établi par la Commission Consultative pour la Production d'Électricité d'Origine Nucléaire (PEON). Éléments de décision concernant le 5e Plan et développement des différentes filières : filière à eau ordinaire, filière uranium naturel-graphite-gaz, filière uranium enrichi-graphite-gaz (AGR), filière à eau lourde; on traite de l'enrichissement de l'uranium; on évoque l'amélioration des techniques pour les différentes filières. On termine par des conclusions concernant le 5e Plan et les perspectives du 6e Plan.

924 ISOTOPIC SEPARATION OF URANIUM.

Nucl. Engng internation., GB, 13, No. 151, 1036-9 (1968).

Compte rendu de la réunion technique internationale sur la séparation isotopique de l'U qui s'est tenue les 1-2 octobre 1968 à Turin.

925 RAPPORT DE LA COMMISSION CONSULTATIVE POUR LA PRODUCTION D'ÉLECTRICITÉ D'ORIGINE NUCLÉAIRE SUR LES PERSPECTIVES DE DÉVELOPPEMENT DES CENTRALES NUCLÉAIRES EN FRANCE, AVRIL 1968.

Bull. Inform. ATEN, Fr., No. 74, 5-34 (1968).

Exposé des travaux de la Commission. Éléments de décision concernant le 5e Plan : le développement de la filière à eau ordinaire, le développement de la filière U naturel-graphite-gaz, la technique AGR, l'enrichissement de l'U, l'acquisition des connaissances et l'amélioration des techniques. Conclusions concernant les 5e et 6e Plans.

926 FAST 1968 NUCLEAR ENERGY SYMPOSIUM. NUCLEAR FUEL UTILIZATION.

Nucl. Engng internation., G.B., 14, No. 153, 97-9 (1969).

Symposium tenu à la Fédération des Associations scientifiques et techniques (FAST), Milan, 12-14 décembre. 4 ses-

sions : stratégie des combustibles nucléaires, disponibilités en U, problèmes d'enrichissement, emploi du Pu et U^{233} dans les réacteurs thermiques.

927 IL CICLO DEL COMBUSTIBILE : REALIZZAZIONI E PROGRAMMI DEL CNEN (CYCLE DU COMBUSTIBLE : RÉALISATIONS ET PROGRAMMES DU CNEN).

Salvetti, C.

Energ. nucl., Ital., 16, No. 3, 166-70 (1969).

Actions proposées pour assurer à l'Italie la fourniture d'U. Procédé chimique pour le convertir en métal ou oxyde. Études sur l'enrichissement de l'U. Méthodes de calcul pour les éléments combustibles et technologie de fabrication. Réalisation d'installations prototypes pour le retraitement des combustibles irradiés.

928 REPROCESSING AS PART OF THE FUEL CYCLE.

Leclercq-Aubreton, M.Y., Rometsch, R.

Nouv. Tech., Suisse, 11, No. 1, 42-8 (1969).

Développement de l'énergie atomique en Europe jusqu'en 1985. Approvisionnement en U et enrichissement de l'U. Manufacture des éléments combustibles. Transport des éléments combustibles irradiés et des matériaux fissiles. Conversions chimiques. Besoins de retraitement en Europe. Coût du retraitement en fonction de la capacité de l'usine.

929 I. NUCLEAR POWER SUPPLY INDUSTRY.

Nucl. News, USA, 12, No. 1, 21-37 (1969).

Le cycle du combustible. Besoins d'U. Réserves d'U. Exploitation des gisements. Conversion d'U_3O_8 en UF_6. Enrichissement. Fabrication du combustible. Gainage de Zr. Retraitement.

930 NUCLEAR POWER IN THE USA-1968.

Bull. Belgicatom, Belg., 14, No. 1, 10-11 (1969).

Nombre et puissance des centrales commandées en 1968; comparaison avec 1966 et 1967. Prospection de l'U. Enrichissement de l'U. Projet Gasbuggy. État des centrales au 31 décembre 1968.

931 LA NUOVA POLITICA DELL'ENERGIA NUCLEARE IN FRANCIA (LA NOUVELLE POLITIQUE DE L'ÉNERGIE NUCLÉAIRE EN FRANCE).

Comit. nazion. Energ. nucl., Notiz., Ital., 16, No. 1, 55-8 (1970).

Réalisation de grandes centrales à U enrichi.

932 NÉCESSITÉ ET POSSIBILITÉ DE NOUVELLES TECHNIQUES DE PRODUCTION DE U^{235}.

Kakihana, H.

J. atom. Energy Soc. Jap., 9, No. 3, 155-8 (1967). (En japonais).

10. ECONOMICAL ASPECTS

933 INDUSTRIAL ASPECTS OF THE FUEL CYCLE IN THE EUROPEAN COMMUNITY.

Fernet, P.

Neue Tech. (Switzerland), Vol. 9, No. B6, 223-30 (Dec. 1967). (In French).

The paper is concerned with the effect of nuclear power on European industry. The economic, technological and industrial factors are all discussed. The whole nuclear power process is dealt with under the headings of extraction of natural uranium, enrichment of uranium, fabrication of fuel elements, behaviour in the reactor core, recovery and treatment after irradiation, and finally, disposal of waste products.

934 GROWTH OF FOREIGN NUCLEAR POWER.

Arthur D. Little, Inc. (United States Atomic Energy Commission).

Rep. to USAEC, TID-22973, (April 1966).

In commissioning this study, USAEC was interested in forecasting demand for enriched uranium in order to plan operation of its enrichment facilities. Examines estimates, by nations, of overall energy requirements, prices for fuels, and the power station market to be captured by nuclear power. The principal economic and social factors underlying nuclear, fossil, and hydro-electric alternatives are discussed. A study is made of capital and operating cost projections for types of nuclear reactors likely to be utilised to 1980.

935 THE EFFECTS OF AN EXPANDING NUCLEAR POWER PROGRAMME ON THE PRODUCTION OF NUCLEAR FUELS IN THE UNITED KINGDOM.

Hill, J.M.

World Power Conf., Sect. Meeting, Tokyo, Section 11B, Pap. 103, Oct. 1966.

A review is given of the programme of reactor development and nuclear power station construction in the UK with particular reference to the associated fuel cycle. In the programme complementary reactor systems are introduced progressively; the supporting fuel service is discussed with reference to the work at Springfields, Capenhurst and Windscale. These factories are operated as an integrated unit, supplying natural uranium fuel elements, uranium enrichment, enriched uranium fuel elements, and plutonium/uranium fuel elements, and also recovery of plutonium and uranium from irradiated fuels. Some generation costs figures are included.

936 COMMISSION OUTLINES STEPS TO COMMON ENERGY POLICY.

Anon.

European Comm., 2, 16-18 (Feb. 1969).

Circumstances that retard an EEC common energy policy are surveyed. Proposals are advocated to ensure that: decisions taken conform to policy, therefore forecasts and guidelines are required; Rome Treaty provisions for a free market are met; and cheap and stable energy supplies by coordinating programmes for oil, gas and nuclear development and energy imports. Proposals for improving structure of the energy sector include a Community isotope separation plant for enriched U and encouraging research.

937 URANIUM NATUREL OU URANIUM ENRICHI (NATURAL OR ENRICHED URANIUM).

Léo, B. (Electricité de France, 75 - Paris. Direction de l'Equipement).

Revue Générale de l'Electricité (F.), Vol. 43, No. 228, pp. 28-33. (En français).

On essaye de donner un aperçu des éléments qui déterminent, pour la France, les choix à faire, sous le triple aspect technique, économique et politique.

938 (CF-49-4-236) MATERIALS TESTING REACTOR; ESTIMATED CAPITAL AND OPERATING COSTS OF PROJECT.

McLain, S. (Oak Ridge National Lab., Tenn.).

April 26, 1949. Decl. Feb. 7, 1957. 11 p. Contract [W-7405-eng-26]. $3.30 (ph OTS); $2.40 (mf OTS).

An estimate is given of the capital and operating costs of the Materials Testing Reactor, its associated facilities, the ^{235}U separation plant, and the Metal Fabrication Plant.

939 ENRICHED OR NATURAL URANIUM.

Lewis, W.B. (Atomic Energy of Canada Ltd).

Nuclear Power, 2, 340-1 (Aug. 1957).

The economic aspects of the natural U v. enriched U question are discussed.

940 PRICING ENRICHED URANIUM.

Hollister, H.L., and Burington, A.J. (U. S. Atomic Energy Commission, Washington).

Nucleonics, 16, No. 1, 54-7 (Jan. 1958).

An analysis of separation-plant economics yields the published U price scale, explains how to calculate equivalent amounts of U at different enrichment and leads to a simple method for estimating reactor fuel burnup cost. (Author)

941 BLENDING V. RE-ENRICHMENT FOR SLIGHTLY ENRICHED URANIUM.

Presented at Nuclear Engineering and Science Conference, held at Chicago, March 17 to 21, 1958. Preprint 2, Session 18.

Kallman, D., and Brennan, J.E. (Babcock and Wilcox Co., New York).

American Institute of Chemical Engineers, 1958, 11 p.

The economic aspects of blending irradiated fuels with highly enriched uranium and the reenrichment of irradiated, but decontaminated, uranium to obtain slightly enriched uranium fuels are considered. It is concluded that blending with highly enriched uranium may be permanently practiced in place of re-enrichment at the diffusion plant because the difference in cost may be small and the flexibility greater.

942 BLENDING VERSUS RE-ENRICHMENT.

Kallman, D., and Brennan, J.E. (Babcock and Wilcox Co., New York).

Nucleonics, 16, No. 7, 101 (July 1958).

Burned-out fuel from a slightly enriched reactor can either be returned to the diffusion plant to be re-enriched or it can be blended with highly enriched U to obtain the desired enrichment. A cost analysis, using the A.E.C.'s enriched U price scale, shows that blending is slightly more expensive than re-enrichment. However, the advantages of using partially decontaminated spent fuel are likely to cause blending to be preferred.

943 URANIUM.
1. THE CASE FOR ENRICHED URANIUM.
2. THE CASE FOR NATURAL URANIUM.
3. URANIUM ALLOYS AND DISPERSIONS.
4. URANIUM OXIDE EXPERIENCE.

Starr C. (Atomics International, Canoga Park, Calif.).

Menke, J.R. (Nuclear Development Corp. of America, White Plains, N.Y.).

Noland, R.A., Schumar, J.F., and Kittel, J.H. (Argonne National Lab., Lemont, Ill.).

Danko, J.C. (Westinghouse Electric Corp., Pittsburgh).

Nucleonics, 16, No. 8, 86-90, 95 (Aug. 1958).

The advantages of the use of enriched uranium, natural uranium, uranium alloys and dispersions, and uranium oxides are discussed in four separate sections. The principal reason for the use of enriched uranium is the consistent indication that this fuel will cost less. Its main disadvantages are the higher basic fuel cost and the necessity for isotope separation plants and chemical reprocessing facilities. The chief advantage of natural uranium fuel is that reactors using it are operable on a universally available fuel. The disadvantage are the cost of the heavy water and the fact that heavy water reactors tend to be larger in size. As a nuclear material, unalloyed uranium has the disadvantage of extensive anisotropic dimensional changes and surface roughening under irradiation. Alloys which are highly effective when combined with suitable heat treatment and/or fabrication techniques are described. Uranium oxide, because of its physical properties and excellent resistance to radiation damage, can be used in reactors operating at low, intermediate, and high temperatures. UO_2 fabrication, physical properties, radiation damage, and fuel-element fabrication are discussed.

944 (A/CONF.15/P/54) ECONOMICS OF ENRICHMENT AND OF THE USE OF PLUTONIUM AND ^{233}U.

Franklin, N.L., Hill, J.M., and Stewart, J.C.C. (United Kingdom Atomic Energy Authority, Risley, Lancs, Eng.), and Rennie, C.A. (Atomic Energy Research Establishment, Harwell, Berks, Eng.).

18 p.

A standard for comparison, the gas-cooled reactor using natural uranium metal fuel is adopted. A brief survey of the cost structure of power produced from such a reactor is given. The effect of the fuel cycle and the reactor size upon the expected reactivity performance using natural uranium fuel is discussed. The cost structure in the production of enriched uranium is reviewed and a typical cost enrichment curve is deduced for the range 0.5 to 2.0 Co. Typical fuel element costs, inventory costs, and repurchase values are presented. The general principles of the use of plutonium in place of uranium 235 are considered for conditions of total plutonium recycle and for plutonium-natural uranium fuels. The major differences between such systems and systems using enriched uranium are discussed under the headings of: Fuel element fabrication and processing; the choice of spikes or uniform enrichment; the nuclear performance of plutonium as a substitute fuel; and the effect upon reactor operation. These considerations are combined to provide estimates of the relative economic worth of plutonium and uranium 235 enrichment. The general principles of the use of uranium 233 as a fuel are outlined. (Author)

945 BLENDING V. RE-ENRICHMENT FOR SLIGHTLY ENRICHED URANIUM.

Kallman, D., and Brennan, J.E. (Babcock and Wilcox Co., New York).

Chem. Eng. Progr., 55, Symposium Ser., No. 23, 31-4 (1959).

Blending with highly enriched uranium may permanently be practiced in place of re-enrichment at the diffusion plant because the difference in cost may be small and the flexibility greater. The economics of both methods are compared relative to first-core loading and fuel-cycle costs. (Author)

946 (Y-1258) COST OF BLENDING URANIUM OF TWO DIFFERENT ^{235}U ISOTOPIC ENRICHMENTS.

(Union Carbide Nuclear Co. Y-12 Plant, Oak Ridge, Tenn.).

Values of Uranium from the "USAEC Unclassified Pricing List". Oct. 14, 1958. 272 p. Contract W-7405-eng-26. OTS.

Cost tables and instructions for calculating the cost of blending two different isotopic enrichments of ^{235}U to form an intermediate assay are presented. A sample calculation is included and information on reactor fuel cycles is given.

947 NATURAL AND ENRICHED URANIUM IN NUCLEAR POWER PLANTS.

Rotter, W.

VDI Zeitschrift, 101, 1697-1701 (Dec. 11, 1959). (In German).

A comparison of the capital outlay per kW of installed capacity of nuclear power plants which use natural or enriched uranium fuel is presented. The economics of using natural uranium v. enriched uranium are discussed relative to separation processes for enriched uranium.

948 (ORNL-TM-191) EFFECT OF REDUCED ^{235}U PRICE ON FUEL CYCLE COSTS.

Bennett, L.L. (Oak Ridge National Lab., Tenn.).

March 7, 1962. Contract [W-7405-eng-26]. 69 p.

A study was made to determine the effect of changes in natural uranium cost and in separative work charges on fuel cycle costs in nuclear power plants. Reactors considered were a Dresden-type boiling water reactor (BWR) and a Yankee-type pressurized water reactor (PWR), with net power ratings of 100, 300, and 500 Mwe. Fuel cycle costs were calculated for these reactors, using either enriched uranium or ^{235}U-thorium as the fuel material. The price schedule for uranium was based on a feed material cost of \$15/kg uranium as UF_6 and separative work costs of \$30/kg uranium (Schedule B) and \$20/kg uranium (Schedule C). The present AEC price schedule for enriched uranium was also used for purposes of a reference case. The results indicate that a reduction in present enriched uranium price to that given by Schedule B would reduce fuel cycle costs for the BWR plants by 0.4 to 0.5 mill/kwh for the enriched-uranium cycle, and 0.4 to 0.7 mill/kwh for the thorium cycle. Reductions in fuel cycle costs for the PWR plants were 0.5 to 0.7 and 0.4 to 0.75 mill/kwh, respectively, for the same situations. (Author)

949 PRESENT STATE OF THE PRODUCTION AND MARKET OF ^{235}U AND HEAVY WATER.

Villani, S. (CISE, Milan).

Energia nucleare (Milan), 9, 212-25 (April 1962). (In Italian).

Due to the exuberant capacity of the AEC plants in the United States, the development of isotope separation processes for the production of uranium-235 and heavy water has come to a standstill. The situation is analyzed mostly on the basis of data and results published in the last three years. (Author) (Trans. 950)

950 (AEC-tr-5200) PRESENT STATE OF PRODUCTION AND OF THE MARKET OF ^{235}U AND OF HEAVY WATER.

Villani, S.

Translated for Oak Ridge National Lab., Tenn. from Energia nucleare (Milan), 9, 212-25 (April 1962), 36 p.

This paper was previously abstracted from the original language and appears in NSA, Vol. 16, abstract No. 20936. (Orig. 949)

951 (NUMEC-P-23) OPTIMIZING URANIUM FEED ENRICHMENT FOR RECYCLE OPERATION.

Puechel, K.H. (Nuclear Materials and Equipment Corp., Apollo, Penna.).

Jan. 25, 1961. Contract AT(30-1)-2389. 15 p.

Given a particular batch of spent fuel and knowing the desired final rejuvenated uranium enrichment, any uranium feed enrichment between the desired value and the highest possible enrichment can be utilized. Calculations were carried out to determine the optimum feed enrichment using AEC price schedules and assuming various values for U-Pu separation and chemical conversion costs. It is shown that the ratio of optimum feed enrichment to initial spent fuel enrichment is independent of the desired final enrichment and varies linearly with the separation cost. (Author)

952 (EUR-6 e) STUDY OF THE ADVANTAGES TO BE DERIVED FROM MIXING URANIUM COMPOUNDS AT VARIOUS DEGREES OF ENRICHMENT.

Biondi, L., Gerini, P.M., Morocutti, O., Patrone, G., and Willems, M. (Italatom SpA, Milan).

March 1962, 21 p.

The possibility of obtaining uranium compounds of a given enrichment by mixing compounds different enrichments on an economic basis was studied. The various possibilities for the economic application of the method were demonstrated together with the advantages it offers from the standpoint of flexibility and relative independence of production. (Author)

953 (TID-8539) CALCULATING ^{235}U OUTPUTS AND CHARGES.

McVey, W.H., Davidson, E.H., and McTigue, G.E. (Division of Operations Analysis and Forecasting, AEC).

1963, 42 p.

A report entitled "Methods of Calculating ^{235}U Outputs and Charges by Use of Ideal Cascade Theory", TID-8522, was extended and updated. The topics covered are single product, multiple products, incremental productivity, cost per unit of contained ^{235}U, cost of ^{235}U consumption, minimum cost of products, blending uranium of different assays, and current AEC schedule of charges for enriched and depleted uranium.

954 ENRICHED URANIUM PROCESSING.

Patton, F.S., Googin, J.M., and Griffith, W.L. (Union Carbide Nuclear Co. Y-12 Plant, Oak Ridge, Tenn.).

International Series of Monographs on Nuclear Energy. Division IX. Chemical Engineering. Volume 2. Oxford, Pergamon Press, 1962, 290 p. £3.50. (TID-15922).

A book is presented as a guide and reference on the processing of enriched uranium in industry. The emphasis is on practical applications and on basic principles and operations. Process chemical, metallurgical, and ceramics operations are discussed in detail. The health, safety, and economic factors in each operation are reviewed.

955 SOME ASPECTS OF THE ECONOMY OF NUCLEAR FUELS.

Gaussens, J., and Thiriet, L.

Chim. Ind. (Paris), 89, 623-35 (June 1963).

The authors highlight the fuel expenditure item in general economic management of atomic power plants, and then go on to deal with outputs, investment and costs of plant involved in the fuel cycle. In this way they arrive at an examination from the point of view of economics, of the extraction, concentration and processing of natural metallic uranium, UO_2, UF_6, enriched uranium, and plutonium, together with manufacture of fuels. Finally, they discuss the stages in chemical processing of irradiated fuels and radioactive effluents. In their conclusion, they stress the complex nature of cost and price estimates in the nuclear field. (Sum. Articles French Tech. Press, No. 6, 1963)

956 ECONOMIC ASPECTS OF NUCLEAR ENERGY. I. PRICE OF URANIUM.

Pascual Martinez, F., Lopez Rodriguez, M., and Delgado Hernandez, E. (Junta de Energia Nuclear, Madrid).

Energia Nucl. (Madrid), 8, 12-25 (Jan.-March 1964). (In Spanish).

Since 1955 there has been a substantial reduction in the cost of natural uranium. The evolution of this reduction is discussed by a resumé of the change in the price of uranium concentrates, in the unit cost of separation, value of improverished uranium, and concentration of ^{235}U in natural uranium. The effects of the separation, optimum composition of tailings, and unit cost of material of composition x_p on the cost or enriched uranium are examined theoretically. Applications to fixing the price of enriched uranium are given. The effect of the fuel cost on the fuel cycle in enriched reactors is shown.

957 (TID-21015) DETAILED LISTING OF BASE CHARGES FOR ^{235}U ENRICHED AND DEPLETED URANIUM AS UF_6.

(Oak Ridge Operations Office. Production Div., AEC).

Sept. 1964, 60 p.

Current base charges are listed for each 0.0001 weight fraction ^{235}U for assays ranging from 0.0038 to 0.98 weight fraction ^{235}U. (See 968)

958 ATOMIC INDUSTRIAL FORUM, 1964 ANNUAL CONFERENCE, NOVEMBER 30-DECEMBER 3, 1964, SAN FRANCISCO, CALIFORNIA, PROCEEDINGS. VOLUME 2. THE STATE OF THE INDUSTRY—1964. A PRIVATE NUCLEAR POWER ECONOMY. THE PRICE-ANDERSON LAW AND SAFETY.

Udell, R.N., ed.

New York, Atomic Industrial Forum, Inc., 1965, pp. 77-144. (CONF-641112 - Vol. 2). $6.00.

Part of the proceedings of the Atomic Industrial Forum's Eleventh Annual Conference are presented. Topics covered include: the atom, catalyst for a 4-mill kwh; costs of enriching uranium in private facilities; European views on toll enrichment, economic and technological aspects of plutonium as a fuel, uranium reserves for nuclear power, the Price-Anderson law, and accomplishments in reactor safety research.

959 (HW-72219) URANIUM PRICE SCHEDULES AND BRED FUEL VALUES.

Eschbach, E.A., and Kanninen, M.F. (General Electric Co., Richland, Wash. Hanford Atomic Products Operation).

Dec. 1964. Contract AT-(45-1)-1350. 82 p. Dep.; $3.00 (cy), 2 (mn) CFSTI.

A basis is established for relating the value of a chemically separable bred fuel (plutonium) to the price of fully enriched uranium. It is shown in a hypothetical situation (wherein the bred fuel has the same nuclear properties as ^{235}U but is chemically distinguishable from ^{238}U which is separated after irradiation) that the value of the recovered bred fuel will be essentially equal to the price of fully enriched uranium regardless of the burn-up situation. This hypothetical concept is used to show that this relationship results from the mathematical representation of the cascade ^{235}U-^{238}U enrichment process upon which the AEC Uranium Price Schedule is based. Data from detailed value calculations are shown to substantiate the analysis of the hypothetical circumstance and to show that the value of plutonium is closely proportional to the price of fully enriched uranium. The credibility of these results is shown to stem from the chemical separability of plutonium and uranium which enables plutonium enrichment of uranium to serve two functions: (1) to exploit the low cost of ^{235}U associated with uranium cascade tails and (2) to recover the costs of isotopic enrichment of ^{235}U in ^{238}U. This dual function is contrasted with bred fuel systems involving no natural fissile species ^{235}U; namely, thorium and pure ^{238}U, in which the bred fuels can only serve function number (2) for which the value is proportional to the ^{235}U burn-up costs of the basic reference case. Included is an extensive theoretical analysis which shows that Hypothium value is made up precisely of two components: the corresponding uranium burn-up costs and the value of the chemical separability of Hypothium from uranium. The chemical separability function is principally the value of the second derivative of the price schedule. If the second derivative is positive, Hypothium value is greater than the corresponding burn-up costs. Even so, Hypothium value is empirically related to the price of fully enriched uranium because the enrichment level of fully enriched uranium must be assigned arbitrarily. (Author)

960 RECENT DEVELOPMENTS IN URANIUM ISOTOPE SEPARATION.

Fiocchi, R. (Univ., Milan).

Comit. Naz. Energia Nucl., Notiz., 11, No. 10, 38-49 (Oct. 1965). (In Italian).

Methods developed since 1958 for the isotopic separation of uranium are reviewed. The theoretical bases for separation procedures and the elements indispensable for evaluation of the economic advantages of the methods are emphasized.

961 (BNWL-189) UCOST—A COMPUTER CODE FOR CALCULATING THE COST OF ENRICHED URANIUM.

Deonigi, D.E., Eschbach, E.A., Kanninen, M.F. (Battelle-Northwest, Richland, Wash. Pacific Northwest Lab.).

Feb. 1966. Contract AT(45-1)-1830. 113 p. Dep. mn. CFSTI $4.00 (cy), $0.75 (mn).

The UCOST code provides a means of calculating the cost of uranium of any enrichment level of ^{235}U in ^{238}U, based on a specified feed composition and cost, specified separative duty cost, and specified or optimum tails composition. The code can produce a schedule of costs, the theoretical burnup costs, and can provide toll enrichment costs for toll enrichment situations, as well as predict the present USAEC optimum price schedule. Examples of current and generalized price schedules, tables, and graphs are appended. (Author)

962 (EUR-2961.f) LES RESSOURCES EN URANIUM DANS LA COMMUNAUTE EUROPEENNE (URANIUM RESOURCES IN THE EUROPEAN COMMUNITY).

(European Atomic Energy Community).

May 1966, 40 p. Dep. mn.

Researches conducted up to 1964 in Community countries revealed resources amounting to about 31 000 tons of U metal exploitable at a price of $8 per lb U_3O_8. Experts believe that uranium resources developable at a comparable price may be increased by means of a prospecting program in three of the Community countries (Germany, France, and Italy). It is difficult to assess the exact tonnage of the probable additional resources; however, they are estimated as about 10 000 tons of U in Germany, 20 000 tons in France, and 10 000 tons in Italy. (Author)

963 LES COMBUSTIBLES NUCLEAIRES (NUCLEAR FUELS).

Sauteron, J.

Paris, Hermann, 1965, 530 p., 180 FF.

A brief review is given of the physical concepts necessary for discussion of nuclear energy. The present and future applications of nuclear energy are summarized. The principal constituents of reactors are examined and the large families of reactors are reviewed together with the different types of fuel elements used. The transformations of U from its mining, ore processing, refining of the concentrates, isotopic enrichment and fabrication of fuel elements up to its use in the reactor are described. The modifications in composition and structure of the fuel induced by reactor radiation are discussed, and reprocessing the irradiated fuel is considered. The characteristics

of Pu and Th as fuels are also discussed. The different fuel cycles and their effects on the cost of nuclear energy are examined.

964 (RT-EC-(66)1) METODO GRAFICO PER LA DETERMINAZIONE DEL COSTO DELL'URANIO ARRICCHITO (ENRICHED URANIUM COST: DESCRIPTION OF A GRAPHICAL METHOD).

(Comitato Nazionale per l'Energia Nucleare, Rome, Italy). 1966, 5 p. (In Italian). Dep. mn.

A graphical method to evaluate the cost of enriched uranium is given. The method allows the costs of feed material and of the separative work to be determined. (Author)

965 (BNWL-312) URANIUM PRICE SCHEDULES BY UCOST CODE COMPUTATION.

Deonigi, D.E., Horton, P.A., and Nail, J.H. (Battelle-Northwest, Richland, Wash. Pacific Northwest Lab.).

Sept. 1966. Contract AT(45-1)-1830. 168 p. Dep. mn. CFSTI $3.00 (cy), $0.65 (mn).

The UCOST code has been used to calculate the price of U of various enrichments, based on the costs of feed material on the price of separative work, and on the credit for waste material. Data are tabulated. (Author)

966 PROVISION OF NUCLEAR FUEL SERVICES IN EUROPE.

Allday, C. (United Kingdom Atomic Energy Authority, Risley, Eng.).

Nucl. Eng., 12, 194-5 (March 1967).

Prospects for the nuclear fuel industry are examined and it is suggested that integration or at least co-operation will be essential. Assuming that 40 000 MW(e) will be installed by 1975 and 90 000 MW(e) by 1980, estimates are made of the required throughput for UF_6 production from ore concentrate, isotope separation, fuel manufacture, and fuel reprocessing for thermal and fast reactors. Figures are given for the proportional costs of the fuel cycle stages.

967 (ORNL-TM-2031) ENRICHED URANIUM PRICE SCHEDULES.

Bennett, L.L., and Gift, E.H. (Oak Ridge National Lab., Tenn.).

Oct. 31, 1967. Contract W-7405-eng-26. 63 p. Dep. CFSTI.

The cost of enriched uranium has been calculated using $26/unit of separative work and a standard tails assay of 0.2% ^{235}U. This corresponds to AEC-announced values which are effective January 1, 1969. Tables of cost v. enrichment are presented for ore costs of 6, 8, 10, and $12/lb of U_3O_8. Cost of converting U_3O_8 to UF_6 was held constant at $2.70/kg uranium. Separative work and ore requirements are presented separately, thus making it easy to consider other ore costs or separative work charges. (Author)

968 (TID-21015(Rev.)) INTERPOLATED VALUES FOR THE SCHEDULE OF BASE CHARGES AND THE STANDARD TABLE OF ENRICHING SERVICES.

(Oak Ridge Operations Office (AEC), Tenn. Production Div.).

Dec. 1967, 245 p. Dep. CFSTI.

The United States Atomic Energy Commission published in Federal Register Notice 32 FR 16289 dated November 29, 1967, a revised schedule of base charges for uranium as UF_6, to be effective January 1, 1968, and a standard table of enriching services. The schedule of base charges is applicable to uranium as UF_6 sold or leased by the AEC. The standard table of enriching services, which lists the units of feed and separative work required per unit of product, is applicable to uranium as UF_6 obtained through toll enriching contracts with the AEC. The base charges and the enriching services feed and separative work units listed in the Federal Register notice are for assay increments which vary from 0.02 to 10.00 weight percent ^{235}U. Interpolated values to the nearest 0.01 weight percent ^{235}U assay using the Federal Register values as the reference values are presented as a supplement to the Federal Register. (See 957)

969 (PG-Report-824) ALTERNATIVE ECONOMICAL SOURCE OF ENRICHED URANIUM FUEL.

Franklin, N.L. (United Kingdom Atomic Energy Authority, Risley, England. Production Group).

1968, 7 p. Dep. CFSTI. UK.

It is postulated that the technical efficiency of plants designed for uranium enrichment will help to offset the effects of escalation in capital cost. In addition, attempts are being made to minimize operating costs, both in terms of direct labor and materials, and of indirect expenses by the maximum use of automatic control and programming of the plants. However, the capital charges which must be met impose a very serious burden in seeking a competitive position. The net effect is that costs of the order of 15% greater than the present US price are expected to be achieved when the second phase of the expansion of Capenhurst gets underway in the early 1970's. A 15% increase in the cost

of separative work represents an increase of some 7 or 8% in the price of enriched uranium at the enrichment levels common in power reactors or some 0.08 mills/kwh in the generating cost. The costs of transport of enriched uranium, together with associated charges for stockholding etc., may be somewhat less for supply from a plant in Europe than for the case where transatlantic transport is involved. The margin in total cost to the reactor operator may therefore be less than the cost figures imply. (Author) (See 970)

970 GREAT BRITAIN: AN ALTERNATIVE ECONOMICAL SOURCE OF ENRICHED URANIUM FUEL.

Franklin, N.L.

Atom, No. 135, 8-12 (Jan. 1968).

The subject is discussed under the following headings: introduction; supply and demand; estimated separative work requirements 1975 to 1980 (UK, USA, Euratom countries, other European countries); cost targets for an alternative supplier; and the UK position (scale of programme, electricity tariff, escalation of construction costs, rate of return on capital, and UK terms for supply for enrichment). (See 969)

971 STUDY OF URANIUM ENRICHMENT SERVICES CRITERIA AND PROJECTED CHARGES.

(Report of the Study Committee on Toll Enrichment. New York, Atomic Industrial Forum, Inc.).

1965, 13 p. $4.00.

The AEC Uranium Enrichment Services Criteria and the conclusions of the study committee on these criteria are presented. The proposed enrichment services are considered to be responsive to the needs of the nuclear power industry and the ceiling charge of $30 per kg of separative work appears reasonable and fair.

972 U.S. AEC'S NEW STANDARD TABLE OF ENRICHING SERVICES FOR URANIUM HEXAFLUORIDE.

Nozawa Reikichi (Tokyo Inst. of Tech.).

Nippon Genshiryoku Gakkaishi, 10, 75-84 (Feb. 1968). (In Japanese).

USAEC has recently revised its standard table of enriching services. The new schedule of base charges for enriched and depleted uranium in the form of UF_6 can be computed according to formulas in the theory of ideal cascade on the basis of taking natural uranium having an assay of 0.711 wt% ^{235}U as having a zero separative work component and on the basis of a tails assay of 0.20 wt% ^{235}U. No optimization of the size of stripping section is made in the schedule. An estimate of separative work costs and capacities of enriching facilities in UK, France and Red China is included. (Author)

973 NUCLEAR FUEL CYCLE.

Nucl. News, 11, 30-5 (Jan. 1968).

It is predicted that demands for U for nuclear power plants in 1980 in the USA will be three times as great as the present U production facilities. Brief descriptions are given of U resources, the cost of U processing, enrichment facilities and costs, reactor fuel fabrication methods and costs, the reprocessing of reactor fuels, and the use of Pu and Th as reactor fuels.

974 SHOULD THE EUROPEAN COMMUNITY PRODUCE ITS OWN ENRICHED URANIUM ?

Michaelis, H.

Euratom Rev., 7, No. 1, 24-9 (March 1968).

A description of fuel requirements for power reactors in the Euratom community is presented. Proposed power requirements between 1970 and 1980 are established, and discussion as to the types of reactors for power production is presented. A review of world-wide power requirements is presented, and an analysis of enriched uranium supply-and-demand status is discussed. Economic and legal aspects of European produced enriched uranium are presented.

975 (CONF-670550) PROCEEDINGS (OF THE) SYMPOSIUM ON TOLL ENRICHMENT AND PRIVATE OWNERSHIP, FRANKFURT/MAIN, MAY 2 AND 3, 1967.

(Atomic Industrial Forum, Inc., New York. Deutsches Atomforum eV, Düsseldorf, West Germany).

165 p.

The tape recorded discussions of the papers presented at the first joint symposium of the Atomic Industrial Forum and the Deutsches Atomforum held at Frankfurt/Main on May 2 to 3, 1967 is presented. These proceedings include introductory remarks and discussions of papers, but not the papers prepared for the conference.

976 (ORO-665, pp 73-84) ENRICHING SERVICES AND NUCLEAR POWER.

Johnson, W.E. (Atomic Energy Commission, Washington, D.C.).

The availability, capacity, and cost of uranium enrichment services in the U.S., and policies related to these service are discussed.

977 (ORO-665, pp 85-119) REVIEW OF ENRICHED URANIUM FUEL CYCLE.

Hibbs, R.F. (Union Carbide Corp., Oak Ridge, Tenn. Nuclear Div.).

Details of the enriched uranium fuel cycle which will accompany the operation of a 1 000 MW(e) light water reactor in 1980 are discussed and include: uranium mining and milling; conversion to UF_6; enrichment; UO_2 fuel assembly fabrication; fuel management and irradiation; spent fuel processing, shipping, and storage; and waste management. The predicted cost of each operation is given.

978 ENRICHED URANIUM SUPPLY AND DEMAND. ECONOMIC FACTORS.

Witzke, R.L., Smith, E.E., and Bach, J.H. (Westinghouse Electric Corp., Pittsburgh).

Proc. Amer. Power Conf., 30, 211-22 (1969).

From 30th Annual American Power Conference, Chicago, Ill. See CONF-680418.

Available data on uranium reserves and resources were studied in an evaluation of future trends of nuclear power. Uranium availability will influence the nuclear industry but in an orderly expansion of nuclear capacity, there need be no concern about the availability of U for the plants committed at any one time. The availability of enrichment services at reasonable prices will influence nuclear capacity. The possible transfer of enrichment services to private industry was studied and it was found that private industry can supply enrichment services at no significant price increase over AEC prices. Factors affecting the economics of enrichment services are described.

979 THE U.S. URANIUM ENRICHMENT INDUSTRY.

Benedict, M. (Massachusetts Inst. of Tech., Cambridge).

Chem. Eng. Progr., 65, No. 6, 83-6 (June 1969).

The uranium enrichment industry in the U. S. is discussed. The government-owned plants are being considered for sale to private companies. The increased demand for separative work is formulated with projected needs. Problems involved in the private ownership of the enrichments plants and possible solutions are presented.

980 FORATOM REPORT ON URANIUM ENRICHMENT.

Com. Naz. Energ. Nucl., Notiz., 15, No. 3, 89-101 (March 1969). (In Italian).

The full text of the Foratom report on uranium enrichment in Europe is presented. The report recommends that the construction of a uranium enrichment plant in Europe be considered. The European needs for enriched uranium and the economic aspects of uranium enrichment in Europe are discussed.

981 (AD-684030) A RE-EXAMINATION OF THE NUCLEAR PROLIFERATION PROBLEMS PRESENTED BY WORLD-WIDE REQUIREMENTS FOR ENRICHED FUEL, RELATING THE FEBRUARY 1965 OPTIONS TO TODAY.

Kramish, A. (RAND Corp., Santa Monica, Calif.).

Aug. 1968, 17 p. (P-3923). CFSTI.

The current upsurge of serious interest in several European nations, Japan and elsewhere, in acquiring domestic or regional facilities for the production of ^{235}U for nuclear power plants, coupled with expression of the desire of U. S. industry to acquire private ownership and operation of government uranium enrichment facilities makes it imperative that policy on such facilities be re-examined now in all of its facets. Technical developments that could lead to a proliferation of independent natural nuclear weapon capabilities are discussed. The vigour and meaning of the Non-Proliferation Treaty will be profoundly affected by the nature of the solutions of the fuel problem, and regions other than Europe must also be considered. Some of the action options, or variants, which were available three years ago are beginning to vanish. (Author)

982 URANIUM ENRICHMENT PROBLEMS AS SEEN BY THE ENGINEER CONSTRUCTOR.

O'Donnel, A.J., and Dyer, G.H. (Bechtel Corp., San Francisco).

pp. 9-20 of Problemi della Separazione Isotopica dell'Uranio. Roma, Comitato Nazionale Energia Nucleare, 1968.

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy. See CONF-681015.

Aspects of isotope separation capacity are discussed. Information is included on matching supply and demand, separation facility investment costs, auxiliaries such as UF_6 production facilities and power supplies for separation plants, and separation facility operating problems.

983 REFLECTIONS ON A CONVERSION PLANT FOR CONCENTRATING URANIUM IN UF_6 AND RECONVERTING THE UF_6 TO ENRICHED UO_2: CONNECTIONS WITH AN EVENTUAL PLANT FOR ISOTOPIC SEPARATION ON A LARGE SCALE.

Donato, M. (Commissione delle Comunità Europee, Brussels).

pp. 183-96 of Problemi della Separazione Isotopica dell'

Uranio. Roma, Comitato Nazionale Energia Nucleare, 1968. (In Italian).

From Symposium on Problems Bearing on Isotope Separation of Uranium, Turin, Italy. See CONF-681015.

The problems of the long-term supply of enriched uranium and the availability of a European enrichment plant have long been the objects of study by international organizations. An analysis is presented of the existing situation and the desirability of a European enrichment installation that is based on studies by individual members of the European Community on the construction of a U enrichment plant. The plants and processes used in the United States and Europe for the transformation of concentrates into UF_6 and of enriched UF_6 into UO_2 are summarized. The characteristics of isotopic separation plants and their auxiliary installations are outlined. The relative investments for enrichment plants and auxiliaries are indicated.

984 EUROPEAN URANIUM ENRICHMENT PLANT: COMPARISON BETWEEN THE EURATOM-REPORT AND THE FORATOM-REPORT.

Brüchner, H.J. (AEG-Telefunken, Frankfurt am Main).

At. Strom, 15, 151-4 (Sept. 1969). (In German).

The development of a European uranium enrichment plant is discussed. A comparison is made of the Euratom report and the Foratom report especially in view of the expected cost of separative work in a European enrichment plant. (Author)

985 (NP-18050) REPORT ON EUROPEAN URANIUM ENRICHMENT. ANNEX I. ESTIMATION OF EUROPEAN REQUIREMENTS. ANNEX II. ECONOMIC ASPECTS OF URANIUM ENRICHMENT IN EUROPE.

(Forum Atomique Europeen).

Jan. 1969, 31 p. Dep. CFSTI (U. S. Sales Only).

The contribution of nuclear power plants to the European electricity supply are given and the projected capacity and requirements to 1980 are discussed. The processes for the enrichment of uranium are summarized along with research and development progress of each country. The economic aspects of uranium enrichment in Europe with regard to each process are discussed.

986 AN OUTLOOK ON THE PROSPECTS FOR URANIUM ENRICHMENT IN THE U.S.A.

Nichols, K.D. (Atomic Industrial Forum, Inc., New York).

pp. 143-152 of Utilizzazione del Combustibile Nucleare. Roma, Comitato Nazionale Energia Nucleare (1969).

From 10th International Nuclear Energy Conference, Milan, Italy. See CONF-681219.

Costs and production capacity of existing uranium enrichment facilities in the U. S. and the prospects for these facilities meeting U. S. and international requirements are discussed. The prospects for increasing the capacity of existing facilities in the 1970's by cascade improvements and plans for preproducing enriched material for future requirements are presented. The conclusions and recommendations made by the Atomic Industrial Forum Study Committee on Private Ownership and Operation of Uranium Enrichment Facilities, feasibility and economic considerations of private ownership, prospects for additional U. S. enrichment facilities to meet future U. S. and international requirements, and technical and economic considerations pertaining to new facilities are summarized. (Author)

987 PROSPECTS FOR A EUROPEAN ISOTOPE ENRICHMENT PLANT.

Michaelis, H.

pp. 153-66 of Utilizzazione del Combustibile Nucleare. Roma, Comitato Nazionale Energia Nucleare (1969).

From 10th International Nuclear Energy Conference, Milan, Italy. See CONF-681219.

The countries of the European Community obtain their uranium supplies only from the United States. The development of nuclear energy in the world suggests that the capacity of the present enrichment facilities will be totally absorbed before the end of the seventies, and that therefore new uranium enrichment plants will have to be installed. According to the latest estimates and predictions as to plant types, the demand on separation plants by Community power plants installed by 1980 will amount, already in 1978, to 4 to 6 million kilograms/year. The Community's energy policy envisaged ways of increasing the margin of supply by reducing requirements, diversifying the sources and improving the conditions of foreign supplies, and increasing the self-supply by installing in the Community area enrichment facilities. The monopoly in fact held by the USAEC and the planned transfer of the property of facilities to private U. S. corporations create serious problems for the European users. Many advantages are offered by European enrichment plants but authorities are concerned with the solution of the choice of the process, the economic parameters, the status of the enterprise and the sales policy. Preliminary data available to the Committee suggest that in the European case the UTS/kg cost could be slightly higher than the $26 charged by the AEC.

988 (ORO-674) THREE METHODS OF EVALUATING CAPITAL EXPENDITURES IN THE PUBLIC SECTOR IN WHICH THE TIME VALUE OF MONEY CONCEPT IS USED.

Tucker, A.St.G. (Oak Ridge Operations Office, AEC, Tenn. Operational Planning and Power Div.).

Dec. 1969, 153 p. (OPP-4 (Rev. 2)). Dep. CFSTI.

Three proven and accepted methods of evaluating capital expenditures are discussed and applications presented. The concept that the value of money is time related is used in each method. This concept holds that a dollar in hand is worth more than a dollar due in the future. The three methods are annual cost, present worth, and rate of return. Sensitivity analysis and dealings with uncertainties in forecasts are discussed. Examples of analyses at U. S. nuclear installations are made.

989 URANIUM ENRICHMENT PRICING CRITERIA. HEARINGS BEFORE THE JOINT COMMITTEE ON ATOMIC ENERGY, CONGRESS OF THE UNITED STATES, NINETY-FIRST CONGRESS, SECOND SESSION, JUNE 16 AND 17, 1970.

Washington, D.C., Joint Committee on Atomic Energy (1970). 255 p. GPO $1.00.

On June 16 and 17, 1970 the Joint Committee on Atomic Energy held hearings on the AEC proposed increase in the price of uranium enrichment services and new criteria for pricing. The statements of witnesses before the committee are reported verbatim. Press releases on the subject from the AEG, JCAE, Senator Gore, and the White House are included as well as correspondence and 11 appendixes of published information pertinent to the subject.

990 DIRECTION OF THE DEVELOPMENT ON A NUCLEAR FUEL CYCLE. URANIUM ENRICHMENT.

Takei Mitsuo (Japan Energy Economic Research Inst., Tokyo).

Genshiryoku Kogyo, 16, No. 4, 50-4 (April 1970). (In Japanese)

It is generally agreed that nuclear power generation in the 1970's will be by light-water reactors. The enrichment of uranium will be a major problem in nuclear fuel cycles. The uranium enrichment is now nearly monopolized by the United States, however, the joint enrichment program by three European countries is proceeding steadily. The world state of uranium enrichment, and also its demands, are described. Information is included on uranium enrichment capacity with speculation of the future nuclear power generation in the United States. Information is also included on economic evaluation of the supply sources, dealing with the cost of uranium enrichment in the United States and in the European three-nation program; and emergence of European joint-plants based on the three-country program.

991 BASIC PROGRAM OF THE DEVELOPMENT AND UTILIZATION OF ATOMIC ENERGY FOR FISCAL 1970.

Kagaku Gijutsucho Geppo.

No. 166, 1-4 (June 1970). (In Japanese)

A program for the development and utilization of atomic energy for fiscal year 1970 is described. In the fiscal year (from April 1970 to March 1971), activities include the start of construction on a prototype advanced thermal reactor, the furthering of research and development on uranium enrichment and nuclear fusion, the start of construction on a nuclear fuel reprocessing plant, the start of equipment on the first nuclear-powered ship, and commissioning of a number of atomic power stations. The program of the development and utilization of atomic energy for the fiscal year 1970 is described, including the basic policy, research and development, utilization, safety measures, fuel supplies, cooperation, and budgets and personnel.

992 SEPARATION ISOTOPIQUE DE L'URANIUM ET SON ECONOMIE (URANIUM ISOTOPE SEPARATION AND THE CORRESPONDING ECONOMICS).

Meeting Held in Paris, France, November 27, 1970.

Rueil-Malmaison, France, Société de Chimie Industrielle (1971). 96 p. (CONF-701133).

A separate abstract was prepared for each of the 6 papers presented at the conference. (France)

993 CONSTRUCTIVE USES OF ATOMIC ENERGY.

The First Report on the International Conference Held in Washington, 10-14 November, Deals with General Topics, Enrichment, Uranium, Plutonium, Finance and Safeguards

(Nuclear Engineering International, 14 (1968), No. 152, p. 42-5).

This first report on the International Conference on the Constructive Uses of Atomic Energy held in Washington, 10-14 November, deals with general topics, enrichment, uranium, plutonium, finance, and safeguards. In the panel on plutonium utilization, the problems of plutonium stockpiling and plutonium recycling in thermal reactors are discussed.

994 NUCLEAR FUEL CYCLE COST TRENDS UP TO 1980.

Bonanni, M., Dollard, W.J., Smith, D.R., Smith, E.E.

(Economics of Nuclear Fuels, Proceedings of the Symposium on the Economics of Nuclear Fuels. Held by the Inter-

national Atomic Energy Agency in Gottwaldov, 27-31 May 1968. Vienna: Internat. Atomic Energy Agency 1968.

S. 13-24, 6 Fig., 4 Tab. (Proceedings Series) (STI/PUB/188)

During the past decade fuel cycle costs for water reactors have dropped by a factor of four. To a large degree this decrease has been due to improvements in fuel design and fuel management techniques. Future improvements in fuel design will have less effect. It is now necessary therefore to concentrate on individual items of the fuel cycle itself for future cost reductions. The cost trends in each of the major components of the nuclear fuel cycle are predicted. Cost trends in uranium procurement and conversion to UF_6 are forecast, and the most recent announcements by the USAEC on cost of separative work are interpreted.

995 METHODEN ZUR BEURTEILUNG VON KERNKRAFTWERKSENTWICKLUNGEN, INSBESONDERE DER SCHNELLEN BRÜTER.

Jansen, P. (KFK-1066 (1970) getr. Zählg, 13 Fig., 78 Tab.)

The purpose of the study is to make available to the managers of the Fast Breeder Project an up-to-date set of tools for judging long-term decisions. At the same time, this enables a judgement of the development tendencies of nuclear power stations in the Federal Republic of Germany. Particular emphasis is laid on a description of the problem associated with models forming the basis of decision preparation, and it is attempted to provide an input for subjective weighting and forecasting factors to the methods of analysis offered. This is followed by an investigation of special economic problems associated with high performance breeders which result especially in a new and comprehensive criterion of Fast Breeder optimization. The third part deals with an important parameter for judging Fast Breeders, the price of plutonium. Initially, the plutonium worth is determined for the different power station concepts. Since plutonium is produced already by some types of nuclear power stations used in the energy market and is required by the Fast Breeders, the competition of these partners is investigated in the light of the mathematical theory of games, possibilities of coalitions are discussed and a conclusion is drawn for the plutonium price with respect to the evaluation of Fast Breeders. The fourth part includes an applied systems analysis of the situation of nuclear energy in the Federal Republic of Germany for the coming decades. Special significance is assigned to the discussion of the problem of satisfying or reducing the demand with respect to the amount of separative work required to enrich uranium for some types of nuclear power stations. For this purpose, the possible representative combinations of power stations are selected, the nuclear energy requirement is estimated, methods of uranium enrichment are compared with respect to the state of development and economic prospects, and economic comparisons are made for the electricity producing industry with alternative combinations of nuclear power stations, especially of Heavy Water Reactors. Useful alternatives are finally outlined with the inclusion of export possibilities and political aspects; they are subdivided into preferences with respect to different criteria. (Author)

996 DIE NEUEN PREISE DER USAEC FÜR URANHEXAFLUORID.

Eschnauer, H.

2 Abb., 3 Tab.

Atomwirtschaft, Jg. 7 (1962) Nr. 8/9, August/September, S. 454-455.

Angereichertes Uranhexafluorid — abgereichertes Uranhexafluorid — Entwicklung der Grundpreise der USAEC für angereichertes Uranhexafluorid nach den Preisfestsetzungen vom November 1956, Juli 1961 und Juli 1962 — % Anreicherung des ^{235}U im UF_6 — Kaufpreis — Pacht pro Jahr.

997 LA SITUAZIONE DELL'ARRICCHIMENTO DELL'URANIO IN EUROPA.

Scuricini, G.B.

Notiziario, 15 (1969), n. 4, p. 43-45.

L'entità degli interessi politici, economici ed industriali legati al problema dell'arricchimento dell'uranio — Problema recentemente messo a fuoco da due appositi Gruppi di studio Foratom ed Euratom sui lavori dei quali il presente articolo fornisce alcuni commenti e chiarimenti.

998 ONLY HIGH GAIN BREEDER REACTORS CAN STABILIZE URANIUM FUEL REQUIREMENTS.

Rengel, J.C.

Atompraxis, 15 (1969), No. 2, p. 100-104.

Present sodium-cooled fast breeder reactor designs use a primary sodium loop and a secondary sodium loop to isolate reactive primary sodium from the steam loop — uranium enrichment process is demonstrated for a 1000 MW (e) nuclear water reactor. The $30 million cost of a typical reactor core is divided into three approximately equal parts — cost of natural uranium, uranium enrichment, and core fabrication.

999 DIE NUTZUNG DER KERNBRENNSTOFFE.

Müller, W.D.

Atomwirtsch. Atomtech., 14 (1969), Nr. 2, S. 93-94.

Bericht über die FAST-Tagung (Federazione delle associazioni scientifiche e tecniche) vom 12.-14. Dez. 1968 in Mailand — technische und wirtschaftliche Fragen der Kernbrennstoffnutzung : die Versorgung mit Uran zu günstigen Preisen, die Urananreicherung, die Plutoniumverwendung und die Wiederaufarbeitung — künftige Entwicklung.

1000 KOSTEN FÜR DIE ANREICHERUNG VON URAN UND KAPAZITÄTEN DER VERSCHIEDENEN ANLAGEN HIERFÜR (COSTS AND SUPPLIES OF ENRICHED URANIUM).

Power Reactor Technol. 3 (1960), 2, 19/20.

1 Schrifttumsangabe.

1001 **EXTRAITS DE LA CONFERENCE PRONONCEE LE 9 OCTOBRE 1964, A LA MAISON DE LA CHIMIE.**

Goldschmidt, B.

Bull. Inform., Ass. tech. Energ. nucl., Fr. (1964), nº 50, 14-6.

Exposé sur «la 3e Conférence atomique internationale de Genève» : moins scientifique mais plus technique et commerciale que les précédentes; séparation isotopique de l'U; insuffisance des réserves; dessalement de l'eau de mer; fusion contrôlée, électricité d'origine nucléaire; programmes des grandes puissances. Intérêt économique.

1002 **LA TROISIEME CONFERENCE ATOMIQUE INTERNATIONALE DE GENEVE.**

Goldschmidt, B.

Energ. nucl., Fr. (1964), 6, nº 8, 465-72.

Exposé général sur cette conférence : l'organisation, le programme, la séparation isotopique de l'U, les ressources en U, le problème du dessalement, la fusion et la propulsion nucléaires, métallurgie et chimie nucléaires, les réacteurs prototypes, la production d'électricité, les programmes des grandes puissances. Intérêt économique.

1003 **IL SIMPOSIO SULL'ARRICCHIMENTO DELL'URANIO IN EUROPA (UTRECHT, OLANDA, 30 MAGGIO 1969) (COLLOQUE SUR L'ENRICHISSEMENT DE L'URANIUM EN EUROPE (UTRECHT, HOLLANDE, 30 MAI 1969)).**

Brigoli, B. (Laboratori CISE, Segrate, Milano).

Energ. nucl., Ital. (1969), 16, nº 9, 582-4, bibl. (8 réf.).

Compte rendu du colloque consacré aux aspects techniques et économiques de l'enrichissement de l'uranium.

1004 **ATOMIC INDUSTRIAL FORUM— ANNUAL REPORT 1968-1969.**

(Atomic Industrial Forum Inc., New York).

1969, 44 p.

Programme nucléaire pour l'année fiscale 1968-1969. Prévision des achats de U. Conversion de U. Fabrication et retraitement des combustibles. Coût d'une installation d'enrichissement de U. Licences d'utilisation de réacteurs. Protection dans les installations nucléaires. Transport des matériaux radioactifs. Projets d'applications de l'énergie nucléaire. Production de radio-isotopes. Applications de l'irradiation. (CEA).

1005 **ARRICCHIMENTO DELL'URANIO IN EUROPA — CONFRONTO TRA I RAPPORTI DEI GRUPPI DI STUDIO EURATOM E FORATOM (ENRICHISSEMENT DE L'URANIUM EN EUROPE. COMPARAISON ENTRE LES RAPPORTS DES GROUPES D'ETUDE EURATOM ET FORATOM).**

Scuricini, G.B.

Comit. nazion. Energ. nucl., Notiz., Ital. (1970), 16, nº 3, 33-7.
Besoins. Aspects économiques.

1006 **THE SECOND FORATOM CONGRESS SECTION Ia. URANIUM RESOURCES (LE SECOND CONGRES FORATOM. SECTION Ia. RESSOURCES EN URANIUM).**

Closs, H.

Nucl. Engng, G. B. (1965), 10, nº 114, 415.

Prévision des besoins à long terme en U. Etat actuel des ressources. Nécessité de prospecter. Egalisation des prix entre les différents pays pour U et Pu et comparaison des prix du minerai et du procédé d'enrichissement. Discussion.

1007 **GRUNDLAGEN UND BEDEUTUNG DER NEUEN USAEC-PREISE FÜR ANGEREICHERTES URAN.**

Hummel, U.

Atomwirtschaft 6, Nov. 1961, Nr. 11, S. 543-44. 3 Diagr., 4 Lit. (Wolfgang bei Hanau, NUKEM, Nuklear-Chemie u. Metallurgie GmbH).

Die Herabsetzung der Preise der USAEC für niedrig angereichertes U um bis zu 34% u. für hoch angereichertes U um etwa. 20%, die am 1.7.1961 in Kraft trat, wird auf eine Anpassung an die eingetretenen Preissenkungen für U-Konzentrate zurückgeführt. Aber auch die Herstellungskosten des UF_6 müssen beträchtlich niedriger geworden sein. Für Anreicherungen bis zu 90% wird der vermutliche Anteil des Ausgangsmaterials u. der Trennkosten am Gesamtpreis graphisch dargestellt.

ABSTRACT NUMBERS CONCERNING ECONOMICAL ASPECTS AND ALREADY INCLUDED IN THE DIFFERENT ISOTOPE SEPARATION METHODS.

2, 8, 15, 17, 19, 20, 21, 22, 23, 24, 25, 44, 52, 53, 55, 56, 63, 65, 67, 68, 74, 76, 77, 78, 80, 92, 95, 99, 102, 104, 110, 114, 115, 116, 119, 120, 123, 125, 126, 128, 129, 131, 132, 133, 134, 135, 137, 138, 139, 140, 142, 145, 146, 150, 151, 155, 157, 158, 159, 160, 161, 165, 168, 169, 170, 175, 179, 180, 181, 185, 186, 187, 190, 192, 196, 197, 199, 211, 212, 244, 251, 256, 258, 264, 272, 273, 274, 277, 280, 281, 282, 283, 284, 297, 299, 305, 310, 311, 312, 317, 319, 328, 329, 330, 332, 335, 339, 342, 343, 351, 352, 354, 356, 357, 358, 359, 360, 361, 363, 365, 367, 369, 370, 374, 375, 376, 379, 380, 382, 384, 385, 388, 391, 392, 393, 398, 399, 400, 405, 406, 407, 408, 409, 410, 413, 415, 447, 450, 461, 511, 593, 613, 649, 651, 658, 697, 727, 742, 743, 744, 745, 752, 755, 757, 759, 761, 762, 767, 768, 771, 772, 776, 777, 782, 784, 786, 787, 788, 789, 791, 793, 794, 795, 798, 799, 800, 801, 804, 805, 806, 810, 811, 813, 837, 857.

11. BIBLIOGRAPHIES

1008 A REVIEW OF THE SEPARATION OF STABLE ISOTOPES.

Gverdtsiteli, I.G. (Fiz.-Tekh. Inst. Gos.-Kom. Ispol'z. At. Energ., Sukhumi, USSR).

Abh. Deut. Akad. Wiss. Berlin, Kl. Math., Phys. Tech., 1967 (1), 79-85. (In Russian).

An outline is given of the application of stable isotopes in various fields of science and technology in recent yrs. An anal. is made of methods of sepg. stable isotopes and of the design of app. for measuring the isotopic compns. A description is given of the various methods of sepg. isotopes including the vapor flow diffusion method, the distn. method, and the method of chem. exchange. Development of automatic control systems for the sepn. process is considered. 35 references.

1009 PHYSICAL METHODS FOR THE SEPARATION OF ISOTOPES.

Kekeh, A. (Sorbonne, Paris, France).

Rev. Chim. Miner., 1968, 5 (3), 645-82 (Fr.).

The irreversible methods for the sepn. of isotopes are (the reversible methods are not discussed here): (I) action of electromagnetic fields, the most polyvalent and flexible method; (II) diffusion of matter; (1) gaseous diffusion: (a) without porous wall, (b) with porous wall; this method is rapid, has rather high sepn. factors, and is particularly suited for lab. application; (2) thermal diffusion, a method which, wherever tech. feasible, is excellent for massive production of extremely enriched isotopes; (3) electromigration: (a) in an aq. medium; (b) in molten salts; (c) in counter-flow; (d) electrolysis; (4) Becker method; (5) mol. distn., method to be taken into account for Li; (6) centrifuging methods, particularly suited for heavy elements: (a) by evapn.; (b) by centrifuge with continuous discharge; (c) by counter-flow centrifuge; (7) chromatography in the gaseous phase, a method which was used originally for the purification of isotopes but is beginning to be of interest for the sepn. of isotope mixts. and has good chances over conventional techniques because of the speed of operations and relative simplicity of the equipment; (III) special methods: (1) sepn. of ^{3}He from ^{4}He by film and filtration methods; (2) photochem. excitation of mercury. 39 references.

1010 SURVEY OF THE PRESENT STATE OF ISOTOPE SEPARATION METHODS.

Groth, W.

Z. Electrochem. Physik. Chem., 54, 5-12 (Jan. 1950). (In German).

The author discusses, in a nontechnical manner, the various techniques for isotope separation and their degrees of success. In addition to the electromagnetic, thermal diffusion, and porous barrier methods, he includes, among others, those based on the peculiar liquid properties of HeII, the selective absorption of light by certain isotopic molecules in photochemical reactions, the removal of the slower traveling particles from a molecular stream by a rotating diaphragm, the centrifuge principle, exchange reactions, and differential recombination after dissociation in a gaseous discharge. He concludes with some of the geologic processes effecting a natural separation of isotopes.

1011 THERMAL DIFFUSION; A BIBLIOGRAPHY.

(Atomic Energy Research Establishment).

Report No. AERE-Inf/Bib-59 (Feb. 10, 1950), 32 p.

This bibliography contains a comprehensive collection of references (322) to the process of thermal diffusion in fluids, its theory, its experimental investigation, and its application to the separation of isotopes. References to published literature have been obtained from Chemical Abstracts, Science Abstracts A, and Nuclear Science Abstracts. These sources have been searched from the beginning of publication to December, 1949. In addition, a number of references have been taken from "The Separation of Isotopes by Thermal Diffusion" by Jones and Furry (Revs. Modern Phys., 18, No. 2, 151-224 (April 1946).

1012 ISOTOPE SEPARATION AND ISOTOPE EXCHANGE; A BIBLIOGRAPHY OF UNCLASSIFIED LITERATURE.

(Technical Information Service, AEC).

Begun, G.M. (Oak Ridge National Lab.) and Allen, R.E. (Technical Information Service, AEC, comps.).

Jan. 23, 1953, 82 p. (TID-3036).

A total of 785 references are compiled from the open literature on isotope separation and exchange.

1013 ISOTOPE SEPARATION AND ISOTOPE EXCHANGE. A BIBLIOGRAPHY OF UNCLASSIFIED LITERATURE.

(Technical Information Service, AEC).

Begun, G.M. (Oak Ridge National Lab.) and Allen, R.E. (Technical Information Service, AEC, comps.).

Revised June 1954, 126 p. (TID-3036 - rev.).

The literature is covered from 1907 through 1953 on isotope separation and isotope exchange reactions involving B, C, Cl, H, Fe, Li, N, O, S, and U. Many additional references on isotopes of other elements are presented; however, their coverage is incomplete. Isotope properties, ratio, and kinetic effects are also included. This is a complete revision of TID-3036 issued January 23, 1953. (Author)

1014 ENRICHMENT OF URANIUM ISOTOPES BY THE GAS CENTRIFUGE PROCESS.

Groth, W. (Universität Bonn).

Nukleonik, 1, 68-73 (July 1958). (In German).

A survey is presented on the enrichment of uranium isotopes by gas centrifuge processes. Emphasis was placed on the studies performed in Germany since 1941. 27 references. (See 1019)

1015 (TID-5229) LIQUID THERMAL DIFFUSION.

Abelson, P.H., Rosen, N., and Hoover, J.I., eds. (Naval Research Lab., Washington, D.C.).

Sept. 10, 1946. Decl. Feb. 12, 1957. TISE Issuance date Aug. 1958. 258 p. (NRL-0-2982). $4.00 (OTS).

A revised and expanded version of NNES-IX-1.

The liquid thermal diffusion method for the separation of isotopes is described. The discussion includes the experimental aspects of the method, description of equipment, and the theoretical aspects of the process as applied to the design, development, and performance criteria. A short history of the liquid thermal diffusion method from 1940 to 1945 is presented along with a survey of relevant literature prior to 1940. The remainder of the report is concerned with theoretical aspects.

1016 (UCRL-5116(Pts. I and II) GASEOUS THERMAL DIFFUSION.
PART I. BIBLIOGRAPHY OF OPEN LITERATURE, 1940-57.
PART II. A BIBLIOGRAPHY OF THE REPORT LITERATURE, 1941-1957.

California. Univ., Livermore. Radiation Lab.

McFadden, C., comp.

Frost, F.E., comp.

Jan. 1958. (Pt. 1, 29 p., and Pt. II, 7 p.). Contract W-7405-eng-48. Pt. 1, $4.80 (ph OTS); $2.70 (mf OTS); Pt. II, $1.80 (ph OTS), $1.80 (mf OTS).

These two parts were issued separately, but are cataloged as a unit.

This bibliography includes references on separation of gases by thermal diffusion, thermal diffusion column technique, theory of separating gases by thermal diffusion, and design of thermal diffusion equipment.

1017 (LS-23) LITERATURE SURVEY ON ISOTOPE SEPARATION.

(Atomic Energy Commission, Tel-Aviv, Israel).

Nov. 1958, 26 p.

This survey includes 199 references from the published literature on isotope separation. Physics Abstracts, Vol. 51 (1948) through Vol. 58 (1955), was the source.

1018 (K-1420) A NEW APPARATUS FOR LIQUID PHASE THERMAL DIFFUSION (THESIS).

Von Halle, E. (Oak Ridge Gaseous Diffusion Plant, Tenn.).

June 24, 1959, 363 p. Contract W-7405-eng-26. $5.00 (OTS).

The design and construction of a thermal diffusion column free of ramification caused by the forgotten effect are reported. The operating characteristics of this column were also investigated. A comparison is made between the separating efficiency of the horizontal thermal diffusion column and that of the thermogravitational column. An extensive compilation of the results obtained by previous investigators of liquid phase thermal diffusion and an annotated bibliography on all phases of thermal diffusion containing 690 references are included.

1019 (IGRL-T/CA-103) THE ENRICHMENT OF URANIUM ISOTOPES IN THE GAS CENTRIFUGE.

Groth, W.

Translated by B. Rigby (UKAEA, Risley) from Nukleonik, 1, 68-73 (1958), 12 p.

This paper was previously abstracted from the original language and appears in NSA, Vol. 12, as abstract No. 13307. (Orig. 1014)

1020 (ORNL-2852) ISOTOPE SEPARATION AND ISOTOPE EXCHANGE.

A Bibliography with Abstracts.

Begun, G.M. (Oak Ridge National Lab., Tenn.).

Oct. 28, 1959, 239 p. Contract W-7405-eng-26. OTS.

The unclassified literature covering 2498 reports from 1907 through 1957 has been searched for isotopic exchange and isotopic separation reactions involving U and the lighter elements of the periodic chart through atomic number 30. From 1953 to 1957, all elements were included. Numerous references to isotope properties, isotopic ratios, and kinetic isotope effects were included. This is a complete revision of TID-3036 (Revised) issued June 4, 1954. An author index is included. (Author)

1021 (MLM-1088) THERMAL DIFFUSION: A BIBLIOGRAPHY.

Grove, G.R. (Mound Lab., Miamisburg, Ohio).
June 30, 1959, 60 p. Contract AT-33-1-GEN-53. OTS.

A comprehensive compilation of references from the technical literature on thermal diffusion is presented. Most of the references are from journals covered by Chemical Abstracts, Physics Abstracts, or Science Abstracts. The authors, titles, and standard references of over 900 publications from 1856 through 1957 are listed. The journal articles were selected for their direct applicability to gaseous or liquid thermal diffusion or because they contained very closely associated discussions. Also, the references to a number of books and graduate theses are included. It is believed that the journal articles listed represent the most nearly complete and accurate bibliography on thermal diffusion available in a single source. Reprints, photocopies, or the journals themselves were examined in nearly every case to insure pertinency and accuracy of the references. (Author)

1022 (DEGIS-48(R)) BIBLIOGRAPHY ON GAS SEPARATION BY CENTRIFUGE.

Thomas, J.R., and Maughan, G.I. (United Kingdom Atomic Energy Authority. Development and Engineering Group, Risley, Lancs, England).

Nov. 23, 1959, 9 p. BIS.

Sixty-one unclassified references from UKAEA. Abstracts Index, Nuclear Science Abstracts, Chemical Abstracts (1937 to 57), and Science Abstracts "A" (1936 to 58) on centrifugal gas separation are presented. The emphasis is on applications in isotope separation.

1023 (TID-3554) ISOTOPE SEPARATION BY GASEOUS DIFFUSION AND CENTRIFUGATION.

A Literature Search.

Jacobs, J.M., comp. (Technical Information Service Extension, AEC).

May 1960, 20 p. OTS.

A total of 141 references to the unclassified report and published literature is included.

1024 (CEA-tr-A-857) LA SEPARATION DES ISOTOPES (THE SEPARATION OF ISOTOPES).

Becker, E.W.

Translated into French by B. Moreau from Kerntechnik, 227-61 (1958), 91 p.

A review is presented of isotope separation in connection with nuclear energy. The discussion includes electromagnetic, chemical exchange, distillation, diffusion, gravity, and electrolytic or electromigration methods. 76 references.

1025 TEORIYA RAZDELENIYA IZOTOPOV V KOLOUNAKH (THEORY OF ISOTOPE SEPARATION IN COLUMNS).

Rozen, A.M.

Moscow, Atomizdat, 1960, 438 p.

An analysis is made of various methods of isotope separation: distillation, exchange, thermal diffusion, mass diffusion, and centrifugation. The processes are studied through the general concepts of regular mass transmission in physico-chemical hydrodynamics. The concepts of mass transmission coefficients, concentration, and the height of the transition unit are used in the analyses of thermal and mass diffusion. Such an approach reduces the unique characteristics of various processes to the concentration coefficient value, which in turn demonstrates the dependence of the transition unit height on the hydrodynamics and physico-chemical properties of the admixtures and the apparatus geometry. The general column and cascade calculation methods are examined, and the methods and aspects of engineering diffusion processes are correlated with the general separation theory. The theory and the calculation methods for columns (rectangular cascades) were further developed, and general separation theory was used for selecting the optimum parameters. The optimum conditions are determined for two-phase separation (distillation and exchange). Relatively simple formulas are developed for calculating the approach to equilibrium in various columns. A similarity is developed for non-stationary processes and electric circuits. allowing column and cascade kinetics to be modeled. Various separation devices are described. 217 references.

1026 (NUCLEAR-52) SEPARATION OF ISOTOPES GAS CENTRIFUGE PROCESS: SURVEY OF PUBLICATIONS.

Roe, A.V. (Canada Ltd. Orenda Engines Div., Malton, Ont.).

Jan. 1, 1962, 65 p.

A chronological listing of 125 unclassified references on gas centrifuge technology as applied to the separation of isotopes is presented. The survey covers the period from 1919 to 1962. An abstract of the original publication is given in most cases. Separate tabulations are included for cross referring between authors, report numbers, NSA reference numbers, and patent numbers. A summary of pertinent news released since 1959 is also given. (Author)

1027 (LS-101) ISOTOPE SEPARATION METHODS.

An Annotated Bibliography.

Gazith, M. (Atomic Energy Commission, Rehovoth, Israel).

June 1962, 152 p.

A bibliography on isotope separation is presented covering the period 1922 to 1961; however, in the section on thermal diffusion some applications to non isotopic systems are included. The 498 references are arranged within sections by year of publication or declassification, then alphabetically according to author. The following topics are used as sections: bibliographies, reviews and theory, gaseous diffusion and porous membranes, thermal diffusion theory and applications, gas centrifuge and separation nozzle, and chemical and miscellaneous methods. Author and report and patent number indexes are included.

1028 (MLM-1088(Suppl.)) SUPPLEMENT TO THERMAL DIFFUSION: A BIBLIOGRAPHY.

Grove, G.R., and Wallach, K.S., comp. (Atomic Energy Commission, Rehovoth, Israel).

July 1962, 14 p.

A list of available abstract references from Chemical Abstracts for all the titles included in G.R. Grove's Bibliography on Thermal Diffusion is presented. The order of the titles is the same as for the original bibliography. The name of the first author is given.

1029 THE SEPARATION OF STABLE ISOTOPES.

Chen Wan.

Hua Hseuh Tung Pao, No. 8, 10-20 (1963). (In Chinese).

The methods used for the separation of stable isotopes are reviewed. They include methods based on the difference in the mass of the isotopes, such as electromagnetic and centrifugal methods; on molecular kinetic characteristics, e.g., diffusion, thermal gradient, molecular distillation, and electrophoretic methods; on thermodynamic properties, such as distillation, chemical exchange, chromatographic, absorption, crystallization, and extraction methods; on chemical reaction kinetics of the isotopes, for example, methods based on the kinetic isotopic effect, photochemical properties, and electrolysis. A fifth class, the method based on biological effects, is also reviewed. Industrial use of these theoretically possible systems depends on the relative physical properties of isotopes considered, such as the relative volatility of given compounds. Energy requirements and capital costs determine the cost of industrial methods, among which are those relying on gaseous diffusion, centrifugation, distillation, and chemical exchange. Electrolysis is suitable for both small, and large-scale separation of lithium and hydrogen isotopes. The electromagnetic method is of interest for separating microamounts of isotopes regardless of the atomic weight involved. Diffusion and centrifugation are considered as most suitable for the separation of isotopes of heavy elements and chemical exchange and distillation for those of light elements. (49 references)

1030 (IA-832) SEPARATION OF ISOTOPES BY ELECTROMIGRATION.

Literature Review with Tabulated Comparison of Reported Experimental Results.

Gazith, M., and Roy, A. (Atomic Energy Commission, Israel. Soreq Research Establishment, Nahal Soreq).

Feb. 1963, 44 p.

A survey of the literature on the separation of isotopes by electromigration in aqueous solutions and fused salts is presented. A summary is given of several forms of the equations used for the evaluation of the elementary separation factors from experimental results. Reported separation factors for both aqueous solutions and fused salts are shown on a common graph. Details of about seventy experiments described in the literature are collected in several tables where materials, apparatus, electrical input, separation results, etc., are compared. A comprehensive bibliography is included. (Author)

1031 (AED-C-24-01) INFORMATION ON NUCLEAR ECONOMICS IN THE UNITED STATES. ECONOMICS OF NUCLEAR FUEL. BIBLIOGRAPHIES.

Lamarsh, J.R., comp. (New York Univ., New York).

July 1964, 147 p. Dep. (mn).

A keyword bibliography is presented of the American literature in 1955-1963 on the economics of nuclear fuels. Among the topics covered are costs and prices of ore mining, processing of ores, isotope separation, fuel element fabrication, fuel services, etc. Author and subject indexes are included.

1032 (CEA-Bib-52) SEPARATION ISOTOPIQUE DES ELEMENTS LOURDS (ISOTOPIC SEPARATION OF HEAVY ELEMENTS).

Lambert, I. (Commissariat à l'Énergie Atomique. Centre d'Études Nucléaires, Saclay, France).

Oct. 1964, 20 p. Dep. (mn).

The methods of separating the natural isotopes of the heavy elements Hg, Tl, Pb, and U are reviewed, with the exception of electromagnetic separation, centrifuging, and gaseous diffusion. The methods are: 1. Reversible statistical processes using equilibria between two phases. 2. Irreversible statistical processes: electromigration, thermal diffusion and molecular distillation. 3. Photochemical separation in the particular case of mercury. None of these methods has given satisfactory results for lead and thallium. By photochemistry it is possible to isolate the isotopes 198 and 200 of mercury in an almost pure state. Of the many methods tried out for the $^{235}U/^{238}U$ separation, only thermal diffusion leads to marked enrichment. Chemical methods however can be used for a pre-enrichment before carrying out electromagnetic or thermal diffusion separations. (Author)

1033 (ORNL-TM-1133) NUCLEAR FUEL CYCLE RESEARCH IN RUSSIA : A LITERATURE SURVEY.

Gresky, A.T. (Oak Ridge National Lab., Tenn.).

Mav 13, 1965. Contract W-7405-eng-26. 512 p. Dep. (mn); $8.12 (cy), 8 (mn) CFSTI.

A rather general literature survey of Soviet nuclear fuel cycle research is presented, along with compilations of contributing scientists, their institutes, several thousand of their publications or articles which have appeared in the open literature, and several representative abstracts of these articles. The publication period covered is mostly the interval between 1955 and mid-1963; however, a few papers extending back to the early 1940's are listed because of their historical interest. Though primary attention is given to the chemical or chemical engineering aspects of the fuel cycle, a considerable number of the selected articles deal with related aspects of metallurgy and solid state physics, as well as reactor physics, high energy physics, health physics, biology and medicine, isotope separations, radio-isotope utilization, and so forth. (Author)

1034 (CEA-Bib-56) SEPARATION PHOTOCHIMIQUE DES ISOTOPES (PHOTOCHEMICAL ISOTOPE SEPARATION).

Rozenberg, J. (Commissariat à l'Énergie Atomique, Saclay, France. Centre d'Études Nucléaires).

May 1965, 14 p. Dep. mn.

The principle and the physico-chemical conditions of isotope separation using photo-chemical reactions are examined. The experimental attempts made up to the present have led to variable results. The present report is concerned more particularly with mercury, chlorine, uranium, and hydrogen. The isotopic separation of mercury is sufficiently well developed, after numerous studies, for mention to be made of an industrial application. The possibility of extending the use of the photo-chemical separation method to other elements such as lithium is discussed. Finally the application of a photo-thermal process to uranium isotope separation is mentioned. This literature survey covers the period 1920-1964 and includes 38 references. (Author)

1035 SEPARATION OF ISOTOPES.

Blum, J.M.

Energ. Nucl., 8, 207-11 (May 1966). (In French).

A bibliographic review is presented on the chemical and physical methods of isotope separation. Topics covered include: statistically reversible procedures, statistically irreversible procedures, and separation by specific methods (photochemical and electromagnetic methods). (78 references)

1036 PROGRESS IN PRODUCING STABLE ISOTOPES.

Wetzel, K.

Isotopenpraxis, 2, 277-84 (July 1966). (In German).

The following topics are surveyed: physico-chemical basi of producing stable isotopes: production of stable isotope on the basis of chemical-thermodynamic isotope effects (countercurrent distillation, chemical exchange, exchange distillation); production of stable isotopes on the basis of chemical-kinetic isotope effects; production of stable isotopes on the basis of molecular-kinetic isotope effects (thermal diffusion, gas diffusion, separation nozzle, gas centrifuge, electromigration, molecular distillation); and some aspects of producing stable isotopes. (76 references.) (Author)

1037 ROZDZIELANIE IZOTOPOW NATURALNYCH (SEPARATION OF NATURAL ISOTOPES).

Selecki, A.

Warsaw, Panstwowe Wydawnictwo Naukowe, 1965, 538 p.

A brief review is given on the isotopic separation theory and of applications of isotopes in research and technology. Isotopic effects in optical spectra and in chemical relaxation are analyzed. Isotopic analysis by densimetric, pycnometric, spectrometric, and magnetic resonance methods are reviewed. Cascade isotope separation, rectification, distillation, and chemical relaxation methods are discussed. Data are also given on isotopic separation by electrochemical, thermal diffusion, and diffusion methods. Selective isotopic separation is also discussed.

1038 REVIEW OF FUEL PROCESSING TECHNOLOGY PRESENTED AT THE 1964 GENEVA CONFERENCE.

Gresky, A.T. (Oak Ridge National Lab., Tenn.).

Progr. Nucl. Energy, Ser. III, 4, 3-34 (1970).

A general summary is presented of the 1964 Geneva Conference papers in the field of reactor fuel processing, together with brief discussions of selected papers on the following topics: ^{235}U separation; hydrogen and heavy water; production of isotopes of other elements; uranium and thorium resources and requirements; prospecting techniques and recovery of uranium from ores; metallic fuels; liquid fuels; ceramic fuels; fuel element fabrication and experience; economics of fuel cycles; safety of chemical processing plants; fuel transport; fuel reprocessing (aqueous processes; fission product and transuranium element recovery); radioactive waste management; and safety aspects of large scale use of atomic energy. (220 references)

1039 HAUPTENTWICKLUNGSRICHTUNGEN

In der Trennung stabiler Isotopen. (Main Trends in the Developpment of Methods for the Separation of Stable Isotopes.)

Sakodynskii, K.I., and Zhavoronkov, N.M.

J. angew. Chemie (russ.), 36, (1963) 12, 2564/2579.

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2 THE SEPARATION OF LIQUID MIXTURE BY CENTRIFUGING.

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12 THE THEORY OF GASEOUS ISOTOPE SEPARATION IN A FORCE FIELD WITH APPLICATION TO THE ULTRA-CENTRIFUGE.

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Murphy, E.J.
Chem. & Eng. News.
Vol. 24, No. 2, p. 182-6.
Eng. Index p. 96. 1946.

Energy mass conversion and nuclear reactions; describes methods of separating uranium isotopes by thermal diffusion, centrifuge, porous barrier and electromagnetic means.

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Cohen, K., Murphy, G.M.
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Vol. 13, p. 165. New York. 1951.

17 SEPARATION OF ISOTOPES IN CALUTRON UNITS.

Savage, W. (ed.)
Oak Ridge, Tenn. : AEC - 437 p.
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18 NEUE WEGE ZUR ERZEUGUNG VON SPALTBAREM MATERIAL. ZWEI VERFAHREN DER ISOTOPENTRENNUNG BEIM URAN.

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21 ISOTOPE SEPARATION IN SUPERSONIC JETS.

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22 GAS ULTRA-CENTRIFUGE SEPARATION OF U ISOTOPES.

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23 ADVANCES IN GAS-CENTRIFUGE ENRICHMENT BRING BIG PROBLEMS.

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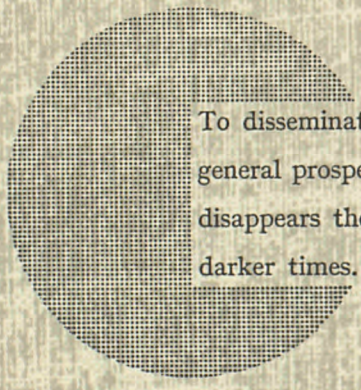

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Alfred Nobel

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