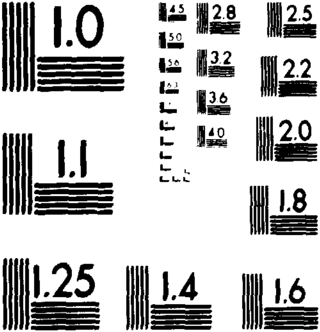

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COMITATO NAZIONALE PER LA RICERCA E PER LO SVILUPPO
DELL'ENERGIA NUCLEARE E DELLE ENERGIE ALTERNATIVE

SARA
A SIMULATION COMPUTER CODE FOR NRTMA PERFORMANCES STUDY AT EUREX PILOT REPROCESSING PLANT

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Riassunto

La Contabilità dei Materiali Nucleari, supportata da misure di Contenimento e Sorveglianza, è uno strumento fondamentale per un'efficace applicazione delle Salvaguardie Internazionali negli impianti nucleari.

La Contabilità è basata sulla verifica che, la differenza tra la quantità di materiale entrante in una determinata area e quella uscente dalla stessa in un certo periodo di tempo, corrisponda alla differenza tra la quantità presente all'interno dell'area alla fine ed all'inizio dell'intervallo di tempo scelto.

Negli ultimi anni le Salvaguardie Internazionali hanno dedicato un particolare sforzo di Ricerca e Sviluppo ad una nuova procedura denominata Contabilità dei Materiali in Tempo Quasi Reale, allo scopo di assolvere all'obiettivo di rivelazione tempestiva di diversioni di materiali strategici.

Il seguente rapporto, sviluppato nell'ambito del Programma Italiano di Supporto all'AIEA, presenta uno studio di fattibilità sull'applicazione di un sistema di NRTMA all'impianto pilota di riprocessamento di EUREX. Tale studio di fattibilità è stato condotto sviluppando un codice di calcolo che simula sia il processo di ritrattamento che le misure di inventario eseguite per l'esecuzione del bilancio di materiali fissili.

Abstract

Nuclear Material Accountability, supported by Containment and Surveillance measures, is a foundamental means for an effective International Safeguard implementation in nuclear plants.

Accountability is based on the verification that, the difference between a material quantity entering a given material balance and the quantity leaving that area in a given period of time, corresponds to the amount of material actually present at the moment of the inspection.

In the recent years International Safeguards appealing to the needs of timeliness in detecting diversion and concealing activities, devoted R&D efforts on a new Dynamic Accountability procedures (NRTMA) with particular concern with reprocessing plants.

The present paper, which is the result of a research activity carried out in the frame of the Italian Support Programme to IAEA for Safeguards implementation, deals with a feasibility study of a NRTMA system to be applied to the EUREX pilot reprocessing plant. Such a feasibility study was performed by developing a computer program based on simulated plant generated data.

1. Introduction

Nuclear Material Accountancy (NMA), with the support of Containment and Surveillance (C&S) measures, is fundamental for an effective International Safeguards implementation in nuclear plants.

The aim of NMA is to assure that in a given plant and during a given period of time no diversion of nuclear materials occurs.

A plant is divided into Material Balance Areas (MBAs) whose boundaries are chosen to facilitate the measurement of all nuclear material transfers and the establishment of the inventory at some strategic Key Measurement Points (KMPs). The inventory is performed by plant operator, which must prepare periodic material balances using the equation:

$$MUF_j = PB_j + X_j - Y_j - PE_j \qquad (1)$$

where

PB_j = beginning physical inventory for the period j

X_j = sum of increases to inventory during j

Y_j = sum of decreases from inventory during j

PE_j = ending physical inventory for the period j

MUF_j = material unaccounted for at the end of j

In ideal conditions MUF should be equal to zero, but this value is never found in practice. The causes of standing off values can be identified in the following:

1 - Increasingly unmeasurable material losses (deposition, precipitation, variable holdups)
2 - Physical inventory and material flow measurement errors
3 - Measurement recording and reporting errors
4 - Unauthorized material diversions

Measurement errors are always present and make MUF a random variable characterized by a mean and an associated uncertainty.

The value of MUF from (1) is significant only in conjunction with its associated standard deviation: in this way it's possible to evaluate if, among the MUF components, an actual diversion is present. This evaluation requires statistical concepts of hypothesis testing.

The closing of material balance and the MUF determination need, in the present practice, the stop of plant operation for Physical Inventory Taking (PIT) once or twice a year.

In the recent years International Safeguards devoted R&D efforts on a new procedure named Near Real Time Materials Accountancy (NRTMA), in order to satisfy the need of timeliness in detecting diversion and concealing activities.

NRTMA is defined as a specific approach to materials accountancy *in which physical inventories are performed at frequent intervals,* without shutting down the plant but using a combination of in-line instrumentations and laboratory analysis.

A rational application of the NRTMA technique is considered to be a powerful mean both to timely detect a diversion and to improve detection sensitivity: in fact, reducing the lenght of the material balance closing reduces the amount of material processed in any one period and at the same time, the uncertainty of a single material balance. Besides, material balance data can be evaluated using statistical procedures which specifically recognize their time-sequential nature.

From the plant operator point of view, the in-process inventory taking procedure ought not to interfere with process operations or operational procedures in any significant manner. Assuming that the basic measurement capability and an automatic data analysis system exists, addition of one or more inventory measurements and balance evaluations should not significantly increase the operator's total workload. Besides, NRTMA data can be used also for process control.

ENEA, knowing that the new approach calls for field experiments, performed a feasibility study of a NRTMA system to be applied to the EUREX pilot reprocessing plant and a computer code, based on simulated plant data, was developed to verify the performances of the system.

The calculation code, named SARA (Simulation Approach of Reprocessing Accountability), includes:

- Dynamic simulation of the process section (MBA2) of the EUREX reprocessing facility
- Simulation of some diversion strategies
- Simulation of the NRTMA measurement system
- Statistical material balance data evaluation

This paper provides a survey of all these aspects, a description of the code and an introduction to the user interface.

2. EUREX Pilot Reprocessing Plant Overview

The EUREX facility, located in the northern of Italy, is a pilot plant for reprocessing spent fuel elements.

It became operational in October 1970 and up to now 506 MTR and 72 CANDU fuel elements were processed, using both TCA and TBP as extractants.

The primary function of the plant activity is the acquisition of know-how through reprocessing experiments on high burn-up elements from power reactors. Significant experience has also been acquired in the area of nuclear material accountancy.

In the framework of the Programme concerning the nuclear fuel cycle, the task of studying TRINO LWR fuel reprocessing was entrusted to the EUREX plant: a coprocessing flow-sheet will be adopted.

The use of a coprocessing flow-sheet, which is the object of the NRTMA analysis reported in the present work, is connected with expected operational and Safeguards advantages: the product obtained constituted by a solution of Pu and U in a given ratio is ready for conversion to MOX and is of reduced strategic importance.

3. Dynamic Simulation of the Process Section of the EUREX Pilot Reprocessing Plant

The process section (MBA2) of the EUREX Pilot Reprocessing Plant, including all the components between the F-307 feed tank and the F-606 storage tanks, was simulated in order to provide data to be processed by the measurement simulation section of the computer code.

SARA simulates process streams (inputs, outputs, internals) and dynamic behaviour of Pu holdup in process components (tanks, contactors, evaporators) under normal operating conditions.

Fig. 1 shows the block diagram of the simulated EUREX process section, operating with a modified Purex batch-type flowsheet. After the chemical adjustment, the dissolution product from the F-303 input accountancy tank enters the F-307 feed tank; it is a solution of plutonium nitrate (~2.5 g/l) and approximately ten times as much uranyl nitrate, in 2 M HNO_3. When the feed tank is filled, the content (1AF) is pumped to the first cycle mixer settlers extraction unit (D-401, D-402, D-403), where an early fission products decontamination is carried out. The aqueous and the organic waste streams (1AW, 1CW) are transferred to the respective collecting tanks and the first cycle product stream (1CP) is sent to F405 tanks for analysis and then to the buffer tank F406. The 2AF stream, produced by means of the concentration adjustment of 1CP, feeds the second cycle mixer settlers extraction unit where, after a further fission products decontamination, an U partial stripping is performed. The organic stream (2CW) contains a fairly high amount of uranium (~50 g/l). Before being transferred to the C603 concentrator, the second cycle product stream (2CP) is sent to a triple buffer tank (F506, F507). The concentrated product is collected in the F606 tanks for interim storage.

Table I lists project plutonium concentrations and volumetric flow rates, while in process holdups of tanks and vessels are given in table II.

3.1 - Flow rates

Flow rates of input, output and internal streams are treated as stochastic variables.

If $x(t)$ is the value of a stochastic variable at time t, then its value at time $t+\Delta t$ is given by

$$x(t+\Delta t) = N\,[x(t), \sigma] \qquad (2)$$

under the condition

$$\text{if} \quad abs[x(t+\Delta t) - x_n] \geq 2\sigma x_n \quad \text{then} \quad x(t+\Delta t) = x_n$$

where N : normal distribution

σ : standard deviation of x

x_n : project value of x

Using (2), the time dependance of all flow rates is assumed to be constant over sufficiently short time intervals Δt.

3.2 - Tanks

For an instantaneous and perfectly mixed tank, the conditions of mass and volume conservation are:

$$d\,[V(t)\;C_T(t)]\,/\,dt \;=\; q_{in}(t)\;C_{in}(t) - q_{out}(t)\;C_T(t) \qquad (3)$$

$$d\,V(t)\,/\,dt \;=\; q_{in}(t) - q_{out}(t) \qquad (4)$$

where
- V = volume in the tank
- C_{in} = input Pu concentration
- C_T = in tank Pu concentration
- q_{in} = input flow rate
- q_{out} = output flow rate

3.3 - Solvent Extraction Contactors (Mixer Settlers)

Simulation of the solvent extraction contactors generally requires sophisticated mathematical models able to describe the time dependance of the Pu inventory. Some simulation codes based on very accurate mathematical models already exist for the mainframe computer of C.R.E. Casaccia.

Even if our simulation code can easily be transferred to a mainframe, it was developed and runs on a IBM personal computer, under the MS-DOS operating system. The most important limitation connected with the development of a simulation code on a personal computer is the need of seeking a compromise between a realistic mathematical description of the dynamic behaviour of the system to be simulated and subroutines which don't lead to prohibitively long computation times. For this reason in our code solvent extraction contactors are simulated by means of a simplified dynamic model, neglecting the effects of many complex parameters. The most important assumptions are:

- perfect mixing in the mixer
- istantaneous material transfer between the two phases in the mixer
- total volumetric holdup constant both in the mixer and in the settler
- aqueous and organic volumetric holdups in the mixer proportional to the two phases flow rates
- no mass transfer in the settler
- no concentration gradient in each phase of the settler

Mixer

A schematic diagram of a single stage mixer settler is shown in fig.2.

Most of the evidence suggests that the mixer, which must be well stirred in order to achieve efficient mass transfer, can be modelled as a perfectly mixed tank. The velocity of the mass transfer allows to simulate the time behaviour of the mixer by means of successive equilibrium stages, using the equations:

Mass conservation:

$$q^{A}_{in}(t)\, C^{A}_{in}(t) + q^{O}_{in}(t) C^{O}_{in}(t) = q^{A}_{out}(t) C^{A}_{M}(t) + q^{O}_{out}(t) C^{O}_{M}(t) \quad (5)$$

Equilibrium stage condition:

$$C^{O}_{M}(t) = m\, C^{A}_{M}(t) \quad (6)$$

where A and O indicate aqueous and organic phases while the subscript M refers to the mixer.

The parameter m was estimated for each stage in order to ensure that the separation factors foreseen by the reference flow-sheet are achieved.

Input and output flow-rates are related by:

$$q^A_{out}(t) = q^A_{in}(t) \; [1+K^A \; (C^A_M(t) - C^A_{in}(t))] \qquad (7)$$

$$q^O_{out}(t) = q^O_{in}(t) \; [1+K^O \; (C^O_M(t) - C^O_{in}(t))] \qquad (8)$$

where K^A and K^O are parameters which take into account volume transfer between the two phases.

Settler

The outputs of the mixer are inputs for the settler; after evaluating the new equilibrium conditions for the mixer at t time, the settler Pu concentration for each phase and the relative holdups are determined by assuming the concentrations and flow rates, leaving the mixer, constants between t and t+Δt.

The following relationships, modelling each settler phase as perfectly mixing tank, are used:

mass conservation:

$$d\,[V^A_S \; C^A_S\,(t)] \,/\, dt = q^A_{in}(t) \; C^A_M(t) - q^A_{out}(t) \; C^A_S\,(t) \qquad (9)$$

$$d\,[V^O_S \; C^O_S\,(t)] \,/\, dt = q^O_{in}(t) \; C^O_M(t) - q^O_{out}(t) \; C^O_S\,(t) \qquad (10)$$

phase volumes conservation:

$$d\,V^A_S(t) \,/\, dt = q^A_{in}(t) - q^A_{out}(t) \qquad (11)$$

$$d\,V^O_S(t) \,/\, dt = q^O_{in}(t) - q^O_{out}(t) \qquad (12)$$

where subscript S refers to settler.

3.4 - Concentiator

The concentrator operates in three successive steps:

1) filling step - during this step the concentrator is modelled as a simple vessel; when the nominal volume V_n has been reached the concentration process starts

2) concentration step - the process is carried out at "constant volume"; the distilled amount is integrated by feeding the intermediate product;

3) product transfer step - the evaporation process is considered to be completed when an intermediate product batch has been processed; final concentrated product is then transferred to the storage tank.

The concentration unit was modelled using the following relations:

- Filling step

$$dV_{ev}(t) / dt = q_{in}(t) \qquad (13)$$

- Concentration process step

$$dV_{ev}(t) / dt = q_{in}(t) - q_{dist}(t) \qquad (14)$$

where $q_{in}(t)$ and $q_{dist}(t)$ are stochastic variable.

For both (1) and (2) steps the following relationship is used:

$$dM_{ev}(t) / dt = q_{in}(t)\ C_{in}(t) \qquad (15)$$

where $V_{ev}(t)$ and $M_{ev}(t)$ are respectively the volume and the Pu mass contents of the concentrator.

- Product transfer step

Only a stochastic type transfer efficiency is used to model the product transfer step.

3.5 - Simulation results

The simulated time dependance of the total Pu holdup in the first and in the second cycle extraction batteries from the startup to the end of the first batch is shown in fig. 3 and in fig. 4.
Fig. 5 shows the dynamic behaviour of the Pu holdup in the evaporator feeding triple tank.

4 - Diversion Simulation

If requested, SARA simulates a diversion of nuclear material from the storage tank, which represents the most critical point of the plant from the Safeguards point of view: in fact it contains a concentrated and decontaminated Pu solution.

It's possible to simulate both constant and abrupt diversion; in the latter case the user of the code can select the balance period in which the diversion occurs as well as the amount of diverted material.

5 - NRTMA System Simulation

Implementation of NRTMA requires both in-process inventory taking and I/O measurements at KMPs. In our NRTMA system simulation model the F-303 input accountancy tank (IAT) is the only I/O KMP, while all the other tanks, the contactors and the concentrator are inventory KMPs.

In-process inventory is assumed to be evaluated by existing process instrumentation, as far as tanks are concerned, and by a simplified dynamic model for solvent extraction systems and concentrator.

The inventory in minor process components such as pipes is fully neglected.

The computer code allows the user to investigate the influence both of a new instrument or measurement procedure and of other dynamic models on NRTMA system performances.

5.1 - Tanks

Each tank is assumed to be equipped with probes for volume and concentration measurements according to the Volumetric Method.

The measurement system is simulated by means of some different subroutines characterized by the same error model: measured values are obtained on the basis of the simulated "true" data generated by the program section described in the previous paragraphs.

The measured value Q of a "true quantity" q is given by

$$Q = q\,(1+\varepsilon+\delta) + d \qquad (16)$$

where ε is the relative error due to instrument precision (random error), δ is the relative error due to instrument calibration (systematic error) and d is a factor taking into account instrument calibration drift.

Both errors ε and δ are assumed to be independent and normally distributed with zero mean and variances σ_ε^2 and σ_δ^2 respectively.

In the measuring system simulation a value of ε is sampled for each measurement whereas a value for δ is periodically sampled with the frequency of instrument recalibration.

The parameter d is a linear function of the time and it is set to zero at each instrument recalibration.

The numerical values of uncertainties for both volume and concentration measurements used in the investigation are shown in table III. Since the proposed NRTMA system is based on existing process instrumentation, these values were taken from EUREX plant literature and operators suggestions.

Triple tanks

A characteristic of the simulated process flowsheet is the arrangement of three tanks for the decoupling of important process stages. For example (Fig.1) the 1CP stream from D-403 is taken up alternatively by F-405 A and B tanks. These tanks work as batchers as well as analysis tanks; after sampling, the tank content is transferred batch-wise to F-406, which acts as a debatcher, providing continuous input to the next stage of mixer-settlers. The typical time dependance of the volumetric holdup in F-405 A-B and in F-406 tanks from the startup to the end of the first operating day is shown in Fig. 6.

This so-called "Triple Tanks Concept" is of particular relevance to the establishment of the in-process Pu inventory and hence to the implementation of NRTMA. The main difficulty comes directly from the impossibility to perform concentration measurements in feed tanks since they have just instruments for volume measurement. This, coupled with the possibility of mixing in the other tanks, contributes to a degree of uncertainty in the total holdup of the system: in fact the Pu concentration in the feed tank is only approximately equal to that previously measured in the analysis tank.

Let H_{TRUE} be the "true" instantaneous inventory of all the three tanks:

$$H_{TRUE} = V_1C_1 + V_2C_2 + V_3C_3 \qquad (17)$$

The "estimated" inventory is given by:

$$H_{EST} = V_1C_1 + V_2C_2 + V_3C_{PREV} \qquad (18)$$

where C_{PREV} is the concentration measured in the analysis tank during the previous batch.

The degree of uncertainty introduced by the triple tank concept is dependent upon the size and rapidity of fluctuations of Pu concentration in the continuous feeding stream; since an analytical treatment seemed to be impossible, it was decided to estimate it by means of the simulation code itself, according to:

$$\sigma^2(H_{EST}) = 1/(n-1) \sum_{i=1,n} (H_{EST}^i - H_{TRUE}^i)^2 \qquad (19)$$

where $\sigma^2(H_{EST})$ is the standard deviation of the estimated inventory from the true inventory and n is the number of observed batches.

Using n=1000 to give a statistical meaning to the estimation, a value ≈ 0.1% for $\sigma(H_{EST})$ was found. Making a comparison to the EUREX plant operators estimates of buffer tanks measurement errors (table III), it may be concluded that the uncertainty introduced by the triple tank concept can be neglected.

5.2 - Concentrator and Mixer Settlers

The accuracy of in-process inventory for NRTMA purposes on nuclear fuel reprocessing facilities is limited by the amounts of nuclear materials contained in the solvent extraction contactors and in the concentrator, which are not measured directly.

Since the Pu holdup in contactors and concentrator is quite small if compared with the total in-process inventory, as a first approximation it can be neglected.

Undoubtly, if the process is at equilibrium and the components are running normally, it is to be expected that their holdups will be fairly constant and hence cancel out in the material balance closing. However, fluctuations in Pu holdup of mixer-settlers, even when they are operating under steady-state conditions, can occur due to small changes in external parameters as input flow-rates, extraction flow-rates and TBP concentration. If process noises occur these fluctuations will be larger: in some plants the true inventory of a contactor can vary from 0.8 to 4 times the flowsheet design value.

In view of the possibility of large variations in contactors and concentrator unmeasured inventories, an estimate will be very useful for improving the total accuracy of NRTMA system.

The contactor inventory can be estimated by means of SEPHIS or similar computer codes. However, as it has just been underlined in this paper, these computer codes are not useful for NRTMA purposes because they require a large computer and a considerable amount of chemical data on the flowsheet. Generally in NRTMA field unmeasured inventory are estimated by means of simple mathematical models using a minimum amount of input data. Our computer code uses such a model: the "true" inventory data are degenerated by means of random extractions from a Normal Distribution, the associated uncertainty being taken by literature.

5.3. - Frequency of material balance closing

The choice of the frequency of material balance closing is very important for the implementation of a NRTMA system since it influences directly its performances.

Performances of a NRTMA system are connected with the concepts of loss-detection sensitivity and detection time. Because of the statistical nature of nuclear material accounting, loss-detection sensitivity can be described as the probability of detecting some amount of loss while accepting a certain false alarm probability. Detection time is the time required by the system to reach some specified level of loss-detection sensitivity.

Criteria for the evaluation of the performances of a NRTMA system are generally given in terms of Detection Probability, False Alarm Probability, Significant Quantity and Detection Time. For example, a specific criterium suggested by IAEA for decontaminated Pu handling plant is a 0.95 probability of detecting the loss of 8 Kg of Pu over 10 days with a 0.05 false alarm probability. The Significant Quantity of 8 Kg was selected as being related to that quantity of Pu required for a single nuclear explosive device, while the 10 days Detection Time is connected with the time required to convert nuclear material to weapon form.

Detection Probability and False Alarm Probability are not indipendent but are related by a continuous function that depends on the uncertainty associated to the balance period and on the particular statistical test applied to the balance data.

Whatever test is adopted, Detection Probability and False Alarm Probability for a given loss of nuclear material are respectively inversely and directly correlated with the uncertainty associated to the material balance. A high frequency of material balance closing reduces the quantity of nuclear material to be measured during a balance period and consequently the uncertainty associated to the balance period itself: Detection Probability is high and False Alarm Probability is low.

Obviously also Detection Time is directly correlated with the frequency of material balance closing, but a too high frequency increases plant operator's total workload.

A compromise between NRTMA system performances and operator's needs becomes necessary: in our code a weekly frequency of material balance closing was selected as a default value, in order to achieve the Detection Time suggested by IAEA for decontaminated Pu handling plant (10 days); a twice weekly frequency was also tested obtaining good values both for detection and for false alarm probability.

6. Material Balance Data Evaluation

Material balance data are evaluated by means of both a simple Neyman-Pearson test and a sequential test.

The Neyman-Pearson test is based on the balance statistic MUF defined by (1); it is the optimal test for an abrupt diversion.

The sequential test is based on the balance statistic CUMUF, defined by the following relationship:

$$\mathrm{CUMUF}\ (n) = \sum_{i=1,n} \mathrm{MUF}\ (i) \qquad (20)$$

where n and i are referred to the material balance periods. Such a test is expected to offer good performances for a constant diversion scenario.

The simulated values of MUF and CUMUF for 16 material balance closings are shown in Fig. 7 and in Fig. 8. Fig. 9 and Fig. 10 show the calculated values of the uncertainties associated to respectively MUF and CUMUF.

Performances of the NRTMA system were statistically calculated by means of the computer code: a very high number of runnings was performed to give a statistical meaning to the calculation. A MUF Test Detection Probability of 0.94 was obtained for an abrupt diversion of 330 g of Pu during the 14° material balance period, characterized by a MUF associated uncertainty of about 100 g of Pu; the MUF Test False Alarm Probability was ≈0.04. A CUMUF Test Detection Probability of 0.98 was obtained for a constant diversion of 30 g of Pu/batch, that is about 4% of the Pu treated during a batch; the CUMUF Test False Alarm Probability was ≈0.01. Going from a weekly to a twice weekly frequency of material balance closings the performances of both MUF and CUMUF test became only a little worse.

These results may be considered very good, especially taking in consideration that our NRTMA system makes use of the existing EUREX process instrumentation, that was not designed taking expressly into consideration the needs of nuclear material accountancy.

7. - Calculation code description

Our calculation code has been written using Fortran 77 computer language. It was implemented on a IBM PC/AT under the operating system MS-DOS.

The structure of SARA is shown in Fig. 11, while Fig. 12 gives a synthetic flow-chart of the code.

The main program controls input-output operations and manages the set of subroutines which perform the simulation steps reported in Fig.11. A short description of the most significant subroutines is given in the following:

- Subroutine "SIMULA" : Performs process simulation. It receives process data inputs and gives as output the "true state" of the plant, by means of other subroutines that simulate the dynamic behaviour of the single components.

- Subroutines "DIVCOS", "DIVABR": If requested by the user, performs diversion (respectively constant and abrupt) simulation giving as output the "diverted state" of the plant.

- Subroutines "MISIMP", "MISIF": Perform measurement system simulation. They receive the "true state" or the "diverted state" and give as output the "measured state" of the plant.

- Subroutine "RANDOM": Performs random variation of the stochastic variables involved in both process and measurement system simulation.

- Subroutine "STATAN": Performs balance data evaluation.

8 - Introduction to the user interface

As it has just been underlined in the previous paragraph, one of the most important tasks of the main program is the user interface control; for this reason its first part consists of an interactive procedure working by means of video screenings.

The video screenings generated by the computer code during its running can be classified as follows:

1) Data input screenings

2) Option screenings

The data input screenings are generated by the subroutines SCHERMO and ISCHER; if requested by the user, they show the default values of respectively real and integer variables, giving him the possibility of changing one or more of these values for the current running. For example, the user can modify the project value of a process flow-rate or the uncertainty associated to a measurement method, simulating the effects of a process noise or the introduction of a new instrument in the plant.

The default values of all the variables as well as the titles and the writings of all the screenings are memorized on two indipendent database and so they are modifiable without entering in the structure of the code; they are loaded at the beginning of every running by the subroutines CARICA e CARPAR respectively.

The option screenings are generated by the subroutine SCELTA. They allow the user to select the options he is interested in; for example, the user can decide of simulating a diversion or not and eventually he can choose between a constant and an abrupt one.

To make the code easy to operate a hierarchical option structure was adopted. In practical terms this means that, instead of presenting the user with a list of options at the same point, the options are presented one by one and only if they take part of the logical stream.

To assist the user of the code, an in-line HELP facility was implemented: an explanatory message describing the choices open to the user appairs on the video at every option point. The hierarchical option structure allowed the HELP facility implementation without making the user interface too heavy; on the other side, the user of the code is not compelled to wait for long and involved menus to appair.

The explanatory messages are memorized on indipendent files and they are loaded and shown on video by the subroutine GRAFO.

In addiction to selecting options, the user of the code must enter, when requested, some other data such as the main output file name (default name is DATAOUT) and the initial value of the seed used for random calculations. Both the process simulator and the NRTMA system simulator use indipendent streams of random numbers to provide stochastic rather than deterministic values for the generated data. The stream of random numbers is controlled by a seed: the random numbers generator will always generate the same stream if it starts with the same seed. For this reason in our code there is no default value for the seed and the user must enter it at every running.

The calculation code is called into execution by entering the command SARA; it memorizes the name and the new value of all the modified input variables, the options selected by the user and the calculation results on the main output file. The most significant of the calculation results are also shown on video at the end of every running. If requested by the user, the calculation code opens two auxiliary files named SIMOUT and ACCOUT. In the first it memorizes process simulation results at the time-lenght selected by the user, while in the second it memorizes NRTMA system simulation results in a form available for plotting. SIMOUT and ACCOUT were created as inputs for the graphical task of the code, but they can be used also for other purposes.

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Contribution to the DWK-LANL workshop on NRTMA, Hannover - 1986

R. AVENHAUS
"Safeguards Analysis"
New York - 1986

R. AVENHAUS, et al.
"Comparative investigation of Test Procedures for NRTMA DATA in the Wackersdorf Reprocessing Plant"
Contribution to the DWK-LANL workshop on NRTMA, Hannover - 1986

R. GALE
"CIMACT: an operating data management system for Near Real Time Accountancy"
IAEA SM 293/171 - 1986

F. ARGENTESI, C. COSTANTINI
"NEWSIM: a simulation environment for the study of Safeguards Systems"
ISPRA - 1986

Stream	Flow-rate l/h	Description	Pu g/l	U g/l	HNO_3 M	TBP %
1AX	6	Input organic 1°Cycle	-	-	-	30
1AF	2.2	Feed 1°Cycle	2.5	250	2	-
1AW	3.51	Aqueous waste 1°Cycle	$2\ 10^{-4}$	$4.8\ 10^{-4}$	2.2	-
1CW	6	Organic waste 1°Cycle	$1\ 10^{-5}$	$1\ 10^{-2}$	$5\ 10^{-4}$	-
1CX	9	Reducing strip (HAN=0.1M)	-	-	0.01	-
1CP	9	Product 1°Cycle	0.6	59	0.144	-
1BS	1.5	Scrub 1°Cycle	-	-	3	-
2AX	10	Input organic 2°Cycle	-	-	-	30
2AF	13.5	Feed 2°Cycle	0.41	40.5	2	-
2AW	17.3	Aqueous waste 2°Cycle	$2\ 10^{-5}$	$6\ 10^{-5}$	1.8	-
2CW	10.2	Organic output 2°Cycle	-	50	0.033	30
2CX	2	Reducing strip (HAN=0.3M)	-	-	0.3	-
2CP	2	Product 2°Cycle	2.7	17.8	0.52	-
2BS	2	Scrub 2°Cycle	-	-	0.5	-
2B'S	2	Scrub 2°Cycle	-	-	2	-

Tab.I - Project Pu concentrations and flow rates

Identification	Volume (l)	Description	Pu g/l
F-307	360	Feed 1°Cycle	2.5
F-404	180	Aqueous waste 1°Cycle	$2\ 10^{-4}$
F-408	350	Organic waste 1°Cycle	$1\ 10^{-5}$
F-405	35	Batcher 1°Cycle	0.41
F-406	35	Feed 2°Cycle	0.41
F-505	100	Aqueous waste 2°Cycle	$2\ 10^{-5}$
F-508	350	Organic waste 2°Cycle	-
F-506	40	Batcher 2°Cycle	2.7
F-507	40	Feed Evaporator	2.7
C-603	14	Evaporator	100
F-606	125	Storage	100
D-401	54.4	Codecontamination battery 1°Cycle (8 st.)	
D-402	68	Scrub battery 1°Cycle (10 st.)	
D-403	68	Strip battery 1°Cycle (10 st.)	
D-501	74.8	Codecontamination battery 2°Cycle (11 st.)	
D-502	74.8	Coscrub battery 2°Cycle (11 st.)	
D-503	108.8	Partial partition battery 2°Cycle (16 st.)	

Tab.II - In process project holdups of the components of EUREX plant.

	Quantity	Method	σ_r(%)	σ_s(%)
INPUT TANK	Volume	Differential Pressure Gauge	0.3	0.3
	Concentration	Isotopic Dilution Mass Spectrometry	0.6	0.3
INTERMEDIATE TANKS	Volume	Differential Pressure Gauge	0.5	0.5
	Concentration	Potentiometric Titration	0.4	0.4
WASTE TANKS	Volume	Differential Pressure Gauge	1	1
	Concentration	TTA extration/α counting	4	2
STORAGE TANK	Volume	Differential Pressure Gauge	0.3	0.3
	Concentration	Isotopic Dilution Mass Spectrometry	0.6	0.3
CONCENTRATOR	Holdup	Mathematical model	3	-
MIXER-SETTLERS	Holdup	Mathematical model	10	-

Tab.III - Typical uncertainties in EUREX in-process inventory

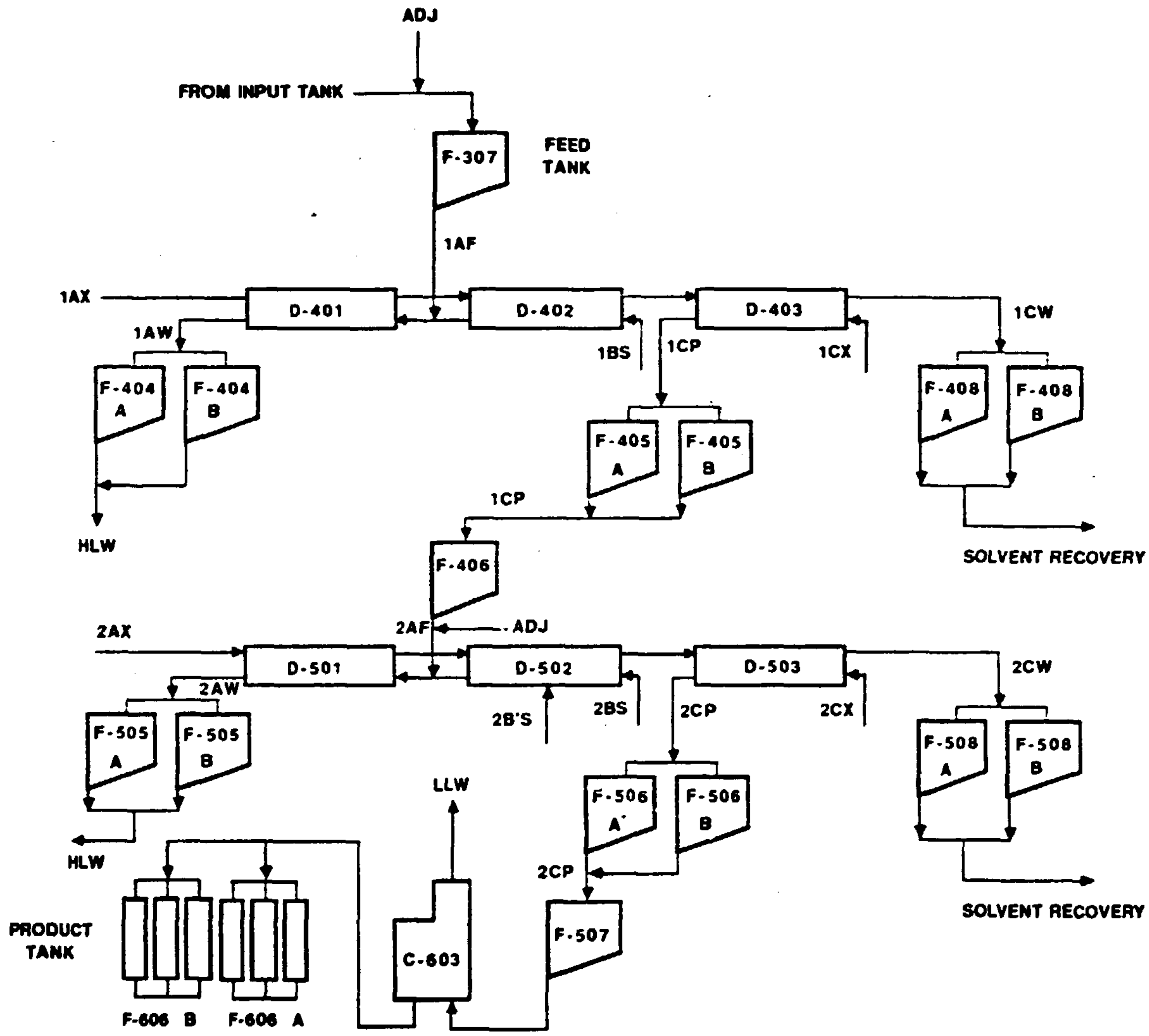

Fig.1 - Block Diagram of the simulated EUREX process section

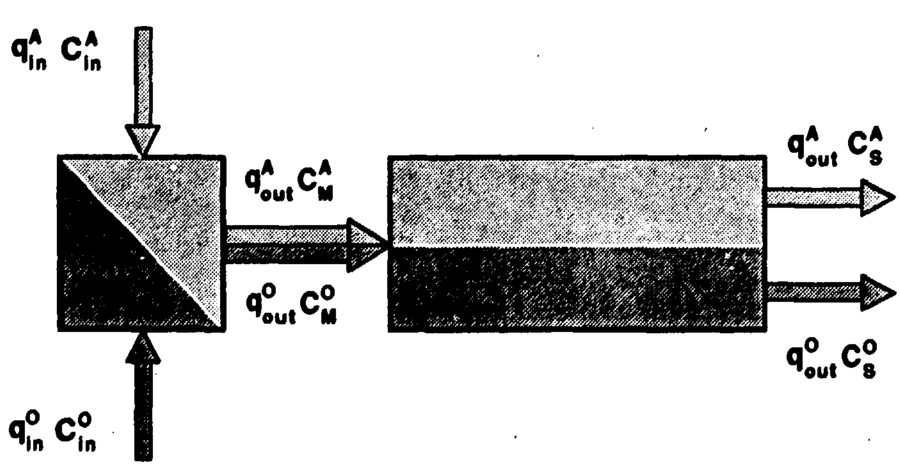

Fig. 2 - Schematic Diagram of a Single Stage Mixer Settler

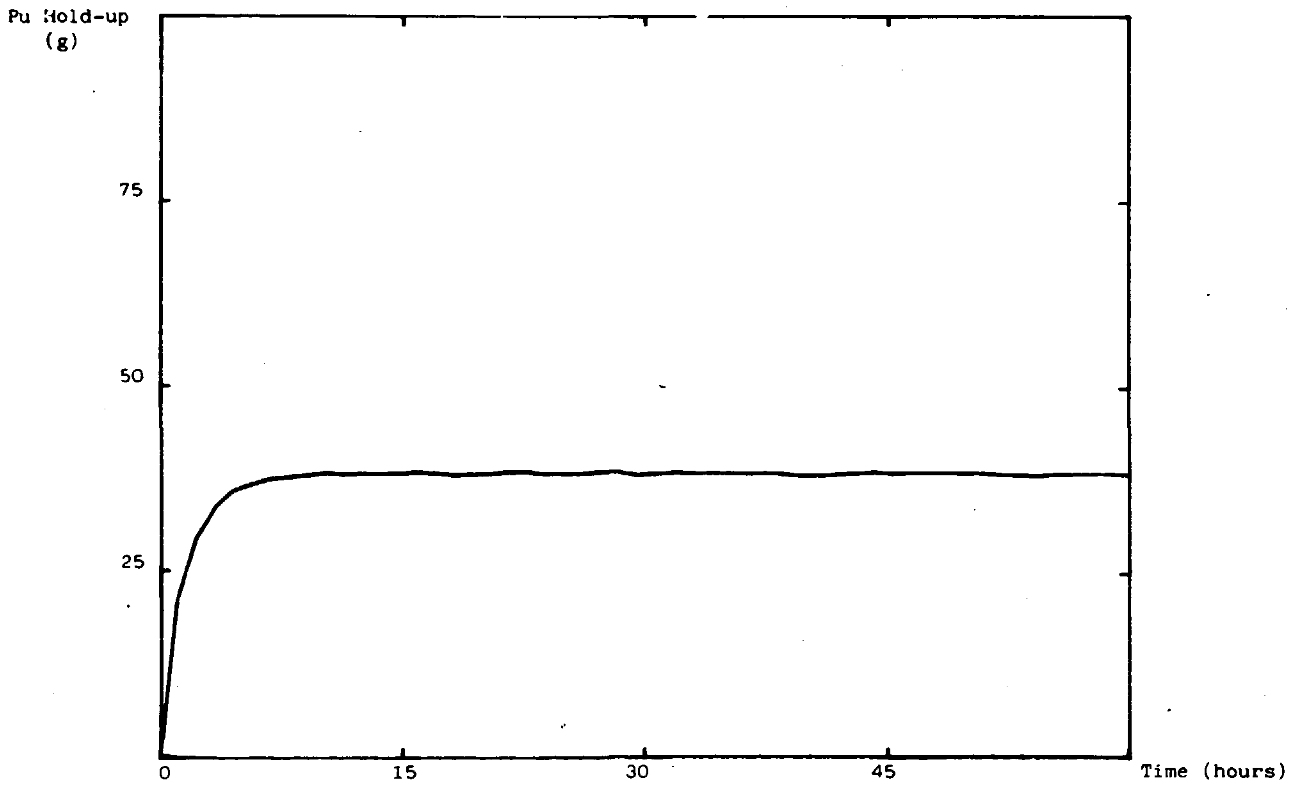

Fig. 3 - Total Pu Hold-up in the first cycle extraction batteries

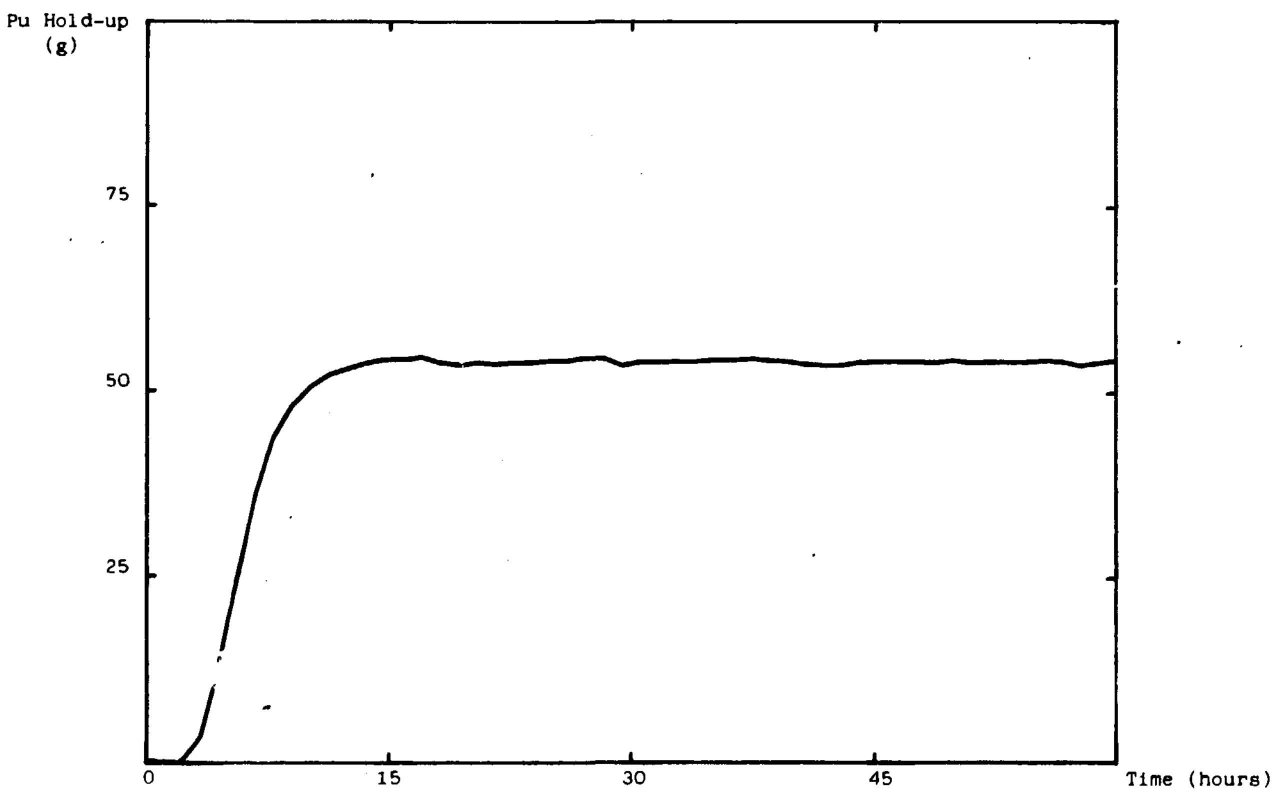

Fig. 4 - Total Pu Hold-up in the second cycle extraction batteries

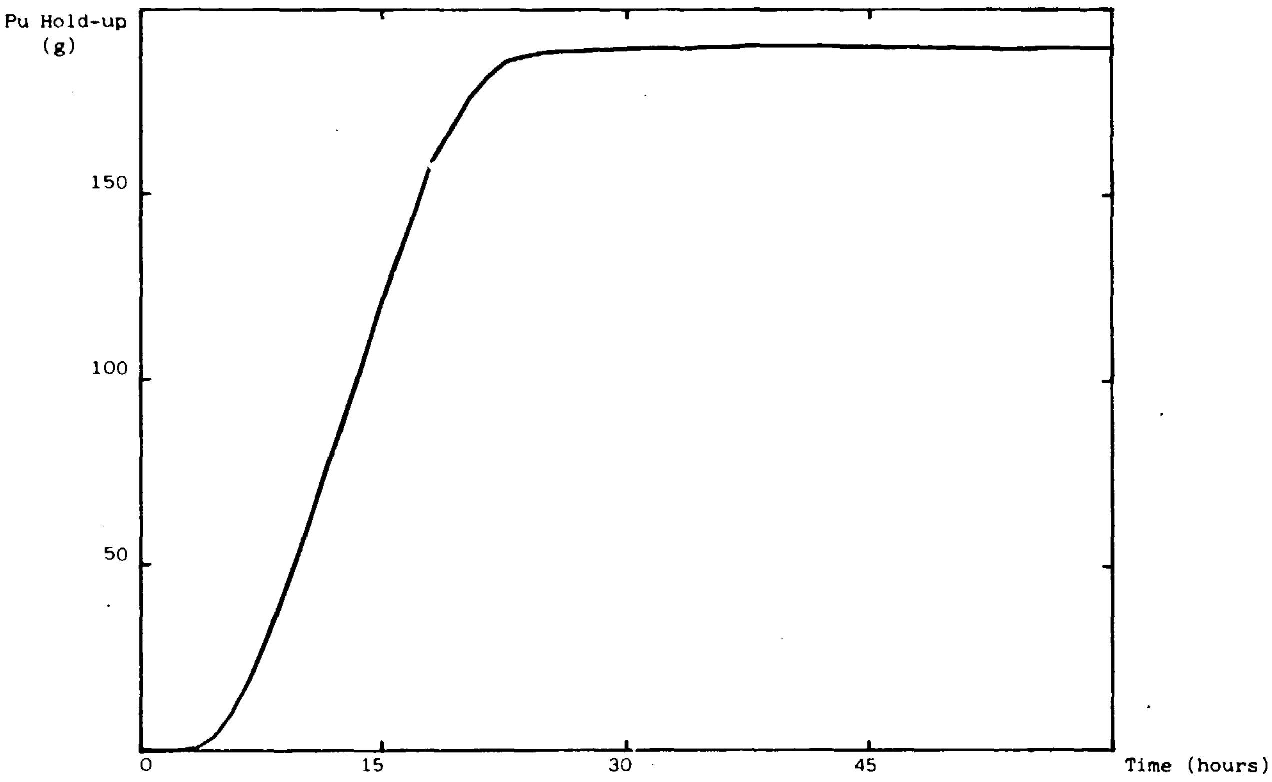

Fig. 5 - Pu Hold-up in the concentrator feeding triple tank

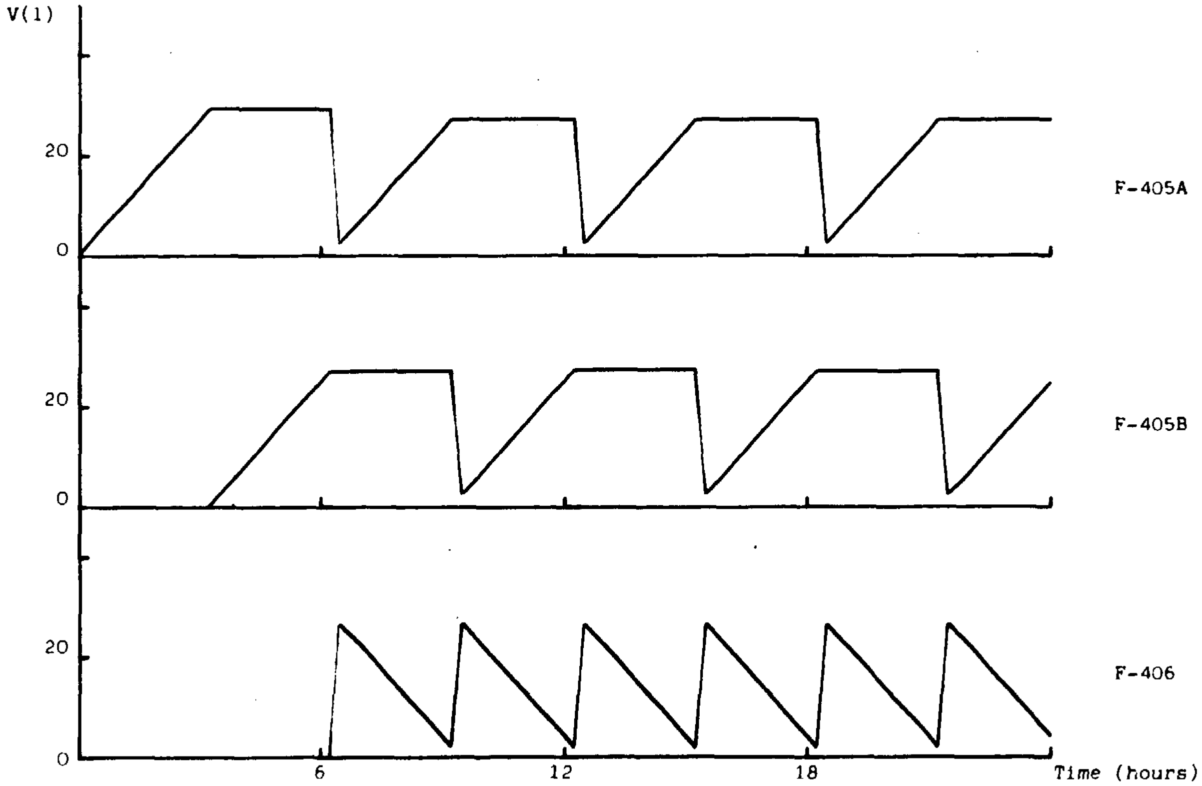

Fig. 6 - Typical time dependance of the volumetric Hold-up in F-405A, F-405B and F-406 tanks

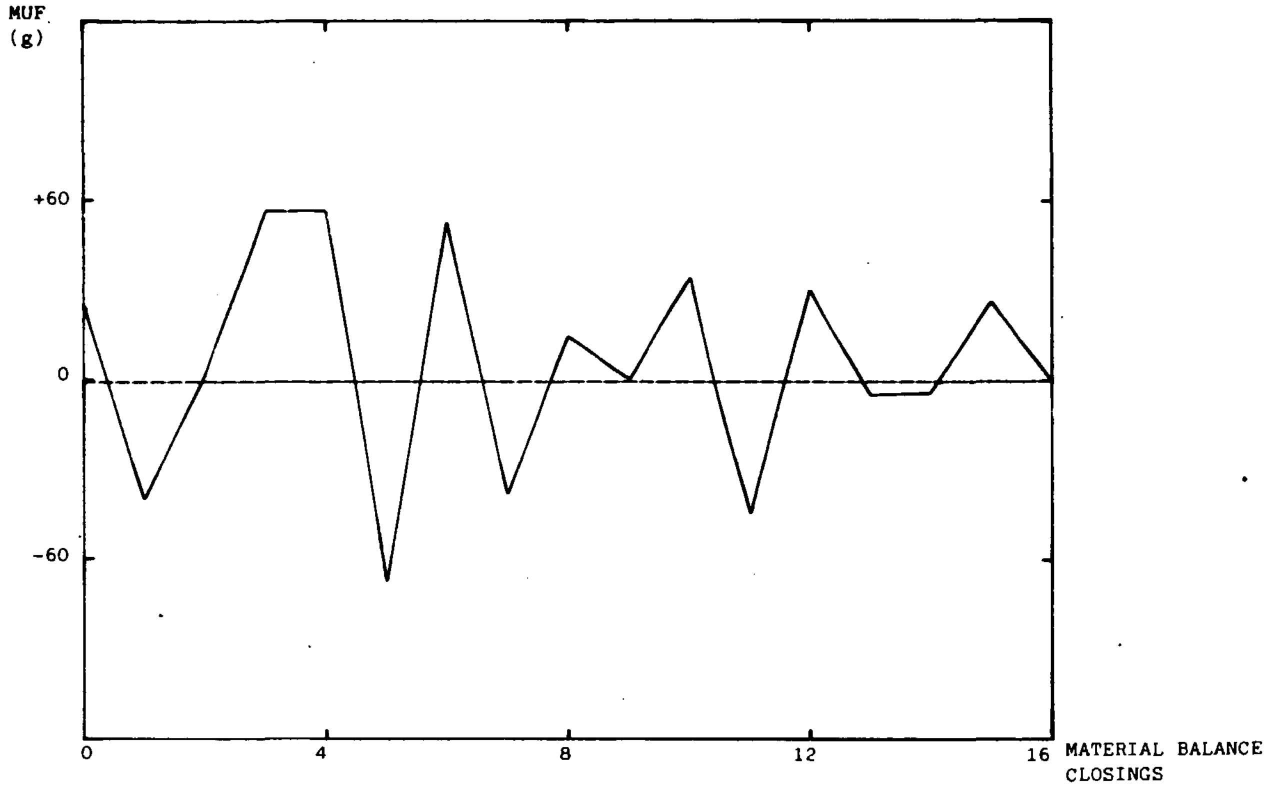

Fig. 7 - MUF simulated values for 16 material balance closings

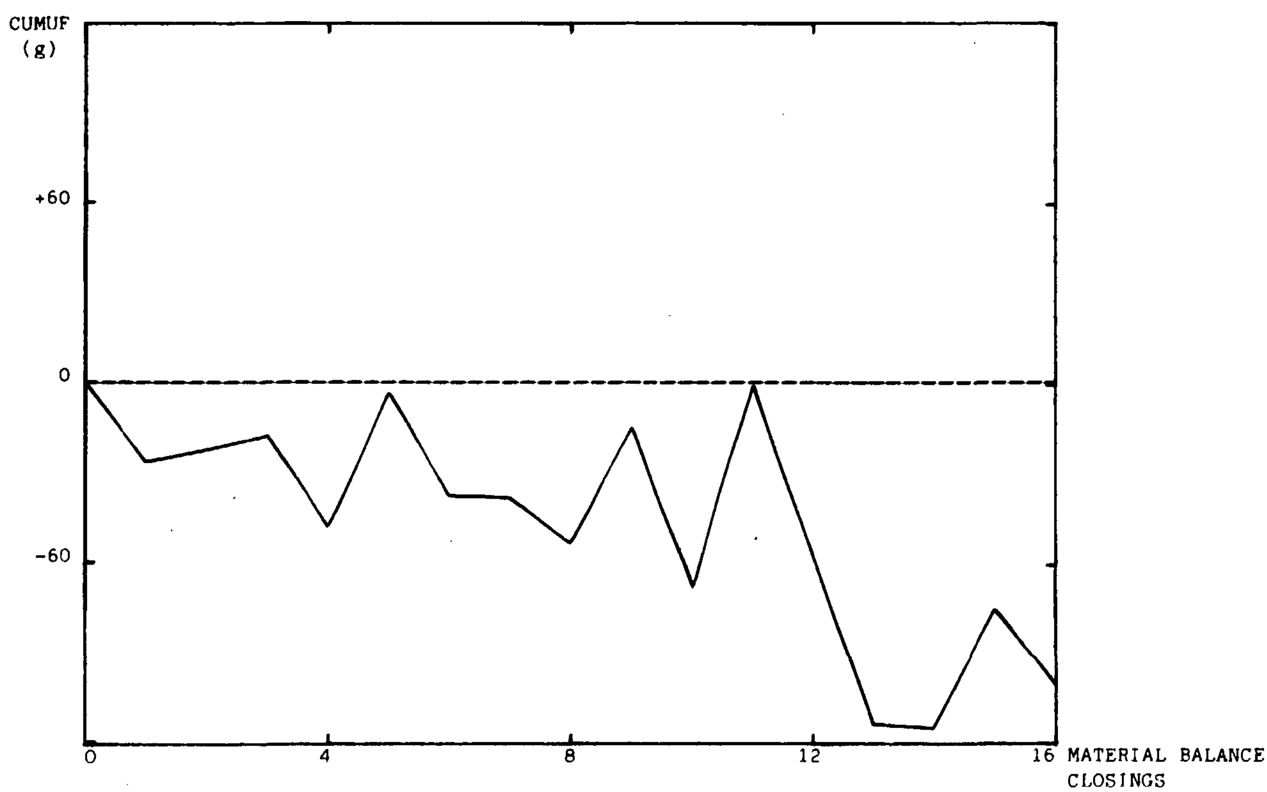

Fig. 8 - CUMUF simulated values for 16 material balance closings

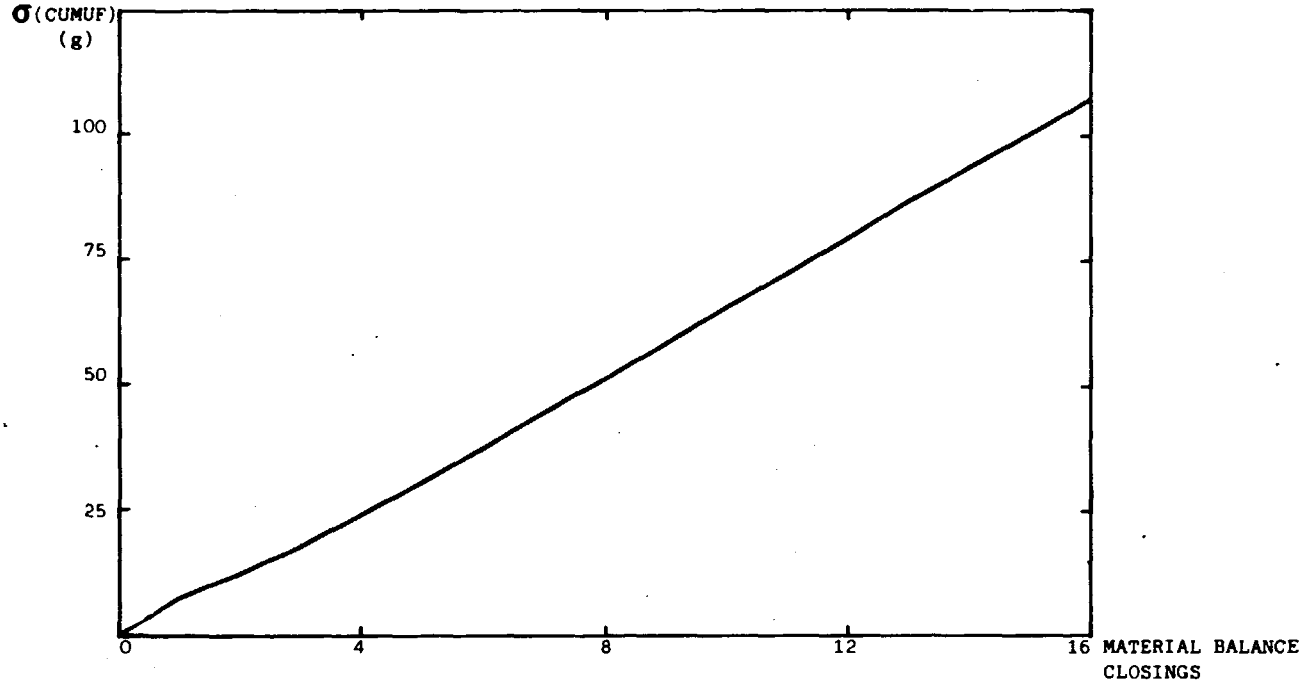

Fig. 10 - σ(CUMUF) simulated values for 16 material balance closings

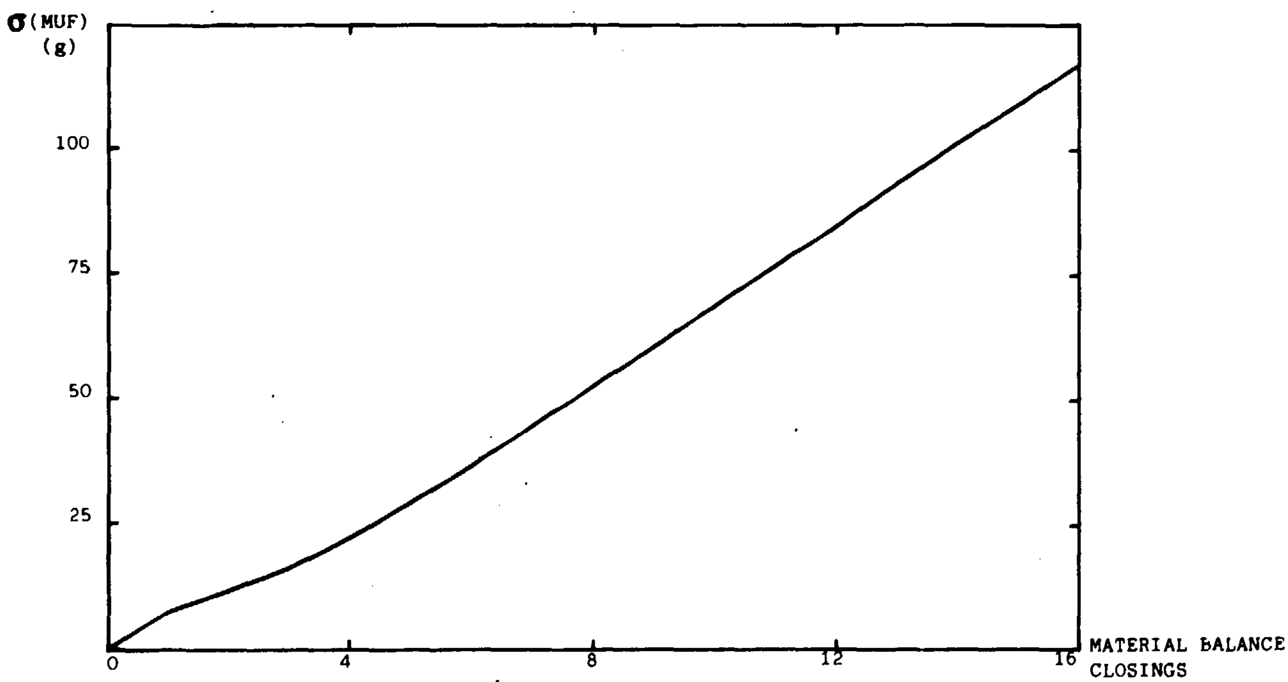

Fig. 9 - σ(MUF) simulated values for 16 material balance closings

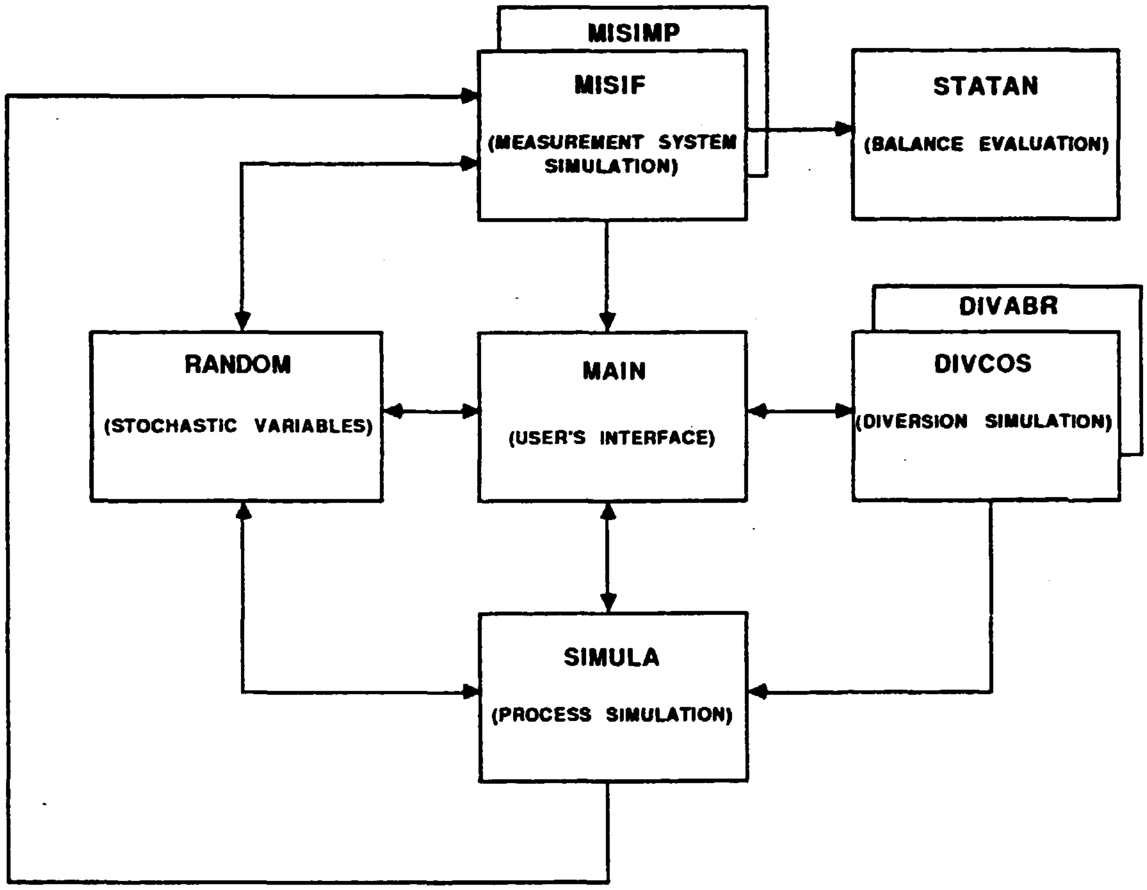

Fig.11 - Structure of the code

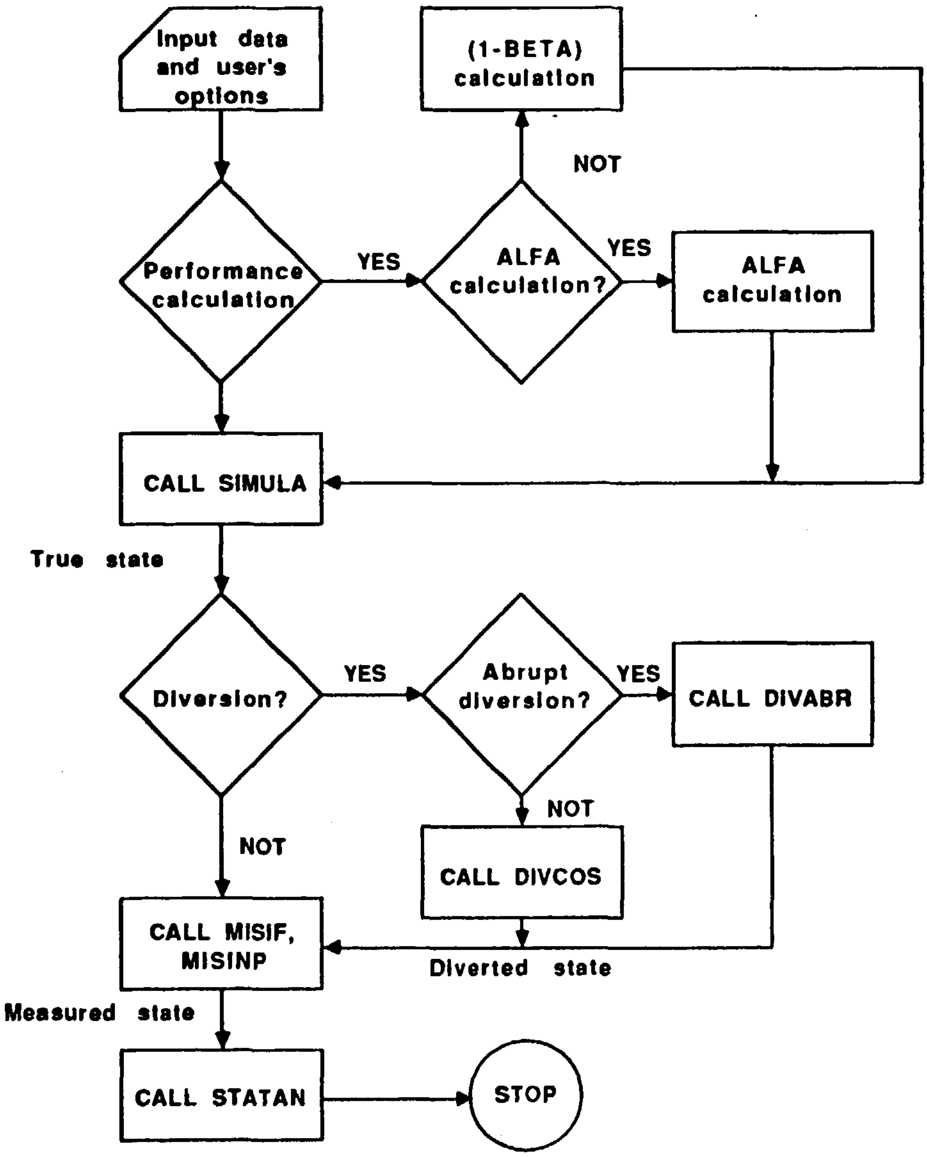

Fig. 12 - Code flow-chart

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