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RESEARCH AND DEVELOPMENT OF SAFEGUARDS MEASURES FOR THE LARGE SCALE REPROCESSING PLANT AT ROKKASHO-MURA

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1. BACKGROUND

A large scale reprocessing plant operable on a commercial basis is now under construction in Rokkasho-mura as a part of the national nuclear fuel cycle policy of Japan (Figs 1–10). From an early stage of the plant design, the Government of Japan has been considering the safeguards measures to be applied. Having concluded that a near real time material accountancy (NRTMA) system and an unattended operation system comprising non-destructive assay (NDA), and containment and surveillance (C/S) would be essential for the plant, the Government recognized that such systems are included in the safeguards concepts of commercial size reprocessing plants under the bilateral agreement for co-operation between Japan and the United States of America.

In addition, the international forum on large scale reprocessing plant safeguards, LASCAR, obtained fruitful results in the spring of 1992, finding that a wide range of techniques was available or being introduced for safeguarding the large scale reprocessing plants envisaged for the late 1990s.

The research and development of safeguards measures for the Rokkasho Reprocessing Plant (RRP) should progress similarly, in all regards.

2. BASIC CONCEPTS

To date, a number of studies of safeguards measures for the RRP have been conducted by the Nuclear Material Control Center (NMCC) since 1989, under contracts with the Government of Japan. The basic concepts of the studies are: to establish an accurate and precise material accountancy system, to achieve the timeliness goal and to possibly reduce inspection efforts by introducing an unattended mode inspection system.

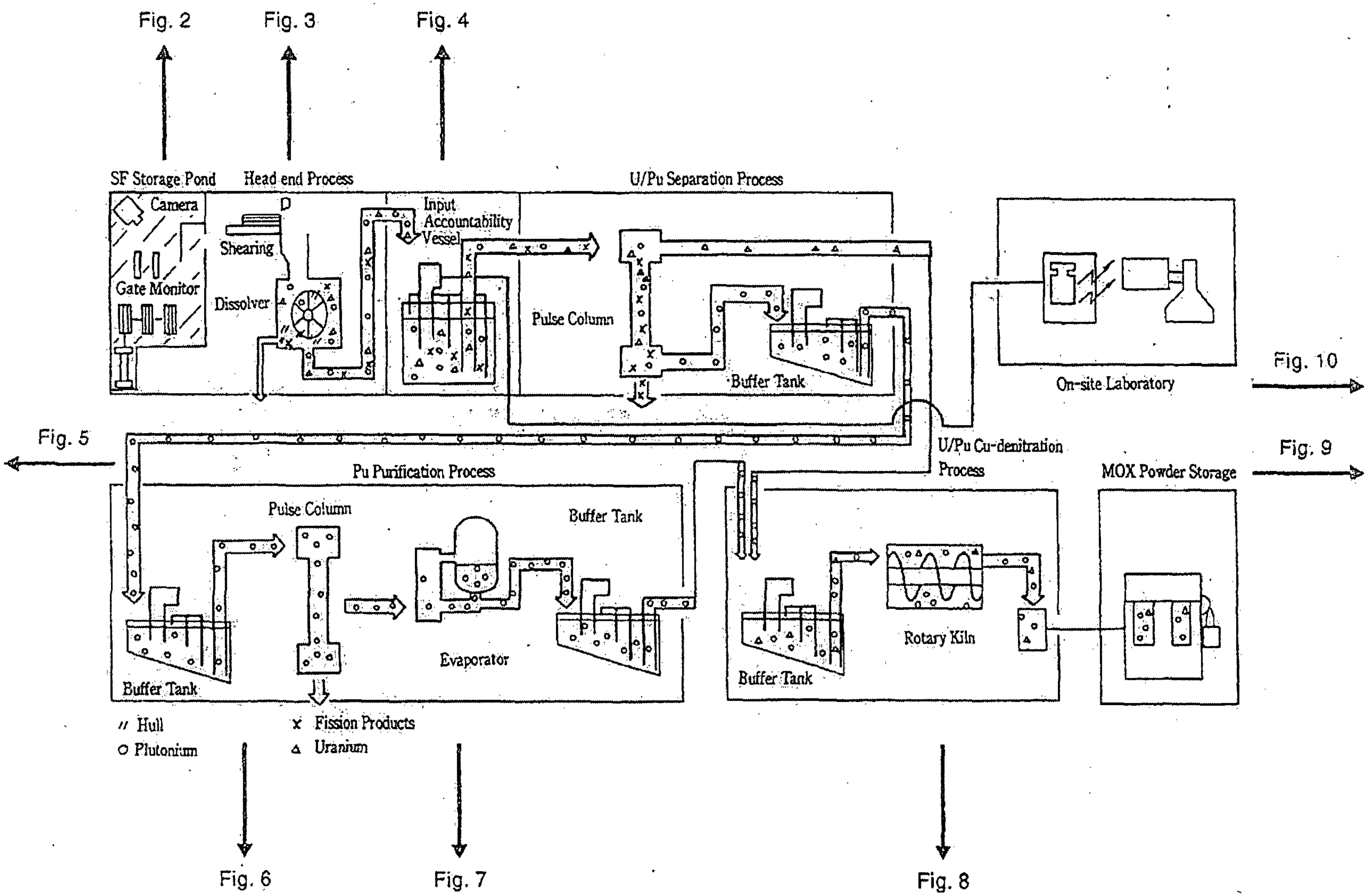


FIG. 1. Conceptual layout of large scale reprocessing plant.

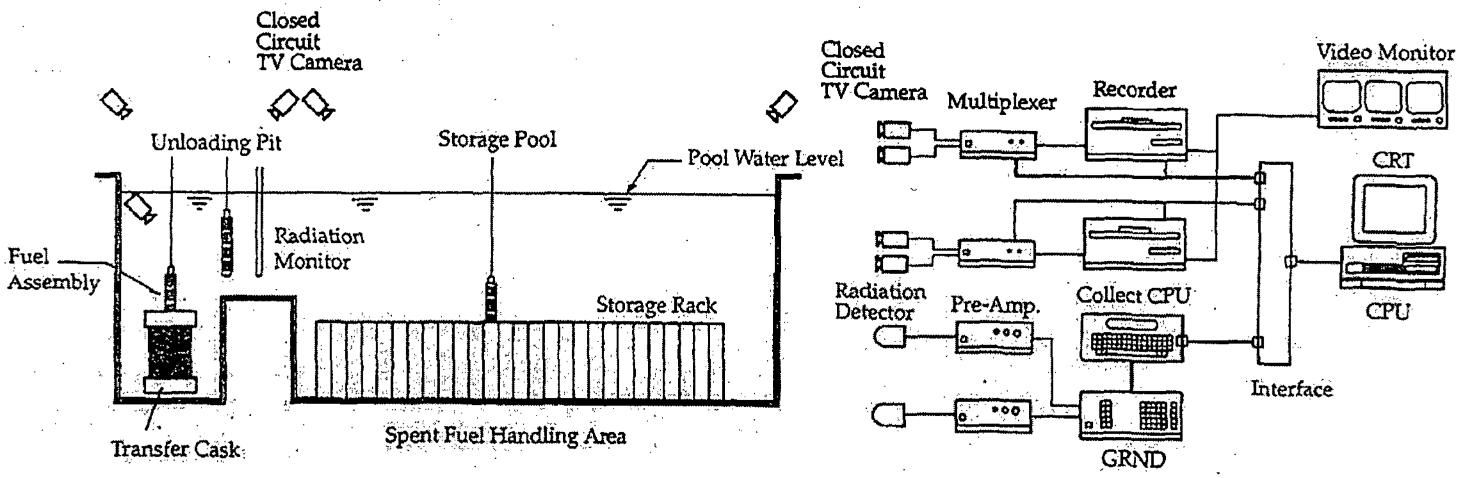


FIG. 2. Storage pond: integrated containment/surveillance system.

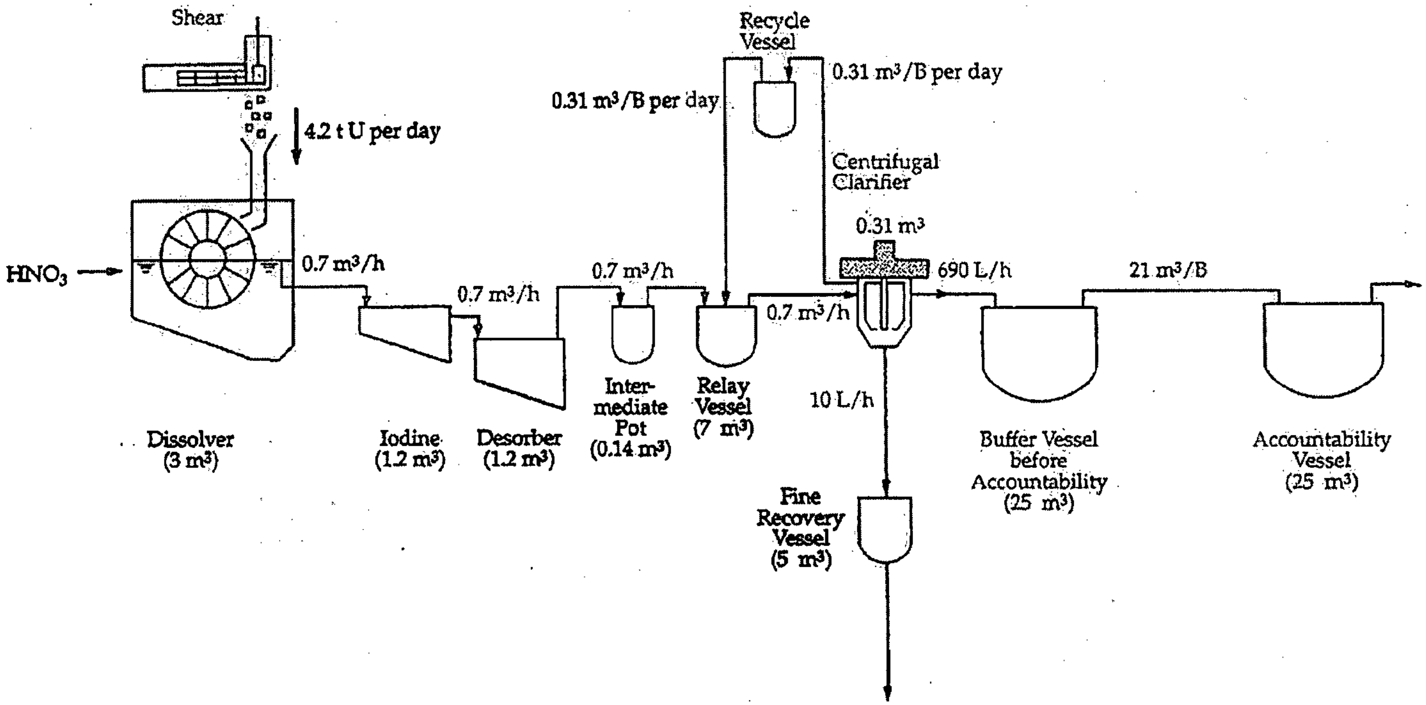


FIG. 3. Process flow sheet for model head end area.

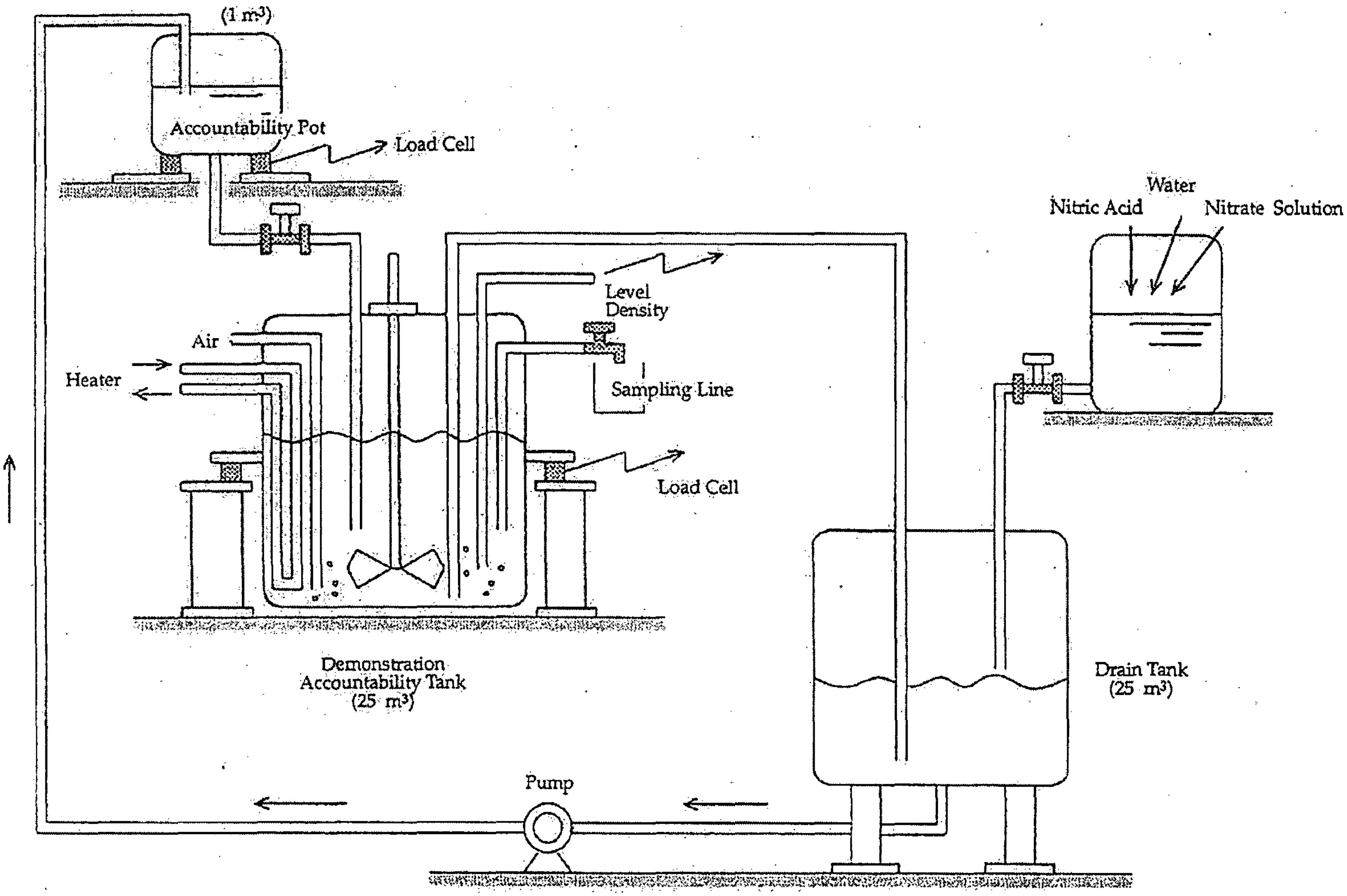
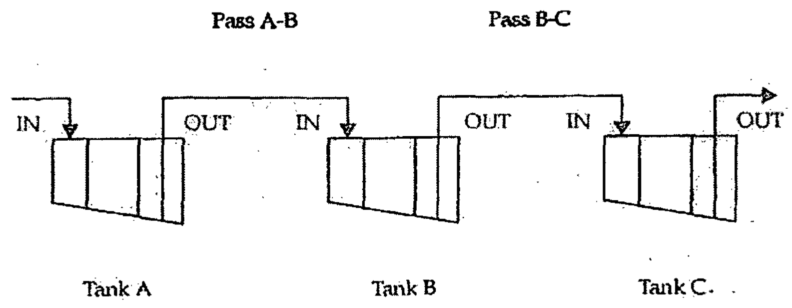
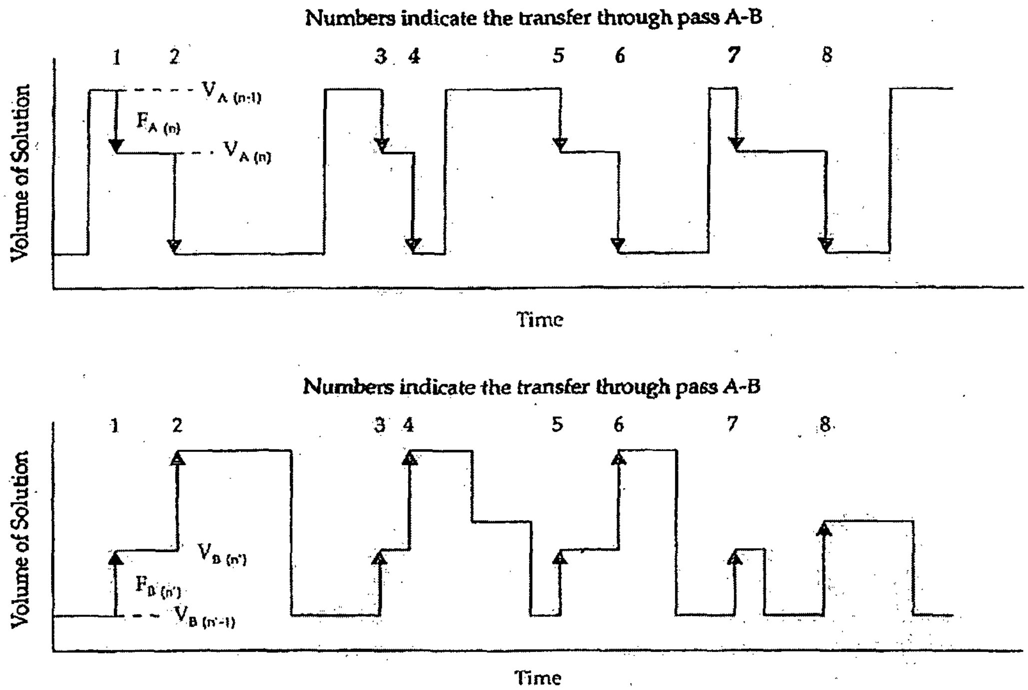


FIG. 4. Input accountability tank.



A model for inventory monitoring approach



Example of volume variation in each tank in the model

FIG. 5. Sequential tanks.

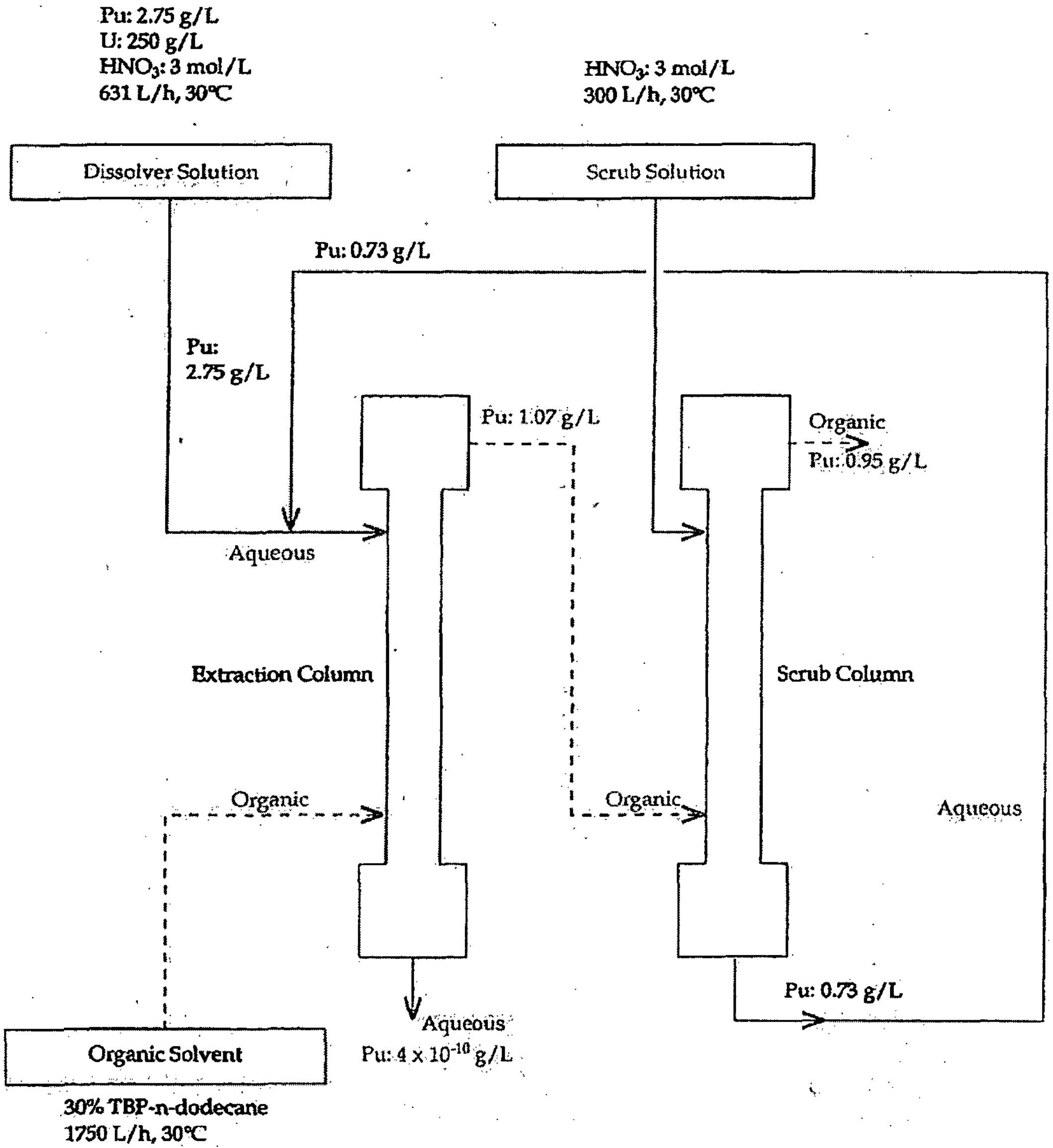


FIG. 6. Pulsed columns.

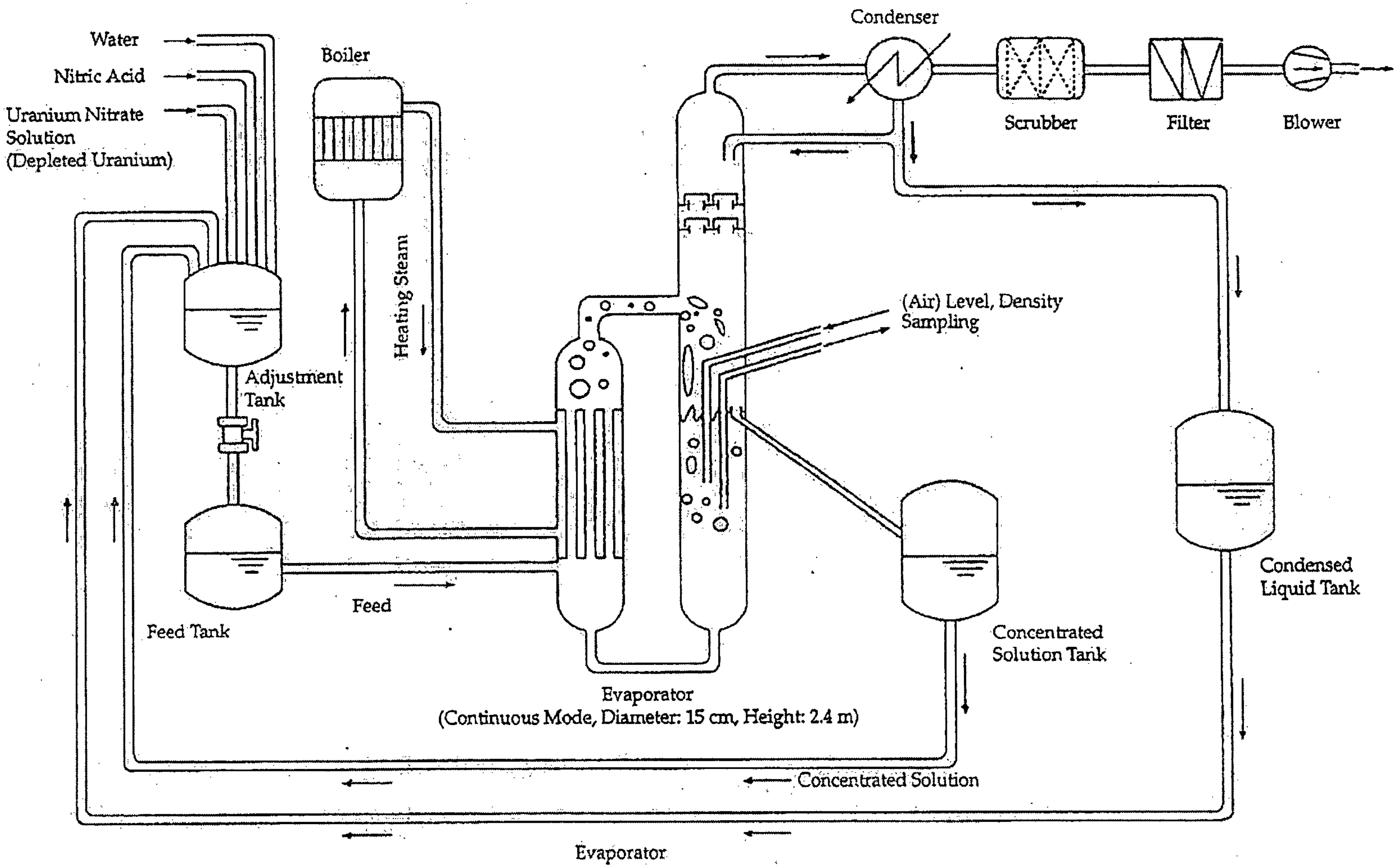


FIG. 7. Evaporator.

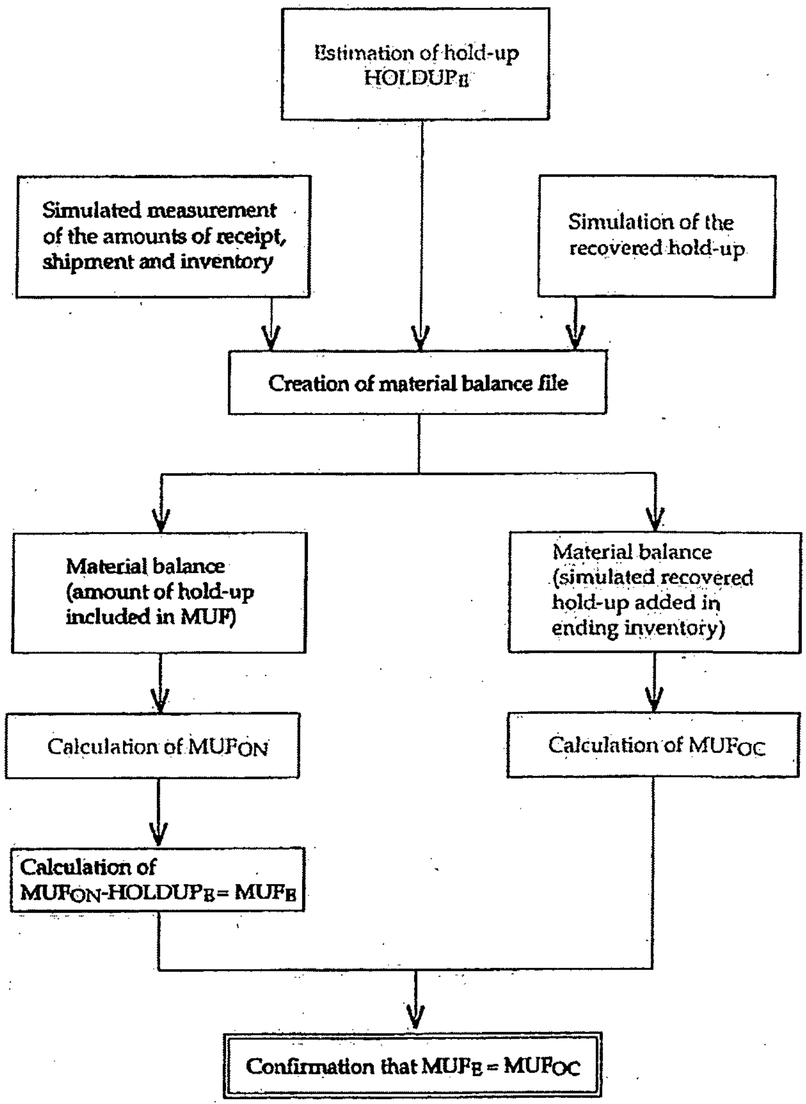


FIG. 8. Simulation procedure.

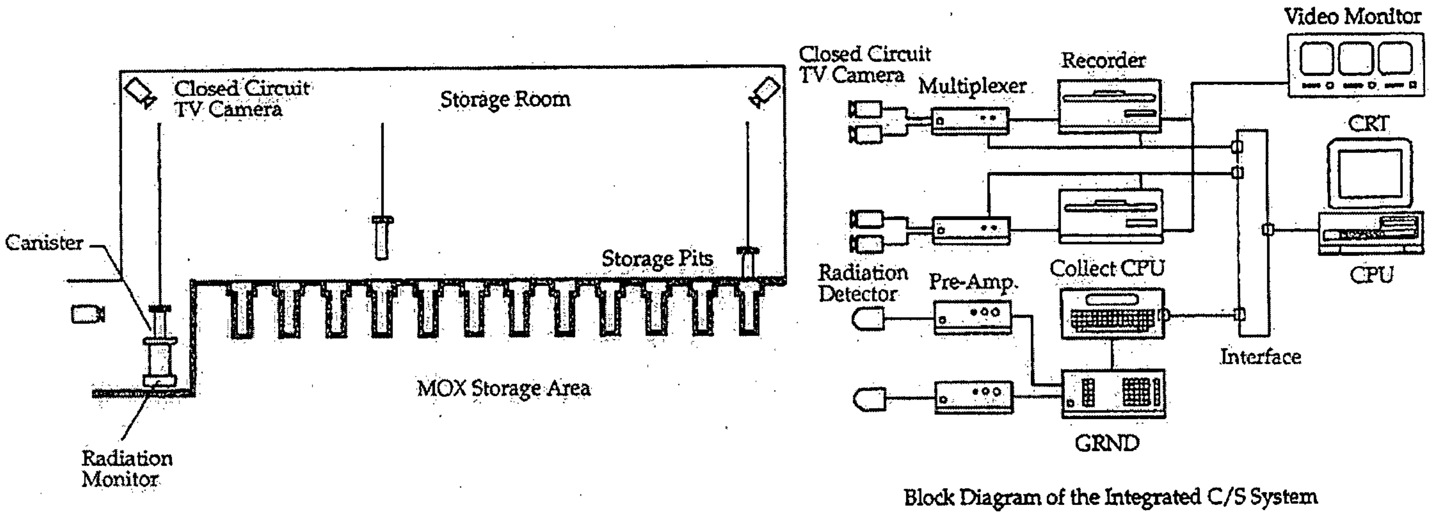


FIG. 9. MOX powder storage: integrated containment/surveillance system.

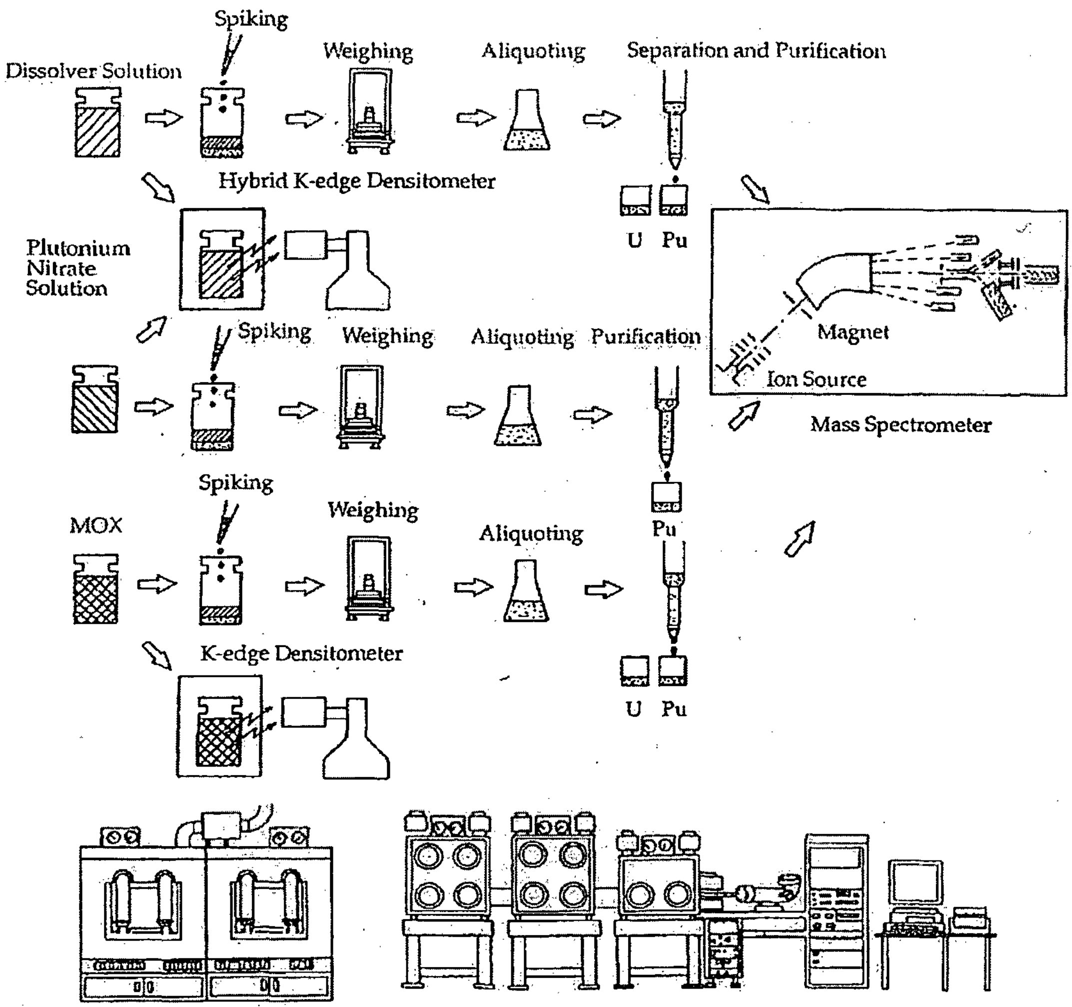


FIG. 10. System design of on-site laboratory.

3. PREMISE OF SAFEGUARDS APPROACH AND R&D ITEMS

3.1. Spent fuel storage area and mixed oxide product storage area

To reduce the inspection efforts for the transportation of spent fuel and mixed oxide (MOX) product, an integrated system combining NDA and surveillance equipment for flow verification should be installed at the entrance and exit gates of these areas. An optical surveillance system for area surveillance should be installed in the storage area. The basic requirements of these systems are as follows:

— to provide efficient data review
— to maintain continuous data monitoring and surveillance for suitable periods, and
— to enable easier maintenance for the inspectorates.

An integrated spent fuel assembly verification system has been developed since 1992 and a conceptual specification of the system has already been agreed by the Government of Japan and the IAEA.

3.2. Process monitoring for the head end area

As RRP has adopted the continuous dissolution process, the materials in the process could not be followed up on a batch basis. The proposed process monitoring is expected to be a good guide towards establishing a monitoring system of material loss in the head end area, using dynamic shipper–receiver differences (SRDs) as a characteristic that will be continually calculated throughout a material balance period.

To reduce influences from the hold-up fluctuation, measurable hold-up was subtracted from the simple shipper–receiver difference values. The SRD_d value is defined by the following equation:

$$\mathrm{SRD}_{d_n} = \Sigma(\Sigma S_j)\mathrm{i} - \Sigma R_i - (\Sigma MI_k)\,n \tag{1}$$

where (ΣS_j) represents the sum of dissolved uranium weight in a unit interval, ΣR_i is the receiver's data obtained at the input accountability tank and (ΣMI_k) represents the amount of measurable hold-up in the process equipment such as iodine disrobers and buffer vessels.

As the results of the simulation considered some error elements, the uranium balance is expected to be usable for loss detection measures in a head end process.

3.3. Experiments in large scale tank calibration (LASTAC) projects

Simulations have shown that accurate measurement in the input accountability tank is an extremely important element in maintaining an accurate material balance in the bulk form material treatment area. On average, the measured volume in each period is 20 m^3 and each measurement is performed at intervals of 30 hours. If there were enormous uncertainties in a measurement, the error would be accumulated throughout the material balance period.

As the measurement is executed very frequently, an automated verification system is essential. Suitable authentication measures should be installed.

The full size mock-up input accountability tank in RRP is now under construction in the NMCC, Tokai, and experiments will be carried out from 1995 to 1997, including:

- some calibrations of the measurement system, such as volume measurement using a load cell for the reference value;
- heel measurement;
- confirmation of influences leading to uncertainty of measurement, e.g. temperature;
- establishment of a calibration method for differential pressure and volume.

3.4. Solution transfer monitoring for sequential tanks

It is feared that some solution may sometimes remain in the long piping between the sequential tanks. These residuals would increase the uncertainty of near real time accountancy (NRTA). Solution transfer monitoring for sequential tanks would be performed by comparing the decreased and increased amount of solution in the shipping tank and receiving tank, respectively. The difference between these amounts is calculated by the following equation:

$$(D_s - \mathrm{r})i = [V_s(n-1) - V_s(n)] - [V_r(n-1) - V_r(n)] \qquad (2)$$

where $V_s(n-1)$ and $V_s(n)$ show the volume that is measured in the shipping tank before and after transfer. $V_r(n-1)$ and $V_r(n)$ show the volume that is measured in the receiving tank before and after transfer. The total residual amount of solution in the piping can be monitored by the cumulative sum of $D_s - r$ defined by the following equation:

$$CUD_s - r = \Sigma(D_s - r)k \qquad (3)$$

where k = total number of transfers.

The simulations for the transfer of low concentrated solution have shown good results. It is thought that 2% of the total transfers may be residual.

3.5. Pulse column inventory: methods of estimation

Direct measurement of the inventory in pulse columns is almost impossible to achieve during operation. However, NRTA is required to total this inventory in its material balance. It is thought that monitoring of the axial temperature distribution of the extraction column could be used as a characteristic to detect any inventory change.

Numerical analyses are made on extraction and scrub columns using a refined simulation code called DYNAC. If the parameters of the solvent feed flow rate to the extraction column change, the peak region of exothermic reaction also varies. Changing the parameters also causes a change in the extraction efficiency and thereby a change in the plutonium inventory in the column.

Calculated results indicate a correlation between the maximum temperature and the plutonium inventory in the extraction column. Hence, if quantitative correlation curves can be established, these can provide a means of estimating the inventory in the pulse column, too.

3.6. Evaporator inventory: methods of estimation

As the evaporator for plutonium nitrate will be operated continuously in the RRP, constant amounts of plutonium will almost always exist in the evaporator and cannot be measured directly, It is clear from the simulation that the plutonium there would amount to almost 70% of the unmeasured inventory in the chemical separation area. As the NRTA is also required to total the inventory of the evaporator, it is necessary to estimate it accurately.

To establish the method of estimation, a mock-up evaporator will be constructed in the NMCC, Tokai. Its throughput is approximately five times less than that of the full scale evaporator (8 kg/d; 0.2% depleted uranium (DU) will be used in this experiment). However, the temperature, pressure, density and liquid level would be identical to those of the full scale evaporator.

Two types of experiments will be carried out from 1996 to 1997, specifically:

— to learn the conditions in the operating evaporator through measurement of the liquid circulation;
— to calculate the balance via the concentrate throughput, input and output.

3.7. Powder treatment process inventory: methods of estimation

The hold-up amount of material in the powder treatment process, especially in the rotary kiln that is used for calcination and reduction, cannot be ignored in the NRTA. Although these amounts could be verified in a timely manner by the NDA hold-up counter, the operator must, nevertheless, declare the amount of hold-up material.

Learning from experience, an estimation of the total amount of hold-up could be achieved by deriving a special function based on the ratio of hold-up to throughput. In determining the function, it is necessary to accumulate data from experience, e.g. with equipment tests and cold tests, also between campaigns. The hold-up is defined as the differences between the input and output of the processor. These data would tend to fit a polynomial curve that could have various shapes. This method could be used for the powder treatment process in the RRP.

3.8. System design of an on-site laboratory

Japanese and IAEA experts discussed the design and utilization of an on-site laboratory (OSL) for safeguards at RRP. The discussion focused on the number and type of samples to be measured, the analytical methods to be applied and the layout of a laboratory for joint use by Japanese and IAEA inspectors. The requirements for testing joint analysis procedures and proper authentication of measurement systems were identified.

The suitability of various analytical techniques was discussed. Isotope dilution mass spectrometry was identified as the most widely applicable destructive assay (DA) technique. For NDA, hybrid K-edge densitometry/X ray fluorescence spectrometry would be available for analysis of input, solution product and certain other process streams. MOX and uranium powder would be measured by neutron counting (inventory sample counter) or X ray fluorescence spectrometry.

The construction of the OSL will be co-ordinated with the construction schedule of the RRP.

4. CONCLUSIONS

The inspectorates should consider the best way to reduce the long term running costs of inspection. From our experience of inspection at the Tokai Reprocessing Plant, it is clear that if a systematic inspection system were not introduced in the RRP, inspection person-days would inevitably increase. Therefore, the inspection system should be modernized, using instruments that are sufficiently automated and integrated into the plant.

To maintain an effective safeguards approach to the RRP while saving inspection resources, the IAEA should co-operate with the State's system of accounting and control as well as the Member States' support programmes.

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