*Development and Evaluation of Methods for
Safeguards Use of Solution Monitoring Data*

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DEVELOPMENT AND EVALUATION OF METHODS FOR SAFEGUARDS USE OF SOLUTION MONITORING DATA

by

Tom Burr and Larry Wangen

ABSTRACT

This report describes our effort to develop, implement, and evaluate data analysis methods for solution-monitoring measurements in the plutonium nitrate storage at the Tokai Reprocessing Plant (TRP). The intent is to address TRP-specific issues to some extent, as well as to anticipate the data analysis needs at future reprocessing plants (especially the new Rokkasho reprocessing plant (RRP)) in Japan. The essential difference between a plant like TRP and a more modern plant like RRP is that we expect more and better instrumentation in the tanks in a modern plant. Because the TRP solution monitoring hardware is scheduled to be upgraded, we de-emphasized our effort to handle "information-poor" plants like TRP where, for example, some of the tanks do not have an in-line density measurement. This report mostly describes our analysis methods and software for finding and identifying all key tank events. An accompanying report¹ describes the quantifiable benefits in terms of enhanced diversion-detection ability. To a large extent we had to experiment with several candidate methods for implementing our analysis objectives. Therefore, we chose to use a prototyping software system called S-PLUS, which is an object-oriented statistical programming and graphics package. The intent is to eventually implement selected portions of our current solution-monitoring toolkit in a more robust and user-friendly system. We describe our current software system as being far more than we needed for our own in-house use (menus are provided for the user who doesn't want to type any S-PLUS commands), but less than is needed for a fieldable system. Mostly as a result of working on this project, we have come to conclude that **solution monitoring is a potentially very valuable asset to nuclear safeguards** at a modern reprocessing plant. We hope to convince the reader of that in this report and the accompanying report.¹

1. Introduction

The purpose of this work has been to develop and evaluate data-analysis methods for solution-monitoring measurements in the plutonium nitrate storage area at the Tokai Reprocessing Plant (TRP). The storage facility at TRP, shown schematically in Fig. 1, consists of the product plutonium nitrate accountability tank, seven storage tanks, and one sampling pot servicing the storage tanks. Transfers are possible between any pair of the seven storage tanks (not via the sample pot but via rather complicated piping that connects each pair of tanks). In principle, the accountability tank can ship to any of the seven storage tanks. In practice, the accountability tank only ships to any of the first three storage tanks. Unfortunately, the first three storage tanks are not as instrumented as the other four storage tanks, as we explain below.

Fig. 1. The output accountability can in principle ship to any of the seven storage tanks. In practice, it ships only to tanks 2-4. All seven storage tanks can ship among themselves and to the sample pot. The output accountability tank has its own sample pot, not shown here (we have no data from the accountability tank sample pot).

We anticipate that all tanks will eventually be equipped with dip tubes for measuring pressures at three heights within the tank that can be used to estimate the level and density (L, D) of tank solution. Temperature (T) is also measured. See Fig. 2. The volume is then obtained from the level measurements via a tank-calibration procedure.

Fig. 2. Fully instrumented tank with three dip tubes, each of which measures pressure at a different height inside the tank. If solution level falls below the density pressure dip tube then no density measurement is available. The separation between the density pressure dip tube and the level pressure dip tube is known.

At the time of this writing (Spring 1996), tanks 5-8 at TRP are equipped for measuring L, D, and T while tanks 2-4 and the sample pot are equipped only with a "level" pressure measurement probe, located near the tank bottoms. Therefore, in tanks 2-4 and the sample pot, to convert the "level" dip tube pressure into a Level measurement, either the density of a solution sample must be estimated in a laboratory, or, if possible, the density can be estimated based on application of simple mixing laws (based on conservation of mass) using a history of all receipts by the tank.

To develop and evaluate methods for using solution monitoring data for safeguards purposes, we obtained historical data from TRP. The measurements obtained for each vessel are listed in Table 1.

About 200 days of pressure and temperature measurements were obtained for the plutonium nitrate storage facility. Though the main purpose of this work has been to develop methods, rather than to evaluate historical data, this real data set is our best source of realistic data on which to test our methods.

TABLE 1. Measurements Obtained by Vessel^a

	Level Pressure Change	Density Pressure Change	Temperature
Accountability Tank (1) ^b	X	X	X
Storage Tanks (2,3,4)	X		
Storage Tanks (5,6,7,8)	X	X	X
Sample Pot (9)	X		
^a Data was available at intermittent times, usually when some type of significant change, for example, a transfer or a sampling event, occurred.			
^b Numbers are subsequently used to identify the vessels.			

2. Solution Monitoring

Before describing the software and data evaluation, we will briefly discuss solution monitoring to provide some background and context for subsequent discussions. The idea of using process data from the facility operator for safeguards purposes has been advocated for quite some time. Recently some of these general ideas have become more concrete as a consequence of advocates within the International Atomic Energy Agency (IAEA) who see solution monitoring as a potential safeguards approach for large reprocessing plants. In particular the ideas of F. Franssen are noteworthy.²

For safeguards purposes we **define** solution monitoring as the *essentially continuous monitoring of solution level, density, and temperature (L, D, and T) in all tanks in the process that contain, or could contain, safeguards-significant quantities of nuclear material*. For safeguards purposes these measurements should be authenticated and independently verified.

The proposed **purposes** of solution monitoring from a safeguards perspective include:

- Provide data for verifying that each tank or vessel is operating in a manner consistent with operator declarations.
- Provide assurance that no unauthorized alterations have been made to tanks (related to design verification).
- Enable consistency checks to be made on solution transfers. These can be made automatically in real time if desired.
- Maintain a running inventory of nuclear material for each vessel. This requires a means for estimating nuclear material concentrations.

In addition to these, other uses of solution-monitoring measurements have also been suggested.

- Monitor the quality of measurements.
- Identify all normal events that affect the solution in a tank, such as mixing or sparging.
- Estimate and partially remove bias in tank calibrations, thereby reducing σ_{MB} (the theoretical standard deviation of the materials balance (MB), which includes all sources of measurement error), and increasing loss detection probability.
- Estimate hold-up in pipes between tanks.
- Identify abnormal events.
- Partially validate measurement error models. Unfortunately, many safeguarded facilities do not document their measurement-control information to fully support their measurement-error models. In such cases, when a large MB occurs, the first thought is often that σ_{MB} is understated. We will show in Section 3 that solution monitoring can provide considerable assurance that measurement error models are acceptable, and therefore, provided the variance propagation is done correctly, the **estimate** of σ_{MB} should be quite good.

Solution monitoring is considered to be one very good way to provide assurance that large reprocessing plants are being adequately safeguarded. Monitoring will help to verify the continuity of design verification, as well as provide a continuous surveillance of key process components not otherwise observed.

2.1 Data Preprocessing

The historical data (raw data) consisted of the specified measurements made at regular times. However, we had access only to “change data,” which is a subset of the original data. The “change data” includes measurements only when some user-defined amount of change has occurred, such as a level change of 10 units. Because we want essentially continuous data for solution monitoring, we interpolated between successive data point in the raw data. This was essentially* a linear interpolation of the density and level pressures as a function of time. Noise was added to the interpolated values to better simulate measurements. Interpolated values were obtained at five-minute intervals. We anticipate that the IAEA will have access to data at approximately one- to five-minute intervals.

2.2 Software Development and Data Analysis

In this part of our analysis, we selected a subset of 15 continuous days from the 200 days of raw data to develop the solution-monitoring data-interpretation methods. For this discussion, our purposes are to both analyze this data and explain the software. Use of real data from TRP adds realism to our work and enables us to develop meaningful methods. Level pressure readings as a function of time for 15 days are shown in Fig. 3 for each of the nine vessels.

*Occasionally successive data points had a level pressure change that would be typical for a transfer but the time difference was too large for a transfer. For such data, we extrapolated the level pressure from the first measurement as a constant until 30 minutes before the next level reading from which we used linear interpolation. If this type of interpolation was not done, some transfers took abnormally long times and would have been viewed as abnormal events.

Fig. 3. Fifteen days of level readings at five-minute intervals for all nine tanks.

Some **informal** observations from Fig. 3 include the following:

- Tank 1 makes 11 shipments and is sampled prior to each shipment.
- Tank 2 receives 2 of the Tank 1 shipments and Tank 3 receives the other 9.
- Tanks 5, 6, and 7 exhibit very little level change during these 15 days, but there are 2 relatively large level changes that should be explained in Tank 5, and 1 relatively large level change that should be explained in Tank 6.
- Tank 3 shipped to Tank 8 at approximately 132 000 minutes.
- Tank 4 shipped out of the storage area at approximately 143 000 minutes.
- The sample pot was used at approximately 132 000 minutes and between approximately 151 000 to 152 000 minutes.

On the basis of our experience with various event detection and recognition methods on this data, we believe that the human eye (perhaps aided by plotting differences in level rather than level itself) is as good at event detection and recognition as any algorithm in software. Therefore, we are in the habit of comparing the output from our software to plots like Fig. 3 to help adjust parameters in our algorithms. Also, we ultimately check volume changes to confirm our event recognition results. In Fig.4 we plot **the change in tank volumes** for the same data shown in Fig. 3.

Fig. 4. Volume change at five-minute intervals for all nine tanks.

Our general approach is designed to be easily understood by others who might have to interpret, maintain, or modify the approaches we use for solution monitoring in the future. Separate computer software modules were developed for each logically different data-treatment purpose. We assume these approaches will be used at two different levels of training and expertise: (1) routine use by trained IAEA inspectors in the normal course of their work and (2) analytical use by data analysts trained in the analysis of the results for investigation of unexplained or not-found events, etc. These methods as presently developed are intended to provide a significant beginning for the continued development of tank monitoring systems for use at future reprocessing facilities as well as at older facilities such as TRP.

Using Fig. 4, we begin to confirm our **informal** observations made from Fig. 3 as follows:

- Tank 1 makes 11 shipments and is sampled prior to each shipment: Fig 4 shows 11 shipments from tank1 in the 35–60-L range, which is expected for shipments to a storage tank.
- Tank 2 receives 2 of the Tank-1 shipments and Tank 3 receives the other 9: Fig 4 shows 2 receipts by Tank 2 of about 50 L corresponding to the first 2 shipments by Tank 1.

- Tanks 5, 6, and 7 exhibit very little level change during these 15 days, but there are 2 relatively large level changes that should be explained in Tank 5, and 1 relatively large level change that should be explained in Tank 6: Fig. 4 confirms that the volume change in Tanks 5, 6, and 7 is very small, but there are 2 volume changes in Tank 5 that are not caused by measurement fluctuation alone. Either the change is real or there is a measurement malfunction and in either case, an explanation is needed. There is 1 large (too large to be explained by measurement error) volume change in Tank 6 that should be explained.
- Tank 3 shipped to Tank 8 at approximately 132 000 minutes: Fig. 4 indicates that about 330 L was shipped from Tank 3 to Tank 8.
- Tank 4 shipped about 400 L at approximately 143 000 minutes: Because there are no corresponding receipts in the other tanks, this shipment was to outside the storage area.
- The sample pot was used at approximately 132 000 minutes and between approximately 151 000 to 152 000 minutes: Figs. 3 and 4 indicate that Tank 3 was sampled at approximately 151 000 minutes, and it is not yet clear which tank was sampled at approximately 132 000 minutes.

2.3 Approach

We have developed one class of algorithms to analyze solution-monitoring data and a second class of algorithms to implement computer-aided manual investigation to confirm results of the first class of algorithms. For this version we have concentrated on analyzing and evaluating the events occurring in a tank that involve the movement of nuclear material; i.e., sampling and transfer events. The data consists of L, D, T and volume (V) (from level) collected in every vessel at five-minute intervals. Our analysis assumes that the basic pressure readings have been collected and transformed to L, D, and V. Reliable temperature information is not available for this data, thus we have not considered any systematic ways to use it. Many operations will result in characteristic temperature behavior so it would be desirable to include temperature-based rules.

The main three algorithms are designed to (1) find all tank events, (2) classify all tank events, and (3) perform consistency checks on all tank events.

1. The **Events Finder** module identifies significant changes in the L measurements as an unspecified "event," and finds the approximate start and stop point of each "event."
2. The **Events Classifier** module classifies the events found by Events Finder by comparing the L behavior to a small library of recognized L behaviors. For example, sample events should exhibit a modest drop in L, followed within about 30 minutes by a return to nearly the original L.
3. The **Events Reconciler** module tries to reconcile each event with an accompanying event either in the same tank for sampling events or in another tank for transfers. For example, the reconciler will attempt to find the receiver tank for each "ship-to-tank" event. The volume or mass shipper-receiver difference (SRD) should not exceed some tunable threshold.

We have written these modules to have both generic and facility-specific features. We use generic "change-detection" methods and facility-specific threshold values for event-durations and volume or mass loss. These thresholds are user defined in a data definition source routine that is executed

only once unless the thresholds need to be changed. The general approach should fit nicely into an "expert system" methodology.

2.3.1 The Automatic Events Finder Module

The Events Finder module steps through the data to determine whether there has been a significant change in the current data value when compared to the previous data value(s). It is designed to be modifiable; more events, such as mixing or sparging, can be added to it as desired. Currently it is designed to find short-term changes in level that would occur only in a sampling or transfer event. The main steps followed by the current module are

1. On the basis of previous value(s), forecast the current L value.
2. Calculate the difference between the current value and the forecast to determine the current ERROR.
3. Compare the ERROR to user-defined thresholds to determine whether there has been a change sufficient to signal that an "event" has occurred.
4. Determine the start time (and data point index) of the event.
5. Determine the stop time (and data point index) of the event.

Both the start and stop times of an event may be determined by different criteria, e.g., successive level changes that are small, a significant change in slope, etc. The primary result of Event Finder is a newly created data set containing information about events; i.e., times when the level measurements were changing in some specified manner. This is illustrated in Table 2 for the data corresponding to Tank 3.

We experimented with applying various cusum statistics to the errors to monitor for protracted events. Because most events are abrupt, we now prefer using tunable thresholds to compute the final level minus initial level to test whether a protracted event occurred during the "nonabrupt-event" section.

2.3.2 The Automatic Events Classifier Module

The Events Classifier module attempts to recognize (classify) each event found by Event Finder by comparing the event time duration and level change with historically observed changes for the same tank. For a given event to be correctly classified, there must be enough experience with or data on similar events so that rules can be constructed to characterize the event. For example, shipments from Tank 1 to Tank 2 might be known to always involve approximately 10,000 L, but the volume range around 10,000 L should also be used in the rules. After the commissioning period at the Rokkasho Reprocessing Plant (RRP), we anticipate that a data base for each category or class of event will exist to help construct these type of event-classifier rules. This module, then, is essentially a pattern classifier that uses an "Expert System" approach based on historically observed events. This data base of events can easily be expanded to include information for recognizing other events not presently included. In general, there are separate data for each tank and for each different event, although much of the code could be generalized if desired.

TABLE 2. Events Finder Results for Tank 3

Event No.	Start Index	Stop Index	Start Time	Stop Time
1	326	0334	131625	131665
2	910	919	1345454	134590
3	1583	1589	137910	137940
4	1907	1915	139530	139570
5	2255	2263	141279	141310
6	2830	2836	144145	144175
7	3270	3275	146345	146370
8	3594	3599	147965	147990
9	3933	3940	149660	149695
10	4121	4126	150600	150625
11	4127	4133	150630	150660
12	4298	4303	151485	151510

Events currently recognized by the event classifier are shipments, receipts, shipments to sample, receipts from sample, and unknown. "Shipment" and "receipt" refer to transfers to and from other tanks or the process. Events Classifier adds an "Event Class" column to the data set produced as shown in Table 3.

As our understanding evolves and a historical data base of solution monitoring becomes available other events that we wish to find and classify,² such as mixing, sparging, evaporation and chemical adjustments, can be added to these modules.

2.3.3 The Automatic Events Reconciler Module

The Events Reconciler module processes each event found by Events Finder and classified by Events Classifier and attempts to find another event with which it will be consistent or reconciled. Reconciliation is based on user-defined, allowed errors in masses (or volumes) shipped as compared to those received. It is assumed that these errors are related to how well we measure the levels, densities, and volumes. Transfers and sampling events can be reconciled on the basis of either mass or volume. To reconcile one event with another, the module must find that both occurred within a specified time interval. Given appropriate assumptions and history, levels could also be used as a basis for reconciliation. If an event cannot be reconciled, it is flagged as such for investigation by the inspector. Possible return values from the Events Reconciler module are Reconciled, Not Reconciled, or Possible. The "Possible" return value indicates that another event

occurred within the specified time window but the masses or volumes of the two events did not agree within the specified limits (they did agree within somewhat larger limits). If an event is reconciled, then Events Reconciler also identifies the other event (and the other tank, in the Other.tank column) with which this event was reconciled and provides information on the volumes and/or masses transferred so that records of differences, cumulative differences, etc. can be kept. Such information can be used for evaluation of tank calibrations and pipe hold-up (pipe holdup is material that remains in the pipes that connect the tanks).

TABLE 3. Events Classifier Adds a Class Column ^a (Tank 3)					
Event No.	Start Index	Stop Index	Start Time	Stop Time	Event Class
1	326	334	131625	131665	Shipment
2	910	919	1345454	134590	Receipt
3	1583	1589	137910	137940	Receipt
4	1907	1915	139530	139570	Receipt
5	2255	2263	141279	141310	Receipt
6	2830	2836	144145	144175	Receipt
7	3270	3275	146345	146370	Receipt
8	3594	3599	147965	147990	Receipt
9	3933	3940	149660	149695	Receipt
10	4121	4126	150600	150625	Ship to Sample
11	4127	4133	150630	150660	Receipt from Sample
12	4298	4303	151485	151510	Receipt
^a Shipment means a transfer out of the tank and receipt means a transfer into the tank.					

To check our results of these three modules, we use interactive graphics aided by algorithms to build event files such as that given in Tables 2-4 to "manually" find and classify all tank events. We then compare our "manual" results to the results of Event.Find, Event.Classify, and Event.Reconcile.

TABLE 4. Events Reconcile Adds a Reconcile Column^a (Tank 3)

Event No.	Start Index	Stop Index	Start Time	Stop Time	Event Class	Event Reconcile
1	326	334	131625	131665	Shipment	Reconciled
2	910	919	1345454	134590	Receipt	Possible
3	1583	1589	137910	137940	Receipt	Reconciled
4	1907	1915	139530	139570	Receipt	Possible
5	2255	2263	141279	141310	Receipt	Reconciled
6	2830	2836	144145	144175	Receipt	Reconciled
7	3270	3275	146345	146370	Receipt	Reconciled
8	3594	3599	147965	147990	Receipt	Possible
9	3933	3940	149660	149695	Receipt	Possible
10	4121	4126	150600	150625	Ship to Sample	Reconciled
11	4127	4133	150630	150660	Receipt from Sample	Reconciled
12	4298	4303	151485	151510	Receipt	Reconciled

^aShipment means a transfer out of the tank and receipt means a transfer into the tank.

3. Details of Software Implementation and Functionality

Our toolkit is written entirely in S-PLUS, which is an object-oriented statistical and graphical programming language. We have working versions for both Unix work stations and for PCs with Windows 3.1, 3.11, 95, or NT. Only the Unix and Windows 3.11 versions have been tested. During the project's early stages we planned to implement the toolkit in C++ so we do have some C++ classes designed that could be used at some later stage. It soon became apparent that we were in an experimental mode with the software because there were no clear choices for how to detect and recognize all key tank events. As we see in Figs. 3 and 4, the human eye is the best event finder and recognizer, so we tried to emulate what the eye does in a very natural way. We think that the current three modules (find events, classify events, reconcile events) implement such an approach.

The S-PLUS toolkit is a library of functions with a menu interface. The menu interface under Windows 3.1 is slightly more user-friendly than the interface under unix, but future graphical user interfaces for S-PLUS will improve the unix version. There are approximately 40 S-PLUS functions, most with help files. Due to time constraints we could not bullet proof the software nor provide hypertext links between function help files. At this stage it would be premature (although

do-able) to take the software to that level. In the next two subsections we provide some examples of the S-PLUS functions and menu system. The toolkit has been demonstrated to several IAEA personnel, but for completeness we provide some idea of its capability in this section.

We separated the TRP and RRP efforts into separate toolkits, though both share many of the same functions, which is achieved with using parameter lists that hold specific tank information. We will illustrate the TRP toolkit here.

The "driver" menu, roadmap.trp, produces the menu shown in Fig. 5.

Fig. 5. The roadmap.trp function for menu access to S-PLUS functions.

Each of the seven main menus has submenus, which we briefly explain here.

Preprocess data: (1) read data, (2) interpolate raw data if necessary, (3) smooth raw data. As mentioned, the data we had available from TRP was at erratic intervals, mostly determined by level change criteria. We found it convenient to interpolate that data to have a specified interval, usually five minutes. In our interpolation functions we add user-specified noise, and in sections having large time gaps we interpolate by repeating the last actual data point (plus noise) until approximately 30 minutes prior to the current data point, at which time a linear interpolation is used, to duplicate the often seen approximate 30-minute events.

Preliminary plots: (1) plot any one tank, (2) plot all tanks, (3) strip-chart plot for any one tank.

Preliminary analyses: (1) find all events for all tanks, (2) classify all found events for all tanks, (3) reconcile all found events for all tanks, (4) “manually” classify all events for a given tank by interactively using mouse to label and classify events, (5) automatically do (4) using different criterion than (2), and (6) compare manual classification results to automatic classification results. We have worked with both simulated data from RRP and real data from TRP. The real data from TRP was very valuable in suggesting that the results from any “automatic” event finder should be “manually” compared to what the human eye recognized by scrolling through the time series plot of data for the given tank. Some of the “automatic” event finder results do not quite find the correct start and stop points for an event, and some of the “automatic” event finder results can be false alarms. We have written our event finders to accept tunable parameters to help mitigate these undesired results, but know that our event finders still need improvement, which would be implemented as experience is accumulated at a facility.

Specialized plots: (1) plot any of L, D, T versus any other of L, D, T and zoom plot if desired, (2) superset of (1), includes derived values like volume, (3) plot the volume or mass shipper-receiver differences between any specified pair of tanks (assuming at least one SRD between the specified tank pair was found and classified by the event finder), (4) plot the entire data set for a given tank, but only near the times at which events were found by the event finder.

Specialized analyses: (1) summarize the volume or mass shipper-receiver differences between any specified pair of tanks, (2) estimate evaporation rates using all nonevent sections of data from any tank, (3) inspect all unreconciled events.

We show the “specialized analyses” submenu in Fig. 6.

Fig. 6. The “specialized analyses” submenu of roadmap.trp.

Manual snapshots: (1) two manual snapshots, (2) more than two manual snapshots.

The manual snapshots are specific for TRP; we expect to compare the monthly plutonium concentration measurement (and density measurement) to that predicted by applying simple mixing rules using the events file to update the estimated plutonium concentration after each receipt by the given tank (shipments are assumed not to affect the density or plutonium concentration in the shipping tank).

Generate reports: Four different reports (simple ASCII files) are available, which identify, for example, the number of transfers by a given tank and the times at which unreconciled events occurred.

4. Summary and Recommendations

4.1 Summary

This task has developed methods for the analysis of level, density and volume data from the monitoring of plutonium nitrate solutions. This work is intended to develop and evaluate methods that the IAEA might use as part of their safeguards approach at reprocessing plants. The present work focused on finding, classifying and reconciling transfers and sampling events occurring within the plutonium nitrate storage area at the TRP in Japan. Methods for automatically performing these functions were developed. Methods for the confirmation of automated assignments using computer-aided manual identifications were also developed.

The approach finds events using changes in levels as a function of time and classifies the found events as shipment, receipt, or sampling based on historical or process parameters related to the time durations and level changes corresponding to each class of event. Following classification, the events are reconciled by a search for corresponding events, either in the same tank, or in connecting tanks, having complementary changes in mass or volume. If there are no connecting tanks in the system, an event is assumed to be either a shipment to or a receipt from process if the quantities correspond to process transfers. Data is available for calculating cumulative amounts shipped and received for each tank and between tanks so that other records can be maintained and long-term consistency evaluated.

The work has been valuable for the development of solution monitoring as a potential safeguards approach for reprocessing plants. Use of "real" data from TRP has provided a better understanding of potential problems of using solution-monitoring data for safeguards and thus enabled development of more useful approaches. The overall approach envisioned for analyzing solution-monitoring data is probably amenable to implementation using an "Expert System." However, the two commercial expert systems that we investigated (G2 by GENSYM and EXSYS by EXSYS) did not meet our needs. We currently believe that there are so many safeguards-specific functions needed (such as estimating loss during wait modes and during transfer modes as described in Ref. 1) that **it would be simpler not to use a commercial expert system.** In effect, the current software is a very simple expert system. Fairly general functions can be coded which can be used

at different facilities with only moderate customizing. Most of the customizing is done through use of data or parameter definition which is facility specific. However, the data analysis and information management aspects of using solution monitoring data for safeguards purposes is not difficult (but must be done carefully) and practically any reasonable programming language would be acceptable, including G2 or EXSYS.

4.2 Recommendations

We have stated quite strongly in this report and the accompanying report (Ref. 1) **that the benefits of solution monitoring greatly outweigh the cost of implementation. In that spirit we suggest here some specific enhancements to the current software.**

1. Continued generalization and refinement of functions. For example, we do not yet attempt to distinguish between evaporation and actual diversion. Evaporation should be recognizable as having very little mass loss and some volume loss, while actual diversion should look different.
2. Addition of methods for processing, analyzing and evaluating the raw pressure measurements.
3. Addition of standard deviations to the basic L, D, and T data; the raw data will be similar to that described in Ref. 2 in which each 20-second (or so) measurement is actually an average and standard deviation of more frequent measurements.
3. Simulation of other events within the tanks which we desire to find and classify.
4. Development and evaluation of the data base and methods for finding and classifying these added events.

Finally, we also suggest that the S-PLUS version continue to serve as a rapid prototyping tool, from which selected functionality is chosen to be coded into C++ or another language for an on-line system. A separate inspector's toolkit would look something like the current S-PLUS version but perhaps other platforms should be considered. If Visual Basic becomes object oriented, then Visual Basic would be our choice.

5. References

1. Tom Burr and Larry Wangen, "Enhanced Safeguards via Solution Monitoring," Los Alamos National Laboratory report LA-13186-MS (ISPO-390) (September 1996).
2. F. Franssen, C. Foggi, and B. Hunt, "Tank Data Acquisition and Evaluation in a Large Scale Reprocessing Plant," in *Proceedings 17th Annual Symposium on Safeguards and Nuclear Material Management* (Joint Research Centre, Ispra, Italy, 1995), ESARDA 27, pp. 383-388.