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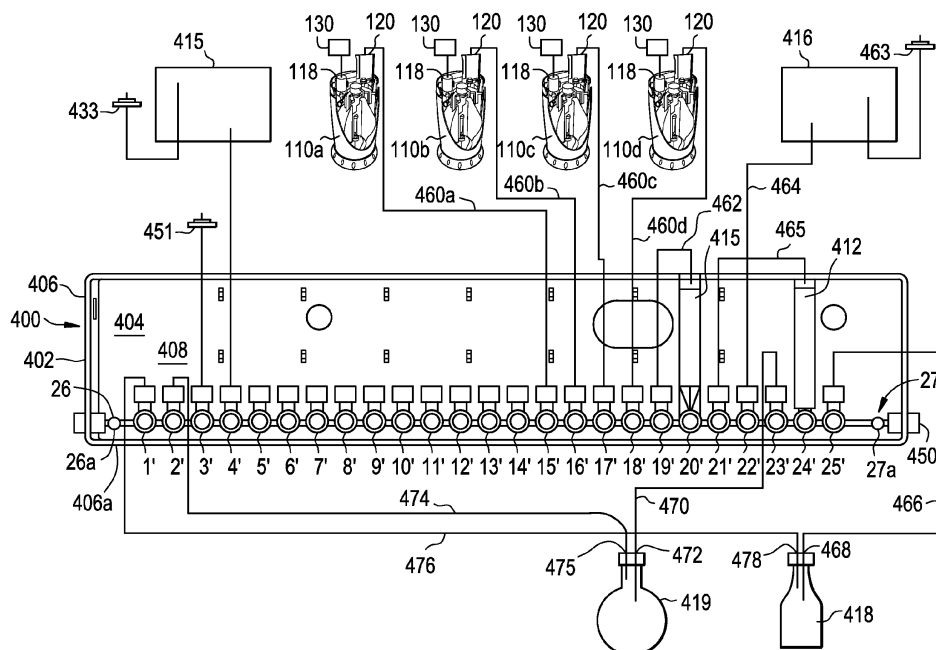
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(54) **Computer program product for managing a multiple generator elution system**

(57) A multiple generator elution system for selectively eluting from a plurality of parent-daughter generators (110a-d) according to an elution schedule it calcu-

lates taking into account supply data, demand data, and available activity in each of the generators.

FIG. 8



Description**Field of the Invention**

5 **[0001]** The present invention relates to the field of radioisotope generators. More specifically, the present invention is directed to a multiple generator elution system.

Background of the Invention

10 **[0002]** Fission-produced Mo-99 supply is in a state of uncertainty. Only two reactors, the Canadian NRU reactor and the Petten HFR reactor, represent approximately 60-70% of the world's supply of fission produced Mo-99. When either of these reactors goes off-line, whether for scheduled maintenance or for unscheduled repairs, the result is to effectively reduce nuclear medicine procedures to only essential cases. All the reactors used to manufacture fission Mo-99 are nearing the end of their respective working lives, currently only one replacement reactor is planned, the Petten replacement called Pallas. Of additional concern is the proliferation of highly enriched uranium (HEU), the target material for fission Mo-99, falling into the hands of terrorists or rogue governments. HEU is used for manufacturing nuclear weapons.

15 **[0003]** Alternatively, a gel-based generator uses Mo-99 obtained from neutron activation (n,γ) of natural molybdenum, which can be performed in any nuclear reactor including power reactors. Unfortunately, Mo-99 produced from n,γ methods tends to be of low specific activity when compared to Mo-99 produced from fission of U-235, whether HEU or low enriched uranium (LEU). Low specific activity means the Mo-99 must be either placed on a very large alumina column to absorb all the inactive molybdenum, or turned into an insoluble gel matrix that reduces the overall volume of the elutable column (e.g. zirconium molybdate or titanium molybdate). Subsequently, large elution volumes are required to elute the column of the Tc-99m daughter nuclide, particularly if an alumina column is used. The prior art fails to address all of the issues encountered with low specific activity and or low activity generators.

20 **[0004]** Nucl.Med.Comm., 25 609-614 (2004) discusses the need to obtain high radioactive concentrations of Tc-99m from zirconium molybdate gel generators (higher concentrations are often required for "cold kit" compounding, as well as economic reasons in larger radiopharmacies).

25 **[0005]** US patent 5,729,821 discloses a method for concentration of Tc-99m from Mo-99 sorbent on an alumina based column. The system requires multiple columns to achieve concentration of the eluate. Multiple columns must be used because the Tc-99m is eluted off the primary column by means of ion exchange with the chloride ion in saline. The cation (sodium) is then removed by the secondary column (in this case a silver halide based), and the pertechnetate is concentrated in the tertiary anion column for subsequent elution with saline to form sodium pertechnetate. This method requires the use of an acid salt or weak acid to separate and elute Tc-99m from the parent nuclide Mo-99 (e.g. alumina columns), as well as a cation ion column to remove the cation from the elution, so that the pertechnetate ion can be concentrated on an anion column.

30 **[0006]** Applied Radiation and Isotopes 66 (2008) 1814-1817 discloses a method which extracts Tc-99m from a solution containing Mo-99. This is a complicated procedure that requires the use of organic solvents (tetrabutylammonium bromide solution in methylene chloride) to extract and concentrate the Tc-99m.

35 **[0007]** Applied Radiation and Isotope 66 (2008) 1295-1299 discloses a method cited which is a variant of the above method where a low specific activity alumina based generator is eluted with saline to remove the Tc-99m. The eluate is concentrated on strong anion exchanger Dowex column. The Tc-99m is removed by elution with tetrabutylammonium bromide solution with methylene chloride into a collected in a vial. The organic solvent is removed by vacuum pumping to dryness and reconstituted with saline for use with cold kits. This method is impractical because of time required to prepare the concentrated Tc-99m.

40 **[0008]** U.S. Patent 6,157,036 discloses a method for low specific activity ion exchange type generators (i.e. alumina). The system uses multiple columns similar in method to U.S. Patent No. 5,729,821. The method uses positive pressure instead of safer negative pressure to move fluids - negative pressure (vacuum) is inherently safer for transfers involving radioactive materials.

45 **[0009]** There is therefore a need for a system which manages grow-in of the daughter nuclide for efficiency purposes. There is also a need in the art for an elution system which minimizes the waste and maximizes the use of the daughter nuclide produced by a series of generators. There is further a need for an elution system which can reduce the risk of proliferation of HEU. There is also a need for a manifold kit which is operable by an automated actuation system for directing the eluate from a series of generators to a collection vial.

Summary of the Invention

50 **[0010]** In view of the needs of the art, the present invention provides a multiple generator elution system, comprising a plurality of parent-daughter nuclei generators and a control system for tracking the grow-in of the activity of each of

the parent-daughter nuclei generators.

[0011] The control system receives demand data indicating requirements for activity production and is configured to elute from selected ones of the generators with a first eluate in order to provide a desired amount of a daughter nuclide. A receiving unit receives demand data which includes at least an amount of daughter nuclide to be produced and a schedule for the production of the amount of daughter nuclide. The receiving unit is operable with the control system so that the control system will schedule the elution of the daughter nuclide from the plurality of generators to meet the demand represented by the demand data. The receiving unit will also receive supply data

[0012] The present invention also provides a concentration column for collecting the generator daughter nuclide from the selected ones of the plurality of generators. The concentration column contains an appropriate column media. For example, when the daughter nuclide is Tc-99m, concentration column is desirably an anion column from which the daughter nuclide is eluted. Also provided is a collection container for receiving the daughter nuclide from said concentration column.

[0013] Additionally, the present invention provides a control system a multiple generator elution system which tracks the grow-in of the activity of each of the parent-daughter nuclei generators and schedules elution from among the generators to meet an inputted demand for the daughter nuclide.

[0014] The present invention may also provide a source of second eluent to elute the columns. Depending on the application, the second eluent may be different from the first eluent or both may be the same. Additionally, in embodiments where the same eluent is used to elute both the generators and the concentration column, the eluent may be drawn from a single source. Alternatively, the source of first eluent may be provided individually to each generator, rather than from a common source. The present invention also provides that when highly pure water, such as water for injection, is provided from a common reservoir for eluting the generators, this water may also be used to rinse the components of the elution system between elution runs. The present invention also contemplates that a source of highly pure water may be provided only for the purpose of rinsing components of the multiple generator elution system.

[0015] Additionally still, the present invention provides a method for operating a multiple generator elution system which coordinates inputted demand data for the daughter nuclide produced by the generators, tracks the available activity in each of the generators over time, and schedules elution from among the generators to meet the inputted demand for the daughter nuclide.

[0016] Furthermore, the present invention provides a kit for a manifold system which may be operated by a control system to direct the elutions from among a plurality of parent-daughter generators to a separations column.

[0017] The present invention solves problems for those skilled in managing and operating generators in a nuclear pharmacy. Using Tc-99m/Mo-99 generator for purposes of illustration, and not of limitation, the present invention combines and concentrates the daughter nuclide technetium [Tc-99m] pertechnetate elutions from multiple generator units and extends the useful life of decayed or low activity generators. The present invention automatically manages the isotope "grow-in" for maximum efficiency and cost savings, in conjunction with demand data from an ERP system or manual inputs. The present invention also allows operating personnel to model "what-if" scenarios such as when modeling supply shortages and unexpected increases in demand. Additionally, the present invention may be housed behind a radiological shielding that safely stores generators, as well as all components handling radioactivity. The present invention allows a gamma gel based Mo-99 generators to be more operationally competitive with fission based generators, thus facilitating a viable alternative to Mo-99 produced by the irradiation of highly enriched uranium (HEU), and thus reducing the proliferation of nuclear bomb grade material. Moreover, the present invention provides prescription compounding data interchange for electronic medical records.

[0018] The Mo-99 isotope used in Tc-99m/Mo-99 generators typically represents 75% or more of the total cost of a generator. Generator and isotope purchases are typically the largest single expense item. Mo-99 decays into Tc-99m at a known exponential rate, Tc-99m also decays at a known exponential rate. A typical generator contains a known amount activity when delivered. When the generator is eluted the Tc-99m is removed leaving the Mo-99 behind to continue to decay into Tc-99m. The calculations required to accurately determine the amount of available Tc-99m on a generator at any given time are very complex, and not easily performed. The present invention provides a control system incorporating software for easily and quickly executes these calculations. Utilizing this software in conjunction with the multiple generator elution system allows the control system to select an efficient combination of generators for any given demand. Additionally, historical or real-time demand can be obtained by either manual operator entry, or by data link from an enterprise resource planning system.

[0019] A titanium molybdate "gel" based generator uses very low specific activity Mo-99, which leads to elutions that are less concentrated and of generally lower total radioactive content than the industry standard fission Mo-99 based generator. The multiple generator elution system of the present invention eliminates these issues allowing the gel-based generator to be more operationally competitive than the industry standard fission based generator.

Brief Description of the Drawing**[0020]**

Figure 1 is a cross-sectional schematic of a parent-daughter generator of the prior art.

Figure 2 depicts an activity decay curve for a Mo-99/Tc-99m generator.

Figure 3 depicts the decay curve for Tc-99m in a Mo-99/Tc-99m generator after serial elutions of the Tc99m isotope ions.

Figure 4 depicts a multiple generator elution system for gel-based Mo-99 generators.

Figure 5 depicts an alternate representation of the elution system of Figure 4.

Figure 6 depicts a multiple generator elution system for alumina-based Mo-99 generators.

Figure 7 depicts an alternate representation of the elution system of Figure 6.

Figure 8 depicts a cassette-based manifold as part of a multiple generator elution system of the present invention.

Figure 9 is a flow-chart depicting a method of the present invention.

Figure 10 depicts a screen shot of a graphical user interface (GUI) of the present invention for providing supply information for a multiple generator elution system of the present invention.

Figure 11 depicts a screen shot of a GUI for an elution management system for a multiple generator elution system.

Detailed Description of the Preferred Embodiments

[0021] The present invention concentrates eluates from large volume elutions for reconstitution with "cold kits" that require higher radioactive concentrations. In one embodiment, the present invention provides a system for concentrating Tc-99m. The present invention can concentrate eluates in larger radiopharmacies to achieve work flow efficiencies, particularly with QC testing of eluates, and eliminates time consumed eluting multiple generators individually. Additionally, the present invention allows generators nearing expiry, which tend not to be used because of low yields and thus lower radioactive concentration of eluate, to be more fully utilized to expiry, achieving cost savings. The present invention incorporates software to better match demand with supply, thus achieving cost savings and minimizing waste and loss. The present invention obviates the need for using organic solvents, thus eliminating waste and use of hazardous organic solvents.

[0022] The present invention provides a multiple generator elution system which uses multiple parent-daughter generators, tracks the in-growth relationship for the parent-daughter isotopes in each of the generators, and concentrates the output of the generators which are eluted. Bringing all three of these concepts together solves inherent issues with low specific activity generators, in both in application and efficiency of use.

[0023] The multiple generator elution system is desirably enclosed within a radiation-shielding enclosure, such as a lead-walled hot cell. While the present invention would work for managing elution from a single generator, in the preferred embodiment, multiple generators are managed. One embodiment of the present invention utilizes a number of Mo-99 titanium/ Tc-99m titanium [Mo-99] molybdate gel generators utilizing Mo-99 obtained from neutron activation of natural molybdenum (n, γ Mo-99). While particular reference is made to managing the elutions from Mo-99/Tc-99m parent-daughter generators, the present invention contemplates that other types of generators may also be employed to elute and other daughter isotopes, or daughter nuclides.

[0024] Thus in one embodiment of the present invention, a lead-shielded enclosure contains 1 or more Mo99/Tc99m generators. The generators are connected together via a fluid path system, which enables any combination of generator to be eluted onto a concentration column or columns. In the case of Tc-99m, the concentration column is an anion column. The concentrated Tc99m is subsequently eluted off the concentration column into a collection vial at the required radioactive concentration ready for use in the radio-pharmacy. The control system selects the most efficient combination of generators based on demand, available supply and future demand.

[0025] Both the available supply of activity and the current and future demand for activity may be manually entered or electronically transferred into the receiving unit and into the control system from the generators themselves and from

the radio-pharmacy Enterprise Resource Planning (ERP) system, respectively. For example, data transferred from the generators themselves could be electronically read or scanned from a label on the generator, such as a bar code. Such data regarding the generators, also called the 'supply data', can include the calibration data for the generator, providing both date and activity. Additionally the supply data is contemplated to include the time and date that the generator is available for use and the time and date of the first elution off set. Similarly, the demand data, including the required activity and the time such activity is required from the system may be either manually or electronically entered into the control system. The present invention contemplates that a data receiving unit is configured for the manual and/or electronic input of the demand data.

[0026] Using the supply data, the control system can calculate the available activity in each generator, desirably in set intervals, e.g. every thirty minutes, and displays the same to an operator. The demand data is desirably similarly displayed over the same time intervals as the supply data. The control system includes a computer to calculate the best fit elution profile, or schedule, for selecting which of the available generators will be eluted at a given time to meet the demand data in the most efficient way possible, thus maximizing the useful life of each generator and minimizing waste. The control system is desirably programmed to perform a Generalized Reduced Gradient Algorithm analysis of the demand data and the activity levels of the plurality of generators to determine the optimum elution schedule for minimizing waste. Alternatively, the present invention contemplates that the control system is programmed to run simulations of various elution schedules from the plurality of generators and selecting the elution schedule resulting in the lowest amount of waste of the daughter nuclide upon meeting the demand data. The elution schedule will also be provided to the operator.

[0027] Desirably, the display of the elution schedule is provided on a GUI which gives the operator the option of overriding the calculated optimized elution schedule by instead scheduling different generators for elution at a given time. When the operator decides to modify the elution schedule, the control system will recalculate the elution schedule and display the both the updated activity availability over time for each generator as well as the scheduled time of elution from each of the generators. If the updated elution schedule is satisfactory to the operator, the elution instructions will be followed for eluting the selected generators according the schedule. In this way, the present invention provides the option of an 'operator-in-the-loop' to oversee and manage the elution from the generators and allow the operator to override the calculated schedule. Alternatively, the present invention is able to operate without the need for operator intervention and can thus perform the scheduled elutions automatically without operator input, thereby freeing the operator to tend to other pharmacy duties.

[0028] The elution instructions will be used to electronically control the elution of the selected generators. As the generators are eluted, the control system will update the ingrowth calculations and update the elution schedule if necessary. The present invention contemplates that either an operator or the system will perform the step of confirming that the selected generators were in fact eluted.

[0029] Calculations used in populating the elution schedule will desirably take into account known constants such as the parent nuclide half-life and decay equation, the daughter nuclide half life and decay equation, the elution yield efficiency as well as the fraction of the elution available the parent nuclide decay. Additionally the control system will consider the equilibrium equation for the parent-daughter and the expiration time for the generator. Most generators have a 2 week life - this is a pharmaceutical expiry requirement - but it could be much longer if the parent isotope has a long half life, e.g., Sr-90 / Y-90

[0030] The present invention offers numerous advantages both technically and economically. The present invention is thus able to perform as a concentrator of the activity eluted from the selected generators for each elution run. Not only does this allow the efficient utilization of the generators, but it also allows that generators nearing expiry can still be utilized in combination with each other as their activities are concentrated together. Automated operations can reduce exposure to the doses by the pharmacy staff. Labor efficiencies are realized as well. For example, if four generators are to be individually eluted, then four distinct quality control tests are required. The present invention, by concentrating the individual elutions, allows that only a single quality control test be performed on the concentrated elutions, allowing for more activity to be retained in the collection vial for clinical use.

[0031] The present invention makes the use of gel generators a commercially viable option, despite their lower comparative specific activity to fission generators. The multiple generator elution system (MGES) of the present invention is intended to eliminate the disadvantages of gel based generator systems discussed above. Additionally, the use of gel generators improves the management of isotope supply during outages or shortages by the conventional sources.

[0032] The system desirably includes a shielded area that houses two or more gel generators. These generators are connected to separate valve manifolds, which can be selected by the control system to elute the selected generator(s) at the appropriate time to meet planned demand. The Tc-99m is eluted by passing an eluent through the selected one or more generators. The Tc-99m is collected on an alumina concentration column. When the collection(s) from the generator(s) is complete, the control system elutes the concentration column with eluent into an industry standard shielded collection vial. The eluent can be drawn from a reservoir or from individual saline vials currently used to elute generators.

[0033] All the fluid paths, concentration column, and collection vial equipment are desirably shielded by a hotcell to provide radiological protection to the operators. Shielding of individual components may be also provided within the radiation-shielding hot cell.

[0034] Various methods of concentrating Tc-99m elutions have been documented. The calculations for determining the in-growth relationship for parent daughter isotopes are widely known, but not often used because of complexity. The use of n,γ Mo-99 in gel generators systems and other generator systems is also known. The present invention brings all three of these concepts together into a single elution system that manages the supply data, the available activity, and demand data for a plurality of generators, and overcomes issues inherent with low specific activity generators, in both in application and efficiency of use.

[0035] The present invention will work with zirconium or titanium molybdate gel generator systems. With modification, the present invention (as detailed) will work with alumina based systems as well. To work with alumina based systems additional columns and fluid paths therefore will be required.

[0036] The concept of a titanium molybdate gel generator design has been proven. The gel is produced post irradiation from irradiated natural molybdenum metal. The established method includes irradiating the pre formed gel or molybdenum trioxide. Irradiating metal offers yield, safety, and processing efficiency advantages.

[0037] Referring now to Figure 1, a parent-daughter generator 110 of the prior art and incorporated into the multiple generator elution system of the present invention includes a long-lived parent nuclide that decays to a shorter-life daughter nuclide. As the parent and daughter nuclides are not isotopes, it is possible to chemically isolate the daughter nuclide. An eluent is directed through a column containing the parent and daughter nuclides, but carries off only the daughter nuclide as eluate from the column. After the elution, the parent nuclide (remaining in the generator) will decay to provide a fresh supply of daughter nuclide. The generator is thus able to provide a fresh supply of daughter nuclide as needed until the parent activity is depleted.

[0038] Generator 110 includes a generator body 112 formed from a radiation-shielding material such as lead. Generator body 112 defines a column cavity 114 containing a column 116 holding the parent nuclide. Generator body 112 defines an elongate eluent channel 118 and an elongate eluate channel 120 extending in fluid communication between column cavity 114 and an eluent cavity 122 and a collection cavity 124, respectively. Column 116 contains a media 126 to which the parent nuclide binds but from which the daughter nuclide therein may be eluted. Eluent cavity 122 supports an eluent vial 130 and collection cavity 124 supports a collection vial 132 therein. An eluent conduit 134 extends in fluid communication between eluent vial 130 and column 116 so as to deliver the eluent from within vial 130 into column 116. At each end, eluent conduit 134 terminates in an elongate needle 125a and 125b for puncturing septums of vial 130 and column 116, respectively. An eluate conduit 136 extends from column 116 to collection vial 132 so as to deliver the eluate from column 116 into vial 132. At each end, eluate conduit 136 terminates in an elongate needle 129a and 129b for puncturing septums of vial 132 and column 116, respectively. Typically, collection vial 132 is an evacuated vial so that the low pressure within the vial draws the eluent fluid from eluent vial 130, through column 116 and thereinto. A separate air inlet conduit 140 extends in fluid communication between eluent vial 116 and an air intake filter 142 so as to assist the evacuation of the eluent from eluent vial 130. Typically, collection vial 132 is housed within its own radiation shield 144 such that removal of shield 144 from collection cavity 124 will carry the now-filled collection vial 132 with it to where a pharmacist may withdraw the collected eluate for further processing.

[0039] In one embodiment, column 116 contains Mo-99 which decays into Tc-99m with acidic alumina as the sorbent. Column 116 would then be an acidic alumina column although other types of columns, as previously described, may also be used. The present invention contemplates incorporating multiple generators 110. As will be shown hereinbelow, the present invention further contemplates providing that the collection vials are replaced for each generator with a conduit leading to a common collection vial. Additionally, the present invention contemplates that instead of each generator having its own eluent vial 130, a common source of eluent may be provided which may be directed to any and all of the generators as required. For example, when column 116 is an acidic alumina column with Mo-99, eluent vial 130 may provide a source of saline for eluting the Tc-99m nuclide from the column. Alternatively, for example, for a gel generator, a source of water for injection may be provided as an eluent.

[0040] The present invention contemplates that the generators used by the present invention may be either a fission or n,γ generator. For example, the TechnelLife® (Technetium Tc99m Generator) sold by Lantheus Medical Imaging, 331 Treble Cove Rd., N. Billerica, MA 01862, USA may be used. The TechnelLife generator is what is known as a dry generator, which means that it has an external source of saline to elute the system. Most generators tend to be in this format. Similar to other fission based generators the TechnelLife generator is based on acidic alumina column to facilitate the storage of Mo-99 and subsequent separation of the daughter isotope Tc-99m. Similarly, generator 110 may comprise the Ultra-Technekow™ DTE (Technetium Tc-99m Generator sold by Covidien (Mallinckrodt Inc., 2703 Wagner Place, Maryland Heights, MO 63043, USA. The Ultra-Technekow is very similar to the TechnelLife unit. Alternatively still, the DryTec® (Technetium Tc99m Generator may be used with the instant invention. The Drytec generator is sold by GE Healthcare, The Grove Centre, White Lion Road, Little Chalfont, Buckinghamshire HP7 9LL, UK, and is similar to the other fission generators listed above.

[0041] Moreover, generator 110 may be an n,γ , or gel, generator. One gel generator is the Tc-99m - Geltech Generator sold by the Government of India Dept of Atomic Energy, BRIT/BARC Vashi Complex, Sector-20 Vashi, Navi Mumbai - 400 705, India. The Geltech generator for ^{99m}Tc is a dual column system comprising of a primary Zirconium Molybdate- ^{99}Mo gel column and a secondary purification Acidic Alumina column. These types of generators, while structurally different from the fission type generator, still operate in a similar manner to produce sodium pertechnetate using a saline eluent. While the gel generators are not truly chromatographic, the term 'eluent' will be also be used herein to describe the fluid directed into the generator and the term 'eluate' will also be used herein to describe the fluid exiting the gel generator with the daughter nuclide.

[0042] Figure 2 depicts an activity decay curve for a Mo-99/Tc-99m generator. Figure 3 shows how the available activity decays over time until reaching a point where the generator is not useful. Figure 3 also depicts the decay curve for Tc-99m in a Mo-99/Tc-99m generator after serial elutions of the Tc99m isotope ions. Whereas line A depicts the overall decay of the parent nuclide, Mo-99, lines B-D depict the grow-in of the daughter nuclide, Tc-99m, up to a near maximum at which time the daughter nuclide is eluted so that there is none left in the column of the generator. The parent nuclide will continue to decay into the daughter nuclide so the increase in the available activity of the daughter nuclide is shown over time. Equation 1 is the equilibrium equation that describes the theoretical Tc-99m activity (A_2) present in the generator at any time (t) after the previous elution when one knows the Mo-99 activity A_1^0 present at the time of the previous elution.

$$A_2 = \frac{0.86\lambda_2}{\lambda_2 - \lambda_1} A_1^0 (e^{-\lambda_1 t} - e^{-\lambda_2 t}) + A_2^0 e^{-\lambda_2 t} \quad \text{Eq. (1)}$$

Where λ_1 is the decay constant for Mo-99 and λ_2 is the decay constant for Tc-99m. The present invention links the demand for activity with the calculated availability of activity for each of the generators.

[0043] Figures 4 depicts a multiple generator elution system 200 of the present invention. Multiple generator elution system 200 incorporates a plurality of generators 110. The generators 110 are desirably connected to a manifold (not shown) that includes valves and conduits so that individual ones of the valves are in selectable fluid communication with corresponding individual ones of the generators. Desirably, the manifold is connected to a low pressure, or vacuum source, for pulling the eluents through system 300. The manifold directs the generator eluate output to a concentration column 212. An eluent is directed from a first eluent source 214 to selected ones of the generators 110 and the resulting eluate from the selected generators is all directed to column 212. Concentration column 212 traps the daughter nuclide from the generators therein. A second eluent from a second eluent source 216 is directed through concentration column 212 to elute the daughter nuclide into a collection vial 218. The generators 110, column 212, eluent sources 214 and 216 and collection vial are desirably placed within the cavity 224 of a radiation-shielding hot cell 222 so as to limit exposure of the operators.

[0044] System 200 includes a control system 226 and receiving unit 228. Receiving unit 228 and control system 226 may be provided as part of a single computer system. Receiving unit 228 receives both supply data and demand data, which control system 226 can use to generate the elution schedule for the generators 110 as will be described for Figures 9-12. The supply data allows calculation of the amount of activity available from each of generators 110, based on the calibration data, including the known starting activity and date, the time and date of when the generator was available for use, and the time and date of the first elution off set. The demand data relates to the amount of activity required and when. The demand data may be automatically inputted into the receiving unit 328 from an ERP module 231, such as SAP or Slimline, or it may be entered in manually into receiving unit 228. Control system 226 desirably calculates the elution schedule by determining which generators will be eluted and when so as to match the demand data to the available activity so as to maximize the eluted daughter nuclide with the minimum amount of waste. Control system 226 will then desirably download instructions to an actuation system 235 located within hot cell 222 for conducting the elutions. The present invention further contemplates that control system 226 may be alternatively provided within hotcell 222 either separately from actuation system 235 or as a unitary computerized system performing the functions for both.

[0045] By way of illustration and not of limitation, in this configuration, the generators 110 are Mo99/Tc99m generator (titanium [^{99}Mo] molybdate) gel generators. The first eluent source 214 desirably provides a weak acid as the first eluent for eluting the daughter nuclide Tc-99m from the generators, although highly pure water, such as sterile water for injection may also be used to elute the gel generator. Concentration column 212 includes an alumina sorbent to capture the pertechnetate in the eluate from generators 110. Second eluent source 216 provides saline for eluting the sodium pertechnetate from column 212 and collection in collection vial 218. The sodium pertechnetate may then be used with cold kits for labeling a radiotracer.

[0046] With the present invention, any combination of generators may be eluted and the activity from the eluted

generators collected in column 212. The final radioactivity concentration is determined by the elution of the concentration column 212, which can be eluted in a very small volume. Additionally, because the activity can be collected from multiple generators and concentrated, the generators may be used continuously until expiry.

[0047] Referring now to Figure 5, an alternate presentation multiple generator elution system 200 is shown. In Figure 5, five gel generators 110a-e are shown connected with a valve manifold 250. Manifold 250 is desirably based on the linearly-arranged stopcock manifold used in FASTlab™ cassettes, sold by GE Healthcare, Liege, BE. Manifold 250 includes sixteen 3way/3position stopcocks valves, 1-17. Each of valves 1-17 include three open ports opening to adjacent manifold valves and to a respective luer located therebetween. Each valve includes a rotatable stopcock which puts any two of the three associated ports in fluid communication with each other while fluidically isolating the third port. The present invention further contemplates that the stopcock could include a T-shaped internal passageway therein so as to also allow all three ports to be placed in fluid communication across the valve, but such an embodiment would provide dead spaces which could require additional rinsing so as to prevent the occurrence of contamination between successive fluid flows. Manifold 250 further includes, at opposing ends thereof, first and second socket connectors 18 and 19, each defining vacuum ports 18a and 19a, respectively. Manifold 250 and the stopcocks of valves 1-17, as well as the conduits described below, are desirably formed from a polymeric material, e.g. PP, PE, Polysulfone, Ultem, or Peek. As will be shown in Figure 8, the manifold desirably includes twenty-five 3way/3position stopcocks valves, although the actual number of valves is scaleable to meet the needs of the user. Unused valves may simply have their luer connection capped by a luer fitting and their stopcocks providing fluid communication for flow between adjacent valves.

[0048] Each of the connections at the valves described herein are made at the port defined by its luer connector. As shown in Figure 5, valve 1 supports a filtered vent 251 at its luer connection. Valve 2 is connected to first eluent source 214 by an elongate conduit 252.. First eluent source 214 provides the eluent for eluting the daughter nuclide from generators 110a-e. First eluent source 214 desirably is also connected in fluid communication with a filtered vent 233 to assist the outflow of the eluent through conduit 252 towards valve 2. Valve 3 is connected by an elongate conduit 254 to a second manifold 256 providing open connection to the eluent channels 118 of generators 110a-e. That is, the present invention desirably provides a single source of eluent for eluting each of the generators, although the present invention also contemplates that each generator may have its own source of eluent as shown in Figure 1. The eluate channels 120 of generators 110a-e are connected back to manifold 250 by elongate conduit 260a-e, respectively. Conduits 260a-e extend between the respective eluate channels 120 of generators 110a-e to valves 4-8, respectively.

[0049] Valve 9 is connected by elongate conduit 262 to an input port of concentration column 212 so that eluate from the generators may be directed to column 212. Valve 10 is connected to second eluent source 216 by an elongate conduit 264. Second eluent source 216 provides the eluent to elute the daughter nuclide from column 212. Second eluent source 216 desirably is also connected in fluid communication to a filtered vent 263 to assist outflow of the second eluent through conduit 262 towards valve 9. Valves 11 and 12 are capped by a luer fitting and their stopcocks oriented to provide fluid flow there through between valves 10 and 13. Valve 13 is connected by elongate conduit 266 to an input port 268 of collection vial 218 so as to be able to direct a product fluid therein. Valve 14 is connected by elongate conduit 270 to an input port 272 of a waste vial 219. Valve 15 is connected to the output port of column 212, such that column 212 desirably connects directly to valve 15. Valve 16 is connected by elongate conduit 274 to an outlet port 275 of waste vial 215. Valve 17 is connected by elongate conduit 276 to an outlet port 278 of collection vial 218.

[0050] A sample elution will now be described. An elution schedule has been calculated that requires eluting the activity from generators 110a and 110c. By application of a vacuum (ie, a sufficient low pressure) at port 19a, the first eluent will be drawn from first source 214. Valves 1-17 are set so that the first eluent flows through valves 2 and 3 and conduit 254 into manifold 256. First, valves 5-8 are set to allow for eluate flow from generator 110a to flow through conduit 260a through to valve 9. Valve 9 directs the eluate flow through conduit 262 to the input port of column 212. From column 212 the eluate will be drawn through valve 15 to valve 14 and into waste vial 219. The volume of waste vial 219 will be sufficient to collect all of the liquid thus delivered from column 212. The stopcock of valve 4 is then rotated to isolate generator 110a and the stopcock of valve 6 is rotated so that the first eluent will be drawn from second manifold 256 into generator 110c. The eluate from generator 110c is then directed through valves 6-8 to valve 9. Valve 9 directs the eluate flow through conduit 262 to the input port of column 212. From column 212 the eluate will be drawn through valve 15 to valve 14 and into waste vial 219. The daughter nuclides from generator 110a and 110c have thus been collected in concentration column 212.

[0051] To elute the daughter nuclide from column 212, valve 10 will be set to direct, under suction at port 19a, the second eluent from source 264 through conduit 264 and towards valve 9. The second eluent is drawn through conduit 262 through the input port of column 212 and through column 212. Upon exiting column 212 into valve 15, the column 212 eluate will contain the daughter nuclide for dispensement into collection vial 218. This eluate will be directed to valve 13 and through conduit 266 into vial 218, the suction from port 19a being applied through valve 17 and conduit 276. Vial 218 may then be either removed or drawn from to provide the daughter nuclide for further processing by the pharmacist. Subsequent dispensements from the generators may thus be directed into the same collection vial or otherwise combined with unused eluate from a previous dispensement, as control system 226 has included any leftover activity in its

calculations for dispensing from generators 110a-e in order to meet the requirements of the demand data.

[0052] Manifold 250 is desirably formed to be attached to an actuation system 235 which engages and sets the orientation of the stopcocks of the valves and provides the low-pressure suction, or vacuum, for drawing fluids through the manifold and into the vials. Actuation system 235 includes rotatable arms which engage each of the stopcocks of valves 1-17 and can position each in a desired orientation throughout elution operations. The actuation system 235 also includes a pair of spigots, each of which engages one of ports 18a and 19a in fluid-tight connection to provide a source of low pressure, or vacuum, to manifold 250 in accordance with the present invention. Desirably, manifold 250 is attachable to a FASTLab™ (sold by GE Healthcare, Liege, BE) synthesis device which has been programmed to operate the valves and apply the vacuum. As the FASTlab synthesizer is already designed to operate in a hot cell environment, it is ideally suited as the actuation device for system 200. Actuation system 235 is directed to act by control system 226 according to the calculated elution schedule.

[0053] Figures 6 and 7 depict a multiple generator elution system 300 for alumina-based Mo-99 generators 110. Multiple generator elution system 300 incorporates a plurality of generators 110. In this embodiment, the generators 110 are Mo99/Tc99m alumina generators (ie, incorporate alumina in the generator's column). The generators 110 are desirably connected to a manifold (not shown) that includes valves and conduits so that individual ones of the valves are in selectable fluid communication with corresponding individual ones of the generators. The manifold directs the generator eluate output to a cation column 315. The generator eluate flows through the cation column 315 and then into a concentration column 312. Desirably, the manifold is connected to a vacuum source for pulling the eluents through system 300. The cation column is not used for trapping the daughter nuclide but contains an appropriate media for removing competing ions which adversely interfere with the concentration column. Thus, in system 300 an eluent is directed from a first eluent source 314 to selected ones of the generators 110 and the resulting eluate from the selected generators is all directed through column 315 and to column 312. Concentration column 312 traps the daughter nuclide from the generators therein. A second eluent from a second eluent source 316 is directed through concentration column 312 to elute the daughter nuclide into a collection vial 318. The generators 110, column 312, eluent sources 314 and 316 and collection vial are desirably placed within the cavity 324 of a radiation-shielding hot cell 322 so as to limit exposure of the operators.

[0054] System 300 includes a control system 326 and receiving unit 328. Receiving unit 328 and control system 326 may be provided as part of a single computer system. Receiving unit 328 receives both supply data and demand data, which control system 226 can use to generate the elution schedule for the generators 110 as will be described for Figures 9 and 10. The supply data allows calculation of the amount of activity available from each of generators 110, based on the calibration data, including the known starting activity and date, the time and date of when the generator was available for use, and the time and date of the first elution off set. The demand data relates to the amount of activity required and when. The demand data may be automatically inputted into the receiving unit 328 from an electronic ERP module 331, such as SAP or Slimline, or it may be entered in manually into receiving unit 328 by an operator. Control system 326 desirably calculates the elution schedule by determining which generators will be eluted and when so as to match the demand data to the available activity so as to maximize the eluted daughter nuclide with the minimum amount of waste. Control system 326 will then desirably download instructions to an actuation system 335 located within hot cell 322 for conducting the elutions. The present invention further contemplates that control system 326 may be alternatively provided within hotcell 322 either separately from actuation system 335 or as a unitary computerized system performing the functions for both.

[0055] In this configuration, first eluent source 314 desirably provides an acid salt or weak acid, typically saline, as the first eluent for eluting the daughter nuclide Tc-99m from the generators. As the first eluent is saline, cation column 315 is used first to remove the sodium ion so as to allow concentration on the concentration column 312. Concentration column 312 includes an alumina sorbent to capture the pertechnetate in the eluate from generators 110. Second eluent source 316 provides saline for eluting the sodium pertechnetate from column 312 and collection in collection vial 318. The sodium pertechnetate may then be used with cold kits for labeling a radiotracer.

[0056] With the present invention, any combination of generators may be eluted and the activity from the eluted generators passed through column 315 and collected in column 312. The two column method allows generators based on fission Mo-99 and alumina technology to take advantage of the efficiencies of the concentrator system of the present invention. The final radioactivity concentration is determined by the elution of the concentration column 312, which can be eluted in a very small volume. Additionally, because the activity can be collected from multiple generators and concentrated, the generators may be used continuously until expiry.

[0057] Referring now to Figure 7, an alternate presentation of multiple generator elution system 300 is shown. In Figure 7, five gel generators 110a-e are shown connected with a valve manifold 350. Manifold 350 is desirably based on the linearly-arranged stopcock manifold used in FASTlab™ cassettes, sold by GE Healthcare, Liege, BE. Manifold 350 includes sixteen 3way/3position stopcocks valves, 1-17. Each of valves 1-17 include three open ports opening to adjacent manifold valves and to a respective luer located thereon, the luer port located between the opposed other ports. Each valve includes a rotatable stopcock which puts any two of the three associated ports in fluid communication with each

other while fluidically isolating the third port. The present invention further contemplates that the stopcock could include a T-shaped internal passageway therein so as to also allow all three ports to be placed in fluid communication across the valve, but such an embodiment would provide dead spaces which could require additional rinsing so as to prevent the occurrence of contamination between successive fluid flows. Manifold 350 further includes, at opposing ends thereof, first and second socket connectors 18 and 19, each defining vacuum ports 18a and 19a, respectively. Manifold 350 and the stopcocks of valves 1-17, as well as the conduits described below, are desirably formed from a polymeric material, e.g. PP, PE, Polysulfone, Ultem, or Peek. As will be shown in Figure 8, the manifold desirably includes twenty-five 3way/3position stopcocks valves, although the actual number of valves is scaleable to meet the needs of the user. Unused valves may simply have their luer connection capped by a luer fitting and their stopcocks providing fluid communication for flow between adjacent valves.

[0058] Each of the connections at the valves described herein are made at the luer port defined by its luer connector. As shown in Figure 8, valve 1 supports a filtered vent 351 at its luer connection. Valve 2 is connected to first eluent source 314 by an elongate conduit 352. First eluent source 314 provides the eluent for eluting the daughter nuclide from generators 110a-e. First eluent source 314 desirably is also connected in fluid communication with a filtered vent 333 to assist the outflow of the eluent through conduit 352 towards valve 2. Valve 3 is connected by an elongate conduit 354 to a second manifold 356 providing open connection to the eluent channels 118 of generators 110a-e. That is, the present invention desirably provides a single source of eluent for eluting each of the generators, although the present invention also contemplates that each generator may have its own source of eluent as shown in Figure 1. The eluate channels 120 of generators 110a-e are connected back to manifold 350 by elongate conduit 360a-e, respectively. Conduits 360a-e extend between the respective eluate channels 120 of generators 110a-e to valves 4-8, respectively.

[0059] Valve 9 is connected by elongate conduit 362 to an input port of a cation column 315. Cation column 315 serves to remove competing ions from the eluate from the generators prior to concentration. Valve 10 is connected to second eluent source 316 by an elongate conduit 364. Second eluent source 316 provides the eluent to elute the daughter nuclide from column 312. Second eluent source 316 desirably is also connected in fluid communication to a filtered vent 363 to assist outflow of the second eluent through conduit 362 towards valve 9. Valve 11 is connected to the output port of cation column 315. Valve 12 is connected by elongate conduit 365 to an input port of concentration column 312.

[0060] Valve 13 is connected by elongate conduit 370 to an input port 372 of a waste vial 319. Valve 14 is connected by elongate conduit 366 to an input port 368 of collection vial 318 so as to be able to direct a product fluid therein. Valve 15 is connected to the output port of column 312, such that column 312 desirably connects directly to valve 15. Valve 16 is connected by elongate conduit 374 to an outlet port 375 of waste vial 315. Valve 17 is connected by elongate conduit 376 to an outlet port 378 of collection vial 318.

[0061] A sample elution will now be described. The elution schedule has been calculated that requires eluting the activity from generators 110a and 110c. By application of a vacuum (ie, a sufficient low pressure) at port 19a, the first eluent will be drawn from first source 314. Valves 1-17 are set so that the first eluent flows through valves 2 and 3 and conduit 354 into manifold 356. First, valves 5-8 are set to allow for eluate flow from generator 110a to flow through conduit 360a through to valve 9. Valve 9 directs the eluate flow through conduit 362 to the input port of cation column 315. From column 315 the eluate will be drawn through valve 12 and into elongate conduit 265 into the inlet port for concentration column 312. Waste material will continue to be drawn through column 312 through valve 15 down to valve 13 and into waste vial 319. The volume of waste vial 319 will be sufficient to collect all of the liquid thus delivered from column 315. The stopcock of valve 4 is then rotated to isolate generator 110a and the stopcock of valve 6 is rotated so that the first eluent will be drawn from second manifold 356 into generator 110c. The eluate from generator 110c is then directed through valves 6-8 to valve 9. Valve 9 directs the eluate flow through conduit 362 to the input port of column 315. From column 315 the eluate will be drawn through valve 12 and into elongate conduit 265 into the inlet port for concentration column 312. Waste material will continue to be drawn through column 312 through valve 15 down to valve 13 and into waste vial 319. The daughter nuclides from generator 110a and 110c have thus been collected in concentration column 312.

[0062] To elute the daughter nuclide from column 312, valve 10 will be set to direct, under suction at port 19a, the second eluent from source 316 through conduit 364 and towards valve 12. The second eluent is drawn through conduit 365 through the input port of column 312 and through column 312. Upon exiting column 312 into valve 115, the column 312 eluate will contain the daughter nuclide for dispensement into collection vial 318. This eluate will be directed to valve 14 and through conduit 366 into vial 318, the suction from port 19a being applied through valve 17 and conduit 376. Vial 318 may then be either removed or drawn from to provide the daughter nuclide for further processing by a pharmacist or technician. Subsequent dispensements from the generators may thus be directed into the same collection vial or otherwise combined with unused eluate from a previous dispensement, as control system 326 has included any leftover activity in its calculations for dispensing from generators 110a-e in order to meet the requirements of the demand data.

[0063] Manifold 350 is formed to be attached to actuation system 335 which engages and sets the orientation of the stopcocks of the valves and provides the low-pressure suction, or vacuum, for drawing fluids through the manifold and into the vials. Actuation system 335 includes rotatable arms which engage each of the stopcocks of valves 1-17 and

can position each in a desired orientation throughout elution operations. The actuation system 335 also includes a pair of spigots, each of which engages one of ports 18a and 19a in fluid-tight connection and to provide a source of low pressure, or vacuum, to manifold 350 in accordance with the present invention. Desirably, manifold 250 is attachable to a FASTLab™ (sold by GE Healthcare, Liege, BE) synthesis device which has been programmed to operate the valves and apply the vacuum. As the FASTlab synthesizer is already designed to operate in a hot cell environment, it is ideally suited as the actuation device for system 300. Actuation system 335 is directed to act by control system 326 according to the calculated elution schedule.

[0064] Referring now to Figure 8, an elution cassette 400 for use with a multiple generator elution system is shown. In Figure 8, four alumina generators 110a-d for producing Tc-99m from decaying Mo-99 are shown connected with a valve manifold 450. Cassette 400 includes a case 402 with a planar front wall 404 bounded by a perimetrical wall 406 defining a case cavity 408. Cassette 400 supports an elongate manifold 450 in cavity 408 adjacent to a bottom wall 406a. Manifold 450 is desirably based on the linearly-arranged stopcock manifold used in FASTLab™ cassettes, sold by GE Healthcare, Liege, BE. Manifold 450 includes twenty five 3way/3position stopcocks valves, 1'-25'. Each of valves 1'-25' include three open ports opening to adjacent manifold valves and to a respective luer located thereon, the luer port located between the opposed other ports. Each valve includes a rotatable stopcock which puts any two of the three associated ports in fluid communication with each other while fluidically isolating the third port. The present invention further contemplates that the stopcock could include a T-shaped internal passageway therein so as to also allow all three ports to be placed in fluid communication across the valve, but such an embodiment would provide dead spaces which could require additional rinsing so as to prevent the occurrence of contamination between successive fluid flows and loss of fluid trapped in deadspaces therein. Manifold 450 further includes, at opposing ends thereof, first and second socket connectors 26 and 27, each defining vacuum ports 26a and 27a, respectively. Manifold 450 and the stopcocks of valves 1'-25', as well as the conduit connectors described below, are desirably formed from a polymeric material, e.g. PP, PE, Polysulfone, Ultem, or Peek. As shown in Figure 8, the manifold includes twenty-five 3way/3position stopcocks valves, although the actual number of valves is scaleable to meet the needs of the user. Unused valves may simply have their luer connection capped by a luer fitting and their stopcocks providing fluid communication for flow between adjacent valves.

[0065] Cassette 400 is a variant of a pre-assembled synthesis cassette designed to be adaptable for synthesizing clinical batches of different radiopharmaceuticals with minimal customer installation and connections. Cassette 400 is desirably provided in kit form with all of the conduit tubings and supported connectors and filters to be connected to the generators, vials, and eluent source or sources for eluting a nuclide according to the present invention. Desirably, cassette 400 is provided to users with each connection of the conduits to the luers of its valves already made, so that only the free ends need to be mated with the appropriate component. The cassette so provided may be assembled and packaged in a sterile condition such that if opened in an appropriately clean environment will maintain an appropriate level of sterility for pharmaceutical operations.

[0066] Each of the connections at the valves described herein are made at the luer port defined by its luer connector. As shown in Figure 8, valve 3' supports a filtered vent 451 at its luer connection. Valve 4' is connected to rinse fluid source 415 by an elongate conduit 452. Rinse fluid source 415 provides a rinse fluid for rinsing manifold 250 between elution runs or as desired. Rinse fluid source 415 desirably is also connected in fluid communication with a filtered vent 433 to assist the outflow of the eluent through conduit 452 towards valve 4'. That is, while the present invention contemplates that cassette 400 can provide a single source of eluent for eluting each of the generators as described in Figures 5 and 8, in the embodiment of Figure 8, the present invention includes each generator having its own source of eluent, provided in an eluent vial 130, as shown in Figure 1. Providing each generator with its own eluent source 130 may be desirable so as to prevent the risk of over-dilution of the eluate volume from a common reservoir. Additionally, by providing each generator with its own attached elution source, more of the manifold valves 5'-14' will be available for connection to a generator. The air vent on the manifold is used to bleed off excess or unused vacuum. The eluate channels 120 of generators 110a-d are connected back to manifold 450 by elongate conduit 460a-d, respectively. Conduits 460a-d extend between the respective eluate channels 120 of generators 110a-d to valves 15'-18', respectively.

[0067] Valves 5'-14' are each capped by a luer fitting which seals the luer port for each valve. Valves 5'-14' are available for scaling up cassette 400 to accommodate additional generators, should a user so desire.

[0068] Valve 19' is connected by elongate conduit 462 to an input port of a cation column 415. Cation column 415 serves to remove competing ions from the eluate from the generators prior to concentration. Valve 20' is connected to the output port of cation column 415. Valve 21' is connected by elongate conduit 465 to an input port of concentration column 412. Valve 22' is connected to second eluent source 416 by an elongate conduit 464. Second eluent source 416 provides the eluent to elute the daughter nuclide from concentration column 412. Second eluent source 416 desirably is also connected in fluid communication to a filtered vent 463 to assist outflow of the second eluent through conduit 462 towards valve 22'. Valve 24' is connected to the output port of column 412, such that column 412 desirably connects directly to valve 24'.

[0069] Now the connections to the waste and collection vials will be described. Valve 23' is connected by elongate

conduit 470 to an input port 472 of a waste vial 419. Valve 25' is connected by elongate conduit 466 to an input port 468 of collection vial 418. Valve 1' is connected by elongate conduit 476 to an outlet port 478 of collection vial 418. Valve 2' is connected by elongate conduit 474 to an outlet port 475 of waste vial 415.

[0070] A sample elution will now be described. The elution schedule has been calculated that requires eluting the activity from generators 110b and 110d. By application of a vacuum (ie, a sufficient low pressure) at port 26a, the first eluent will be drawn from first source vial 130 for generator 110b. Valves 1'-25' are set so that the first eluent flows through generator 110b, through conduit 460b to valve 16' and on through to valve 19'. Valve 19' directs the eluate flow through conduit 462 to the input port of cation column 415. From column 415 the eluate will be drawn through valve 21' and into elongate conduit 465 into the inlet port for concentration column 412. Waste material will continue to be drawn through column 412 through valve 24' down to valve 23' and into waste vial 419. The volume of waste vial 419 will be sufficient to collect all of the liquid thus delivered from column 412.

[0071] The stopcock of valve 16' is then rotated to isolate generator 110b and the stopcock of valve 18' is rotated so that the first eluent will be drawn from the vial 130 connected to generator 110d. The eluate from generator 110d is then directed through conduit 460d to valve 18' and then on to valve 19'. Valve 19' directs the eluate flow through conduit 462 to the input port of column 415. From column 415 the eluate will be drawn through valve 21' and into elongate conduit 465 into the inlet port for concentration column 412. Waste material will continue to be drawn through column 412 through valve 24' down to valve 23' and into waste vial 419. The daughter nuclides from generator 110b and 110d have thus been collected in concentration column 412.

[0072] To elute the daughter nuclide from column 412, valve 22' will be set to direct, under suction at port 26a, the second eluent from source 416 through conduit 464 and valve 22' and towards valve 21'. The second eluent is drawn through conduit 465 through the input port of column 412 and through column 412. Upon exiting column 412 into valve 24', the column 412 eluate will contain the daughter nuclide for dispensement into collection vial 418. This eluate will be directed to valve 25' and through conduit 466 into vial 418, the suction from port 26a being applied through valve 1' and conduit 476. Vial 418 may then be either removed or drawn from to provide the daughter nuclide for further processing by the pharmacist. Subsequent dispensements from the generators may thus be directed into the same collection vial or otherwise combined with unused eluate from a previous dispensement, as the control system of the present invention has included any leftover activity in its calculations for dispensing from generators 110a-d in order to meet the requirements of the demand data.

[0073] Cassette 400 is formed to be attached to an actuation system which engages and sets the orientation of the stopcocks of the valves and provides the low-pressure suction, or vacuum, for drawing fluids through the manifold and into the vials. The actuation system includes rotatable arms which engage each of the stopcocks of valves 1'-25' and can position each in a desired orientation throughout elution operations. The actuation system also includes a pair of spigots, each of which engages one of ports 26a and 27a in fluid-tight connection and to provide a source of low pressure, or vacuum, to manifold 450 in accordance with the present invention. Desirably, manifold 450 is attachable to a FASTLab™ (sold by GE Healthcare, Liege, BE) synthesis device which has been programmed to operate the valves and apply the vacuum. As the FASTlab synthesizer is already designed to operate in a hot cell environment, it is ideally suited as the actuation device for cassette 400, receiving its actuation instructions from a control system to operate according to the calculated elution schedule.

[0074] For all embodiments of the cassette and manifold systems of the present invention, including those detailed in Figures 5, 7, and 8, the cassette or manifold is desirably attachable to a FASTlab device. All liquid transfers are performed by the applied vacuum (or low pressure). All connections to the manifold cassette are contemplated to be via standard luer locks. The conduits used to connect to the generator are desirably silicon tubing terminated with a septum to allow penetration by the needles 125a and 129a at the respective port on the generator 110. In the event an eluent vial 130 is attached to a generator, a standard connection may be used. Thus the generators do not need to be modified to work with the present invention.

[0075] Additionally for all embodiments, an external source of rinse fluid, such as water for injection (WFI), may also be connected to the manifold for cleaning and rinsing proposes. When eluting a gel generator, the WFI source may be connected to each generator to also act as a first eluent. As more particularly described for Figure 8, the present invention contemplates that first eluent can be from a reservoir or a pre measured container or "elution vial" individually connected to each generator. A pre-measured source is desirable so as to prevent over dilution of the eluate volume and to free up an additional manifold valve for connection to a generator. The air vent on the manifold is used to bleed off excess or unused vacuum.

[0076] The present invention further contemplates that for some embodiments, depending on the required elution chemistry, the first source of eluent that is connected directly to the manifold (as described for Figures 5 and 7) may be used to elute both the generators and the concentration column, thus obviating the need for a second source of eluent to be connected to the manifold. For example, if system 300 of Figure 7 employs alumina generators and an alumina concentration column, the present invention contemplates that first source of eluent may provide saline that is used both for eluting the generators and for eluting the concentration column.

[0077] The cation column is used to remove competing ions, such as chloride, from the eluate. In some embodiments, the pertechnetate ions flow through the cation column and on to the acidified alumina column where it is captured (concentrated). The liquid is allowed to flow through the column and into the waste collection vessel for future disposal. The acidified alumina column (as stated above) is used to capture and concentrate the pertechnetate (^{99m}Tc). While the pertechnetate is being captured on the alumina column, the liquid (essentially water) is removed from the bottom of the column by vacuum and collected in the waste vessel. Once the concentration step is completed the alumina column is desirably eluted with a small volume of saline to remove the pertechnetate as sodium pertechnetate [$\text{Na}^{99m}\text{TcO}_4$], basically in exactly the same way as current fission generators and collected in the product collection vial.

[0078] With reference to Figure 9, the present invention uses demand data and supply data to determine and execute the most efficiency utilization of a set of parent-daughter generators in a radio-pharmacy operation. The supply data allows the automated calculation of the amount of available activity (of the daughter nuclide) at any given time. Generators are sold with known amounts of activity. The supply data can be obtained from a generator barcode or manual data entry. The demand data is the amount of activity required at specific times to meet customer orders. The data can come from either an ERP software system, for example SAP or Slimline (or equivalent) via an electronic transfer, or by manual entry. Typically, in a radio-pharmacy environment, customer orders are segregated into delivery runs, scheduled at certain times of the day.

[0079] The present invention compares the demand activity requirements with the available activity at any given time. Additionally, the system will attempt to configure the generator elution plan to deliver a best-fit solution representing the best efficiency for eluting from the given generators. Once the best fit solution has been calculated, the operator has several options: a) Execute the elution plan determined by the system, b) reconfigure the elution plan manually - letting the system calculate and display the effect to the operator, or c) model 'what-if scenarios' by inputting certain demand requirements and/or supply data and reviewing the calculated elution schedule determined by the system under the entered constraints.

[0080] The present invention, upon confirmation from the operator the calculated elution plan is acceptable, sends the data to the actuation system to elute the selected generators according the elution schedule. The eluates from the selected generators are all passed through the cassette to concentrate, for example, Tc-99m, onto an alumina column. Once all the generator elutions are complete, the alumina column is eluted in the required volume of eluent, eg, saline, (typically 5-6mL). Once this operation is completed, the control system updates the activity data, re-calculates the grow-in and updates the elution schedule with any required changes.

[0081] Generally, an ERP system is an integrated computer-based application used to manage internal and external resources, including tangible assets, financial resources, materials, and human resources. Its purpose is to facilitate the flow of information between all business functions inside the boundaries of the organization and manage the connections to outside stakeholders. Built on a centralized database and normally utilizing a common computing platform, ERP systems consolidate all business operations into a uniform and enterprise-wide system environment. An ERP system can either reside on a centralized server or be distributed across modular hardware and software units that provide "services" and communicate on a local area network. The distributed design allows a business to assemble modules from different vendors without the need for the placement of multiple copies of complex and expensive computer systems in areas which will not use their full capacity.

[0082] The method of the present invention thus includes an inputting step 610 where the supply data for each of the generators is inputted into a receiving unit of the elution system. The method then includes a second step 620 of inputting into the receiving unit the demand data of what activity is required and when from the multiple generators. This is followed by a calculating and selecting step 630 where the optimum elution schedule for each of the multiple generators is determined according to the inputted supply data and the inputted demand data. The calculating and selecting step 630 desirably compares current demand of activity, future demand for activity, and the available activity from the generators both presently and at subsequent demand points, or elution times, and selects which generators will be eluted and when so as to minimize the waste of daughter nuclide produced by the generators in meeting the demand data. Then, there is an eluting step 670 in which the daughter nuclide is eluted from the selected generators.

[0083] Step 610 further includes the steps of inputting calibration data for each generator, 612, typically the activity and date for each generator, inputting the time and date that the generator is available, 614, and inputting the time and date that the first elution is off-set from a reference time. Steps 612, 614, 616 may be performed manually by manually entering into the receiving unit the information from each of these steps, such information generally being provided with each generator. Alternatively, steps 612, 614, and 616 may be performed electronically, or automatically, by scanning such information from a bar code pertaining to each generator. Likewise, step 620 may be performed either manually or electronically, with the demand data generally being supplied by an ERP system. For manually performing step 620, an operator will take the demand data information and enter it into the receiving unit. Desirably, when the demand data is manually entered, the receiving unit or control system will compiling the information into the demand data set, although the operator may also perform the compilation prior to entering the aggregate demand data. Alternatively, the ERP system may be electronically communicating with the receiving unit so that the individual orders are automatically entered

into the system and the elution schedule calculated.

[0084] The present invention further contemplates that step 610 can include the step of inputting known data constants, 618. Step 618 can provide for the consideration of such data constants in the step 630. The data constants desirably include the parent nuclide half-life and decay equation, the daughter nuclide half life and decay equation, the elution yield efficiency, the fraction of the elution available the parent nuclide decay, the equilibrium equation for the parent-daughter activity, and the expiration time for the generator.

[0085] Step 630 includes the step of calculating 632 and displaying 634 the available activity for each generator, desirably in fixed intervals such as thirty minutes. Desirably, the calculating step 632 employs Equation (1) and the displaying step 634 displays the activity in each generator at the calculated intervals. Moreover, step 630 may include the step of performing a Generalized Reduced Gradient Algorithm analysis of the demand data and the activity levels of the plurality of generators to determine the optimum elution schedule for minimizing waste. Alternatively, step 630 is contemplated to run simulations of various elution schedules from the plurality of generators and selecting the elution schedule resulting in the lowest amount of waste of the daughter nuclide upon meeting the demand data. Additionally, the method desirably includes the step 638 of displaying the demand data over the same intervals as the supply data. Step 630 desirably further comprises the step of calculating the best fit elution profile, or schedule, 638, for selecting which of the available generators will be eluted at a given time to meet the demand data in the most efficient way possible, thus maximizing the useful life of each generator and minimizing waste. The method may then include the step of providing the elution schedule to the operator, 640.

[0086] Desirably, the display of the elution schedule is provided on a graphic-user interface (GUI) and the method includes the steps of offering the operator the option of overriding the calculated optimized elution schedule, 642, by instead scheduling different generators for elution at a given time. If the operator declines to override the system, the method will then progress to the step of sending the elution instructions to the actuation system, 660. If the operator chooses to override the elution instructions from step 638, the method further includes the step of the operator manually entering a modification to the elution schedule, 644. Step 644 allows the operator to select a when particular generators will be eluted. The method then includes the step of recalculating the elution schedule, 646, and displaying both the updated activity availability over time for each generator as well as the scheduled time of elution from each of the generators, 648. Step 646 desirably employs the same algorithm as step 630 in determining the optimum elution schedule, given any additional operator constraints. The method then includes the step of prompting the operator to accept the updated elution schedule 650. If the operator accepts the updated elution schedule, the elution schedule will be set and the control system will provide the appropriate instructions to the actuation system for eluting from the generators, step 660. If the operator does not accept the updated elution schedule, the method will repeat steps 644, 646, and 648 until the operator does accept the elution schedule. Once the updated elution schedule is satisfactory to the operator, the method will proceed to step 660.

[0087] After step 660, the actuation system will perform step 670 and elute the generators according to the elution schedule. Steps 642, 644, 646, 648, and 650 provide the option of an 'operator-in-the-loop' to oversee and manage the elution from the generators and allow the operator to override the calculated schedule. In any event, the present invention is able to operate without the need for operator intervention and can thus perform the scheduled elutions automatically without operator input once the schedule, thereby freeing the operator to tend to other pharmacy duties. However, it is deemed desirable to provide the operator at some point in the cycle so as to accept the elution schedule.

[0088] After the eluting step 670, the method can include the step of confirming that the selected generators were eluted, 672. Additionally, the method desirably includes the steps of re-calculating the activity in-growth 674, modifying the activity data in step 632 and, if necessary, repeating steps 638 et seq. to recalculate the best-fit elution schedule for meeting the demand data.

[0089] The present invention further provides a computer program product for managing the elution from a multiple generator elution system according to the present invention. The present invention further provides a multiple generator elution system which includes computer hardware for executing the computer program product of the present invention. The computer program product includes computer usable medium having computer-usable program code for performing the method of the present invention. The computer program code includes a computer-usable medium having computer-usable program code that manages a multiple generator elution system. The computer program product including computer-usable program code that receives inputted supply data for a number of parent-daughter generators and demand data for activity from the generators. The computer program further includes computer-usable program code that calculates an elution schedule for the generators based on the available activity in the generators and the demand data; as well as computer program code that directs an actuation system of the elution system to elute from selected ones of the generators according to the elution schedule.

[0090] The computer program product desirably further includes computer program code for displaying at least one of the supply data, the demand data, the available activity in the generators, and the elution schedule. Additionally, the computer program code that calculates an elution schedule also includes computer program code for performing a Generalized Reduced Gradient Algorithm analysis of the demand data and the activity levels of the plurality of generators

to determine the optimum elution schedule for minimizing waste. Alternatively, the computer program code for calculating an elution schedule also includes computer program code for running simulations of various elution schedules from the plurality of generators and selecting the elution schedule resulting in the lowest amount of waste of the daughter nuclide upon meeting the demand data. The computer program product desirably also includes computer program code for

allowing an operator to override the calculated elution schedule by inputting new constraints to the computer program product, and computer program code for calculating a new elution schedule based on the new constraints. Moreover, the computer program product desirably includes computer program code for storing the supply data, the demand data, and the elution schedule for future retrieval and can serve for purposes of record keeping or supporting record keeping.

[0091] Figure 10 depicts a screen shot of a graphical user interface (GUI) of the present invention for providing supply data information for a multiple generator elution system of the present invention. Figure 10 shows the supply data input screen 700. Screen 700 provides a Microsoft Excel® screen showing the supply data for the six generators listed in column A, rows 6-11. Column B, rows 6-11 lists the Reference Time for each generator. Column C, rows 6-11 lists the first elution offset (in hours) for each of the listed generators. Lack of an entry will be treated as zero offset. Column D, rows 6-11 list the starting activity at the reference time for each generator. Column E, rows 6-11 lists when each generator was available for use. As an error check for the data entry, the Reference Time in Column A must be at least twelve hours prior to the Available for use time in Column E. Column F, rows 6-11 will show any error messages for each generator. Column E, rows 2-3 provides the Net Efficiency, or elution yield efficiency, for the generators, typically about 0.83.

[0092] Figure 11 depicts a screen shot of a GUI of the present invention for providing the elution schedule calculated for the six generators of Figure 10. Figure 11 shows an elution management window 800 providing the supply data, demand data, and elution schedule for a multiple generator elution system. This is the worksheet or best fit result for balancing efficiency with future activity needs based on the demand. While Figure 11 displays a close-up of the relevant information in rows 46 to 69, representing from July 11, 2010 at 10p.m. to July 12, 2010 at 9:30am, the information of window 800 continues for the life of the generators, typically two weeks and may be scrolled to. Column A, rows 46 to 69, provides the interval times for which the calculations and dispensings occur over the shown time period. The time intervals are given in thirty minute intervals. Column D, rows 46 to 69 lists the time for when dispensing must occur according to the demand data. The listed time takes into account the further processing time required post-elution to get the nuclides to the user in the desired state. Thus, for example, Column D shows that elutions will be run on Monday July 12, 2010 at 12:00am, 2:00am, 4:00am, and 7:00am. Scrolling further down the table to unseen rows will show the demand and other information at later times. Column E provides the balance remaining from any previous elutions that were not used, and shows the decay as time goes forward. Columns F, P, Z, AJ, AT, and BD note when elutions are scheduled for the generators listed in Row 1, Columns G, Q, AA, AK, AU, and BE, respectively. The number '1' is entered into columns F, P, Z, AJ, AT, and BD at the time in which the activity was eluted from the respective generator. As can be seen, for each eluted generator, the next row after elution shows much less activity, indicating that, post elution, activity grow-in is occurring.

[0093] As shown in Column D, row 50, at midnight (row 50) there is a demand for 14,350mCi of activity. The control system has calculated that, in order to best meet all of the known demand in Column D, generator 1 and generator 5 will be eluted to meet this demand, providing an unused balance of 27mCi, which may be incorporated into future elutions. Similarly, at the 2:00am elution (row 54), in order to meet the demand for 15,931 mCi of activity, 2405.5mCi of activity will be eluted from generator 2, 2405.5mCi of activity will be eluted from generator 3, and 11,120.5mCi of activity will be eluted from generator 4, providing an unused balance of 22mCi. The remaining activity from the previous elution will also be included in this elution, so in some instance the current elutions may not total the listed demand on their own.

[0094] An operator may override the provided elution schedule by deleting the '1' from the elute column and selecting another generator to elute from. The control system will re-populate the entries in window 800 to show the new elution schedule as well as the available activity in each generator at each given time, the demand at each elution time, and any balance in activity that is leftover. The modeling feature of the present invention allows, for example, that when a supply shock occurs, the present invention to be particularly useful for evaluating the impact of "what if" scenarios, and ultimately delivering the most doses for the given supply situation. In any event, when the operator is satisfied with the elution schedule, it may be left alone to run automatically as shown. With the elutions performed automatically, the operator will be free to tend to other duties. Additionally, the software provides a record of the elutions performed, simplifying record keeping purposes. Furthermore, while supply data screen 700 and elution management window 800 are tracking six generators, the present invention is scalable in that it is capable of monitoring as many generators as are included in the multiple generator elution system.

[0095] The present invention can provide cost savings to radio-pharmacies. The largest single cost for a radio-pharmacy is the Tc-99m/Mo99 generator that is used to compound the "cold kits" (the diagnostic agents). An action workout with experienced radio pharmacists, showed that the average pharmacy generator efficiency was 65-68%. Post implementation of the new tool average efficiency has steadily risen to 98-100%. Typically, an average pharmacy might consume four 18Ci generators a week. Each generator has a useful shelf life of two weeks. Thus on a weekly basis, the pharmacy

would need to manage eight generators through their decay and use cycles. Currently, using four 18Ci units per week @ \$7,000 each is a cost of \$1.456MM annually. If the same pharmacy improves its efficiency from 65% to 100% by using the present invention, the annual cost is lowered by about \$0.5MM.

[0096] While the particular embodiment of the present invention has been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the teachings of the invention. The matter set forth in the foregoing description and accompanying drawings is offered by way of illustration only and not as a limitation. The actual scope of the invention is intended to be defined in the following claims when viewed in their proper perspective based on the prior art.

Claims

1. A computer program product for managing the elution from a multiple generator elution system, comprising:
 - a computer-usable medium having computer-usable program code that manages a multiple generator elution system, computer program product including: computer-usable program code that receives inputted supply data for a number of parent-daughter generators; computer-usable program code receives demand data for activity from the generators; computer-usable program code that calculates an elution schedule for the generators based on the available activity in the generators and the demand data; and computer program code that directs an actuation system of the elution system to elute from selected ones of the generators according to the elution schedule.
2. A computer program product of claim 1, further comprising computer program code for displaying at least one of the supply data, the demand data, the available activity in the generators, and the elution schedule.
3. A computer program product of claim 1, wherein the computer program code that calculates an elution schedule further comprises computer program code for performing a Generalized Reduced Gradient Algorithm analysis of the demand data and the activity levels of the plurality of generators to determine the optimum elution schedule for minimizing waste.
4. A computer program product of claim 1, wherein the computer program code for calculating an elution schedule further comprises computer program code for running simulations of various elution schedules from the plurality of generators and selecting the elution schedule resulting in the lowest amount of waste of the daughter nuclide upon meeting the demand data.
5. A computer program product of claim 1, further comprising computer program code for allowing an operator to override the calculated elution schedule by inputting new constraints to the computer program product, and computer program code for calculating a new elution schedule based on the new constraints.
6. A computer program product of claim 1, further comprising computer program code for storing the supply data, the demand data, and the elution schedule for future retrieval.
7. A multiple generator elution system comprising a computer for executing the computer program product of claim 1.
8. A computer program product of claim 1, wherein the inputted supply data for a number of parent-daughter generators comprises information allowing calculation of the available activity in the generators into an elution system.
9. A computer program product of claim 1, wherein the inputted supply data further comprises the steps of inputting calibration data for each generator, the date and time that each generator is available for use, the time and date of the first elution off set for each generator.
10. A computer program product of claim 1, wherein the received demand data comprises at least an amount of radioactivity of daughter nuclide to be produced and a schedule for the production of the amount of daughter nuclide.
11. A computer program product of claim 1, wherein the calculated elution schedule is selected by comparing current demand, future demand and the available activity from said plurality of generators both presently and at a subsequent demand point so as to minimize waste of daughter isotope produced by said plurality of generators in meeting the demand data.

- 12.** A computer program product of claim 1, further comprising computer program code for displaying at least one of the supply data, the demand data, the available activity in the generators, and the elution schedule.

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FIG. 1

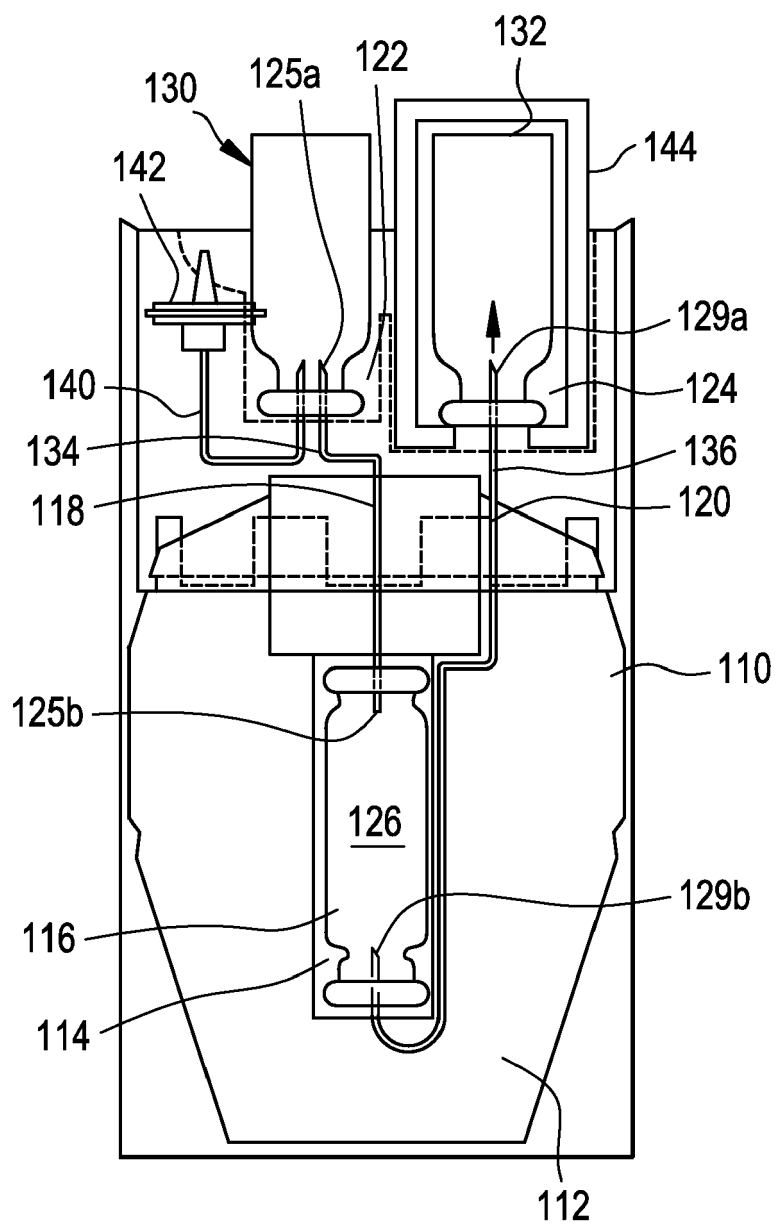


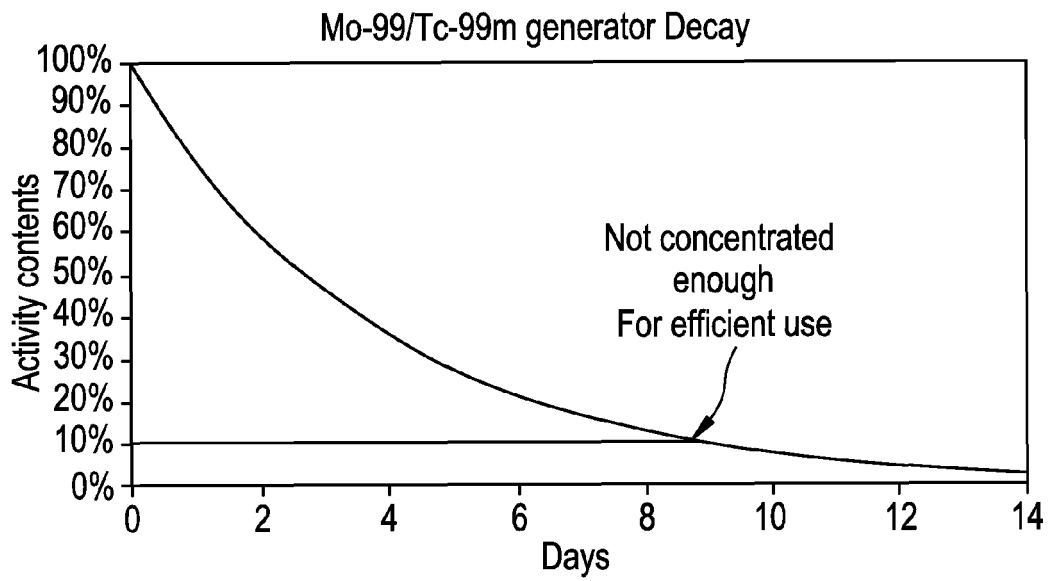
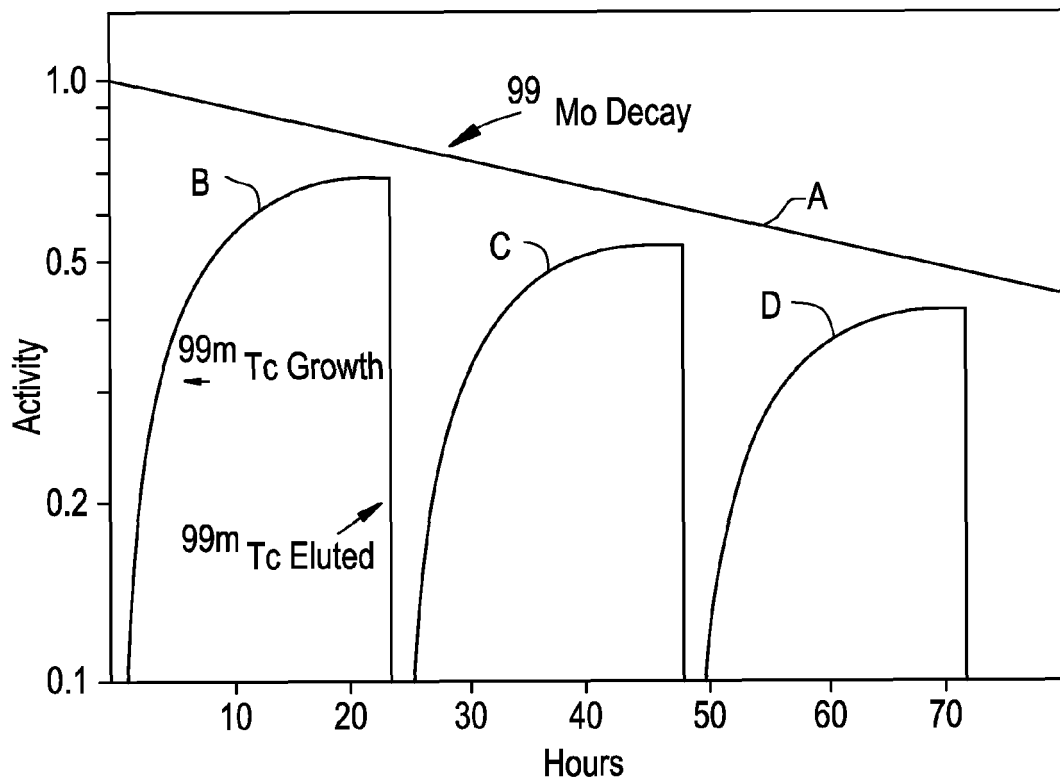
FIG. 2**FIG. 3**

FIG. 4
Activity concentrator Gel based Mo-99

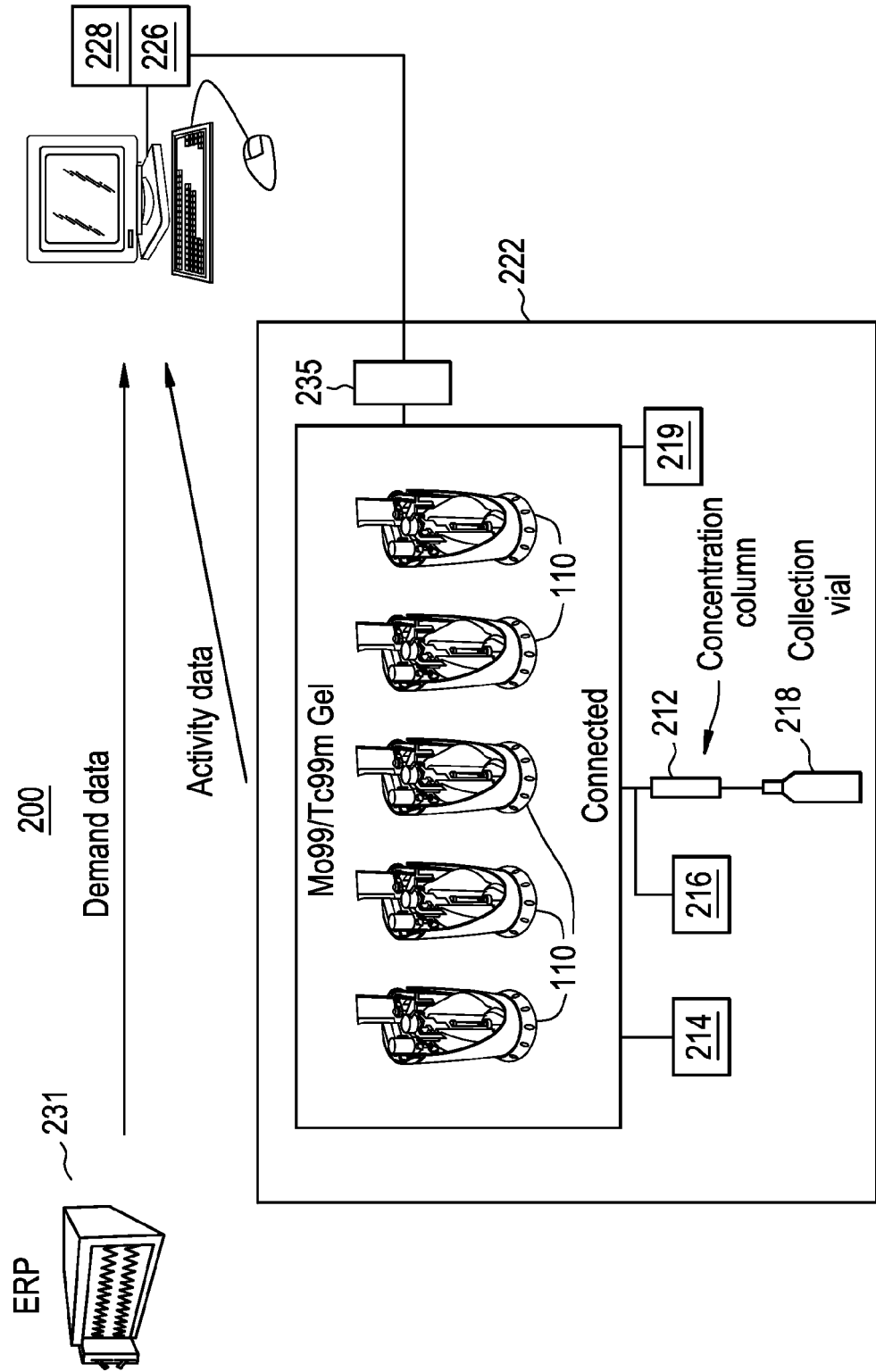


FIG. 5

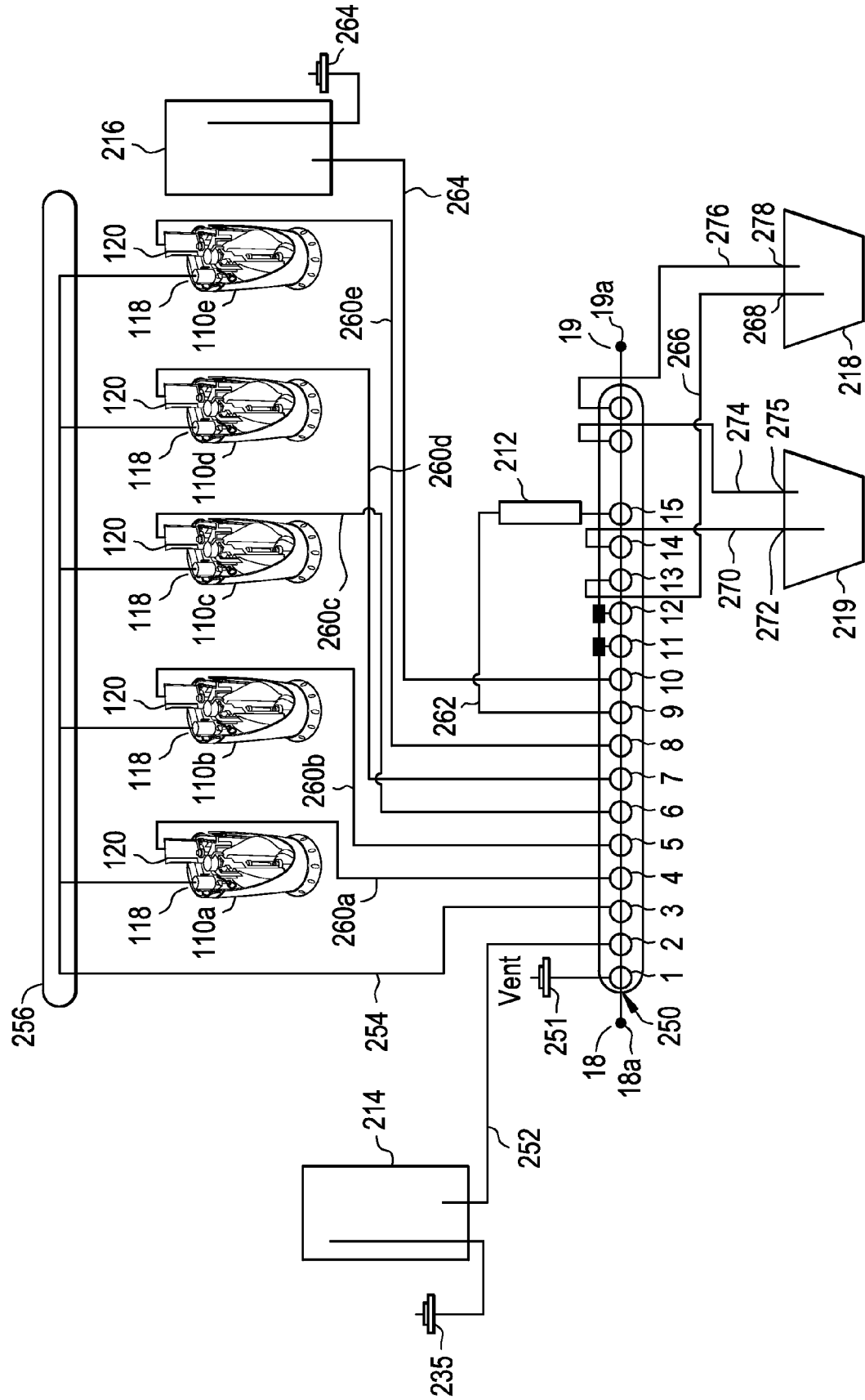


FIG. 6

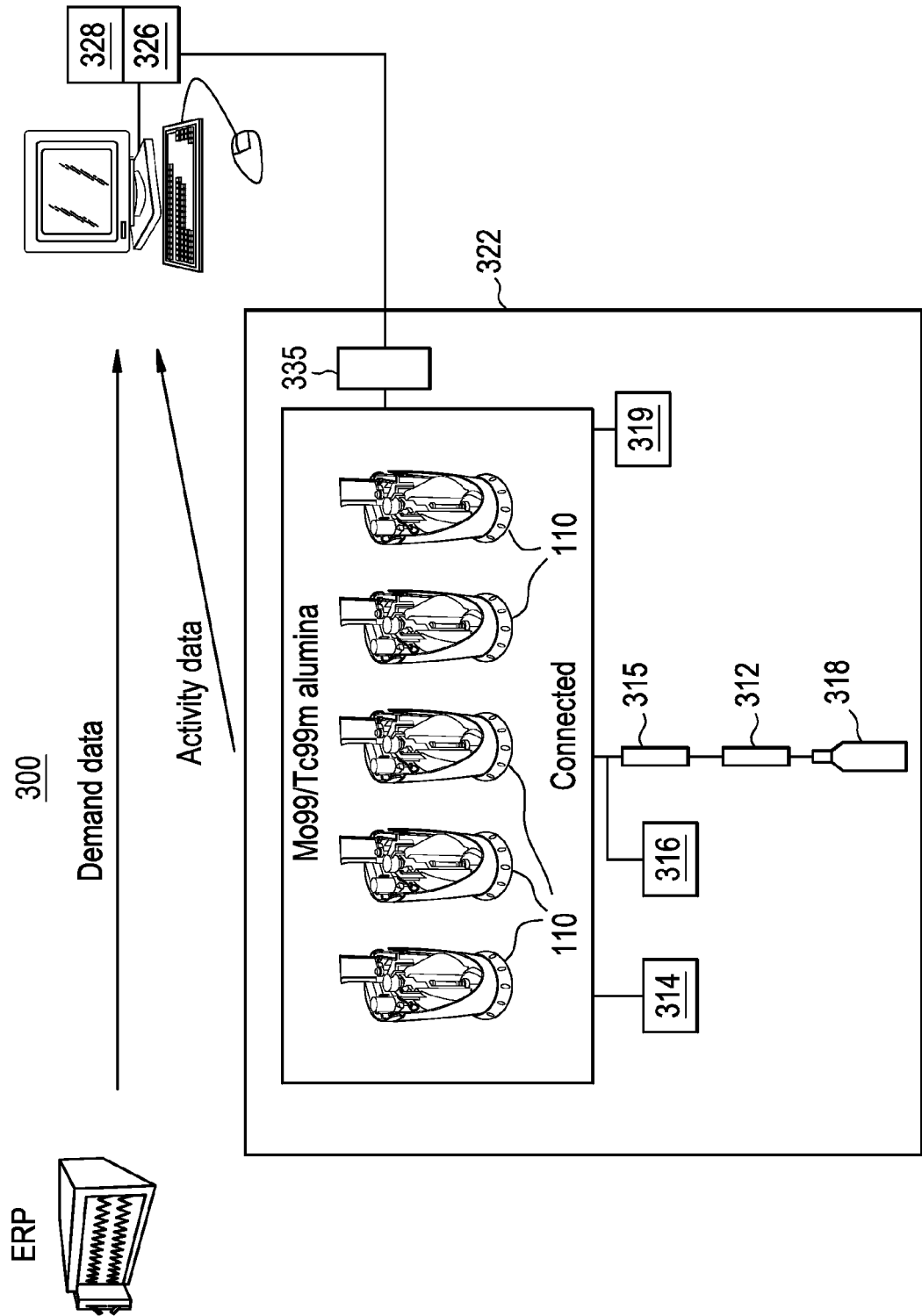


FIG. 7

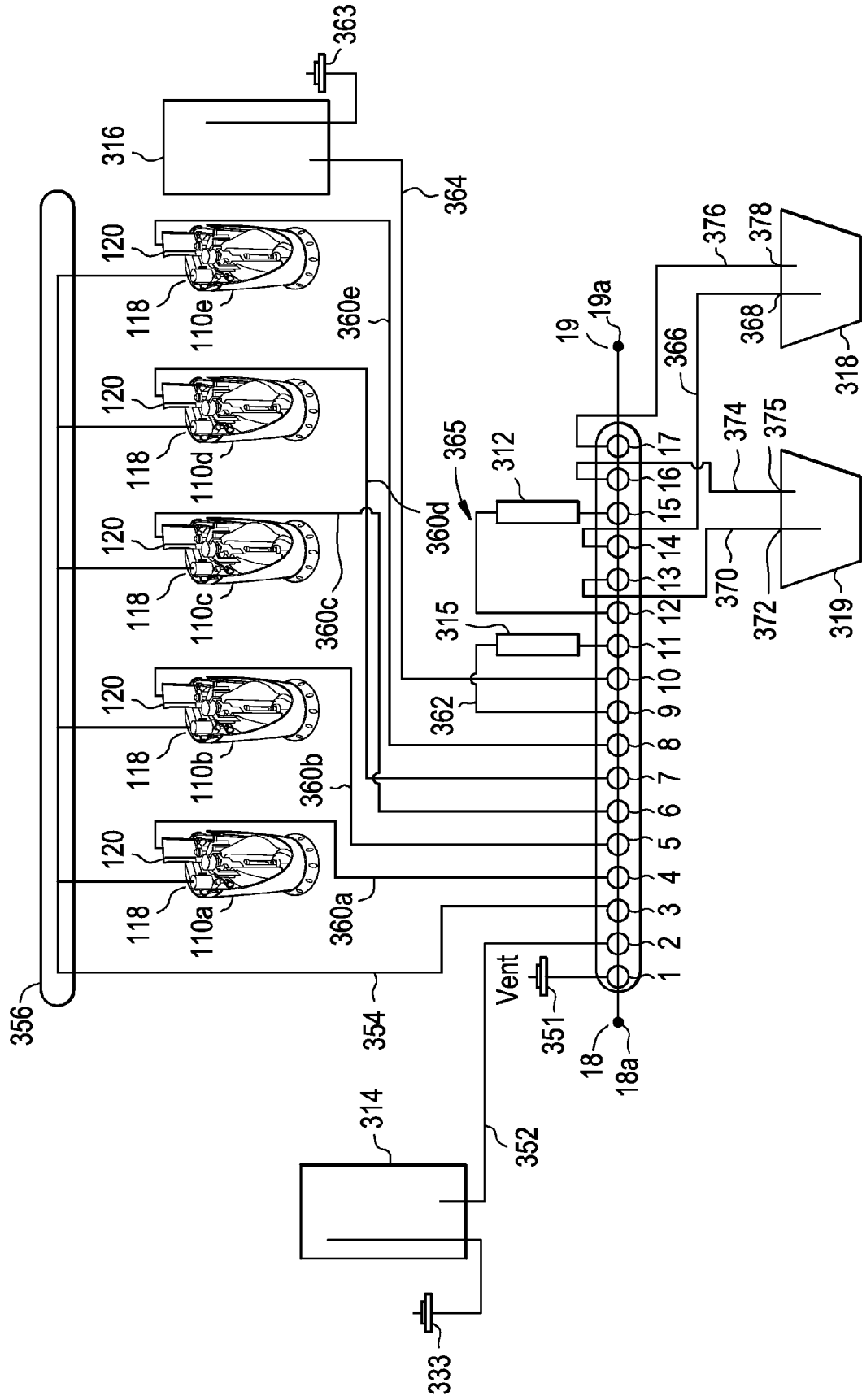


FIG. 8

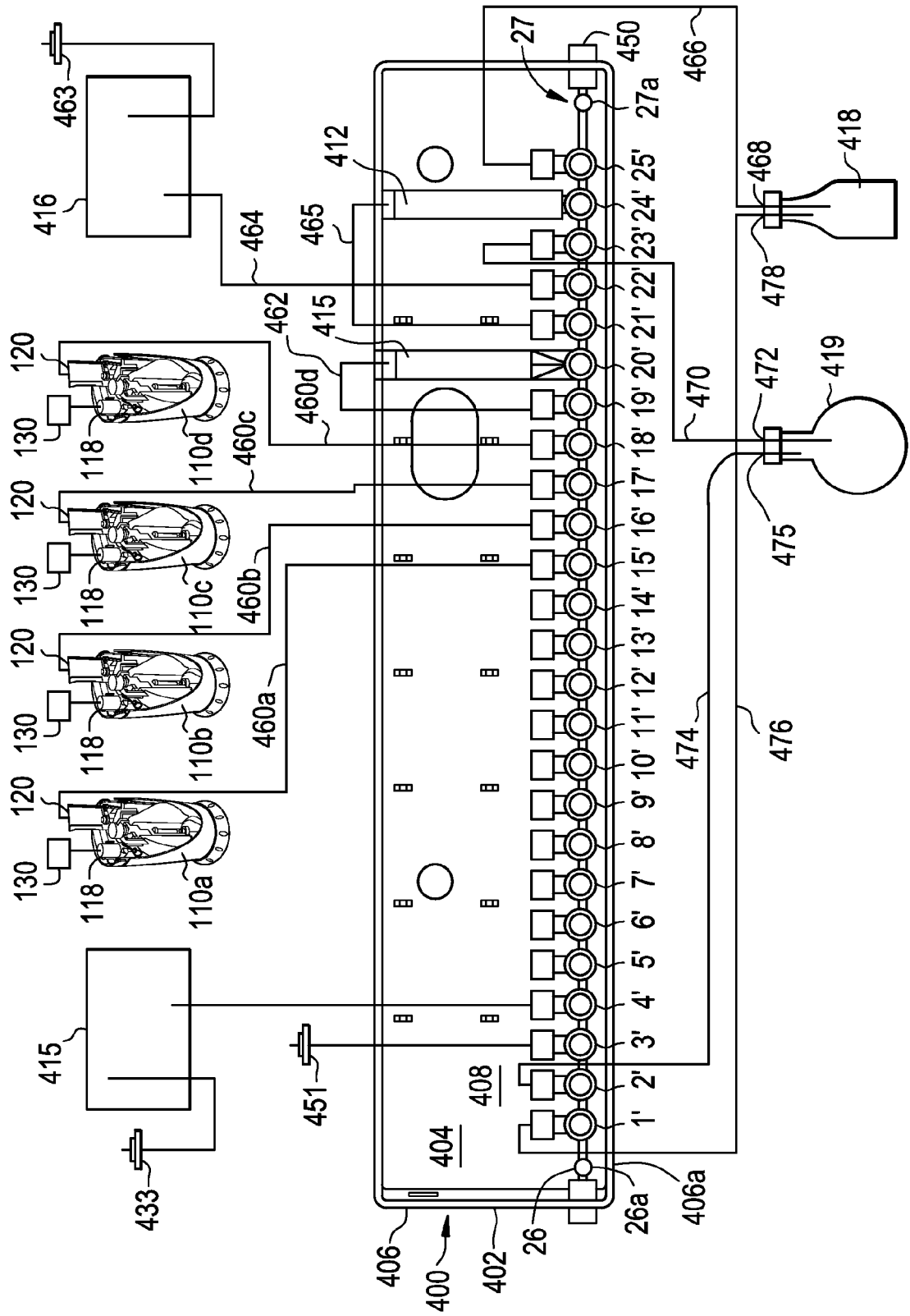


FIG. 9A

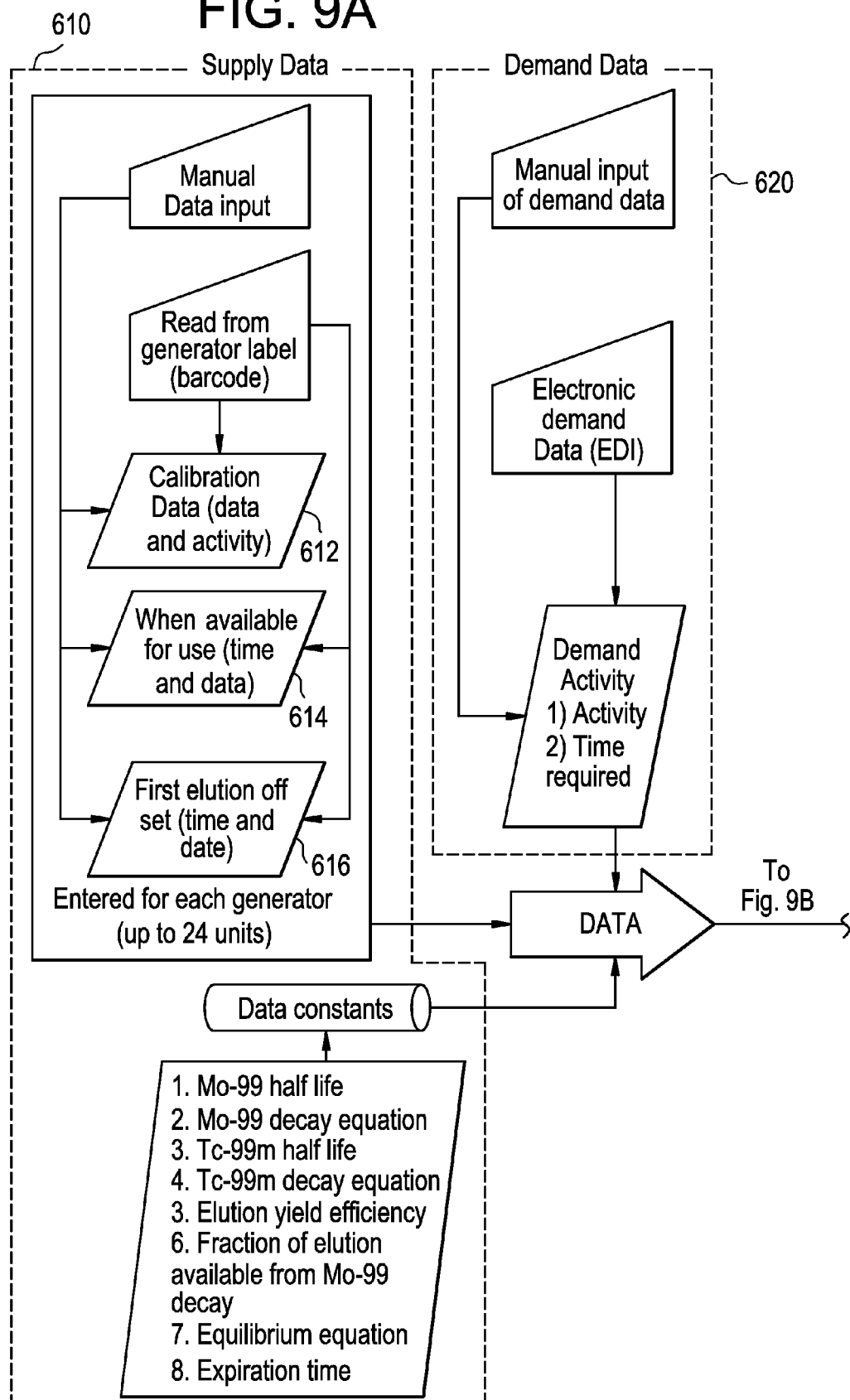


FIG. 9B

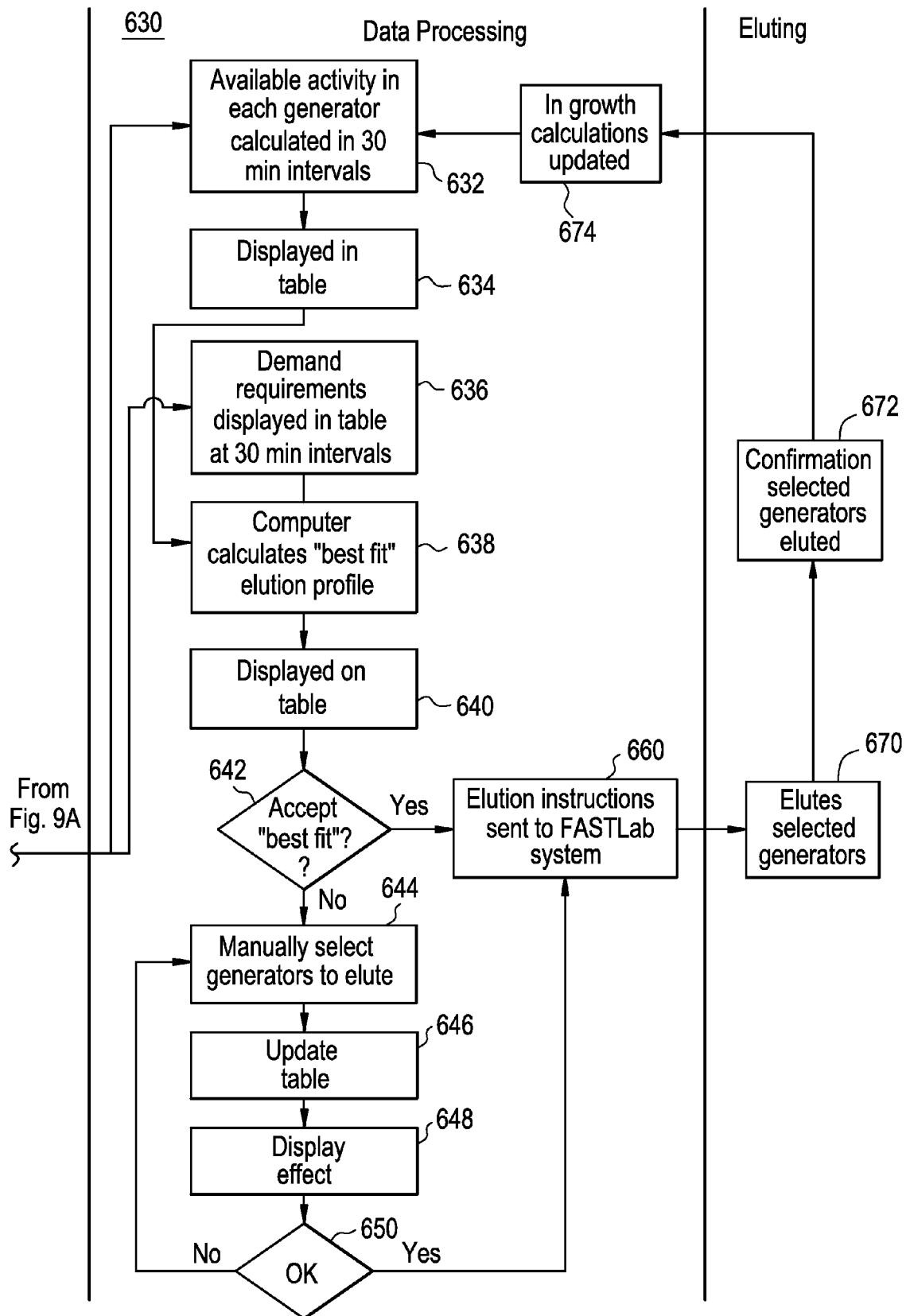


FIG. 10

700

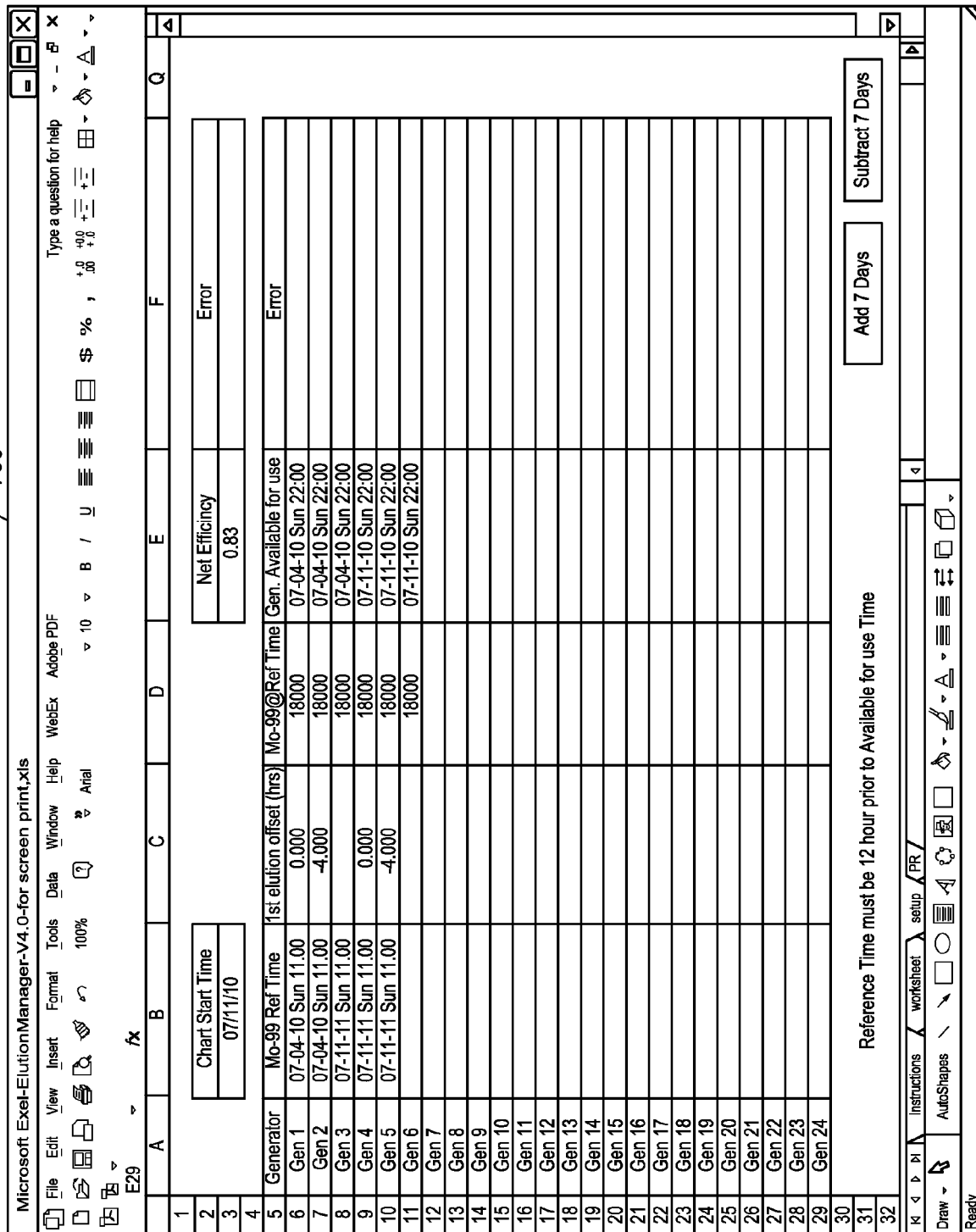


FIG. 11

800

[illegible]



EUROPEAN SEARCH REPORT

 Application Number
 EP 14 15 0578

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 5 May 2014	Examiner Smith, Christopher
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