ADVANCED HIGH-THROUGHPUT ELECTROREFINER DESIGN

Inventors: Eddie C. Gay, Park Forest, IL (US);
James L. Willit, Batavia, IL (US);
Donald E. Preuss, Hinsdale, IL (US)

Correspondence Address:
Harry M. Levy, Esq.
Emrich & Dihlmar
Suite 3000
300 South Wacker Drive
Chicago, IL 60606 (US)

Assignee: The University of Chicago, Chicago, IL

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ABSTRACT

A nuclear fuel electrorefiner for recovering uranium from nuclear material containing uranium. A cylindrical vessel with having a longitudinal axis has a product collector movable axially of the vessel. Circular cathodes extend axially of and radially spaced inwardly of the vessel with a plurality of generally polyhedron-shaped anode baskets having at least one face aligned with a radius of said vessel and circumferentially spaced from adjacent anode baskets and concentric with respect to the cathodes in the vessel. A plurality of axially extending metal rods are insulated from and placed between the anode baskets. Mechanism outside of the vessel rotate the anode baskets and the metal rods with respect to the cathodes, and an electrical power supply in selective electrical communication with said cathode and said anode baskets and said metal rods to cause uranium values to move between the and when current flow is in a first direction uranium values in said anode baskets and the metal rods to the cathodes.
FIG. 1
PCR HTER - Close-up of Top

FIG. 3
PCR HTER - Outer Cathode Removed

10

50 Stripper Mandrel

57 Scraper Assembly

65 Inner Cathode

35

56b

56a

55 Outer Basket

FIG. 6
Anode Basket Removal/Insertion

Inner Basket partially removed
Scraper Assembly Removal/Insertion

Scraper Assembly partially removed

FIG. 8
PCR HTER - Close-up of Bottom

Stripper Mandrel

Scraper Assembly

Inner Cathode

Product Diverter 72

Product Collector 80

Outer Basket

Sweepers 79

FIG. 9
Center Removal of Product Collector

Product Collector partially removed

FIG. 11
ADVANCED HIGH-THROUGHPUT ELECTROREFINER DESIGN

[0001] The United States Government has rights in this invention pursuant to Contract No. W-31-109-ENG-38 between the U.S. Department of Energy (DOE) and The University of Chicago representing Argonne National Laboratory.

FIELD OF INVENTION

Background of the Invention

[0002] Electrorefining is a metallurgical separation technique that has been used to recover uranium from fission products and other components of spent fuel from the Experimental Breeder Reactor-II (EBR-II), as well as to purify impure plutonium metal. The technique is well suited to this application because the separation is based on changes in oxidation state and is accomplished by the addition or removal of electrons at electrodes rather than the use of chemical oxidizing or reducing agents, which can significantly increase the volume of waste generated.

[0003] For the last six years, personnel at Argonne National Laboratory (ANL) have mounted a significant effort to increase the throughput of this process as it is applied to the treatment of spent EBR-II fuel. In that time ANL personnel have moved from a small prototype device to a working unit that was demonstrated successfully at a throughput of 150 kg uranium/month with actual spent fuel in the Fuel Cycle Facility at ANL-West. The throughput still needs to be substantially increased, however, to handle the large inventory of EBR-II blanket fuel and other spent metal fuels at DOE sites. The basic electrochemistry of the process is now well understood and optimized. Consequently, increasing the throughput has focused primarily on improving the engineering of the process.

[0004] In the high-throughput electrorefiner design, uranium was loaded into anode baskets that rotated in a channel between cathode tubes. The anode assembly and the cathode tubes were submerged in a molten LiCl-KCl eutectic. The salt also contained 5 to 7 wt. % uranium cations. Uranium and the elements in the fuel that are less noble than uranium were oxidized at the anode and formed cationic species that dissolved in the molten salt. Uranium cations were then reduced at the cathode, and the reduced uranium metal deposited on the cathode surface. Scrapers mounted on the rotating anode basket assembly dislodged the electrodeposited uranium, which fell to the bottom of the unit where it was collected.

[0005] The schematic of FIG. 1 presents a cross-sectional rendering of the prior art high-throughput concept. FIG. 1 shows 12 anode baskets with attached scrapers in the unit. Four cathode tubes form three channels within which the anode baskets rotate. After being scraped off the cathode tubes, the uranium product is collected in a basket attached to the bottom of the outer cathode tube. With a 10-in. (25-cm) diameter module, uranium can be removed from spent EBR-II fuel at an average rate of nearly half a kilogram per hour. In the Fuel Cycle Facility at ANL-West, four of these units are operated in a single process vessel. One of the key steps required in the opening profile is a periodic reversal of the current to remove a dense layer of uranium that builds up on the surface of the cathode and is not dislodged by the scrapers.

SUMMARY OF THE INVENTION

[0006] Accordingly, it is an object of the present invention to provide next-generation high-throughput electrorefiner that is capable of treating as much as 20 metric tons of uranium per year.

[0007] Another object of the invention is to provide an electrorefiner with a peripherally driven anode assembly, independent removal of the product collector, and electrically isolated stripper rods located between the anode baskets.

[0008] Yet another object of the present invention is to provide a nuclear fuel electrorefiner for recovering uranium from nuclear material containing uranium, comprising a cylindrical vessel having a longitudinal axis containing at the bottom thereof, a product collector movable axially of the cylindrical vessel, at least one cathode generally circular in horizontal cross section extending axially of and radially spaced inwardly of the vessel, a plurality of generally polyhedron-shaped anode baskets extending axially of the vessel, each anode basket having at least one face aligned with a radius of the vessel and circumferentially spaced from adjacent anode baskets and concentric with respect to the cathode, mechanism outside of the vessel rotating the generally polyhedron-shaped anode baskets with respect to the cathode, and an electrical power supply in selective electrical communication with the cathode and the anode baskets for causing uranium values in the anode baskets in the presence of a molten electrolyte containing uranium cations to move between the anode baskets and the cathode where uranium values are reduced to uranium metal and thereafter uranium metal is transported from the cathode to the product collector axially removable from the vessel without removing either the anode baskets or the cathode.

[0009] Still another object of the present invention is to provide a nuclear fuel electrorefiner of the type set forth in which a plurality of axially extending metal rods are spaced circumferentially about the longitudinal axis of the vessel and are electrically insulated from and positioned between at least some of the anode baskets.

[0010] Still another object of the present invention is to provide a nuclear electrorefiner of the type set forth in which there are a plurality of concentrically spaced apart cathodes and a plurality of anode baskets arranged in the annular space(s) or channel(s) between the cathodes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The invention consists of certain novel features and a combination of parts hereinafter fully described, illustrated in the accompanying drawings, and particularly pointed out in the appended claims, it being understood that various changes in the details may be made without departing from the spirit, or sacrificing any of the advantages of the present invention.

[0012] FIG. 1 is a cross-sectional view of a representative prior art high-throughput electrorefiner design known as the Mark V operated at ANL-West;

[0013] FIG. 2 is a peripheral drive center removable (PCR) electrorefiner full assembly;
FIG. 3 is a PCR electrorefiner full assembly illustrated in FIG. 2 showing an enlarged view of the top;
FIG. 4 is a PCR electrorefiner full assembly illustrated in FIG. 2 with the well and heaters removed;
FIG. 5 is a PCR electrorefiner full assembly illustrated in FIG. 2 with the crucible removed;
FIG. 6 is a PCR electrorefiner full assembly illustrated in FIG. 2 with the outer cathode removed;
FIG. 7 is a PCR electrorefiner full assembly illustrated in FIG. 2, showing the removal/insertion of the anode baskets;
FIG. 8 is a PCR electrorefiner full assembly illustrated in FIG. 2 showing the removal/insertion of the scraper assembly;
FIG. 9 is a PCR electrorefiner full assembly illustrated in FIG. 2 showing a close-up of the bottom;
FIG. 10 is a PCR electrorefiner full assembly illustrated in FIG. 2, showing the diverter, sweeper and product collector;
FIG. 11 is a PCR electrorefiner full assembly illustrated in FIG. 2 showing the center removal of the product collector;
FIG. 12 is a cross-sectional view of a PCR assembly; and
FIG. 13 is a cross-sectional view of the PCR assembly of FIG. 12 taken along a different radial line.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention remedies several design inadequacies of the Mark V electrorefiner. Although the PCR design of the present invention includes concentric cathode tubes as well as cathode scrapers and anode baskets in the gap or annular space or channel between the concentric cathode tubes, the present invention is a peripheral drive device in which the center portion of the retifer is free permitting anodes, cathodes and most importantly product to be removed axially independently of each other. Previous designs used a central drive shaft to rotate a plate from which the anode baskets were suspended. In the present design the baskets although suspended from a rotating plate similar to the Mark V electrorefiner is driven by a drive motor positioned outside the vessel so as to free the interior thereof. This inventive design makes possible the center removal of the electrorefined uranium product, unlike the Mark V electrorefiner which requires both the anode and cathode components to be removed prior to removal of the product.

Another important feature of the present invention is that although cathode scrapers are provided, their use is reduced and in fact some cases may be obviated entirely. In the present design, the anode baskets because of their configuration produce a higher current density close to the cathode wall and scarpae uranium product deposited on the cathode into the product collector at the bottom of the unit. In addition, the inclusion of stripper mandrels which are electrically insulated from the anode basket(s) is also an important feature. During operation of the Mark V electrorefiner it was found that a hard uranium dendritic coating formed on the cathodes and the only way to remove it was to reverse the current to the vessel thereby electrolytically removing the uranium from the cathode while simultaneously plating the uranium values on the outside of the anode baskets. While effective in removing the hard or dense uranium dendritic coating on the cathodes, this required the outside coating of uranium on the anode baskets to be removed from the anode baskets prior to removal of uranium from the chopped fuel elements inside the anode baskets after current had been reversed once again. This entire reversal requirement slowed down the electrorefining process to a significant extent. With the use of stripper mandrels as hereinafter described, when the current is reversed, uranium is principally plated onto the stripper mandrels as well as on the anode baskets, thereby reducing the amount of uranium which must be removed from the outside of the anode baskets before the uranium values inside the anode baskets are transported to the cathodes.

It is believed that use of the hereinafter described invention will be able to achieve a 450 kgm throughput. Tables 1 and 2 includes calculations based on the hereinafter described invention for both one channel and two channel PCRs. Two channel PCRs relate to three cathodes and two annular channels of anode baskets with stripper mandrels positioned between each of the anode baskets.

| TABLE 1 |
| Throughput calculations - Basis |
| 1-Channel PCR (25° diameter) | cathode | anode | stripper mandrel |
| Electrode Area, cm² | 13406 | 7392 | 4750 |
| sticking coefficient | 0.8 | N/A | 0.5 |
| deposition current density, A/cm² | 0.135 | 0.15 | 0.15 |
| stripping current density, A/cm² | 0.102 | 0 | 0.287 |
| 2-Channel PCR (36° diameter) | cathode | anode | stripper mandrel |
| Electrode Area, cm² | 26126 | 19712 | 11260 |
| sticking coefficient | 0.8 | N/A | 0.5 |
| deposition current density, A/cm² | 0.178 | 0.15 | 0.15 |
| stripping current density, A/cm² | 0.107 | 0 | 0.249 |

| TABLE 2 |
| Operational Cycle and Throughput |
| A-h | I/A | time/h |
| 1-Channel PCR |
| Deposition | 500 | 1821.3 | 0.27 |
| Rods | 200 | 712.5 | 0.12 |
| Baskets | 300 | 1308.8 | 0.27 |
| Strip | 400 | 1362 | 0.29 |
| Wash | | | 0.10 |
| peak throughput = 1112 g/hr |
| avg monthly throughput = 450 kg/mo |

| 2-Channel PCR |
| Deposition | 500 | 4646 | 0.11 |
| Rods | 200 | 1689 | 0.12 |
| Baskets | 300 | 2957 | 0.10 |
| Strip | 400 | 2904 | 0.14 |
| Wash | | | 0.10 |
| peak throughput = 2077 g/hr |
| avg monthly throughput = 841 kg/mo |
[0029] Referring now to the drawings, there is disclosed a peripheral drive center removal PCR electrorefiner 10 which has an outer vessel 11 cylindrical in design having a cylindrical wall 12 and a horizontal bottom 13. The cylindrical wall 12 ends in an outwardly extending flange 14 at the top of the outer vessel 11. An insulator ring 15 is positioned on top of the flange 14 and receives or carries a plate 17 which is normally Z-shaped cross section as is seen in the left hand portion of FIG. 12. Heater shields 18 are suspended from the plate 17, and there is also provided an insulator ring 19 as seen in FIG. 12.

[0030] A cylindrical crucible 20 is positioned inside the outer vessel 11 and has a vertically extending cylindrical wall 21 and a bottom 22. The double wall nature of the crucible 20 and the outer vessel 11 are safety features. An annular fixture 25 sits on top of the insulating ring 19 and includes a top flange 26 and a bottom flange 27 interconnected by a vertically extending bight 28. An outer ring 29 provides support for a top plate 30 and includes a gear ring 33 on the outer periphery thereof which is engaged by a peripheral drive motor 35 having an output gear 36. A mounting structure 37 mounts the peripheral drive motor 35 to the fixture 25.

[0031] The top plate 30 has a horizontal flange 40 connected to an upstanding vertical flange 41, the horizontal flange 40 being provided with spaced apart circular apertures 42, spaced apart rectangular apertures 43 and spaced apart angular apertures 44, the apertures 43 being wider than the apertures 44, both having the longer dimension positioned radially of the vessel 11.

[0032] A slip ring 45 is mounted interior of the flange 41 and is electrically insulated therefrom and carries a plurality of horizontally extending supports from which extend a plurality of mandrel rods 50, each of the mandrel rods 50 being electrically insulated from the horizontal flange 40 of the top plate 30.

[0033] A plurality of axially extending circumferentially spaced apart anode baskets 55 are positioned within the apertures 43. Each anode basket 55 as seen in FIG. 7 is polyhedron-shaped and may be of any convenient design, such as pentahedron or hexahedron. In the preferred embodiment, the anode basket 55 is a hexahedron with the two faces extending radially of the vessel 11 being longer than the two opposed faces extending perpendicular to the radial faces. More particularly, as seen in FIG. 7, each anode basket 55 includes opposed faces 55(a) which are smaller in dimension than opposed faces 55(b), the faces 55(b) being positioned along the radius of the cylindrical vessel 11. As is well known in the art, the anode baskets 55 are perforated and may be provided with screens to retain fines within the anode basket during the electrorefining process.

[0034] Scrapper assemblies 57 are positioned preferably intermediate each anode basket 55 and each mandrel rod 50. The scrapper assemblies 57 extend axially of the vessel 11 the length of the cathodes 60, 65 and are standard in the art. In the inventive PCR 10, the scrapper assemblies 57 may or may not be required depending on the efficiency of the mandrel rods 50 and the anode baskets 55 scraping deposited uranium from the cathodes, as will be described. There are provided two cathodes, an outer cathode 60 having a cylindrical wall 61 and an inner cathode 65 having a cylindrical wall 66. Cathodes 60, 65 are supported at the bottom of the vessel 11 by means of a cathode support 70, generally U-shaped in vertical cross section to support the outer and inner cathode 60 and 65 respectively, as best seen in FIG. 13.

[0035] As illustrated in FIGS. 8-13, there is provided a product diverter 72 which is mounted to or depends from the cathode support 70, the product diverter 72 having a frustoconical portion 73 and a vertical flange portion 74 which may be mounted, as illustrated in FIGS. 12 and 13 to the outer cathode 60 and/or the cathode support 70. As is known, the product diverter 72 would be electrically insulated from the cathodes 60 and 65 in order to prevent a product from being deposited thereon during the electro refining process. The frustoconical portion 73 of the product diverter 72 is reinforced by a plurality of circumferentially spaced apart struts 76 which may be welded or otherwise fixed to either or both of the inner vessel bottom 22 and the cylindrical wall 21. As best seen in FIG. 10, the product diverter 72 may also include a cylindrical pan 77 in addition to or in lieu of the bottom 22 of the crucible or inner vessel 20.

[0036] Ring structure 78 is internal of the vertical flange 74 and may provide support for a plurality of blade shaped sweepers 79 which may be rotatable independent of the product collector 80 which is a cylindrical container having wall 81 and a bottom 82. A handle 83 extends vertically upwardly through the product collector 80 and preferably is aligned with the longitudinal axis of the PCR 10.

[0037] The materials from which the PCR 10 is made are well known in the art and may include any suitable metal for the inner container or crucible 20 and the outer vessel 11, representative metals being steel, stainless steel, Inconel or other well known metals in the nuclear electrorefining art. Similarly, insulation between the various metal components of the PCR 10 are also well known and are art recognized. Although there is shown in the above figures two cathodes 60 and 65 and a plurality of circumferentially spaced anode baskets 55 between the two cathodes, it should be understood that a larger plurality of concentric cathodes and concentric anode baskets may be employed as illustrated in the prior art shown in FIG. 1, wherein four cathode tubes form three channels within which the anode baskets rotate. A similar configuration may be used in the present invention with rotational driving mechanism being located exterior to the outermost cathode thereby freeing the center of the PCR 10 for removal of the product collector 80 axially of the vessels.

[0038] As is well known in the art, electrical power supplies are available and when a current flows between the anode baskets 55 and the cathodes 60 and 65, uranium values in the anode baskets are transferred through the molten salt electrolyte which contains uranium cations and plate out on the cathode as uranium metal by reduction at the cathode. During operation of the Mark V electrorefiner, dense uranium dendrites build-up on the cathodes requiring scrapers as illustrated in the present invention to remove the uranium on the cathode; however, the dense inner coating often cannot be scraped and can only be removed by reversing the current flow so that uranium metal plated onto the cathodes is dissolved in the electrolyte and plates on the outside of the anode basket. The present invention significantly reduces this problem by providing a plurality of axially extending metal mandrel rods 50 which may be of
any suitable metal from the anodes but electrically connected to said cathodes 60, 65 by an independent power supply so that during current reversal on uranium metal plates onto the rods 50. Accordingly, uranium metal when dissolved from the cathodes 60, 65 will plate onto the mandrels 50 in lieu of the anode baskets 55. This is important because the uranium values which plate on the rods 50 reduce or eliminate the amount of uranium metal plating on the anode baskets 55 during current reversal. Because in the Mark V electrolyzer, uranium metal plates onto the outside of the anode baskets during current reversal, when the current is again reversed, the uranium metal on the outside of the baskets must be removed first prior to any uranium values inside the baskets being transported via the electrolyte to the cathodes.

[0039] As seen in Tables 1 and 2, calculations show a significantly improved transfer rate throughput for the PCR electrolyzer of the present invention. While the Mark V electrolyzer has demonstrated a 150 kg/mo throughput, the PCR of the present invention is calculated to be able to move 450 kg/mo for a second channel refiner and 840 l/mo or a two-channel electrolyzer and this is a significant advantage over the current state of the art.

[0040] In other respects, operation of the current PCR electrolyzer 10 and the Mark V are similar. Both use the same materials of contraction, the same anode and cathode materials, the same electrolytes and operating cycles. The PCR 10 of the present invention provides faster throughput, easier handling and less down time and maintenance, although requiring an extra power supply to the mandrels or rod 50 connected to the cathodes 60, 65.

[0041] While particular embodiments of the present invention have been shown and described, it will be appreciated by those skilled in the art that changes, modifications and improvements may be made, for example in the processing of the materials or in the electrode and/or cell design without departing from the true spirit and scope of the invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A nuclear fuel electrolyzer for recovering uranium from nuclear material containing uranium, comprising a cylindrical vessel having a longitudinal axis containing at the bottom thereof a product collector moveable axially of said cylindrical vessel, at least one cathode generally circular in horizontal cross section extending axially of and radially spaced inwardly of said vessel, a plurality of generally polyhedron-shaped anode baskets extending axially of said vessel, each anode basket having at least one face aligned with a radius of said vessel and circumferentially spaced from adjacent anode baskets and concentric with respect to said cathode, mechanism outside of said vessel rotating said generally polyhedron-shaped anode baskets with respect to said cathode, and an electrical power supply in selective electrical communication with said cathode and said anode baskets for causing uranium values in said anode baskets in the presence of a molten electrolyte containing uranium cations to move between said anode baskets and said cathode where uranium values are reduced to uranium metal and thereafter uranium metal is transported from said cathode to said product collector axially removable from said vessel without removing either said anode baskets or said cathode.

2. The nuclear fuel electrolyzer of claim 1, wherein said cathode is a metal conductor.

3. The nuclear fuel electrolyzer of claim 1, wherein said cathode is steel.

4. The nuclear fuel electrolyzer of claim 1, wherein said cathode is steel coated with tungsten.

5. The nuclear fuel electrolyzer of claim 1, wherein said anode baskets have perforated faces.

6. The nuclear fuel electrolyzer of claim 1, wherein said anode baskets are generally hexahedron shaped having four axially extending faces.

7. The nuclear fuel electrolyzer of claim 6, wherein each anode basket has two axially extending faces aligned with a radius of said vessel and are longer in horizontal cross section than the other two axially extending faces.

8. The nuclear fuel electrolyzer of claim 1, wherein said anode baskets are generally pentahedron-shaped.

9. The nuclear fuel electrolyzer of claim 1, wherein said anode baskets rotate with respect to said cathode and said product collector.

10. The nuclear fuel electrolyzer of claim 1, wherein there is more than one cathode.

11. The nuclear fuel electrolyzer of claim 1, wherein there are a plurality of concentrically positioned cathodes and anode baskets.

12. The nuclear electrolyzer of claim 1, wherein there is at least one cathode external to each anode basket.

13. The nuclear electrolyzer of claim 1, wherein said anode baskets during rotation scrape at least some of the uranium metal deposited on an adjacent cathode to enhance transportation of uranium metal from said adjacent cathode to said product collector.

14. The nuclear electrolyzer of claim 1, and further comprising a product diverter positioned below said cathode sloping toward said product collector to direct uranium metal from said cathode to said product collector.

15. The nuclear electrolyzer of claim 1, wherein at least a portion of said product diverter is frustum shaped.

16. The nuclear electrolyzer of claim 15, and further including a scraper rotatable with said anode baskets for scraping uranium metal from said cathode and/or said product diverter.

17. A nuclear fuel electrolyzer for recovering uranium from nuclear material containing uranium, comprising a cylindrical vessel having a longitudinal axis containing at the bottom thereof a product collector moveable axially of said cylindrical vessel, at least one cathode generally circular in horizontal cross section extending axially of and radially spaced inwardly of said vessel, a plurality of generally polyhedron-shaped anode baskets extending axially of said vessel, each anode basket having at least one face aligned with a radius of said vessel and circumferentially spaced from adjacent anode baskets and concentric with respect to said cathode, mechanism outside of said vessel rotating said generally polyhedron-shaped anode baskets with respect to said cathode, and an electrical power supply in selective electrical communication with said cathode and said anode baskets for causing uranium values in said anode baskets in the presence of a molten electrolyte containing uranium cations to move between said anode baskets and said cathode where uranium values are reduced to uranium metal and thereafter uranium metal is transported from said cathode to said product collector axially removable from said vessel without removing either said anode baskets or said cathode.
metal rods and when current flow is in a first direction uranium values in said anode baskets in the presence of a molten electrolyte containing uranium cations move between said anode baskets and said cathode where uranium values are reduced to uranium metal and when current is flowing reversely to the first direction uranium metal is transported from said cathode to said axially extending metal rods and when current again flows in the first direction uranium values are all transported from said anode baskets and said metal rods to said cathode and to said product collector axially removable from said vessel without removing either said anode baskets or said metal rods or said cathode.

18. The nuclear electrowrefiner of claim 17, wherein each of said anode baskets is generally hexahedron shaped having four axially extending faces, two of said faces being generally aligned with a radius of said vessel and longer in horizontal cross section than the other two axially extending faces.

19. The nuclear electrowrefiner of claim 18, wherein said axially extending anode baskets have the longer faces thereof perforated.

20. The nuclear electrowrefiner of claim 19, wherein at least one axially extending metal rod is positioned between adjacent anode baskets.

21. The nuclear electrowrefiner of claim 20, wherein said anode baskets are carried by an annular plate extending axially from said vessel and said metal rods extend through said plate.

22. The nuclear electrowrefiner of claim 21, wherein there are a plurality of concentric cathodes, each substantially circular in horizontal cross section.

23. The nuclear electrowrefiner of claim 22, wherein said anode baskets are intermediate adjacent cathodes.

24. The nuclear electrowrefiner of claim 23, wherein said anode baskets during rotation scrape at least some of the uranium metal deposited on an adjacent cathode to enhance transportation of uranium metal from said adjacent cathode to said product collector.

25. The nuclear electrowrefiner of claim 24, and further comprising a product diverter positioned below said cathode sloping toward said product collector to direct uranium metal from said cathode to said product collector.

26. The nuclear electrowrefiner of claim 25, wherein at least a portion of said product diverter is frustum shaped.

27. The nuclear electrowrefiner of claim 26, and further including a scraper rotatable with respect to said cathode for scraping uranium metal from said cathode and/or said product diverter.

28. A nuclear fuel electrowrefiner for recovering uranium from nuclear material containing uranium, comprising a cylindrical vessel having a longitudinal axis containing at the bottom thereof a product collector movable axially of said cylindrical vessel, a plurality of concentric radially spaced apart cathodes generally circular in horizontal cross section extending axially of said vessel, a plurality of generally polyhedron-shaped anode baskets extending axially of said vessel, each anode basket having at least one face aligned with a radius of said vessel and circumferentially spaced from adjacent anode baskets and concentric with respect to said cathodes, a plurality of axially extending metal rods spaced circumferentially about said longitudinal axis electrically insulated from and between at least some of said polyhedron-shaped anode baskets, mechanism outside of said vessel rotating said generally polyhedron-shaped anode baskets and said metal rods with respect to said cathodes, and an electrical power supply in selective electrical communication with said cathodes and said anode baskets and said metal rods and when current flow is in a first direction uranium values in said anode baskets in the presence of a molten electrolyte containing uranium cations move between said anode baskets and said cathodes where uranium values are reduced to uranium metal and when current is flowing reversely to the first direction uranium metal is transported from said cathodes to said axially extending metal rods and when current again flows in the first direction uranium values are simultaneously transported from said anode baskets and said metal rods to said cathodes and said product collector axially removable from said vessel without removing either said anode baskets or said metal rods or said cathodes.

29. The nuclear fuel electrowrefiner of claim 28, wherein said anode baskets are generally hexahedron shaped having four axially extending faces at least two of which are perforated.

30. The nuclear fuel electrowrefiner of claim 29, wherein each anode basket has two perforated axially extending faces generally aligned with a radius of said vessel and are longer in horizontal cross section than the other two axially extending faces.

31. The nuclear fuel electrowrefiner of claim 30, wherein an axially extending metal rod is positioned between each anode basket and the adjacent anode basket.

32. The nuclear electrowrefiner of claim 31, and further comprising a product diverter positioned below said cathodes sloping toward said product collector to direct uranium metal from said cathodes to said product collector.

33. The nuclear electrowrefiner of claim 32, wherein at least a portion of said product diverter is frustum shaped.

34. The nuclear electrowrefiner of claim 33, and further including a scraper rotatable with said anode baskets for scraping uranium metal from said cathodes and/or said product diverter.

35. The nuclear electrowrefiner of claim 28, wherein there are independent electrical power supplies between said cathodes and said anode baskets and between said cathodes and said metal rods.

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