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CURRENT STATUS OF PROCESS MONITORING FOR IAEA SAFEGUARDS

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1. Introduction

It has been generally recognized that safeguarding of future large scale reprocessing plants by conventional means (e.g., by conventional materials accounting supported by containment and surveillance) is inadequate. During the IWG-RPS discussions four Member States, France, Japan, the U.K. and U.S.A. proposed safeguards approaches using advanced techniques in order to achieve the IAEA goals. The new elements proposed as part of an advanced safeguards approach were near-real-time accountancy, extended C-S and process monitoring. These approaches were initially presented in the INFCE discussions, and were extensively discussed by the IWG-RPS [1, 2]. A description of the approaches in the Report of Sub-Group IV to the IWG-RPS, and the elements proposed in the approaches are attached as Annex 1.

As is shown in Annex 1, the potential application of process monitoring to safeguards for reprocessing was proposed and discussed in the U.S.A. However, process monitoring was not examined by the IWG-RPS Sub-Group IV and was only briefly described (as one form of extended C-S) in the Overview Report of the IWG-RPS to the Director General of the IAEA [3]. Annex 2 attached, shows the approaches proposed by the U.S.A. and the description of process monitoring, in the Overview Report of the IWG-RPS, attached as Annex 3.

Since then process monitoring has been mainly studied in the U.S.A. and almost all of the literature on process monitoring now available has been written in the U.S. As a result of the ISPO Task C.59, one of the U.S. Support Programmes for IAEA Safeguards, <Process Monitoring for Reprocessing Plant Safeguards - A Summary Review, 1986> [4], was recently published. The main part of the report can be seen in Annex 4, attached.

It is interesting to note that 'process monitoring' has a more varied definition in the U.S. reports. This is perhaps because process monitoring has been studied in the U.S.A. specifically for U.S. national safeguards which includes material accountancy, material control and physical protection. There is, as yet, no accepted definition of process monitoring and that is one of the main reasons why efforts in developing a process monitoring concept for international safeguards application are not active.

The number of articles on process monitoring presented to the so-called "safeguards communities", (The IAEA International Symposium on Nuclear Material Safeguards, the INMM Annual Meeting and the ESARDA Annual Symposium) for the last few years, were very few compared with articles on Near-Real-Time-Materials-Accountancy or on physical protection. At an IAEA Symposium held in November, 1986, only one article on process monitoring was presented although process monitoring was mentioned in other articles [5]. The article is attached as Annex 5.

This report does not define 'Process Monitoring', it surveys the literature, extracts points of interest and tries to answer some of the following questions on process monitoring.

a) What is process monitoring? (see Section 2).
b) What are the basic elements of process monitoring? (see Section 3).
c) What kinds of process monitoring are there? (see Section 4.1).
d) What are the basic problems of process monitoring? (see Section 4.2).
e) What is the relationship between process monitoring and near-real-time materials accountancy? (see Section 4.3).
f) What are actual results of process monitoring tests? (see Section 4.4).
g) What should be studied in future? (see Section 5).

2. <u>What is "Process Monitoring"?</u>

According to various references, the term "Process Monitoring" has been used in different ways by their authors and no general definition of term has been accepted by the "safeguards communities".

2.1 <u>Survey of Various Literature on "Process Monitoring"</u>

A survey of the literature was made to find out:

- in what manner the term "Process Monitoring" has been used;
- what kind of expressions have similar meanings as "Process Monitoring".

Excerpts from the literature are as follows:

i) Looking to possible future developments

- in the area of containment and surveillance. [a].

IAEA suggested that it might be possible to:

- use the operator's own process monitoring sensors, supplemented by additional sensors installed for safeguards purposes; [b].
- look for anomalous process activities. [c].
  <Reprocessing Plutonium Handling, Recycle - Report of INFCE Working Group 4, 1980> [6].

ii) It (= flow follow-up) is a method of:

- monitoring certain processing steps; [b].
- to confirm that they are operating normally and it may provide added assurance against abrupt diversion. [c].
  <Safeguarding of Reprocessing Facilities - STR-77, 1979> [7]. (The same expression can be found in the report of International Working Group on Reprocessing Plant Safeguards on Topic 2 <Flow Monitoring and In-Process Inventory Measurement Procedures and Techniques> [8]).

iii) The IWG-RPS defined process monitoring for safeguards purposes as:

- an extended containment and surveillance measure; [a]
- that uses a selected process that uses control data and other information about the status of the process and of process equipment; [b]
- in order to detect conditions of nuclear material location and of process operation that might indicate diversion. [c]. <Overview Report to the Director General of the IAEA - International Working Group on Reprocessing Plant Safeguards, 1981> [3].

iv) "...... a monitoring system designed:

- to detect unusual movements of plutonium rich solutions through lines not intended for such movements; [b]
- might be used as corroborative evidence in support of near-real-time materials accountancy. [a].

<An Advanced Safeguards Approach for a Model 200 T/A Reprocessing Facility, - STR-140, 1983> [9].

v) Process Monitoring means

- investigation of selected process data for diversion related anomalies and [b], [c];
- is interpreted as an extension of C-S. [a].

  <Preliminary Comparative Assessment of Advanced Safeguards Approaches for Reprocessing Facilities - ESARDA, 3rd Annual Symposium, 1981, FRG>. [2].

vi) - As a further means of authenticating the n.r.t. accountancy data and as a tool for investigating anomalies, ..., [a], [c];

process monitoring is a distinct system which

- monitors process parameters ..... other than accounting data .... and compares the data with a dynamic process model [b].

<The Design of Safeguards Systems for Commercial Plutonium Processing Plants;

- IAEA, International Symposium on Nuclear Material Safeguards, 1986, U.K.> [10].

vii) Process monitoring refers to:

- the monitoring of process operations and variables other than those directly related to the measurement of material flows and inventories; [b]
- with the objective of identifying anomalies or irregularities which might indicate improper movement of material. [c].

In this sense, process monitoring constitutes:

- a form of surveillance. [a].

<International Safeguards for Reprocessing Plants - ORNL.SUB-7605/11, IEAL 180, 1981, U.S.A.> [11].

viii) The concept (of process monitoring for safeguards) involves:

- the use of extensive process control information; [b]
- political judgements about loss or unauthorized removal of material from a facility. [c].

  <Process Monitoring Concepts for Safeguards and Demonstrations at an Oak Ridge National Laboratory Test Facility - INMM, 27th Annual Meeting, 1986. USA> [12].

ix) This process information (process data from plant instruments)

- complements nuclear accountancy and other safeguards containment and surveillance techniques; [a]
- provides assurance that solutions ..... are contained and moved according to specific approved safeguards procedures. [c].

<Evaluation of Process Data from Existing Reprocessing Plant Instruments shows Benefits for Safeguarding Special Nuclear Material - ESARDA, 3rd Symposium, 1981> [13].

x) This (process monitoring) is

- a form of surveillance in which [a]
- a number of processing operating parameters ..... are measured and compared with expected values of these parameters; [b]
- in order to detect potential diversion via those diversion paths that would involve deviation of these parameters from their expected values. [c]

<Evaluation of Different Approaches to Advanced Systems for Safeguarding Reprocessing Facilities (Part of a USA proposal) - Report of Sub-Group IV to the IWG-RPS> [1].

xi) Process Monitoring is

- a supplement to conventional physical security and SNM accountability; [a]
- The information obtained from the process will back up these conventional techniques and should permit a more timely response to a loss of Special Nuclear Material (SNM), either through an operational problem or a possible diversion. [b] [c].

<Analysis of ICPP Process Monitoring System Data Collected during August-October, 1981 - ENICO-1127, 1982, USA> [14].

xii) The concept (process-monitoring function) may be regarded

- as an extension of physical-protection monitoring and surveillance functions into the process line, and as upgrading of the monitoring devices (or appropriate placement of them) to allow gross materials accounting. [a] [c].

The process monitoring system

- collects timely information ..... from a limited set of on-line measurement equipment, etc.; [b]
- to detect a theft in progress; [c]
- detect an abnormal situation with less regard for materials accounting. [c]

Such a process monitoring system can provide

- nearly immediate detection of diversion attempts, by continuous comparison of actual operating conditions with those expected. [c]
  <Coordinated Safeguards for Materials Management in a Fuel Reprocessing Plant - LA.6881, Vol. I, 1977, USA>. [15].
  <Materials Management in an Internationally Safeguarded Fuels Reprocessing Plant - LA 8042, Vol. II, 1980, USA> [16].

These expressions found in the literature, are composed of the following three parts,

- relations with "material accountancy" or "containment and surveillance", [a]
  an extended form of containment and surveillance especially supporting near-real-time material accountancy; (See 4.3).
- contents of "monitoring", [b]
  to make the best use of information mainly acquired by facility operators; (See 3.1, 3.2 and 3.3). And,
- objective, [c].
  to detect unusual conditions that might be indicative of diversions. (See detailed version in 3.4).

One of the answers to this chapter "What is Process Monitoring?" may be as follows:
"Process Monitoring is an extended form of containment and surveillance especially supporting near-real-time materials accountancy that makes the best use of information mainly acquired by facility operators in order to detect unusual conditions that might be indicative of diversions".

Some concepts of process monitoring shown in USA literature for example, xi) and xii) mentioned above, are so broad as to include almost any safeguards or material control measures which use or rely on data or instrumentation

originally justified by the plant operator for physical protection, process control, nuclear safety or quality assurance purposes.
A typical example is the structure of the U.S. National Safeguards System as shown in Fig. 1 [16].

This would be the main reason why the general definition of "Process Monitoring", which is mentioned at the beginning of this chapter, has as yet not been accepted.

2.2 Categorization of Basic Elements of "Process Monitoring"

The following elements may be extracted from various expressions of Process Monitoring:

a) Monitoring Points
Select monitoring points from the process.

b) Data and Sensors
Install various kinds of sensors or other instruments to acquire data from the monitoring points mentioned in a) above.
Make full use of instruments installed by plant operators, and Install additional instruments necessary for safeguards purposes.

c) Computers and other Equipment
Install equipment in order to gather, convert and process data, as mentioned in b) above, and if necessary make high level decisions and issue alarms according to the objective and criteria mentioned in d) below.

d) Objectives and Criteria
Establish objectives and criteria in order to attain safeguards goals.

There may also be various objectives and criteria just as there are various concepts of process monitoring, for example, for International Safeguards, or for the U.S. National Safeguards that include physical protection and process control, etc.
An image of basic elements of "Process Monitoring" is shown in Fig. 2.

Fig. 1 Structure of the U.S. National Safeguards System

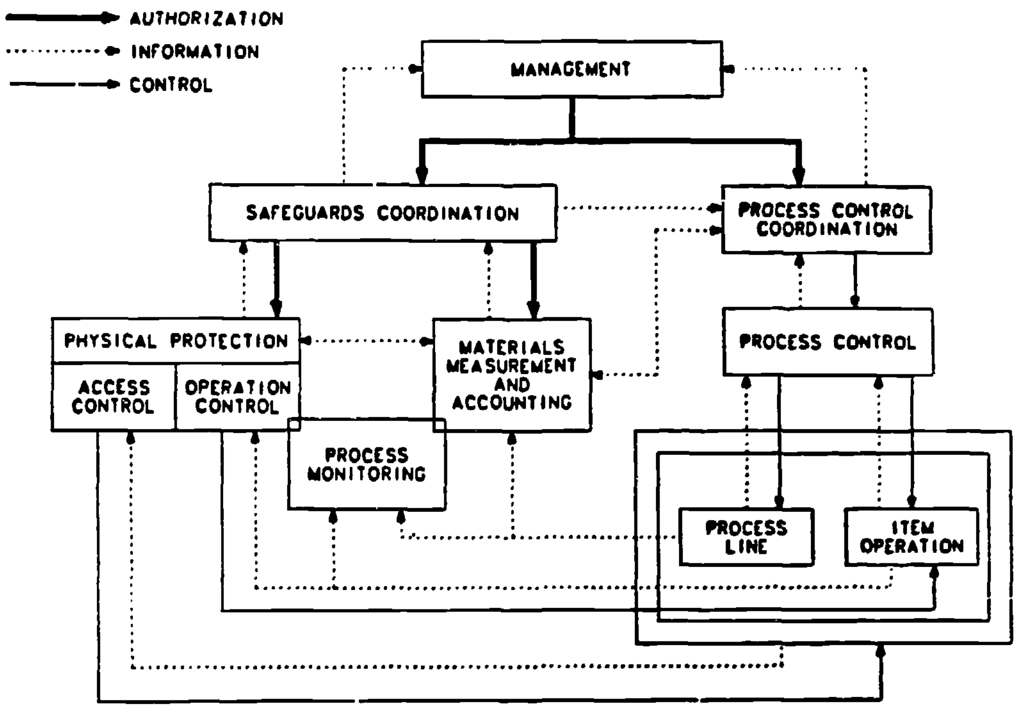
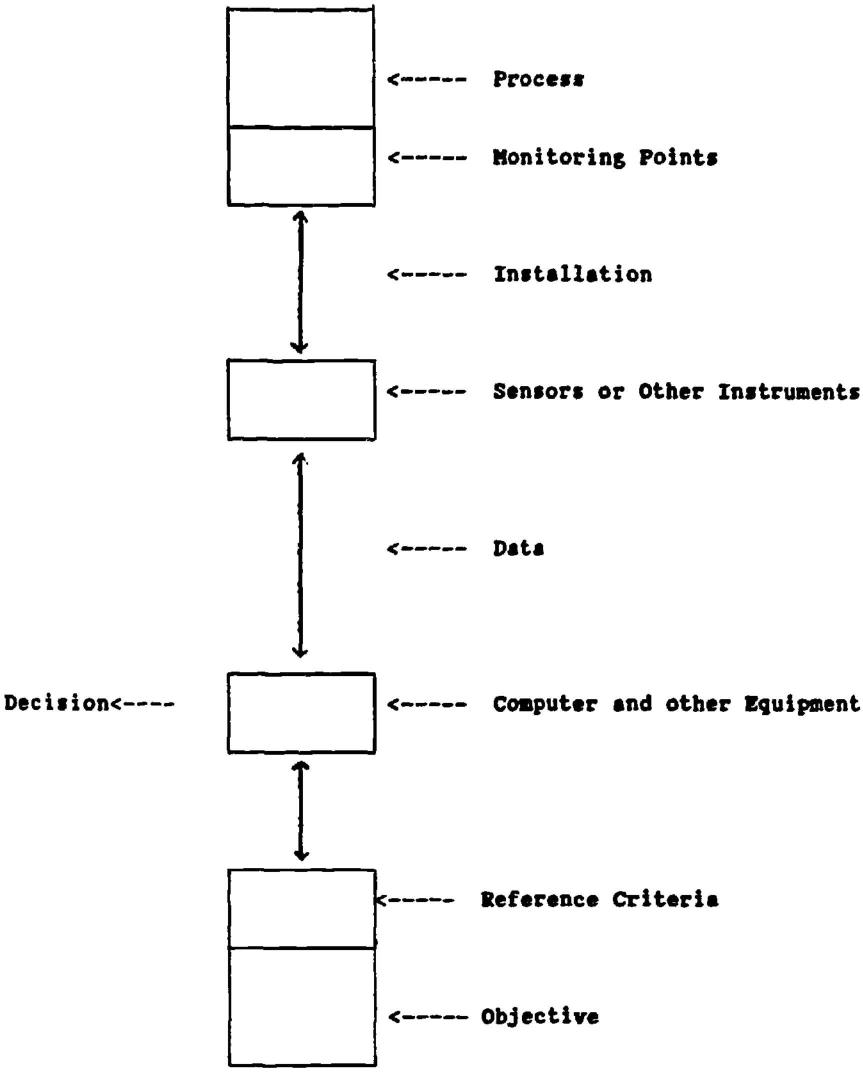


Fig. 2: Basic Elements of Process Monitoring



3. Basic Elements of "Process Monitoring"

3.1 Monitoring Points

According to various references on "Process Monitoring", the term "Process" simply means a chemical process operation. Normally, the term "Process" would mean a chemical operation rather than a mechanical operation and storage. However, there is no basis for limiting the application of process monitoring to chemical operations only. It might be better to apply process monitoring to all operations that begin by receipt of spent fuels at MBA1 and end by shipment of plutonium and uranium products at MBA3, the so called whole "reprocessing process".

Below are monitoring points in the whole reprocessing process:

3.1.1 Spent Fuel Storage [Head End Operations] (MBA1)

a) Spent Fuel Receiving Bay

The Crane Monitoring System at the spent fuel receiving bay that was developed as part of TASTEX Task A may be regarded as one example of process monitoring.

b) (Buckets with Hulls)

The Hull Monitoring System which was also studied as TASTEX TASK C was not regarded as one of process monitoring in any literature.

3.1.2 Chemical Process Operations (MBA2)

a) Tanks, pipes and process equipment that contain purified and concentrated plutonium.

The higher the purity and concentration of plutonium becomes, the more importance to tanks , pipes, etc., is attached.

i) Tanks

- Plutonium product accountability tanks;
- Buffer storage tanks. (Later tanks are more important because they contain more purified plutonium).
- Input accountability tanks.

ii) Equipment

- Plutonium product evaporator.
- Solvent extraction systems.

iii) Other

Various pipes which connect tanks and equipment mentioned above .... etc.

After taking various diversion possibilities and suitable process monitoring means to detect unusual conditions, STR-140 suggested a total of fifteen process points to be monitored as follows:

1. Liquid level in the input accountancy tank;
2. Liquid level in the first buffer storage tank;
3. Liquid level in the second buffer storage tank;
4. Liquid level in the third buffer storage tank;
5. Liquid level in the fourth buffer storage tank;
6. Liquid level in the product evaporator;
7. Flow rate from the input accountancy tank to the first buffer storage tank;
8. Flow rate from the first buffer storage tank to the first extraction cycle;
9. Input flow rate to the second buffer storage tank;
10. Flow rate from the second buffer storage tank to the second extraction cycle;
11. Input flow rate to the third buffer storage tank;
12. Flow rate from the third buffer storage tank to the third extraction cycle;
13. Input flow rate to the fourth buffer storage tank;
14. Flow rate from the fourth buffer storage tank to the product evaporator;
15. Liquid level in the product accountancy tank.

Fig.3 shows the fifteen monitoring points.

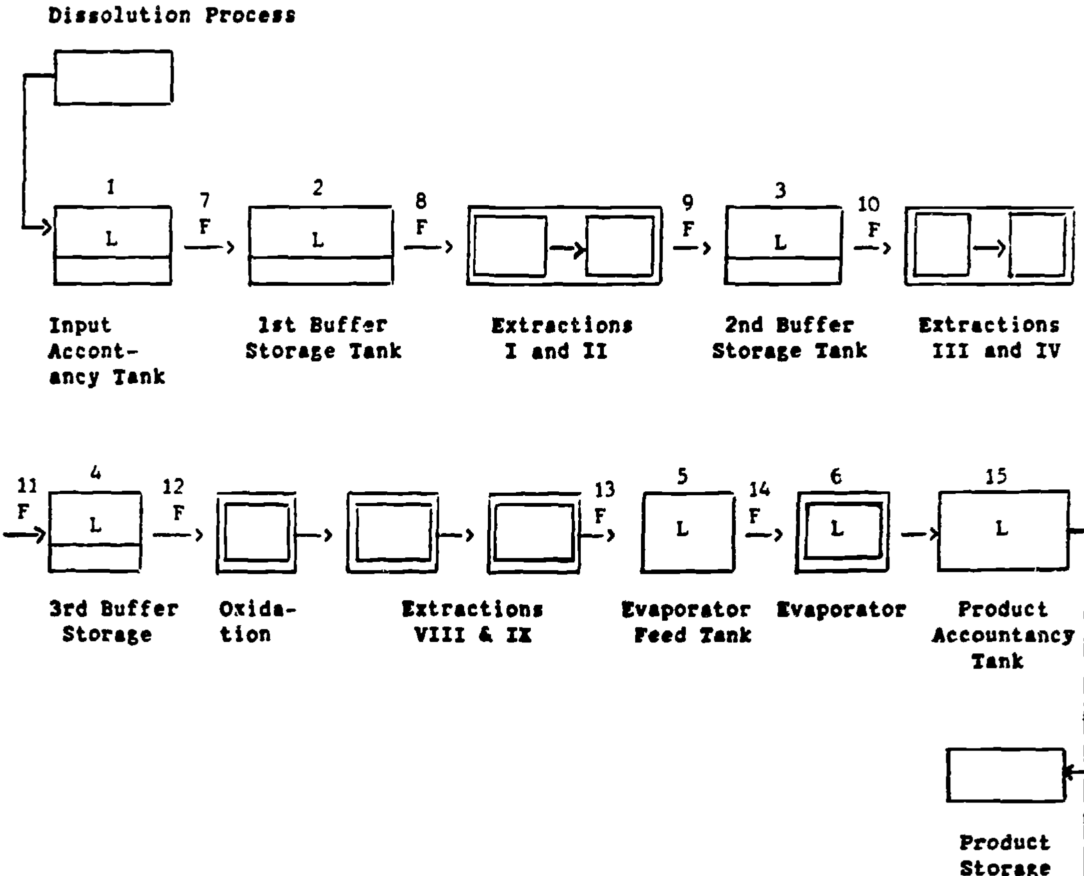
3.1.3 Plutonium Product Storage (MBA3)

- Pu product accountability tank;
- Pu product storage tank.

Pu Monitoring System at the Pu product storage using on-line computer programmes were tested and demonstrated as TASTEX Task I [17].

Fig. 3

Monitoring Points



L = Liquid Level
F = Flow Rate

3.2 Data and Sensors

Sensors and other instruments which are to be installed for acquiring data necessary for safeguards use, are listed below:

3.2.1 Data and Sensors concerning Nuclear Material or Solution

. Level of tanks	-	electromanometer
	-	monitor for pneumatic signals*
. Density	-	monitor for pneumatic signals*
. Specific gravity	-	(computation)*
. Volume	-	(computation)*
. Flow rate	-	flow meter
. Weight		
. Concentration of nuclear material	-	in-line monitor
. Temperature	-	temperature detector
. Existence of nuclear material (radio activity)	-	special nuclear material detector
. Amount of nuclear material	-	(computation)

* Examples are shown in 4.4.

3.2.2 Data and Sensors concerning Process Equipment

. Valve state	-	valve position monitor
. Steam jet		
. Air lift	-	air flow monitor
. Sparge air		
. Transfer pump		

These data show the state of solution containment, solution transfer, and sample taking, etc. [18].

Types and location of sensors required to monitor the operations at ICPP (Idaho Chemical Processing Plant) are shown in Table 2 [15].

Sensors proposed for the input accountability tank of Barnwell Nuclear Fuel Plant (BNFP) and schematic of this tank are shown in Table 3 and Fig. 4 [19].

Table 1

Types of Process Monitoring Data at Fuel Fabrication Facilities

1. Production Control Data

. Definition	-	data representing bulk measurement
. Primary function	-	to indicate the status and completion of production orders and the efficiency of material processing operation
. Example	-	quantity of solution (related to SNM quantity) and calculated yield.

2. Process Control Data

. Definition	-	data specifying process operation parameters and conditions
. Primary function	-	to permit process operations at desired conditions or levels (those that provide safe, efficient and controllable operation)
. Example	-	indicating condition of equipment . temperature . time . pressure
	-	relating to nuclear material flow or properties . flowrate . mass . pH . specific gravity . liquid level

3. Quality Control Data

. Definition	-	data representing measurement of materials chemical and physical attributes
. Function	-	to indicate acceptability of intermediate or final product materials for their intended use
. Example	-	U-235 enrichment (by mass spectrometry or NDA measurement)
	-	U-concentration.

Table 2

Overview of Sensor Device Classes and the Various Applications

The system seeks to provide improved surveillance and control of Special Nuclear Material (SNM). A design criteria document was generated which identified the types and location of sensors required to monitor the operations at the ICPP. This document described device classes and the various applications for each:

Class 1	-	pressure switches to obtain information on valve positions, and on sampler and steam jet operation;
Class 2	-	flow switches to obtain information on sparge and airlift operation;
Class 3	-	monitors for 3-15 psig pneumatic signals, primarily for solution level and density, but useable for anything else in 3-15 psig format;
Class 4	-	devices to detect the presence of liquid in forbidden lines, or to prevent siphon access to process solutions;
Class 5	-	steam jet monitoring thermocouples;
Class 6	-	electrical relays to detect operational status of pumps and other electrical motors;
Class 7	-	high precision level and density measurements;
Class 8	-	manual valve position monitors;
Class 9	-	pneumatic to 4-20 mA current loop transducers for isolated process signals;
Class 10	-	thermocoupes for monitoring solution temperatures;
Class 11	-	current loop monitoring devices;
Class 12	-	flow switches to detect movement of small quantities of process liquids; and
Class 13	-	tamper indicators to detect power and access status of system components.

The computer system can make use of these classes of data to:

1. Audit the accountability system by:

   (a) providing an independent authentication of accountability measurement values,

Table 2 cont'd ....

(b) assuring the validity of accountability measurements by verifying proper sparge mixing, sample recirculation, and solution transfers, and

(c) assuring that no material bypasses the accountability tanks.

2. Assure that SNM in the plants stays there by:

(a) performing solution mass balances on transfers between plant vessels,

(b) verifying that solution flow paths are well defined and normal,

(c) verifying constance of volume in static tanks, and

(d) promptly detecting presence of liquid in abnormal places which indicate possible losses or diversion attempts.

3. Check system integrity by:

(a) monitoring system power supply and tamper indicators,

(b) injecting reference signals for response checks, and

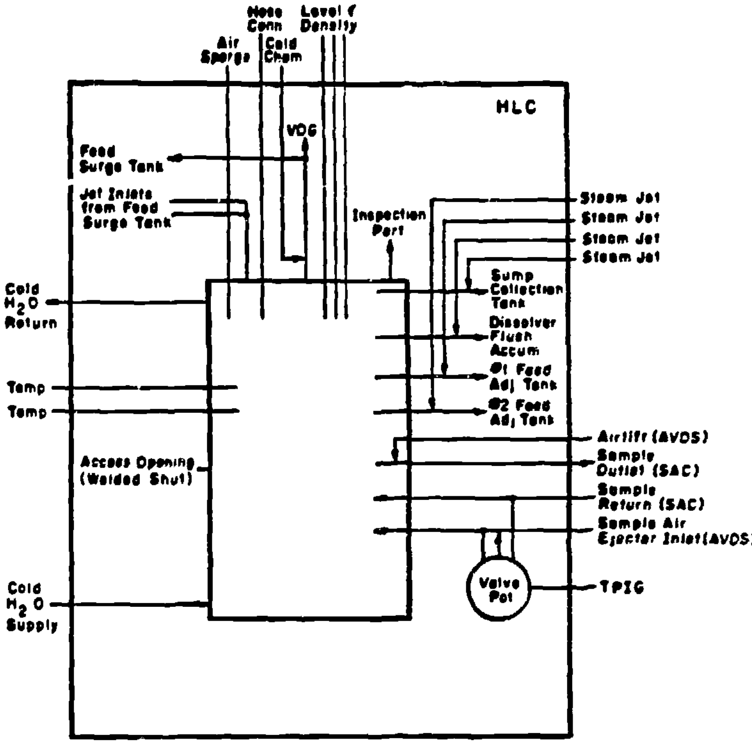
(c) cross-checking redundant data.

4. Provide a data base for troubleshooting abnormal occurences by:

(a) maintaining an accurate, time correlated record of events as data files,

(b) allowing rapid access to these files, and

(c) allowing the use of numerous programs to analyze data and generate tabular or graphical output reports.



Notes: 1. Cold H_2O Enters Jacket Only – Not Tank
2. Temperature Lines are Inside a Pipe Only Where the Vessel is Penetrated.
3. Relative Physical Positions of Connections Not Accurate.

Fig. 4 Schematic of input accountability tank.

TABLE 3

SENSORS PROPOSED FOR THE ACCOUNTABILITY TANK

Lines	No. of Lines	Sensors
Jet inlets	2	Steam jet, flow, liquid-in-line, or radiation monitors
Jet outlets	4	Steam jet, flow, liquid-in-line, or radiation monitors
Air sparge	1	Air flow monitor and liquid-in-line or radiation monitor
Hose connection	1	Liquid-in-line or radiation monitor
Cold chemical	1	Radiation monitor
Vessel off-gas (VOG)	1	Liquid-in-line monitor
Level and density	3	Pressure monitor, purge air flow monitor
Sample system	4	Circulation monitor and liquid-in-line or radiation monitors

Total number of sensors = 19

3.3 Computers and other Hardware Equipment

The TASTEX Task I system which is composed of three major groups of equipment is a good example and is shown as follows [17, 20]:

a) Equipment 1 - Computer System
   - located in the plant operating area
   - control data acquisition
     - analyze data
     - generate report
     - store data

b) Equipment 2 - containing Interface Equipment
   - located behind the plant operating panel;
   - converts the plant sensor signals into digital form for Equipment 1.

c) Equipment 3 - containing Pneumatic Multiplexing and High Precision Transducer Measuring Equipment
   - located deep within the plant access areas
   - multiplex pneumatic bubbler probes signals from plutonium product area tanks into a high precision pressure transducer;
   - transmits frequency signals from the transducers for measurement.

The TASTEX Task I System is shown in Fig. 5. [20].
<Ref. Data acquisition system hardware of an Integrated Process Demonstration Facility (IDP) at Oak Ridge National Laboratory, shown in Fig. 6.> [21].

Figure 5

TASTEX TASK I
MONITORING SYSTEM AT PNC

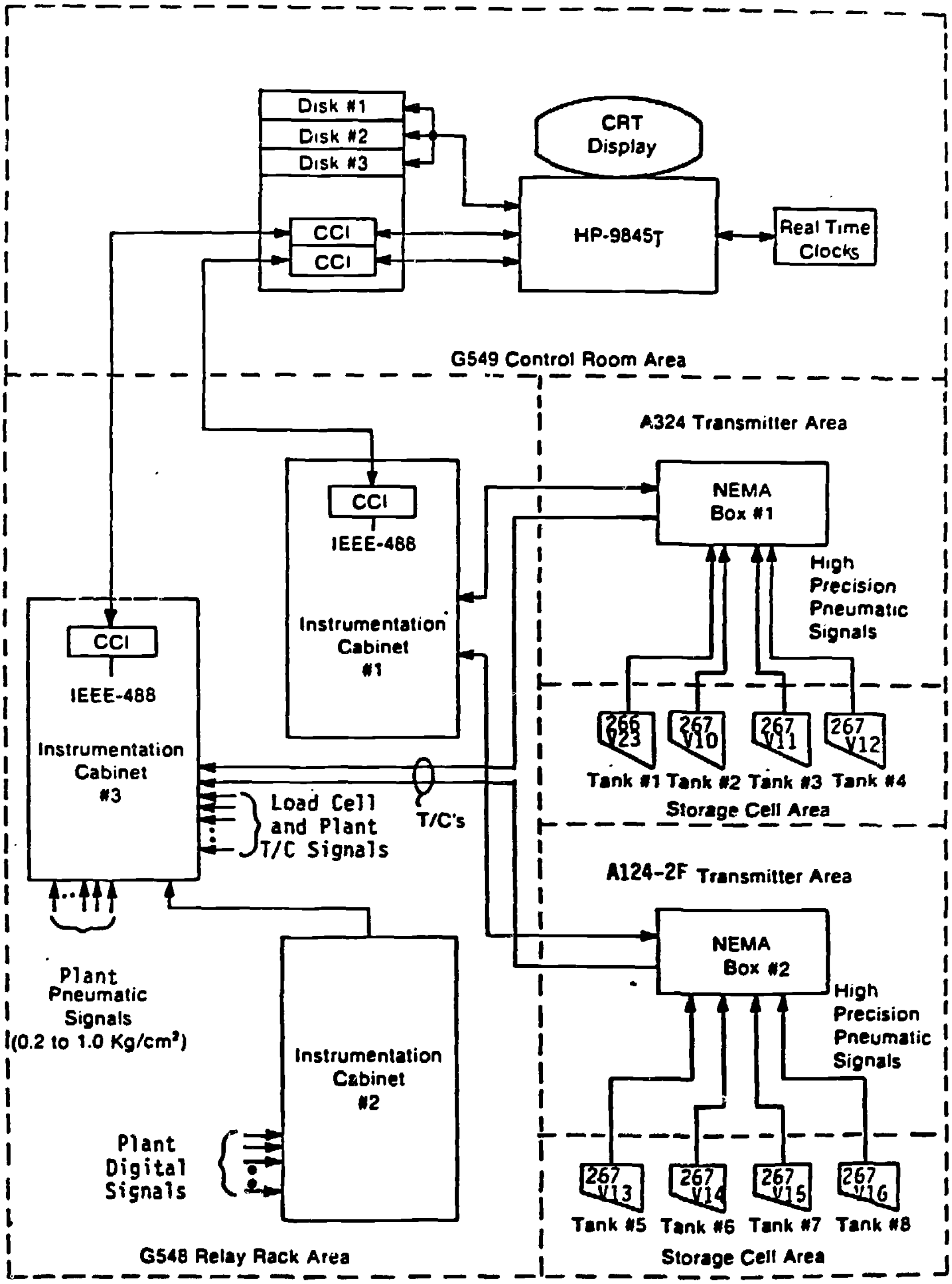
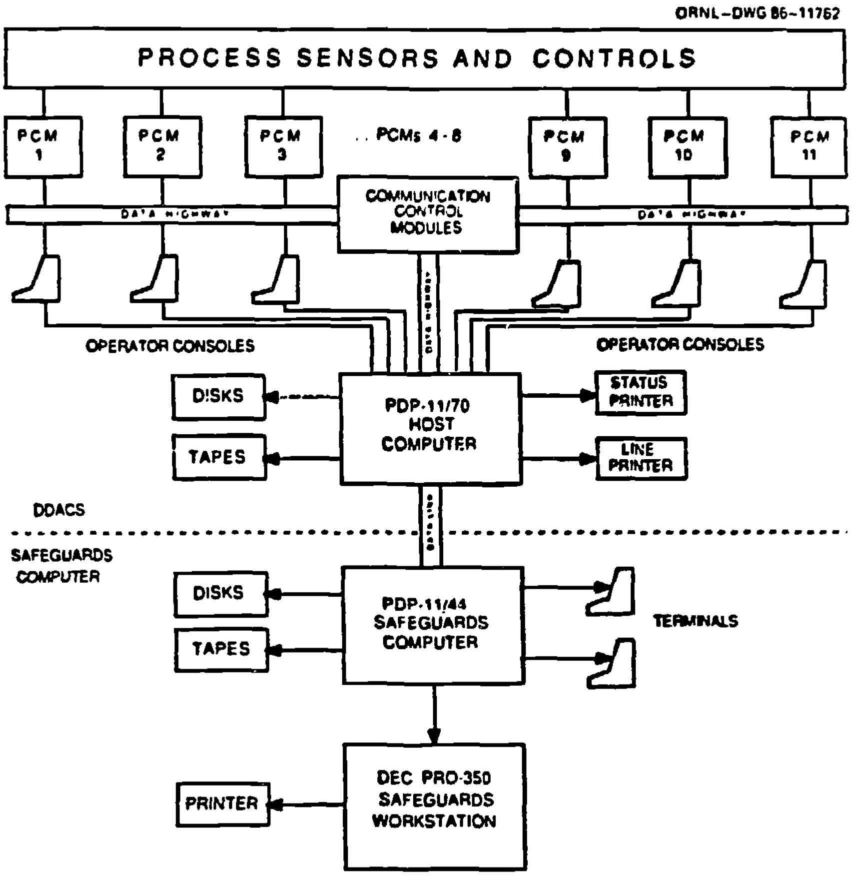


Fig. 6 The data acquisition system hardware configuration.



3.4 Objectives and Criteria

3.4.1 Objectives. It is possible to extract some examples of the "Objective" of process monitoring from various expressions on Process Monitoring shown in Chapter 2.1:

a) to look for anomalous process activities;

b) to provide added assurance against an abrupt diversion;

c) to detect conditions of nuclear material location and process operation that might indicate diversion;

d) to detect unusual movements of plutonium rich solutions ......

e) to investigate the process data for diversion related anomalies;

f) to investigate anomalies ....

g) to provide assurance that solutions .... are contained and moved according to specific approved safeguards procedures

h) to detect potential diversion via those diversion paths;

i) to permit a more timely response to a loss of SNM either through an operational problem or a possible diversion

j) to detect a theft in progress; an abnormal situation with less regard for materials accountancy; diversion attempts immediately ....

The most important and common factors may be summarized as follows:

"to detect, unusual (anomalous, abnormal), conditions (activities, movements, situation) that might be indicative of diversion."

3.4.2 Examples of Unusual Conditions and Detection Criteria. STR-94 demonstrates a basic premise of process monitoring as follows *[22]: "Diverted* nuclear material cannot be invented. It must come from somewhere, and must be removed via some physical process. This removal must also, at least in theory, leave its mark on the process".

Two categories of unusual (anomalous, abnormal) conditions (activities, movements, situation), to be detected, are as follows:

i) the removal process itself,

(e.g., the observation of radiation characteristic of plutonium in piping which should not contain plutonium.)

ii) the effect on the process itself.

Some examples in category ii) can be found in the literature.

a) Deviation from the normal (dynamic-equilibrium) state.
   - a drop in tank level when all valves are closed and a negative pressure in the probe line.
   - an observation of significant increase of Pu concentration in a solvent waste stream.

Some examples of the comparison found in the literature are as follows:

- compare the data with a dynamic process model;
- compare operating parameters with expected values of these parameters.
- compare the actual operating conditions with the expected conditions.

The method of comparison however, is quite difficult to establish, therefore the following questions arise:

- How does one quantify the expected operating condition (values of parameters) as a detection criteria and
- Who or what compares and makes decisions whether unusual conditions have occurred or not? Are they made by human (inspector/operator) surveillance, or by computation?

b) Inconsistency of changes in volume, weight, quantity, at a selected step of the process with changes in the next part of the process.
   - A discrepancy between directly monitored total volume (or liquid level) and volume derived from an inlet and outlet flow. One example is shown below.

A cross-section of Fig. 3 is taken:

```
                    3rd buffer storage tank
                         ____________
      11. flow rate                        12. flow rate
         --------->       4. level          --------->
                         ____________
```

[compare liquid level (monitor 4) to the volume derived from an inlet flow (monitor 11) and outlet flow (monitor 12)]. There are difficulties in establishing the permissible minimum amount of this discrepancy as a detection criteria.

STR-140 shows some interesting figures regarding the PNC-Tokai facility as a model:

.	8 kg	-	amount of plutonium to be diverted over a period of one year.
.	~ 250 days	-	actual process operation period in one year.
.	32g/day	-	minimum diversion rate.
.	2g/1	-	maximum solution concentration required by the process flowsheet.
.	16 1/day	-	minimum diversion amount.
.	1500 1	-	a capacity of a buffer tank.
.	1 - 2%	-	minimum diversion rate (buffer tanks are seldom truly full).
.	~ 2%	-	rate of volume discrepancies to be detected (a kind of detection criteria).

4. Points to Consider

4.1 Kinds of Process Monitoring

Several kinds of process monitoring are found in some of the literature, mainly in STRs.

a) STR-108 <Current Technical Status of Near-Real-Time Materials Accountancy - 1982>, suggests three kinds of process monitoring, in order to detect diversion or to assure the absence of diversion [23]:

i) <u>to monitor all valves, process piping, or in general all paths which might be used to remove nuclear material from the process</u>
a version of extended C-S in which the containment barriers are individual items of process equipment or individual unit process operations. (STR-140 calls this process monitoring, "Penetration Monitoring").

This monitoring system is considered to be of widespread value in international safeguards because of a number of penetrations to be monitored and the lack of suitable monitoring devices.

As an alternative, in the STR-140, a proposal was made to monitor selected points, i.e., a limited number of tanks or process vessels which might be used as the most logical source of plutonium, in order to establish that no plutonium rich solution is being unaccountably lost.

ii) <u>to monitor liquid levels in tanks, transfers between tanks or other items of process equipment, etc.</u>
a form of materials accountancy in which the "material" to be accounted for is the total solution volume rather than nuclear material content.

STR-140 suggests that monitoring of the inlet and outlet flows to the buffer tanks in comparison with tank volume, is sufficient to detect both a diversion from the tank itself, and an abrupt diversion from the aqueous product output of the corresponding solvent extraction system.

This type of process monitoring, called "total solution volume or mass balancing", is based on the principle that in the process and the storage area plutonium cannot be diverted without diverting a quantity of solution.

iii) <u>to identify a critical set of process operations and to detect the abnormal effect (which might be indicative of diversions)</u>
this type of process monitoring is based on the principle that removal of nuclear material from a sequence of process operations must affect those operations.

b) One literature from the U.S. shows several kinds of process monitoring [13]:

i) enhanced solution measurement
By knowing the solution volume or weight, an estimate of the special nuclear material can be made.
(=solution bulk quantity x SNM concentration).
This estimation is also used in n.r.t. accountancy, and will remain on the border line between process monitoring and n.r.t. accountancy. (See 4.3).

ii) <u>transfer monitoring</u>
this is the same as in 4.1 a) ii) above.

iii) <u>diversion path monitoring</u>
this is near enough an approach to 4.1 a) i) above.

c) STR-152 suggests potential process monitoring applications which can be grouped into five categories:

i) Process Monitoring to preserve the integrity of nuclear material inventory information
(the same approach as C-S measures) e.g.,

- crane location monitoring to monitor a continuous knowledge of the inventory of spent fuel;

- TASTEX Task I work on monitoring value positions, solution levels, etc., in the product storage area.

ii) Process Monitoring to provide an assurance against possible undeclared transfers through key measurement points
key element for an extended C-S safeguards approach.

iii) Process Monitoring to provide an assurance against possible undeclared transfers which by-pass key measurement points
It is, in general, difficult to identify process monitoring technqiues which would effectively detect such transfers.

iv) total solution volume or mass balancing
already mentioned in 4.1 a) ii)
e.g., a follow-on activity to the TASTEX Task I,

v) Process Monitoring to detect ambiguous process operation which might be indicative of a diversion
already mentioned in 4.1 c) iii).

4.2 Basic Problems of Process Monitoring

One of the main characteristics of process monitoring is that it makes great use of process instrumentation which has already been installed by facility operators for operational use and if necessary, will be installed by inspectors for safeguards use.

On the other hand however, process monitoring also has inherent problems.

STR-152 suggests the basic problems of process monitoring:

a) Extensive inspector access to process information
Giving the inspector access to process instrumentation should also give him access to sensitive commercial data. Although there may be various definitions of "strategic points", it is universally agreed that safeguards should be applied at key measurement points and other strategic points. There can be one extreme definition in which the entire facility is one large strategic point in order to give inspectors free access to the whole process, however, this is unlikely to be acceptable.

b) Excessive false alarms and inability to interpret process monitoring data in an unambiguous manner
The ideal process monitor is one which never signals an anomaly when diversion is not occurring, (e.g. in cases where essential operational changes are made by facility operators for several reasons), and always signals an anomaly when diversion is occurring. Such unambiguous signals are difficult to define.

c) Complexity of data authentication

The general principle of IAEA safeguards is that operator-generated data may be used for safeguards purposes only if it can be verified or authenticated. Such verification and authentication will require an unacceptable level of effort from IAEA.

4.3 Process Monitoring and Near-Real-Time Materials Accountancy

a) Several literatures make mention of mutually supportive roles of process monitoring and n.r.t. accountancy:

. Statistical techniques which are used to analyze MUF data in n.r.t. accountancy system cannot distinguish between an honest measurement bias and a true diversion attempt.

. An inherent problem in n.r.t. accountancy is that detection sensitivity is achieved at least partly at the expense of a higher probability of "false" positives.

. A process monitoring system which responds to an anomaly caused by a loss or removal of material rather than an anomaly resulted from a measurement error, might be used as corraborative evidence in support of an n.r.t. accountancy.

b) The distinction between process monitoring and n.r.t. accountancy (conventional materials accountancy) however, is not always clear. This is due to the lack of an accepted definition of process monitoring.

. "Process monitoring ..... monitors process parameters (flow rates, concentration, temperature, column weights, etc.) other than accounting data (despite there being a few parameters common to both systems)".

. "Process monitoring ..... refers to a monitoring of process operations and variables other than those related directly to measurements of material flow and inventory".

These two examples try to distinguish process monitoring and materials accountancy by the difference in the data they utilize.

However, another example shows that the data used by process monitoring go beyond those used by n.r.t. accountancy.

. "Process monitoring often uses process control signa that go beyond volume measurements and analytical results thai support near-real-time accounting".

As it is natural that some data be common to both process monitoring and conventional materials accountancy, it seems to be difficult to distinguish between process monitoring and conventional materials accountancy (or n.r.t. accountancy) by data. In distinguishing between process monitoring and conventional materials accountancy, what appears to be more important here, is not what kind of data be used, but how it is used.
The expression found in the Report of IWG-RPS is more appropriate.

. "Process monitoring is not a materials accountancy measure as it does not involve the determination of physical or book inventories"

The relationship between process monitoring and conventional materials accountancy mentioned above, is shown in Fig. 7.

Fig. 7

Relationship between Process Monitoring and Conventional Materials Accountancy

- Process
- Monitoring Points
- Sensors or other instruments
- Data
- Computer

-----> There may be some common elements between process monitoring and n.r.t. accountancy (or conventional materials accountancy)

- Sensors
- Data
- Computer

- Criteria
- Objectives

-----> Both objectives are of course different

- e.g., process monitoring does not involve the determination of physical or book inventories.

4.4 Process Monitoring Tests

4.4.1 Pu Product Storage Area Monitoring System at the PNC Tokai Reprocessing Plant, (TASTEX Task I and the Safeguards Development Programme at the ICPP) [13, 17].

Schematic Pu product accountability and storage area are shown in Fig. 8. (The dark piping illustrates a typical transfer route to the storage).

a) Some typical examples of data plots (tank level vs. time), are shown in Figs. 9 & 10.

Fig. 9 Illustrates

- Product solution transfer from the evaporator into the product accountability tank (266 V23) ------> (A)
- Recirculation mixing

- Start of recirculation mixing ------> (B)
- Level change due to solution hold-up in the recirculation pump and piping ------> (C)
  - Completion of mixing ------> (D)
  - Slow level change due to solution temperature cool down ------> (E)
  - A batch transfer from 266 V27 to the product storage tank (267 V10) ------> (F)

Fig. 10 Illustrates

- A batch transfer from 266 V27 to 267 V10 ------> (G)

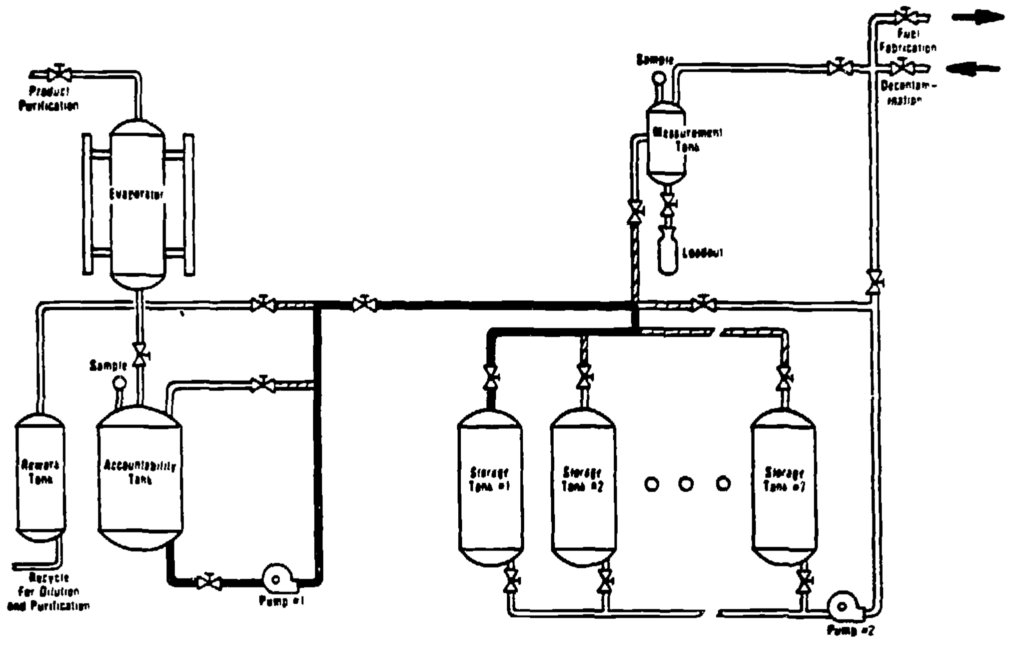


Figure 8 SCHEMATIC OF PNC PRODUCT ACCOUNTABILITY AND STORAGE AREA

G548 Relay Rack Area

Storage Cell Area

FIGURE 9
266V23 LEVEL DATA PLOT FOR A TYPICAL PRODUCT BATCH

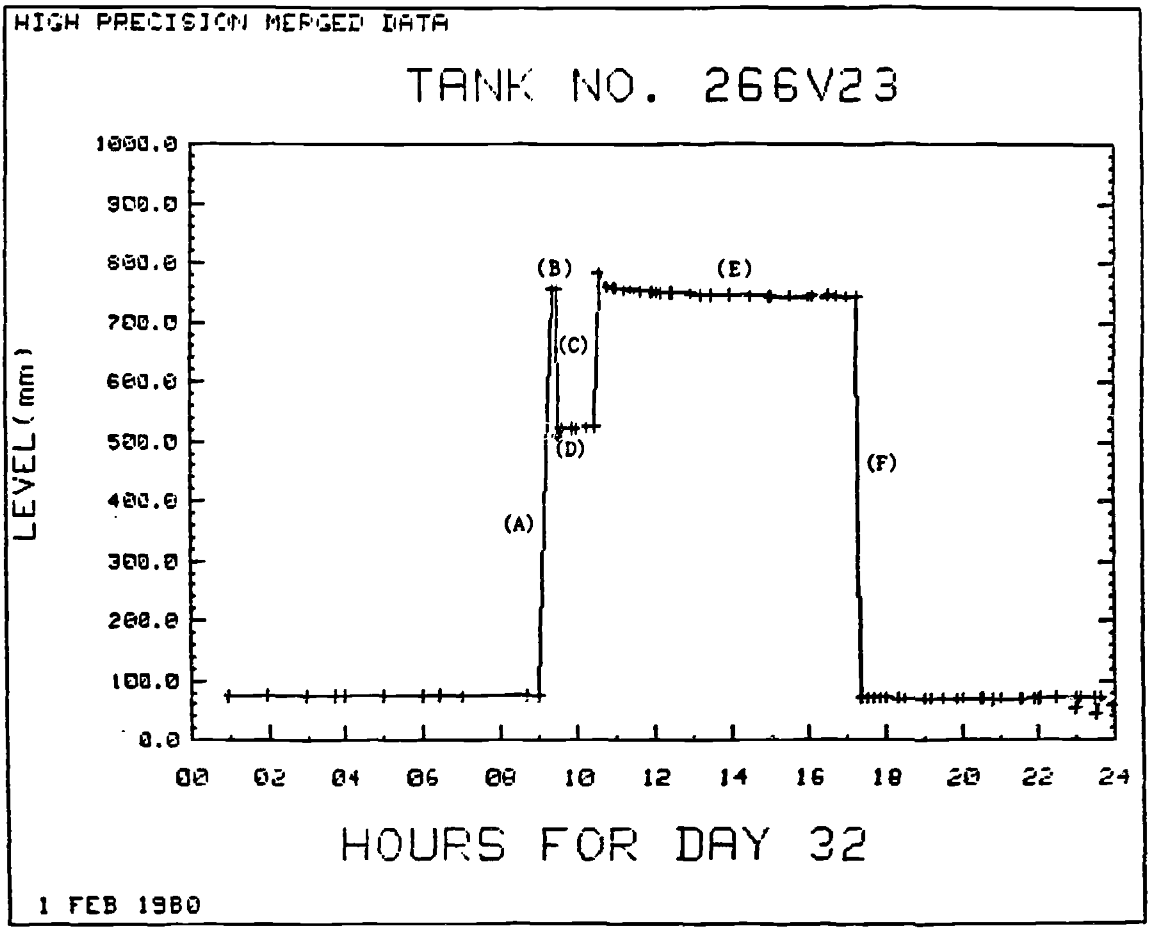
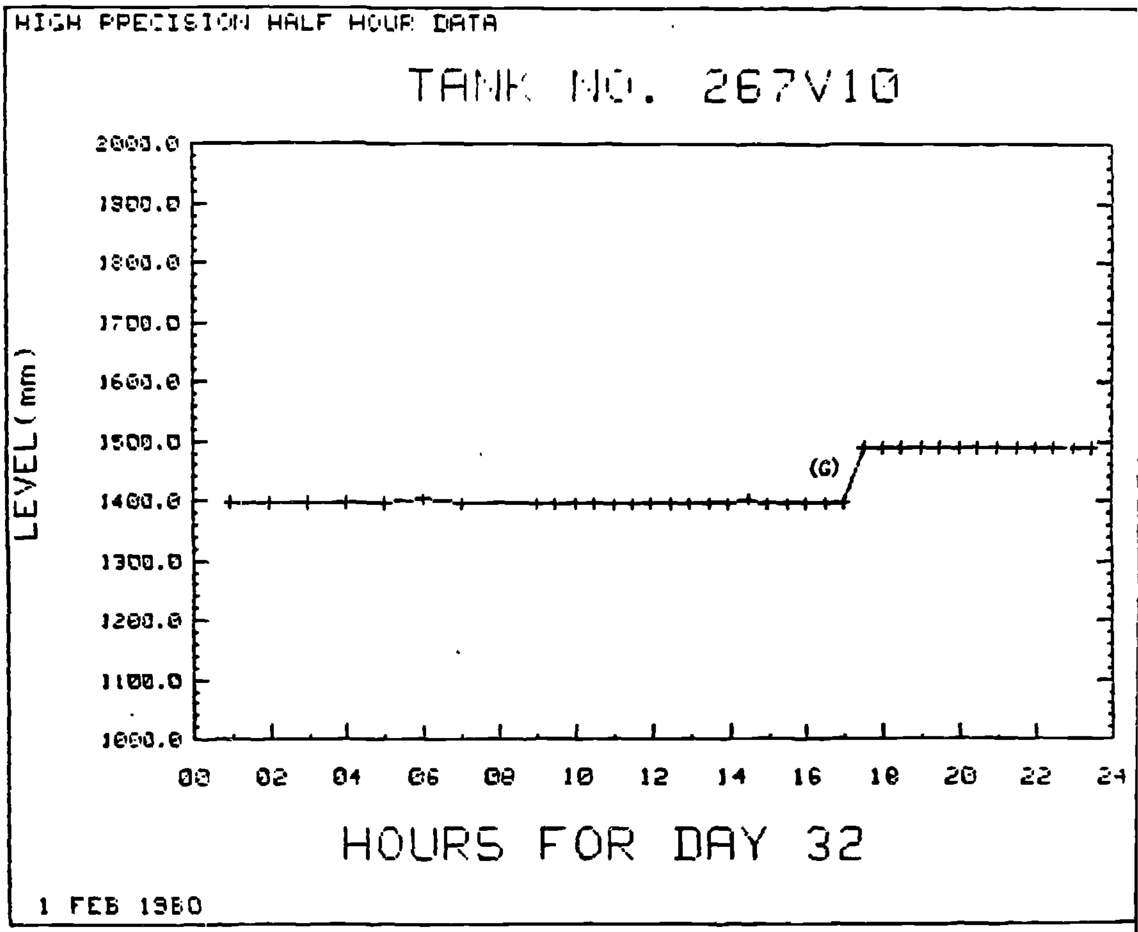


FIGURE 10
267V10 LEVEL DATA PLOT FOR A TYPICAL PRODUCT BATCH ADDITION

(Assumed Density = 1.54 g/cc)



b) Typical activities that have been observed within the monitoring system are as follows:

- Solution transfers can be detected (A, F, G). Both the rate and quantity of transfer can be checked.
- The tank density and temperature can be checked.
- Tank mixing, sampling, cool-down and measurements can be observed and checked against typical operating procedures and time intervals. (B, C, D, E).
- On-line analytical instrument measurements or typical density/concentration relationships permits almost an instantaneous estimate of the nuclear material content.
- Continuous surveillance of the solution level, temperature and density will detect any unexplained variations indicating diversion, leaks, etc.
- The transfer start can be detected where pumps or air-steam lifts are started. Changes in level confirm the transfer initiation, etc.

c) A typical example of the product solution high precision level data for a storage tank is shown in Fig. 11.

Fig. 11 Illustrates

Daily evaporation rate characteristics due to sparging effects.

Measured slope of the level decrease may be used to estimate the density increase.

This technique is more important when applied to storage tanks without effective bubbler probes for continuous density measurement.

d) Two more typical examples of data plots, density data plot and temperature data plot at 266 V23, are shown in Figs. 12 and 13.

FIGURE 11
TYPICAL EXAMPLE OF HIGH PRECISION DATA FOR 267V10

(Assumed Density = 1.54 g/cc)

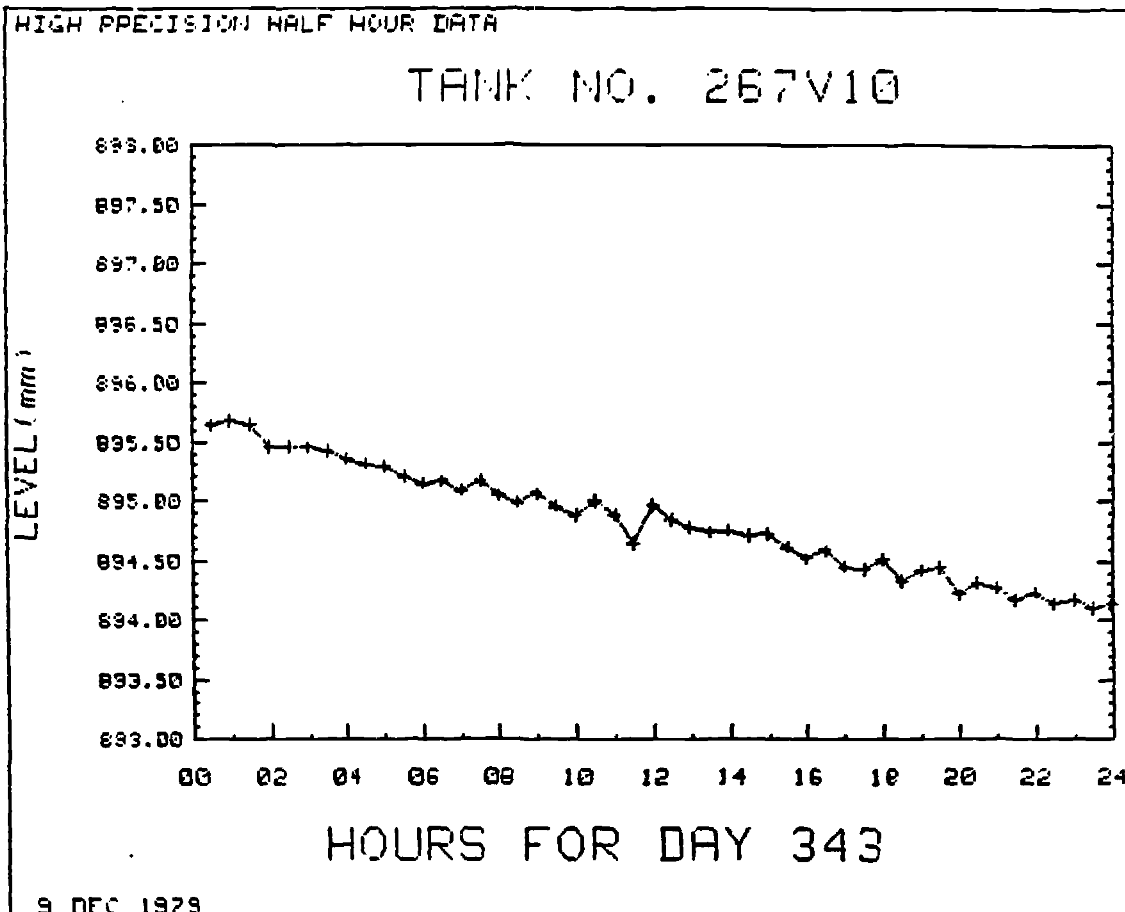


FIGURE 12
266V23 DENSITY DATA PLOT FOR A TYPICAL PRODUCT BATCH

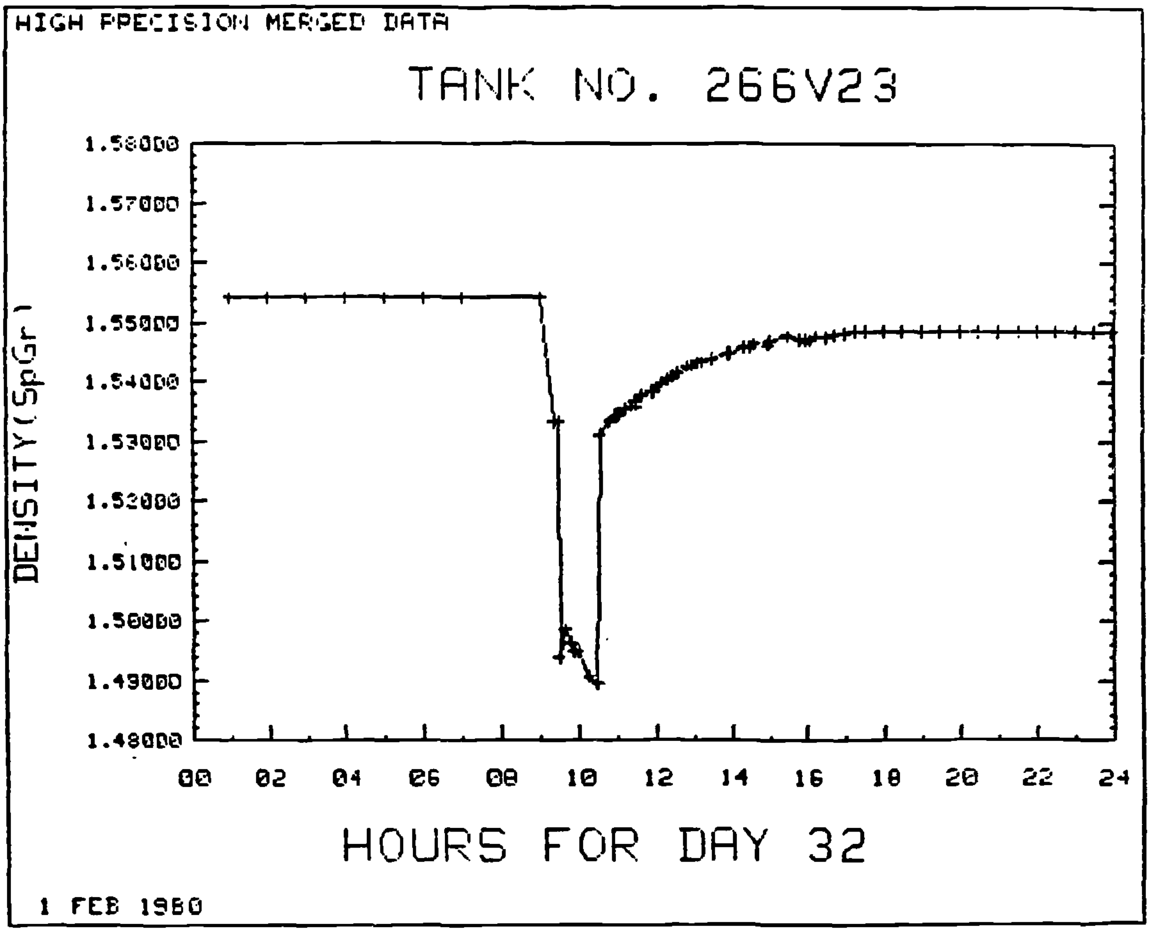
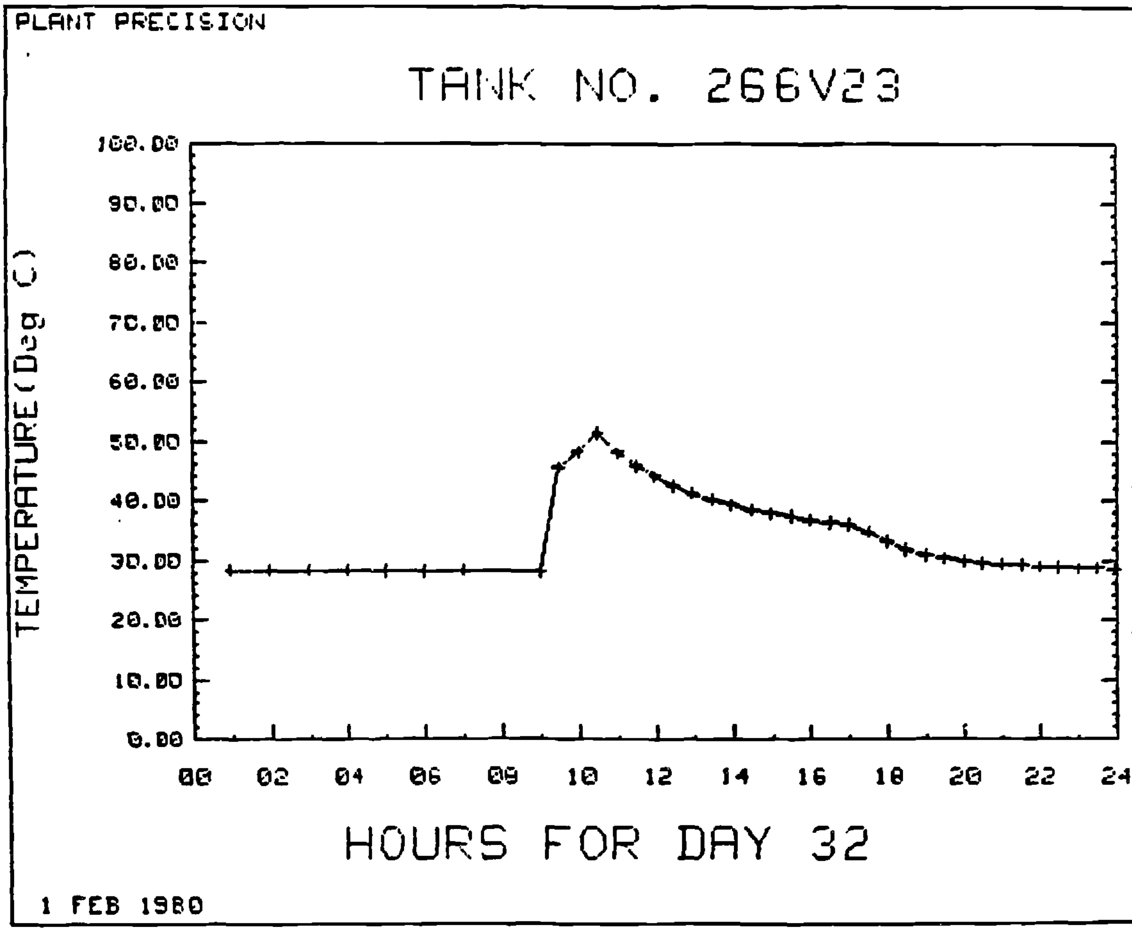


FIGURE 13
266V23 TEMPERATURE DATA PLOT FOR A TYPICAL PRODUCT BATCH



4.4.2 Process Monitoring System at the Idaho Chemical Processing Plant (ICPP)

- The purpose of the plant is to separate enriched uranium from spent fuel.
  A flow schematic of ICPPs First Cycle is shown in Fig. 14.
  The measurement of levels and densities of liquids in plant vessels is made with bubbler probes.
  Plant transducers convert the pressure signals from these probes to pneumatic signals.

- A simplified diagram of the usual measurement system is shown in Fig. 15.

Results of the measurements are as follows:

a) Level (LR) Measurements

A level measurement comes from a plant LR transducer.

A typical LR plot of a transfer into the input accountability tank (G-155) is shown in Fig. 16.

Fig. 16 Illustrates:

- slow feed from the dissolver ------> (A)
- fast transfer to tank G-155 ------> (B)
- steam jet transfer to another tank ------> (C)

b) Density (DR) Measurements

Density measurement comes from a plant DR transducer.
A DR plot for tank G-155 corresponds to the LR plot (Fig. 16), also shown in Fig. 17.

The Approach Proposed by the U.S.A.

Fig. 17 Illustrates

- Liquid added in the second addition had a lower density, indicating a different origin.

c) Specific gravity, level and volume computations

Specific gravity is computed from the DR reading.
Fig. 18 shows the specific gravity plot corresponding to the DR plot (Fig. 17). Task level and volume are computed from each pair of DR and LR readings.
Fig. 19 shows the volume plot corresponding to the LR plots. (Fig. 16).

d) Tank Temperature Measurements

The measurement of the temperature of liquids in plant tanks is usually made with thermocouples. A typical plot of temperature data in the other input accountability tank (G-105), is shown in Fig. 20. Both discontinuities at (A) and (B), are the result of an addition to the tank and an emptying/filling operation.

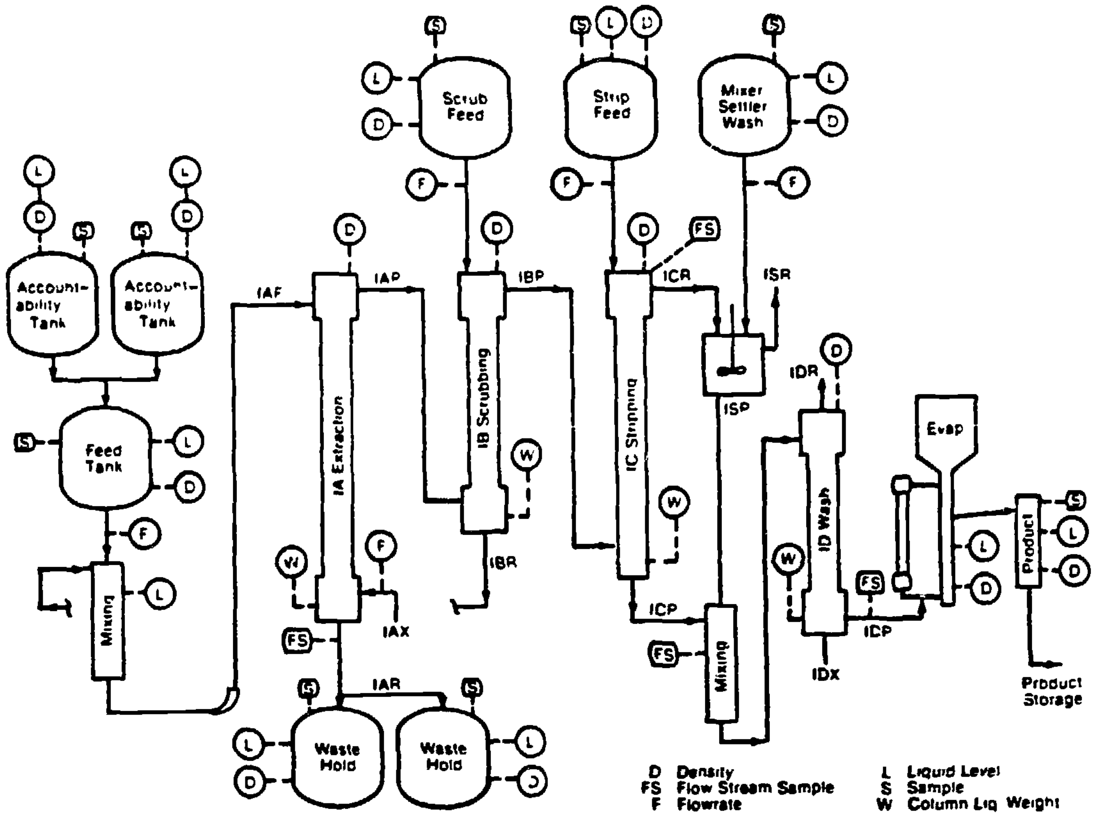


Figure 14 Flow Schematic of ICPP First Cycle

ICPP-A-6708

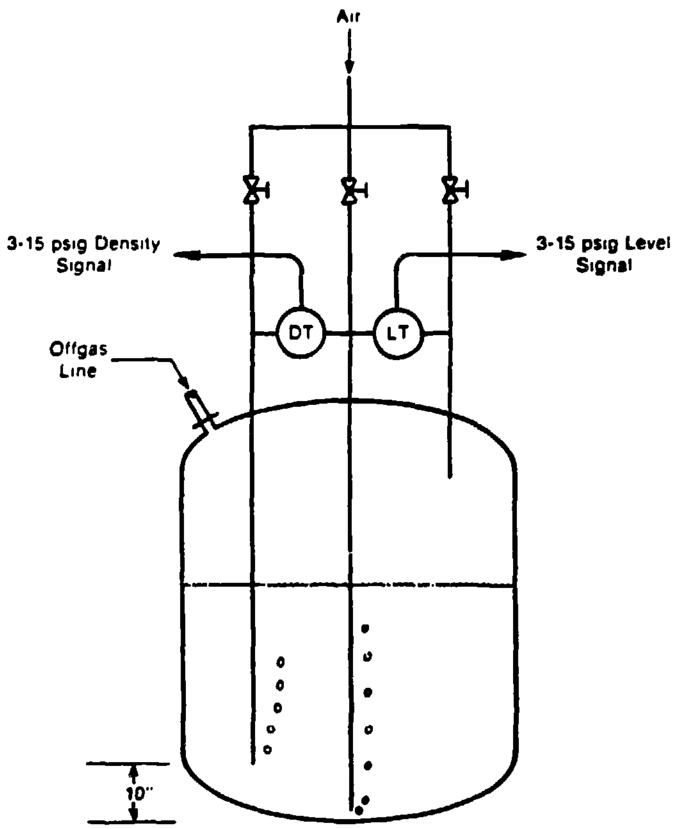


Figure 15 Level and Density Measurements With Bubbler Probes

ICPP-A-8308

Monitoring for Reprocessing Plant Safeguards -

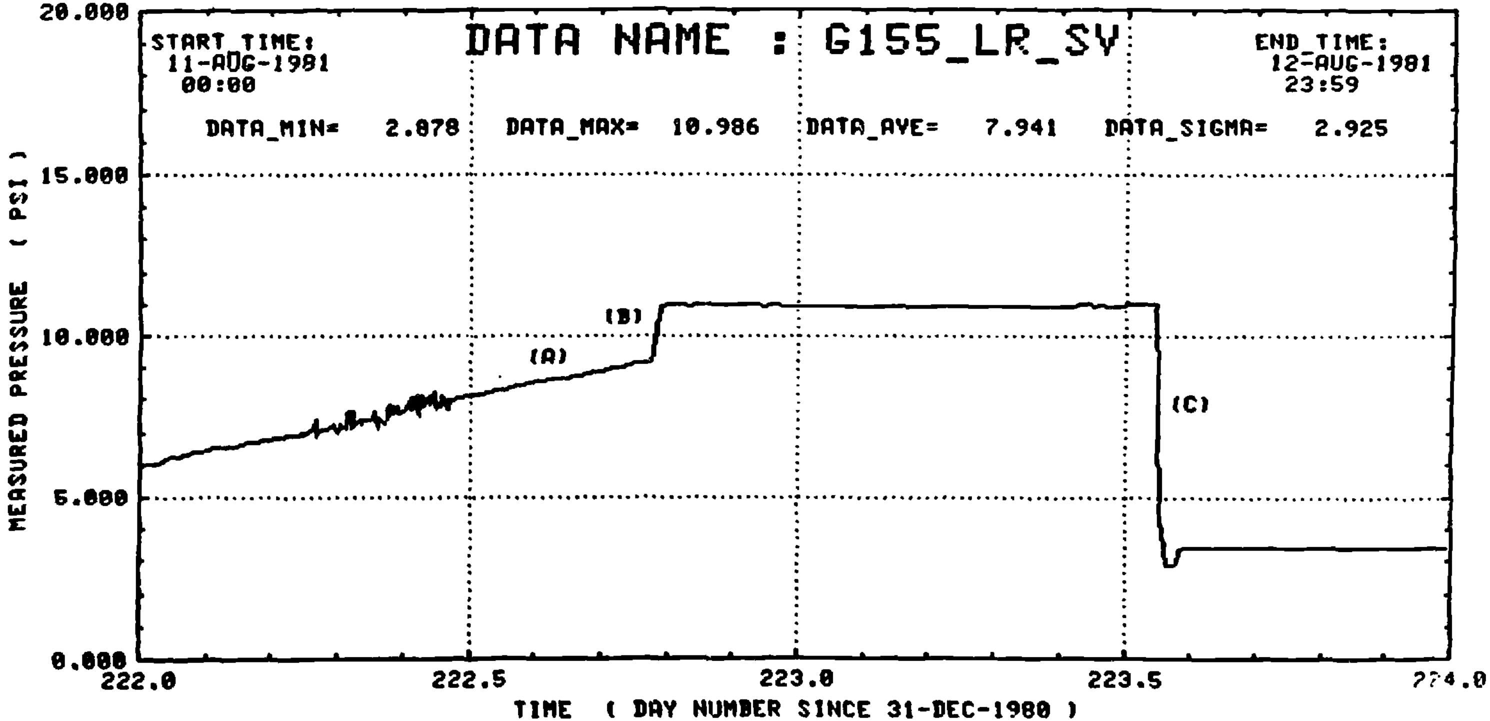


Figure 16 Typical LR Plot for Tank G155 During a Transfer

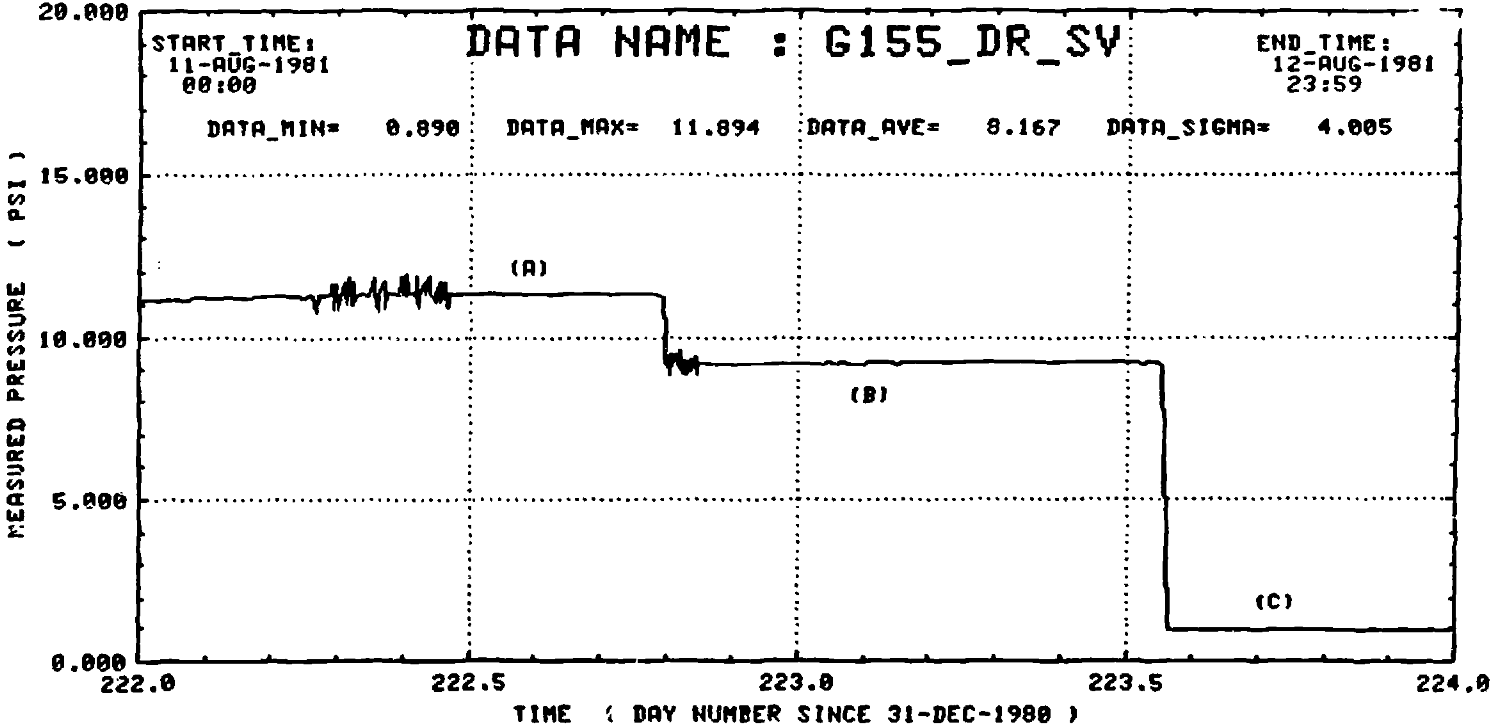


Figure 17 Typical DR Plot for Tank G155 During a Transfer

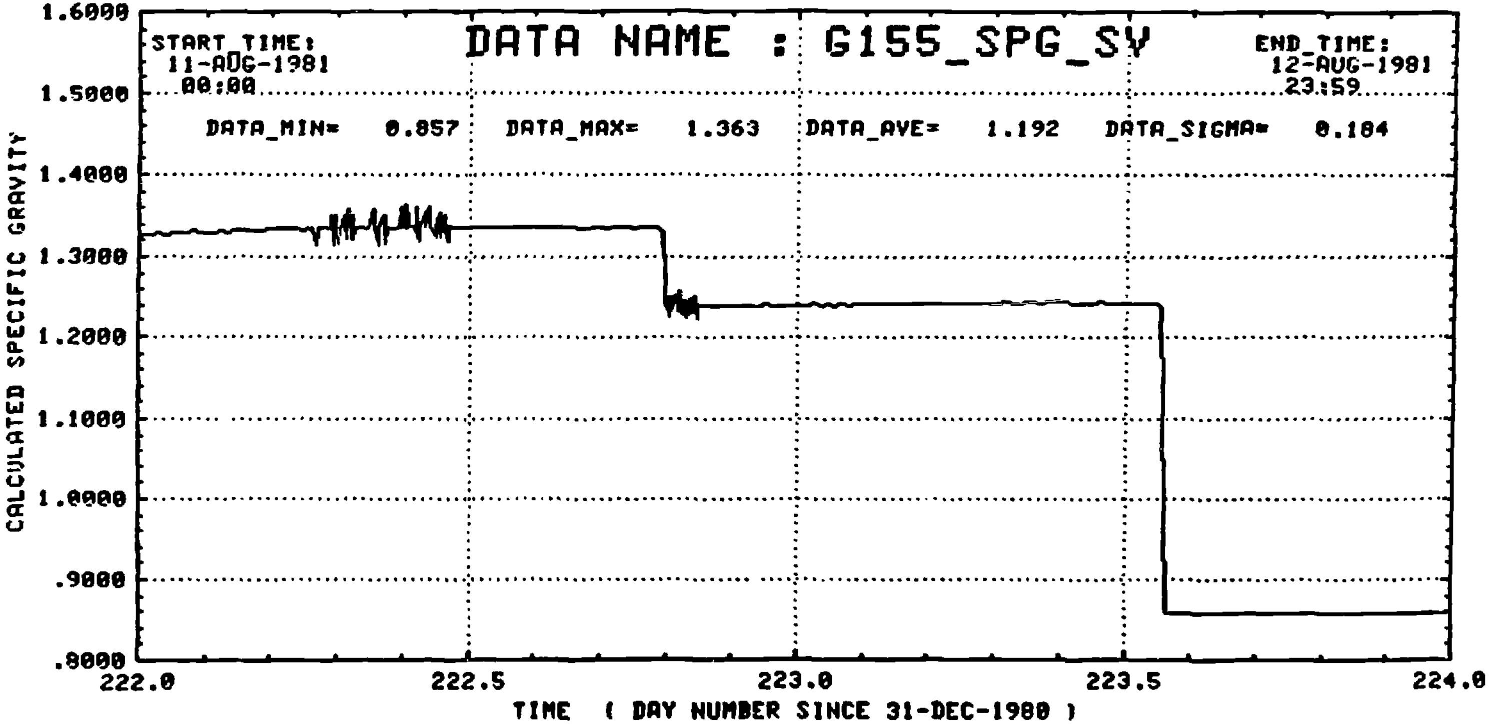


Figure 18 Typical SPG Plot for Tank G155 During a Transfer

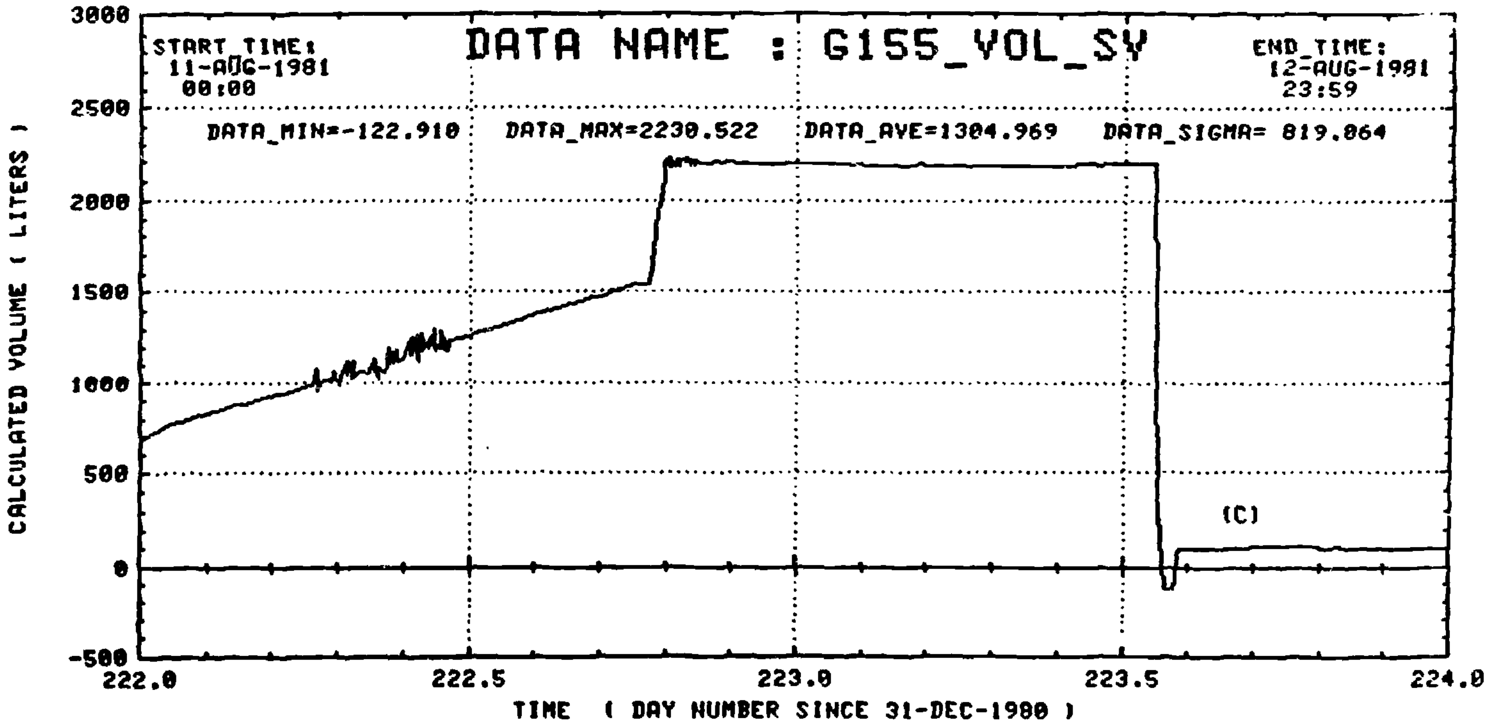


Figure 19 Typical Volume Plot for Tank G155 During a Transfer

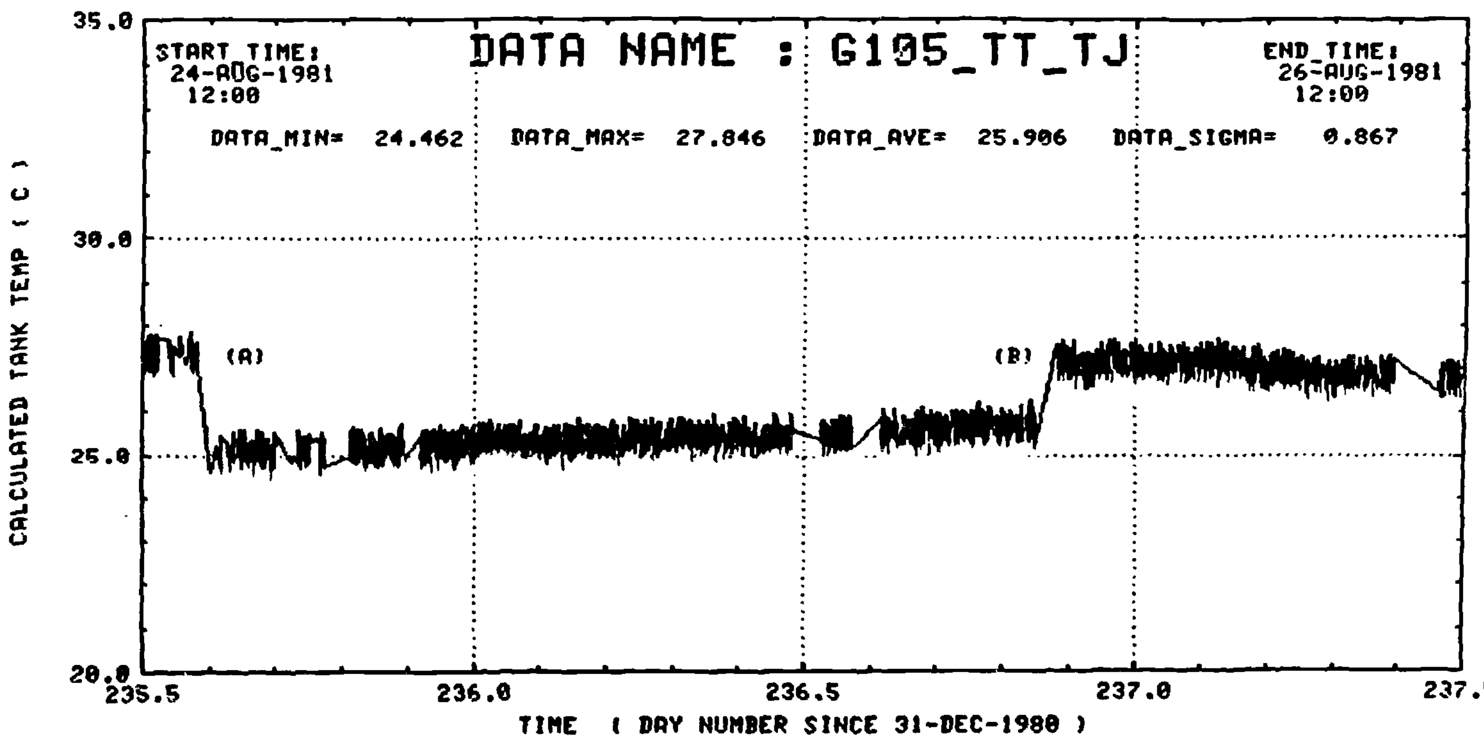


Figure 20 Measurement of Tank Liquid Temperature

5. Future of Process Monitoring - Points to be Studied

5.1 Close Cooperation Between Facility Operators and Safeguards Personnel

As has already been mentioned in 4.2, one of the main features of process monitoring is that it makes great use of process instrumentation which is installed by facility operators. Some results of process monitoring tests, such as TASTEX Task I, show that process monitoring can "benefit both plant operators and safeguards personnel without hampering operations".

Several benefits are shown as follows:

- Decrease the time for recording plant data;
- Automated data collection;
- Simplify data logging and report preparation;
- Minimize errors in data handling;
- Validate results by cross comparison of data;
- Detect tampering or instrument failures.

In general, facility operators will not always be cooperative in applying safeguards (e.g., installing conventional materials accountancy or C-S instruments) which keep watchful eyes on them and do not contribute to improved operation. On the contrary, a process monitoring system, which has the benefits mentioned above, can be installed and demonstrated rather smoothly in cooperation with facility operators. Therefore close consultation and cooperation between the safeguards inspectorate and the facility operators (and the State) from an early stage in the design of a facility are essential in applying process monitoring.

For example, both sides should arrange:

- amounts and kinds of minimum but necessary instruments to be installed in the process (some instruments will be installed by facility operators for process control and some additionally installed by safeguards inspectorate for safeguards purposes).

- frequency which inspectors should access to process instrumentation (i.e. to sensitive information) in order to get necessary information;

- kinds of extra computer system software which should be needed for safeguards purposes.

5.2 *Strategic and Selective Use of Process Monitoring coupled with Near-Real-Time Materials Accounting*

As mentioned in 4.3, process monitoring might be used as corroborative evidence in support of an n.r.t. accountancy. Taking into account the complementary and supportive roles, and the status that R & D of n.r.t. accountancy has been far more intensively implemented, than process monitoring, a limited application of process monitoring which should undoubtedly be used together with n.r.t. accountancy will also be necessary to be studied further. The monitoring point should be limited to the most logical plutonium source that are also of importance in relation to n.r.t. accountancy.

The most logical plutonium source that is mentioned in the STR-140, is as follows:

First Priority

- product accountability tank;
- evaporator immediately preceding the product accountancy measurement.

Second Priority

- one of the buffer storage tanks especially one of the latter, where purification is almost complete.

Third Priority

- aqueous product output from one of the solvent extraction systems, etc.

(See 3.1 for the fifteen most important monitoring points).

5.3 Sophisticated Computer and Instrument Control Technologies

In order to overcome one of the basic problems mentioned in 4.2.b, complexity of data authentication, process monitoring system should be so sophisticated as to provide higher levels of verification and tamper-proofing to ensure the integrity of the safeguards information.

Four categories of the technologies to increase assurance that the containment and surveillance has not been compromised are as follows:

- Process monitoring should have some self-protection features which limit access to equipment and programmes;

- Independent instrument calibrations and data checks confirm hardware integrity.

- Redundant measurements allows independent checks on the collected process data.

- Retailed signal analysis provides additional assurance that the data are not being compromised.

ANNEX 1

A Brief Description of Advanced Safeguards Approaches
Proposed by the Four States

(Report of Sub-Group IV to the IWG-RPS)

The four proposals present a graded spectrum with regard to the relative emphasis placed on containment and surveillance, conventional materials accountancy, advanced or near-real-time materials accountancy, or process monitoring.*

a. The French approach places a heavy reliance on containment and surveillance for detection of diversion along defined credible diversion paths and surveillance of the containment itself. Conventional materials accountancy is used, but is of importance primarily with regard to input and output quantities (continuous flow verification).

b. The U.K. approach similarly places primary reliance on a complete system of containment and surveillance to satisfy IAEA abrupt diversion goals, but combines containment and surveillance with conventional materials accountancy to provide a quantifiable assurance against protracted diversion of small quantities.

c. The Japanese approach places approximately equal reliance on systems of near-real-time materials accountancy and containment and surveillance, both conventional and extended. IAEA goals would be satisfied through a quantifiable assurance derived from the system as a whole. Contrary to the system proposed by the U.K., this quantification is not derived from a combination of separate materials accountancy and C-S quantified assurances.

d. The U.S. approach also combines near-real-time materials accountancy with conventional and extended containment and surveillance, but assumes that quantification of assurance would be derived primarily from accountancy data. The possible use of process monitoring techniques to improve containment and surveillance is also recognized.

B. France [10,11,35,49]

The French design is based largely on improved containment measures. The approach emphasizes that the radioactive nature of plutonium in its pure state and when it is mixed with fission products produces considerable restrictions

* Although "process monitoring" is referred to in some of the national proposals, it was not examined by IWG-RPS/sub IV, and is not discussed in this report.

Elements of the Approaches

Element	France	U.K.	Japan	U.S.A.
Conv. MA	yes	yes	yes	yes
NRTA	no	no	yes	yes
Extended C/S	yes	yes	yes	yes
Process Monitoring	no	no	no	possibly
Quantification of NRTA	-	-	yes	yes
Quantification of C/S	no	yes	yes	possibly

The Approach Proposed by the U.S.A.
(Report of Sub-Group IV to the IWG-RPS)

E. United States of America [1,4,14,15,32,55]

The IAEA safeguards goals are assumed to be those described in III.A. The United States is investigating an approach involving five different types of elements for IAEA safeguards at reprocessing plants. In general, the proposed approach involves all five of these elements with the extent and complexity of each element expected to depend upon the size and other specifics of the particular facility. The United States believes, however, that it is not yet possible to reach conclusions as to how effective any safeguards system will be that involves the more advanced and as yet not fully demonstrated elements.

The five elements in the approach consist of two material accountancy elements and three containment and surveillance elements. While these are listed here as separate elements, they are assumed to be highly complementary and, frequently, highly interrelated.

4. Process monitoring. This is a form of surveillance in which a number of process operating parameters, relevant to the locations, concentrations, and flows of nuclear material within the process MBA, are measured and compared with expected values of these parameters in order to detect potential diversion via those diversion paths that would involve deviations of these parametes from their expected values.

The exact role of *process monitoring* has not been defined; however, work is underway to determine the capabilities and feasibility of this technique.

Process monitoring requires collection of data from various sources and comparison of the data with expected values of process parameters. Therefore, on-line data processing will be required; however, to the extent that small portions of the process can be monitored independently, compact modular data collection systems may be applicable. Data will be acquired mainly from existing process instrumentation.

The assurance provided by process monitoring has not yet been quantified.

ANNEX 3

The Description of Process Monitoring

(Overview Report of the IWG-RPS)

IV-1.2 Description of Process Monitoring

The Group has defined process monitoring for safeguards purposes as an extended containment and surveillance measure that uses selected process control data and other information about the status of the process and of process equipment in order to detect conditions of nuclear material location and of process operations that might indicate diversion. Development and testing of process monitoring was a part of TASTEX and is underway at the Barnwell Nuclear Fuel Plant and at the Oak Ridge National Laboratory.

Process monitoring is not a materials accountancy measure; it does not involve the determination of physical or book inventories. However, the monitoring of parameters such as liquid levels, densities and nuclear material concentrations may be included. The Group have not studied this concept in any detail. In the flow follow-up method of process monitoring selected processing steps would be monitored to confirm that they are operating normally. For batch transfers, instrument readings of volume, density, weight, etc. are recorded each time a transfer is made from one processing step to the next. For both batch and continuous transfers, vessels in sequence are continuously monitored, for example, using electromanometers. The data are analyzed to determine the consistency of changes in volume, weight, quantity, etc. at a selected step in the process with the changes at the next part of the process.

The flow follow-up method is being applied by inspectors at a reprocessing plant and is being evaluated.[1] Experiments at the PNC Tokai plant in Japan under the TASTEX programme successfully demonstrated the potential use of electromanometers in the input accountancy tanks and in the product area.

ANNEX 4

Process Monitoring for Reprocessing Plant Safeguards -
A Summary Review (main part)

2. A PROPOSED DEFINITION OF PROCESS MONITORING FOR INTERNATIONAL SAFEGUARDS

The expression "process monitoring" is widely used in the safeguards literature to denote some safeguards-related functional capability derived from information about process materials and/or equipment. In nearly every case, the "process data" are presumed to be available on a continuous (or nearly continuous) basis via a computerized data acquisition system. The traditional functional capabilities supported by process monitoring generally range from simple alarms for "out-of-limit" parameters to sophisticated automatic process control schemes. These functions are operator oriented and are usually incorporated into the process operations. The safeguards functions supported by process monitoring are dependent on whether the application is for domestic safeguards or international safeguards. Although a general definition of process monitoring has not been accepted, some basic considerations that would likely be incorporated are:

- Acquisition of data from sensors installed in a process environment that indicates directly or indirectly conditions of process materials and equipment.
- Operations on that process data with analysis systems to generate appropriate parametric tests.
- Provision of response criteria that are consistent with stated functional objectives.

If the definition were specifically directed for international safeguards applications, some additional considerations would likely be incorporated:

- A containment/surveillance concept (C/S) is followed in which continuous and direct access to "selected process data" is provided to the inspector.
- The process data are used to generate records and parametric test results that are available to the facility operator and the state but are secured so that modifications can be made only by the international inspector.
- The records and test results are used by the inspector for specified functional objectives.

A definition incorporating the previous features is consistent with the definition proposed by the International Working Group for Reprocessing Plant Safeguards in its final report to the IAEA.

3. BASIC ELEMENTS OF A PROCESS MONITORING CONCEPT

To provide a framework within which process monitoring publications can be compared and contrasted, it is necessary that certain key features or basic elements of a process monitoring system be identified. As a preparatory effort in developing a generic process monitoring concept for IAEA application in reprocessing plants, several basic elements have been proposed for detailed consideration. A brief description will be given for each of the following basic elements of process monitoring:

- Functional objectives.
- Logic structure and test parameters.
- Data requirements, characteristics, and acquisition.
- Performance criteria.
- Alarms, alarm resolution, and response.
- Hardware: sensors and data processing.
- Vulnerabilities, tamper resistance, verification.
- Resource requirements.

3.1 FUNCTIONAL OBJECTIVES

Careful consideration must be given to clearly defining the functional objectives of the process monitoring activity. The principal issue results from fundamental differences between applications in support of domestic safeguards versus international safeguards. For domestic applications, the monitoring activity may be active (i.e., with potential for intervention in process operations) or passive. For international applications, only passive functions are acceptable. Because the objective of Task C.59 is to develop a process monitoring concept appropriate for international application, only passive functions will be included. Most international functions for process monitoring are often described as C/S measures for verification of materials accountancy data. Functional objectives for detection of loss or unauthorized use are also investigated.

3.2 LOGIC STRUCTURE AND TEST PARAMETERS

The process monitoring logic structure is very closely associated with the functional objectives. The logic structure defines the type of information and analyses required to achieve the functional objectives, and test parameters are formulated that permit quantification of the logic structure. For example, if a functional objective is to verify that all materials transferred into and out of the material balance area do pass through a key measurement point, then the logic structure may be to monitor for spurious changes in solution volumes in process equipment that are not associated with declared batch additions. The test parameter may be a volume inventory difference calculated for process vessels in the balance area.

3.3 DATA REQUIREMENTS, CHARACTERISTICS, AND ACQUISITION

If the logic structure has been developed and the test parameters have been defined, the next major elements to consider are what are the data requirements, what are the characteristics of the data, and how are the data accessed from the process system. The needed information can be obtained in some cases from data process control instruments installed, operated, and maintained by the facility operator. These data may be in analog form or in binary form. Data may also be obtained from dedicated instruments installed for safeguards purposes. Analytic data may also be available and used for samples of process material that have been submitted to the operator's analytic laboratory or for which analytic determinations have been made by the inspector. The characteristics of all the data obtained for process monitoring will be important. The precision and accuracy of instrumentation as well as variances introduced by process noise determine the capabilities achievable with process monitoring tests. It is necessary, therefore, that assessments be made of variances associated with the data used for process monitoring. Another important data consideration is that computerized data acquisition will almost certainly be required for viable process monitoring concepts. Attention must be given to the timing and frequency of data acquisition. The sequence in which instruments are read by the computer can be important. The archival techniques used must allow efficient recall of information for safeguards analysis.

3.4 PERFORMANCE CRITERIA

Another major element of process monitoring is the performance criteria to be used for process monitoring tests. Clearly, the specific performance criteria will be dependent upon the functional objectives and the particular test formulation. However, the criteria will necessarily reflect some basic safeguards loss-detection criteria related to goal quantities of nuclear material. For example, IAEA has "as a goal" the detection of losses of 8 kg of plutonium within "a few days." Any process monitoring test can be structured so that the test parameter relates directly or indirectly to that goal. Frequently, the goal must be translated into some parameter (i.e., solution volumes or flow rate discrepancy) that permits a comparative test.

3.5 ALARMS, ALARM RESOLUTION, AND RESPONSE

Once the process monitoring performance criteria have been established and the characteristics of the process data are known, one can begin to address the questions of process monitoring alarms, the resolution techniques appropriate for those alarms, and the response activities associated with failure to resolve alarms. An important but often overlooked aspect of the alarm and alarm resolution activity is the mode of presentation of those alarms to the inspector.

3.6 HARDWARE: SENSORS AND DATA PROCESSING

Another major element of a process monitoring system is the sensors and data processing hardware. It is likely that all process sensors used for international process monitoring applications will be installed, operated, and maintained by the operator. This does not preclude specialized monitoring instruments that would be provided by the inspector but perhaps installed and maintained by the operator under inspector observation. These types of instruments will not have any active capabilities relative to the process, and the operator will have full access to the monitoring data from these instruments.

3.7 VULNERABILITIES, TAMPER RESISTANCE, VERIFICATION

The next major element of the process monitoring system concerns the vulnerabilities of the system, the tamper-resistance features that are appropriate for the process monitoring equipment, and the methods of verification of process monitoring data. Because the process monitoring system is intimately connected with the operator's data acquisition system, one of the most significant and obvious vulnerabilities is a situation in which the access to that process data is interrupted by deliberate operator actions or other similar situations. One might also expect that the process monitoring capabilities could be compromised by conditions that increase the noise aspect of the data and, thereby, limit the monitoring sensitivity. Also, consideration must be given to calibration changes that occur normally for process equipment and process instrumentation. Provisions must be made to either recalibrate or compensate for the calibration changes in terms of performance criteria and alarms. Also, one must consider as a vulnerability the opportunity for an unusual process operation that would defeat the logic associated with certain process monitoring tests.

In spite of these vulnerabilities, process monitoring does afford some opportunities for tamper resistance. Clearly, by providing real-time data access and subsequent protected archiving of that real-time data, limited opportunities occur for operator modifications of the data. Furthermore, by having secured software and hardware for data analysis, the inspector will be able to maintain confidence that the analysis software has not been compromised. Also, there is an inherent tamper resistance with process monitoring because the data used in the monitoring are coupled to other data in a sequential process operation, and this coupling permits some consistency checks that will, in essence, substantiate the data quality. Attempts to compromise any one data point would necessarily require the compromising of successive data points to avoid having a data anomaly occur in the process analysis.

Another verification concept for the data used in process monitoring would be afforded by comparison of process data with sample analysis. Also, the limited use of duplicate sensors dedicated to inspectors at specific process key measurement points would permit continuous comparisons with the process sensors. These inspector-dedicated monitors would be nonintrusive into the process and have no active interface with the process or the process material.

3.8 RESOURCE REQUIREMENTS

The final major element of a process monitoring system is the resource requirements associated with implementing that monitoring system. The description of the resource must be expressed in terms of equipment, manpower, and associated support capabilities. Consideration must also be given to the distribution of resource requirements between the facility operator, the state system, and the international inspector and support organization.

The preceding basic elements of the process monitoring system do not constitute an exclusive set of elements, but rather they provide a set of elements that define a framework within which process monitoring concept proposals can be described and evaluated.

5. SUMMARY

There is almost universal recognition of the potential usefulness of data from the process for international safeguards whether the data are from operator control instrumentation or from specialized instrumentation. The precise nature of the functional objectives and the mechanisms and logic structure by which those objectives are implemented are not fully defined in any particular application. Table 5.1 shows the major efforts and the basic elements of a total process monitoring application that was addressed by specific programs. Furthermore, there is very little practical experience that will permit generalized statements about the quality of process data relative to the safeguards application. Consequently, there has been very little effort associated with alarm definition, methodologies for resolving alarms, and evaluations of resource requirements associated with implementing a fully developed process monitoring system.

This document is to summarize only those few practical attempts to demonstrate process monitoring for safeguards. It should be noted that process monitoring requires extensive computerized plant data acquisition capabilities. This capability does not yet exist in many operating facilities. As process monitoring for safeguards matures, each of the basic elements identified in this report should be addressed. Potentials of process monitoring for safeguards and its role in international safeguards are only beginning to be developed.

Table 5.1. Basic elements of a process monitoring application addressed by major programs

	Functional objectives defined	Logic structure test parameters	Data requirements characteristics acquisition	Performance criteria	Alarms resolution, reporting	Vulnerabilities	Resource requirements
INEL		X	X			X	
TASTEX	X	X	X			X	
JASPAS	X	X	X		X	X	
AGNS	X		X	X			
ORNL	X	X			X		
USNRC	X	X	X	X	X		
IAEA				X		X	

ANNEX 5

An Article on Process Monitoring Presented at
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DEMONSTRATIONS OF SAFEGUARDS PROCESS MONITORING SENSITIVITIES

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Can process monitoring information be incorporated into safeguards tests? What level of sensitivity to removals of materials can be achieved with process monitoring tests? These questions are being answered by a series of tests in U.S. facilities. These tests involve full-scale facilities that simulate operating reprocessing plant conditions with natural or depleted uranium solutions as surrogate feed materials. Safeguards systems are in place to detect loss or unauthorized removals of solutions. As part of the tests, actual removals of material from the operating facilities are made. Removals have ranged from several kilograms down to a few hundred grams of uranium. For purposes of the tests, uranium is considered to be plutonium and is the focus of safeguards concerns.

Initial tests were conducted in 1980 to 1981 at the now closed Barnwell Nuclear Fuel Plant in Barnwell, South Carolina. During these tests, the plutonium purification portion of the facility was isolated from the rest of the facility and operated on a closed cycle with natural uranium substituted as plutonium in the process. Near real time accounting and process monitoring tests were implemented. Some 27 independent removals of material were made from various points in the system. All were detected by a combination of safeguards tests.

Testing now continues at the Oak Ridge National Laboratory (ORNL) as part of the Department of Energy sponsored Consolidated Fuel Reprocessing Program. An Integrated Equipment Test (IET) facility is available for the tests. The IET contains full-scale reprocessing plant equipment, including feed preparation, product concentration, chemical recovery, and a single cycle of solvent extraction. Feed material is simulated by depleted uranium solutions. Solvent extraction functions can be distributed to a pulsed column or centrifugal contactors.

The focus of attention for safeguards demonstrations in the IET facility has been process monitoring. The IET facility features state-of-the-art computer interfaces for automated process control and information archival. The process control safeguards system is superimposed on the control system to demonstrate capabilities for advanced plants.

*Operated by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy.

As with the Barnwell tests, tests in the IET facility have included actual removals of material from various process equipment during operation of the facility. These removals have also ranged from several kilograms to less than 200 g of product material. All have been detectable with the installed safeguards system.

The ORNL tests have focused on the sensitivities achievable with process monitoring techniques. Consideration has also been given to data characterization, false alarm rate experiences, and the verification considerations inherent in the use of process data for safeguards evaluation. This paper discusses the results of tests at both Barnwell and Oak Ridge. It concentrates on the findings of tests in the IET at Oak Ridge, being representative of capabilities for state-of-the-art computer based safeguards systems which should be typical of future facilities.

ANNEX 6

References

[1] "Evaluation of Different Approaches to Advanced Systems for Safeguarding Reprocessing Facilities", Report of Sub-Group IV to the International Working Group - Reprocessing Plant Safeguards, October 1981.

[2] Voss, F., Gupta, D., "Preliminary Comparative Assessment of Advanced Safeguards Approaches for Reprocessing Facilities", Proceedings of the 2nd Annual Symposium on Safeguards and Nuclear Materials Management, ESARDA, pp. 246-251, March 1980.

[3] International Working Group on Reprocessing Plant Safeguards, "Overview Report to the Director General of the IAEA", September 1981.

[4] Kerr, H.T., Ehinger, M.H., Wachter, J.W., Hebble, T.L. "Process Monitoring for Reprocessing Plant Safeguards - A Summary Review", Oak Ridge National Laboratory ORNL/TM-10151, ISPO-255, October 1986.

[5] Ehinger, M.H., Wachter, J.W. "Demonstrations of Safeguards Process Monitoring Sensitivities", IAEA-SM-293-131, Extended Synopses, International Symposium on Nuclear Material Safeguards, Vienna, 10-14 November 1986.

[6] "Reprocessing, Plutonium Handling, Recycles", Report of INFCE Working Group 4, 1980.

[7] Sukhoruchkin, V. "Safeguarding of Reprocessing Facilities", IAEA report STR-77, January 1979.

[8] International Working Group on Reprocessing Plant Safeguards Topic 2, "Flow Monitoring and In-Process Inventory Measurement Procedures and Techniques", August 1981.

[9] Lovett, J., Ikawa, K., Tsutsumi, M., Sawahata, T. "An Advanced Safeguards Approach for a model 200 t/a Reprocessing Facility, Part I, Description and Discussion", IAEA report STR-140, October 1983.

[10] Marsh, R.D., Foulkes, R.W., "The Design of Safeguards Systems for Commercial Plutonium Processing Plants", IAEA-SM-293/24, International Symposium on Nuclear Material Safeguards, Vienna 10-14 November 1986.

[11] Kratzer, M., et al., "International Safeguards for Reprocessing Plants", ORNL, SUB-7605/11, IEAL 180, April 1981.

[12] Wachter, J.W., "Process Monitoring Concepts for Safeguards and Demonstrations at an Oak Ridge National Laboratory Test Facility", Proceedings of the 27th Annual Meeting of the Institute of Nuclear Materials Management, pp.185-189, June 1986.

[13] Harris, W.J., Johnson, C.E., "Evaluation of Process Data from Existing Reprocessing Plant Instruments shows Benefits for Safeguarding Special Nuclear Material", Proceedings of the 3rd Annual Symposium on Safeguards and Nuclear Material Management, ESARDA, pp. 313-318 May 1981.

[14] Harris, W.J., et al. "Analysis of ICPP Process Monitoring System Data Collected during August-October 1981, ENICO-1127, October 1982.

[15] Hakkila, E.A., et al. "Coordinated Safeguards for Materials Management in a Fuel Reprocessing Plant", LA.6881, Vol.I, September 1977.

[16] Hakkila, E.A., et al. "Material Management in an Internationally Safeguarded Fuels Reprocessing Plant", LA.8042, Vol.II, April 1980.

[17] "TASTEX, Tokai Advanced Safeguards Technology Exercise", IAEA publication No.213, Technical Report Series, 1982.

[18] Donelson, S.E., Glancy, J.E., Miles, J.C., "Use of Process Monitoring Data for the Enhancement of Nuclear Material Control and Accounting", NUREG/CR-1013, MLM-2643, September 1979.

* Although "process monitoring" is referred to in some of the national proposals, it was not examined by IWG-RPS/sub IV, and is not discussed in this report.

[19] Hakkila, E.A., et al. "Integrated International Safeguards Concepts for Fuel Reprocessing", LA-8955/SAND 81-1311, December 1981.

[20] Harris, W.J., Ihara, S., "Final Report for the TASTEX Task-I Product Area Monitoring System, Volume 1, System Summary", ISPO-101, July 1980.

[21] Wachter, J.W., et al., "Development of a Safeguards Data Acquisition System for the Process Monitoring of a Simulated Reprocessing Facility", Proceedings of the 27th Annual Meeting of the Institute of Nuclear Materials Management, pp.361-365, June 1986.

[22] Lovett, J.E., Hirata, M., Ikawa, K., Augustson, R.H., "Application of the Basic Concepts of Dynamic Materials Accountancy to the Tokai Spent Fuel Reprocessing Facility", IAEA report STR-94, January 1980.

[23] "Current Technical Status of Near-Real-Time Materials Accountancy", IAEA report STR-108, June 1982.

[24] "Nuclear Material Safeguards for Reprocessing, Part III: Safeguards Concepts and Approaches", IAEA report STR-152 (Draft), September 1986.