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MATERIAL CONTROL SYSTEM DESIGN: TEST BED NITRATE STORAGE AREA (TBNSA)

G. A. Clark
R. A. Da Roza
D. R. Dunn
I. J. Sacks
W. Harrison
J. G. Huebel
W. N. Ross
J. D. Salisbury
R. H. Sanborn
S. Weissenberger

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MASTER

This is an informal report intended primarily for internal or limited external distribution. The opinions and conclusions stated are those of the author and may or may not be those of the laboratory.

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DISCLAIMER

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THIS CONSTITUTES THE QUARTERLY REPORT FOR THE PERIOD OF JANUARY THROUGH APRIL, 1977.

PREFACE

This report was prepared for the U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research under research order no. 60-77-012 and under the auspices of the U.S. Energy Research and Development Administration under contract no. W-7405-ENG-48.

The contents of the report are intended to provide an example of a hypothetical Special Nuclear Material (SNM) Safeguard Material Control and Accounting (MC&A) System which will be used as a subject for the demonstration of the Lawrence Livermore Laboratory MC&A System Evaluation Methodology in January of 1978. This methodology is to become a tool in the NRC evaluation of license applicant submittals for Nuclear Fuel Cycle facilities.

The starting point for this test bed design was the Allied-General Nuclear Services - Barnwell Nuclear Fuel Plant Reprocessing plant as described in the Final Safety Analysis Report (FSAR), of August 1975. The test bed design effort was limited to providing an SNM safeguard system for the plutonium nitrate storage area of this facility for several reasons. These include:

1. The need to limit the resources expended on this non-mainstream effort of the LLL MC&A evaluation project.
2. The requirement to provide a system which protected "Attractive" target material.
3. The need to use an existing facility so as to reduce the design effort.

This test bed design is not intended either as a criticism of the AGNS Fuel Reprocessing facility or as an "exemplary design" of a good safeguard system. It is intended only as an unclassified subject for the development and test of the LLL MC&A evaluation methodology. The design has also not been reviewed in detail for cost effectiveness or for potential safety or compatibility conflicts with the operation of a reprocessing facility.

The test bed design effort was coordinated by Ivan Sacks. The major contributors to the design effort were:

William Ross - Physical Configuration
Stein Weissenberger - Material Control System Decision Logic
William Harrison - Procedure Design
Russell Sanborn - Plutonium Product Analysis
Donald Dunn - Material Estimation

PREFACE (Continued)

Gregory Clark Robert da Roza	- Instrumentation
Jack Salisbury	- Portal Control System
John Huebel	- Material Accountability System

This report was reviewed by several outside individuals. Particular thanks are due to B. M. Legler of Allied General Nuclear Services and the Professor A. Schneider of Georgia Institute of Technology for their valuable comments.

ABBREVIATIONS

A to D	Analog to Digital
AEC	Atomic Energy Commission
AGNS	Allied General Nuclear Services
AIChE	American Institute of Chemical Engineers
ANSI	American National Standards Institute
ARF	Assay Request Form
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing Materials
BNFP	Barnwell Nuclear Fuel Plant
CCAS	Computer Control Access System
CCTV	Closed Circuit Television
CF	Conversion Facility
CFR	Code of Federal Regulations
CMTF	Controlled Material Transfer Form
CRT	Cathode Ray Tube
DOE	Department of Energy
DP	Differential Pressures
DOT	Department of Transportation
ERDA	Energy Research and Development Administration
FSAR	Final Safety Analysis Report
IEEE	Institute of Electrical and Electronics Engineers
IR	Infrared
LDS	Laboratory Data System (in Analytical Laboratory)
LLL	Lawrence Livermore Laboratory
LS	Limit Switch (Valve Position Monitor)

ABBREVIATIONS (Continued)

MAA	Material Access Area
MBA	Material Balance Area
MC	Material Control
MC-1	Material Control Station-1, Security Center
MC-1,0	Material Control Station-1 Operator
MC-2	Material Control Station-2, Process Control Center
MC-2,0	Material Control Station-2 Operator, Process Operator
MC&A	Material Control and Accounting
MDL	Master Decision Logic
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
NC	Normally Closed
NMCO	Nuclear Materials Control Officer
NO	Normally Open
NRC	United States Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Act
P&I	Piping and Instrumentation
PNC	Plutonium Nitrate Storage Cell
PNC-O	Plutonium Nitrate Cell Operator
PNC1	Plutonium Nitrate Cell Number 1
PPC	Plutonium Product Cell
PPC-O	Plutonium Product Cell Operator
Q	Highest Classification of Confinement The safety-related functions of those structures, systems, and components, both active and passive, that prevent or mitigate the consequences of the health and safety of the public, i.e., those which are calculated to result in any one incident exceeding 2% of the limits set forth in 10 CFR Part 100 at the site

	boundary of the BNFP. Items defined as "Q" require the implementation of Quality Assurance Programs as set forth in Appendix B of 10 CFR Part 50.
QC	Quality Control
R&D	Research and Development
SEF	Sampling Enablement Form
SF	Storage Facility (PNC)
SFO	Storage Facility Operator (PNC-O)
SNM	Special Nuclear Material
TDR	Theft Danger Rating
ρ	Density

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1.0 DESIGN OVERVIEW

The design of test bed Material Control (TB-MC) System was undertaken to provide a subject which would allow the testing and further development of the Material Control and Accounting (MC&A) evaluation methodology being developed at the Lawrence Livermore Laboratory. The starting point for this design was the AGNS-BNFP Reprocessing plant as described in the Final Safety Analysis Report, (FSAR) of August, 1975. (Reference 1-1)

Constraints which have been internally imposed in the test bed design include:

- Plant Operations have been left manual, that is operations are not automated, but require a human to perform the actual operations.
- Almost all active decisions relating to security system response have a human as the final step. That is, no security response can occur without human concurrence. There are no automatic door locks, disabling gas releases, etc. It was felt that such automatic responses were hazardous and potentially lethal, especially in a radiation environment which could exist in an upset condition.

This section summarizes the salient features of the test-bed MC System, TB-MC, with detailed information given in the succeeding sections of the report.

1.1 DESIGN PHILOSOPHY

There is a two part philosophy underlying the TB-MC design for the nitrate storage area. The first and most important part of the design philosophy is the reduction of opportunities which could lead to removal of the SNM from the storage tank containment cells. This has been accomplished by the addition of check valves in process and instrumentation lines which pierce the containment cell walls. The only lines which are not blocked in this manner are: the product inlet line from the plutonium product cell, the product transfer line to the PuO_2 conversion facility, the rework lines, and the $Pu(NO_3)_4$ product sample lines. None of the above lines has a connector which is accessible except by physical destruction or major modification except for the sampler lines. Check valves cannot be added to the sampler lines without interferring with their function. Attempted diversion of SNM through these product sample lines will be detected through the monitoring described below and in more detail later in this document.

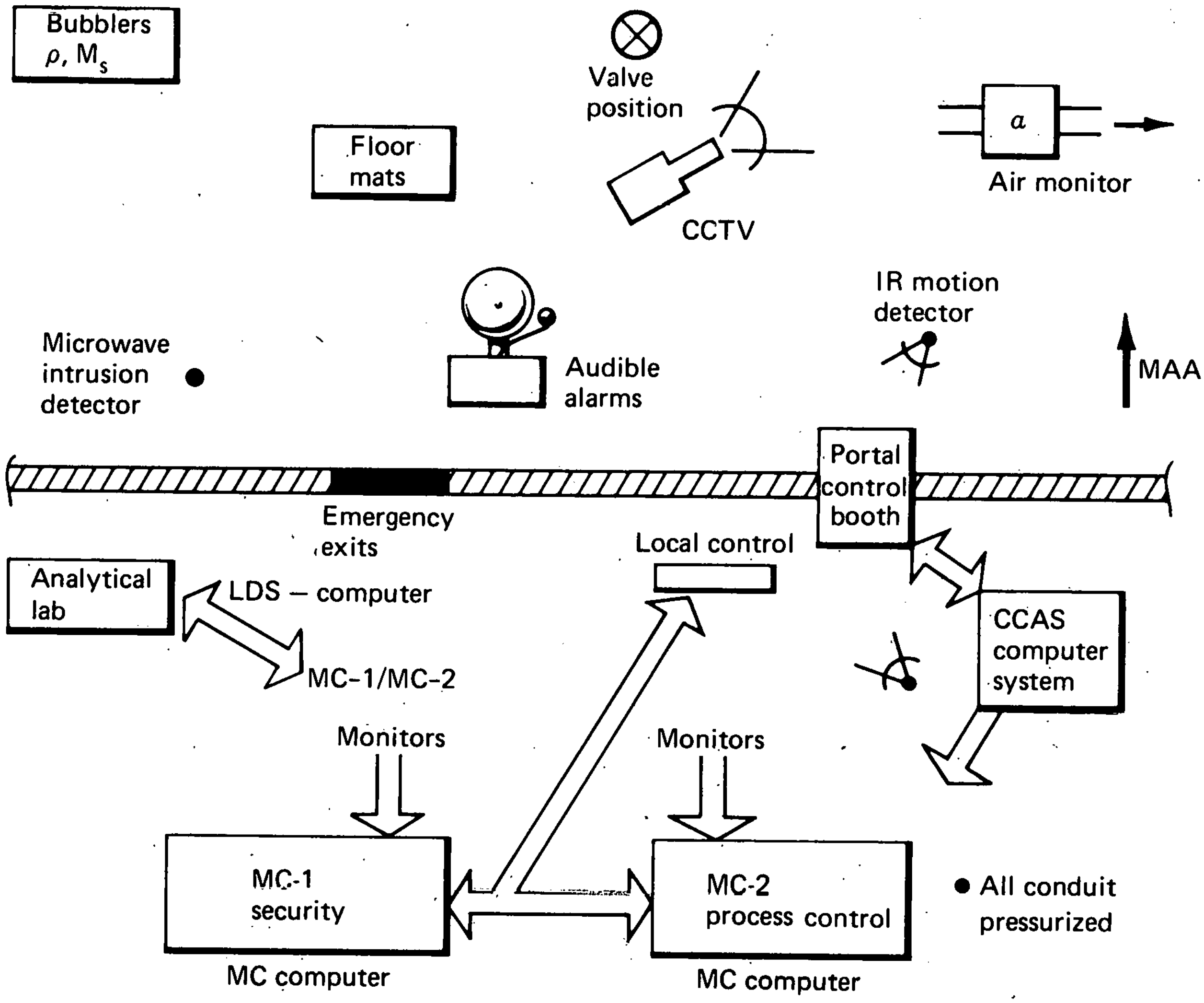
The second aspect of the design is the monitoring of all operating procedures, critical valve positions, operating environments and personnel in the material access area (MAA). Personnel access to the MAA is controlled through the use of a card entry portal booth and the automatic enforcement of a two-man rule for all operating procedures. There are no normal operating procedures in which only one individual would be allowed in the MAA. The positions of critical valves and of pump power during all operations are monitored and compared to prototype templates stored in the dual (redundant) MCS computer Systems. In addition, health physics radiation detectors monitor the exhaust air stream from the MAA and glove boxes for airborne Pu particles. Extensive CCTV monitoring with automatic motion detection (MTI) is used to verify operational procedure compliance. Compliance is also monitored by means of floor pressure mats located in strategic positions throughout the MAA. Access and egress is monitored by radiation and metal detection devices in the Portal Control Booth.

Possible negative safety implications of this design have been minimized by the provision for "unrestricted" emergency access to and egress from the MAA through both the portal control booth and emergency exits. Emergency operation brings the MCS to the highest degree of alert with guards directed to the emergency activated exits.

The MCS is shown schematically in Figure 1.1-1 and discussed in the following subsections--after a brief description of the facility.

1.2 PLANT DESCRIPTION

The plant taken as a basis for this Test Bed is the AGNS-BNFP Reprocessing facility. The Safeguard system has been limited to the Plutonium Nitrate Storage Area of this facility. A nitrate to oxide conversion plant has been added to the basic design so as to provide a receiver for the nitrate product. The facility is shown in Fig. 1.2-1. The portion of plant included in the Test Bed design is included within the heavy outline shown in the plan view of Fig. 1.2-2. The second storage cell, PNC2, has been eliminated to reduce the scope of the design effort. The other major modification made to the basic



Note: See Abbreviations Section for explanation of acronyms and abbreviations.

Figure 1.1-1 Material Control System Schematic

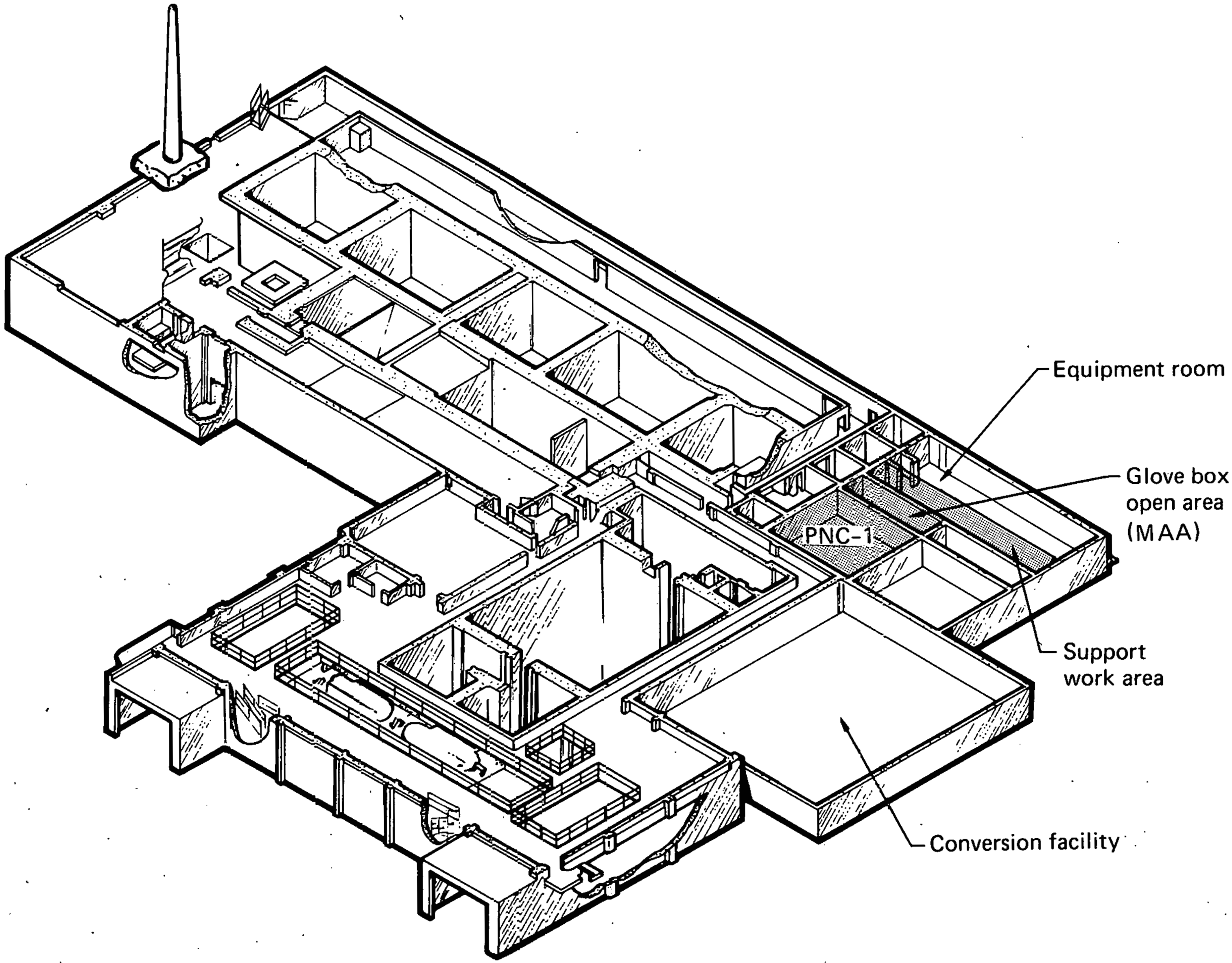


Figure 1.2-1 Modified Reprocessing Facility

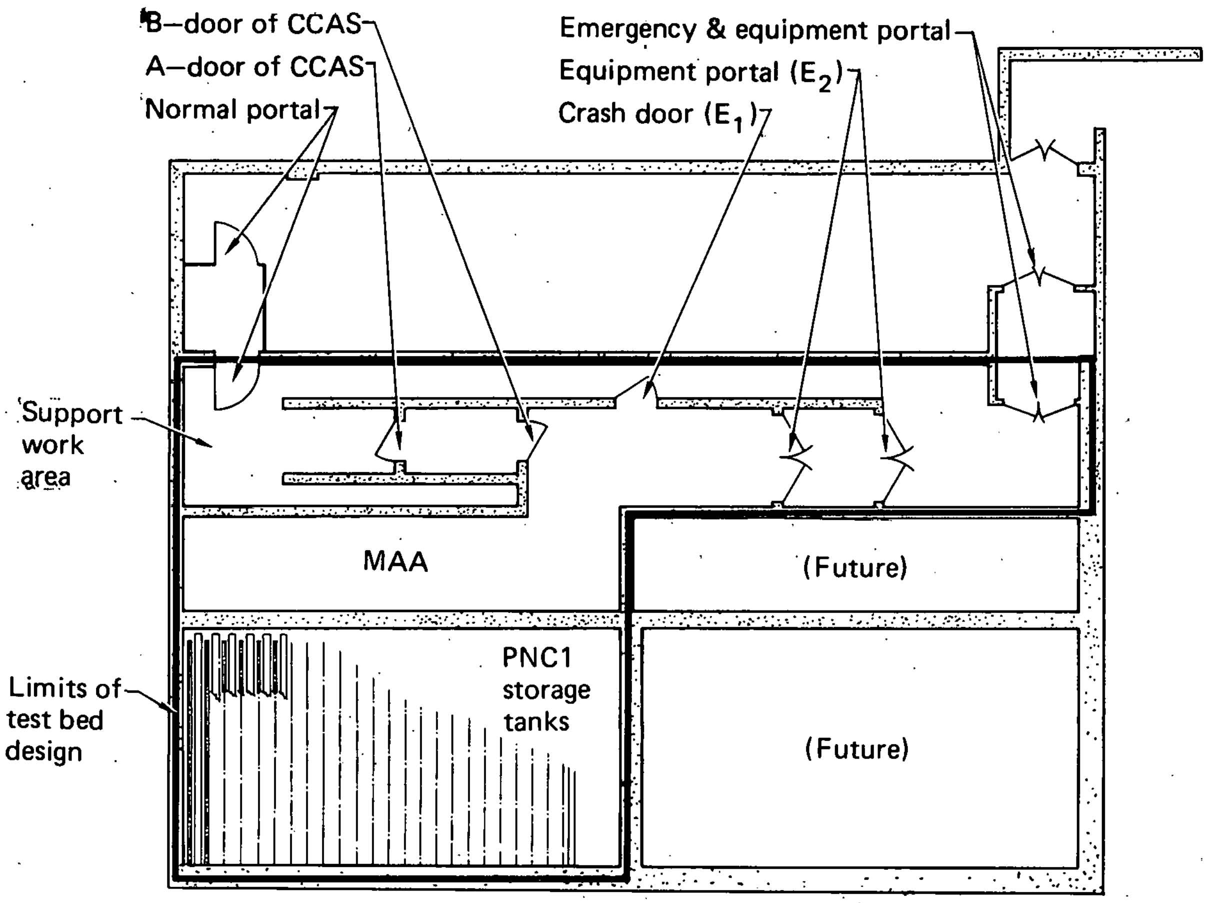


Figure 1.2-2 Plan View of Plutonium Nitrate Storage

facility design is the removal of the nitrate loadout and shipping facility made unnecessary by the addition of the oxide conversion facility (CF).

The storage area is divided into four modules of six slab storage tanks each. (Fig. 1.2-3). All four modules are within one concrete containment cell. The storage tanks are approximately twenty feet long, eight feet high, and two inches wide and are made from titanium. The containment cell is filled with these tanks and moderator slabs. There is not enough room in the containment cell for a person.

The Material Access Area (MAA) is adjacent to the storage cell. This area is used for controlling the nitrate flow into, out of, and between storage tanks and for sampling the tank contents. Valving operations and sampling operations are conducted through the use of glove boxes located at each of the three levels of the MAA. (Fig. 1.2-4). Access to the MAA is made through the Portal Control Booth and is under the supervision of the security station operator. (See Section 1.3.1)

Product for the nitrate storage area is transferred from the plutonium product cell (PPC) approximately twice a week in 730 liter batches. The product is sampled and analyzed prior to transfer.

1.3 MATERIAL CONTROL SYSTEM CONFIGURATION

The configuration of the MC system is shown schematically in Fig. 1.1-1. The basic components used in this system are briefly described in this section and described in much more detail in following sections of this report. The two basic components of the MC system are opportunity reduction and monitoring. Overall control of the MC system resides in computerized Material Control Stations with final authority retained by the Nuclear Materials Control Officer. Because of the importance of these computerized systems, they will be discussed first.

1.3.1 Material Control System Supervision

Material Control supervision resides in two independent MC stations. The first of these, MC-1, is located in the security station and is responsible for the routine monitoring of SNM contained within the plant. The second station, MC-2, is located in the Process Control Center and is responsible for the response to certain abnormal conditions. This station also provides data to the process operator on the detailed state of the process. Each

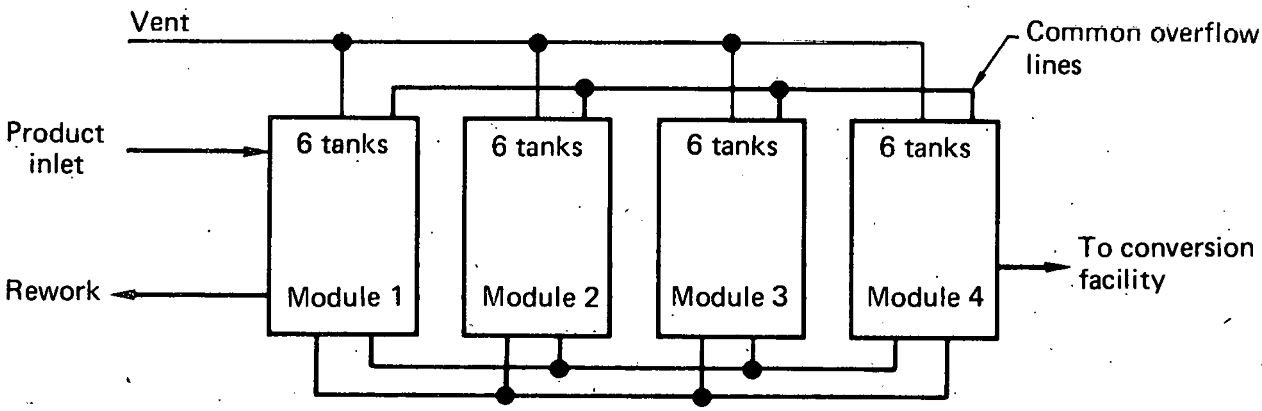


Figure 1.2-3 Storage Tank Configuration

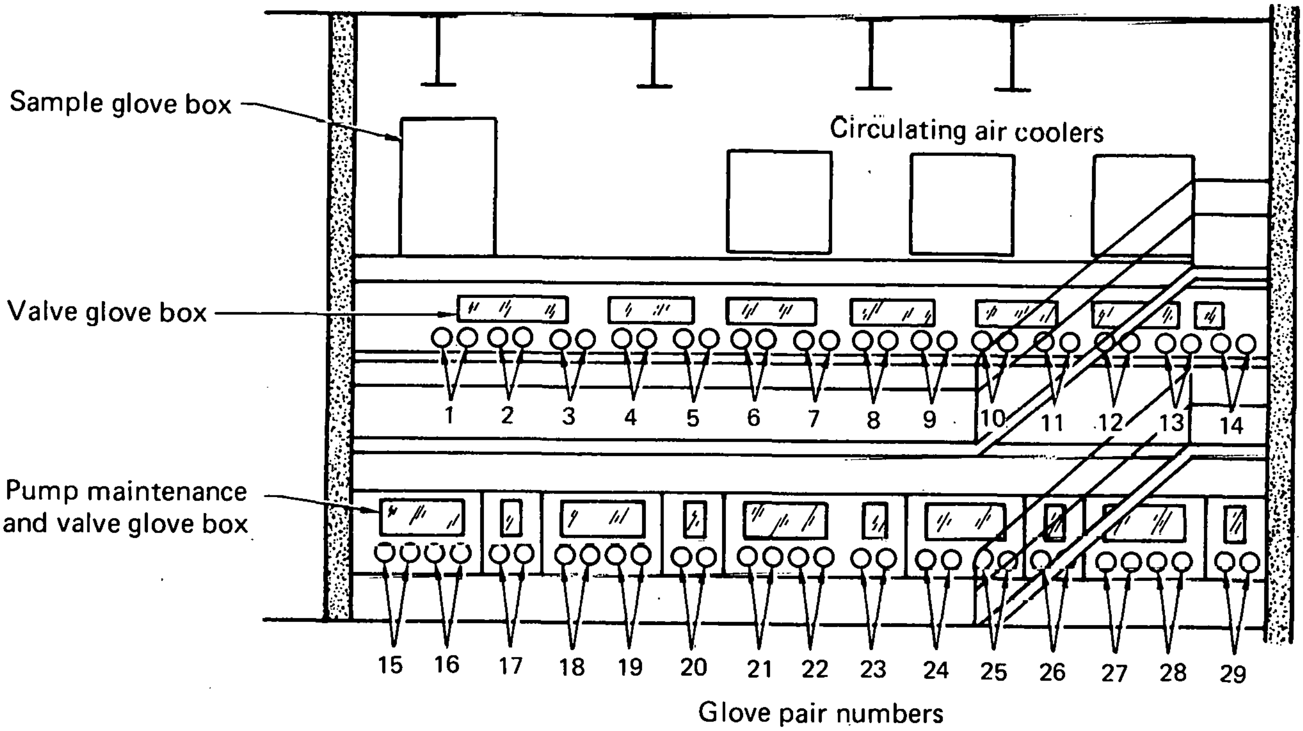


Figure 1.2-4 Glove Pair Numbers

of the MC stations has its own computer system and noninterruptable power supply. The two computer systems are interconnected and have the same data in memory. The software for the two systems is identical except for the following major differences:

- Software modifications can be made only through the MC-2 system
- Daily work rosters can be read only into the MC-2 system
- Personnel authorizations and identities can be read only into the MC-2 system
- MC-2 can reduce the intermediate level theft danger rating (with the concurrence of MC-1) whereas MC-1 cannot do this alone.

A third computer system is located in the analytic laboratory. This laboratory data system (LDS) is used to automatically record the results of all chemical and physical analyses. This system is not supplied from a noninterruptable power supply. Reduced data stored in the magnetic disk memory of the LDS is automatically duplicated in both the MC-1 and MC-2 computer systems. Data from the analytic laboratory along with continuously monitored storage tank measurements is processed in the MC computer systems to maintain a continuous inventory of the SNM in the storage area.

A fourth computer system is used to monitor and control the computer controlled access system, CCAS. This computer is located adjacent to the MC-1 station and is connected to both MC computers. This system is supplied from a noninterruptable power supply.

The Material Control System is composed of both passive and active components. The passive components are related to the reduction of the opportunity of a potential adversary to acquire SNM. The active components include: the monitoring of critical process, personnel, and plant states; the control of access to the MAA; the authorization of steps in plant operating procedures; and the determination of ongoing or past diversion of SNM.

1.3.2 Opportunity Reduction Components

In order to reduce the ability of a potential adversary to acquire SNM, the following components have been designed into the MC system and the plant physical configuration.

1.3.2.1 Flow Restriction

All potential material flow paths from the containment cells and glove boxes into the MAA have been blocked. This has been accomplished by the addition of check valves to the following piping thus preventing reverse flow out of containment:

1) Check valves in the liquid level/density bubbler system for each tank (block liquid flow).
2) Check valves in the pump flush lines (allow inward flow only).
3) Check valves in the nitric acid makeup lines (allow inward flow only).

1.3.2.2 Portal Access Restriction

All personnel entrances and exits to the MAA have been sealed. Use of these entrances is possible in emergency conditions. Opening of the exits causes two events:

- A local gas-powered audible alarm is triggered

and

- a signal is sent to the CCAS computer and to MC-1 and MC-2 computer systems.

1.3.2.3 Equipment Transport

Entry and removal from the MAA of large equipment or tools is accomplished by a special transportation team. Equipment and tools removed from the MAA are scanned with hand held radiation detectors and disassembled when possible.

1.3.2.4 Two Man Rule

A "two-man rule" is enforced for all procedures within the MAA. This rule is enforced through the MC Computer System.

1.3.3 Monitoring Components

The active portion of the MC System is composed of several components. These include:

a) Continuous Monitoring of process variables. This is accomplished through the continuous reading of the instrumentation associated with each storage tank.

b) Automated data collection from the Analytical Laboratory. The Laboratory Data System (LDS) computer collects and reduces all chemical analyses and transfers the reduced results to the MC computer system.

c) Maintenance of a continuous inventory of SNM stored within the containment cell. This is maintained by the MC Computer System and is based on the tank state information and the analytic laboratory measurements.

d) Continuous monitoring of the MAA environment.

The MAA is equipped with the following monitor devices which communicate with the MC computer System:

1.3.3.1 Pressure Sensitive Floor Mats

The entire floor of all levels of the MAA are so equipped.

1.3.3.2 Microwave Intrusion Detectors

Critical Areas in the MAA are monitored.

1.3.3.3 Airborne Pu Detection

An air sampling system monitors approximately 10% of the air flow through the MAA.

1.3.3.4 Closed Circuit Television (CCTV)

Closed Circuit television cameras are mounted at strategic locations in the MAA. The outputs from these cameras are processed by a motion detector. Detection of activity sends an alert to the MC System and activates the TV monitors.

The gloveboxes within the MAA are also equipped with monitoring devices which communicate with the MC Computer System. These include:

1.3.3.5 Glove Box Differential Pressure Detectors

These alarm on the change in the differential air pressure between the MAA and the glove box interior.

1.3.3.6 Glove Box Bag in/out Port Switches

These send signals to the MC Computer System on the detection of an open bag in/out port on the glove boxes.

The valving for the piping and instrumentation is also monitored by the use of limit switches on critical valves. This information provides the MC Computer System with information as to the tank interconnections and hence potential SNM flow paths. The air supply valves for the product sampling lines are also monitored. The ^{239}Pu concentration of product being sampled is also continuously monitored by the use of an in-line γ spectrometer. The output of this device is transmitted both to the LDS and MC Computer System.

1.3.3.7 Portal Monitoring

The normal entry to and exit from the MAA is made through the Portal Control System Booth. Use of this booth requires the use of a personal ID badge and a personal ID number. The booth, in addition, provides monitoring of the following parameters:

1.3.3.7.1 Weight of Booth Contents

This is compared to prestored personnel weights.

1.3.3.7.2 Radiation

Neutron and γ radiation levels are monitored for the indication of the presence of ^{239}Pu.

1.3.3.7.3 Ferrous and Non Ferrous Metals

These are monitored for potential shielding materials.

1.3.3.7.4 Contents of the Booth

The contents of the booth are monitored by means of a CCTV camera system.

1.3.4 Procedure Monitoring and Authorization

The MC Computer System monitors the steps in each operating procedure and alerts the MC operator if a discrepancy between the measured and authorized is detected. This is accomplished by the monitoring of floor mats, glove box ports, piping and instrumentation valve positions, and the Portal Control System Booth. The MC Computer System memory contains procedural sequences for all normal operating procedures. In addition, at the beginning of each work shift, the MC-2 operator loads the approximate time periods for each procedure to be performed that shift, along with the individuals authorized to perform them. The MC Computer System then correlates attempts at access to the MAA with those authorized and plant state with expected state. A discrepancy alerts the MC System.

1.3.5 Alert Levels

The MC System has four levels of alert called Theft Danger Ratings, TDR. The lowest of these, TDR-0 is the normal operating alert level of the plant. The next highest level, TDR-1, corresponds to a minor abnormal situation and requires only an information-gathering response from the plant MC personnel. The next higher alarm level, TDR-2, is reserved for the situation in which it appears that SNM could easily be removed from the MAA. This requires a low level security force response and an information gathering response. The highest level, TDR-3, corresponds to an MC system assessment that diversion has occurred or is occurring. The response to TDR-3 is a full security force response along with the alerting of outside agencies.

The decisions as to the alarm level are made by the MC Decision Logic.

1.3.6 MC System Operator Responsibilities

There are three levels of responsibility in the MC System chain of command. These are:

- The MC-1 operator - responsible for normal plant operation. The MC-1 operator can reduce (autonomously) a TDR-1 to TDR-0.
- The MC-2 operator - in the process control center. This individual loads the work rosters and program changes. Reduction of a TDR-2 alert level (requires both MC-2 operator and MC-1 operator concurrence).
- Nuclear Materials Control Officer (NMCO) - generally not involved in MC <u>operations</u>. The NMCO is responsible for the reduction of a TDR-3 alarm level (requires MC-1, MC-2 operator concurrence). Further description of the function of the NMCO is given in Section 7.4.

References for Section 1

1-1 Barnwell Nuclear Fuel Plant, Separations Facility, Final Safety Analysis Report, Allied-General Nuclear Services, Barnwell, S.C.

2.0 PHYSICAL CONFIGURATION

A plutonium nitrate storage area, similar to PCN1 of the AGNS Barnwell Nuclear Fuel Plant has been selected as the area for the test bed design. This test bed facility follows the general configuration of the AGNS plant but differs from it in detail. In general, the differences reflect an attempt to provide a detailed material control system as a subject for the LLL developed MC&A* evaluation technique. This discussion is based on Reference 2-1.

The test bed storage facility is designed for storage of $Pu(NO_3)_4$ at a nominal concentration of 250 g/l. The facility is sized to provide secure storage for approximately 90 operating days product of plutonium nitrate solution between the plutonium processing cell (PPC) on the upstream side and the conversion facility (CF) on the downstream side.

It must be emphasized again, that the design, although based on the AGNS-BNFP design, is not a detailed operational design, or even an "exemplary design" and must also not be taken as a critique of the AGNS design.

2.1 BUILDING DESCRIPTION**

The plutonium nitrate storage facility consists of a structure of reinforced concrete approximately 64 feet wide, 82 feet long, and 28 feet high. It is located contiguous to both the processing facility and the conversion facility as shown in Fig. 2.1-1. Figures 2.1-2 and 2.1-3 provide plan and elevation views of the region of the test bed design. The Material Control System Test Bed Design is restricted to the areas outlined by the heavy boundary on Figs. 2.1-2 and 2.1-3.

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*MC&A - Material Control and Accounting

**This document describes the configuration for the test bed design. As such, it may deviate from the actual configuration of the AGNS facility.

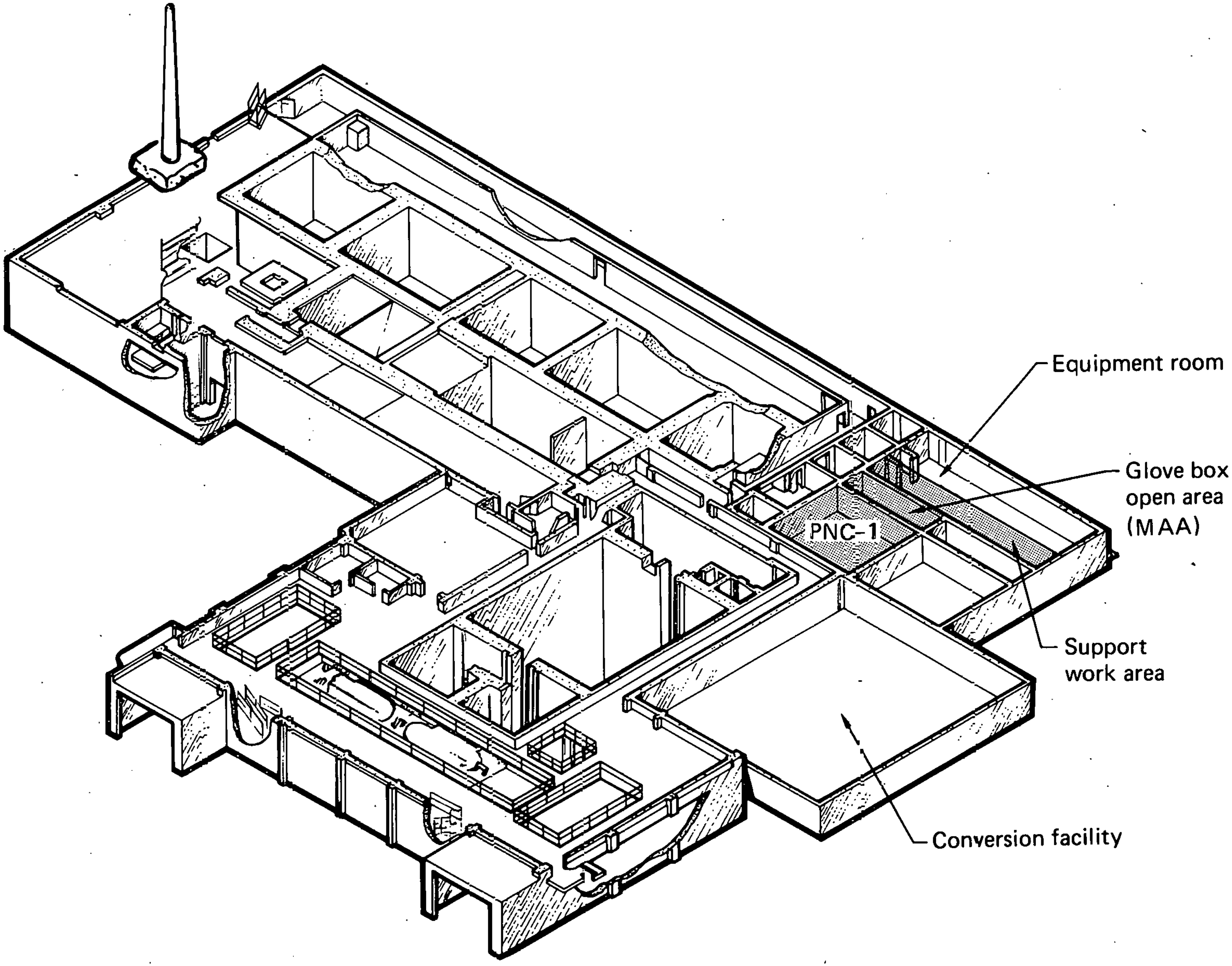


Figure 2.1-1 Reprocessing Facility

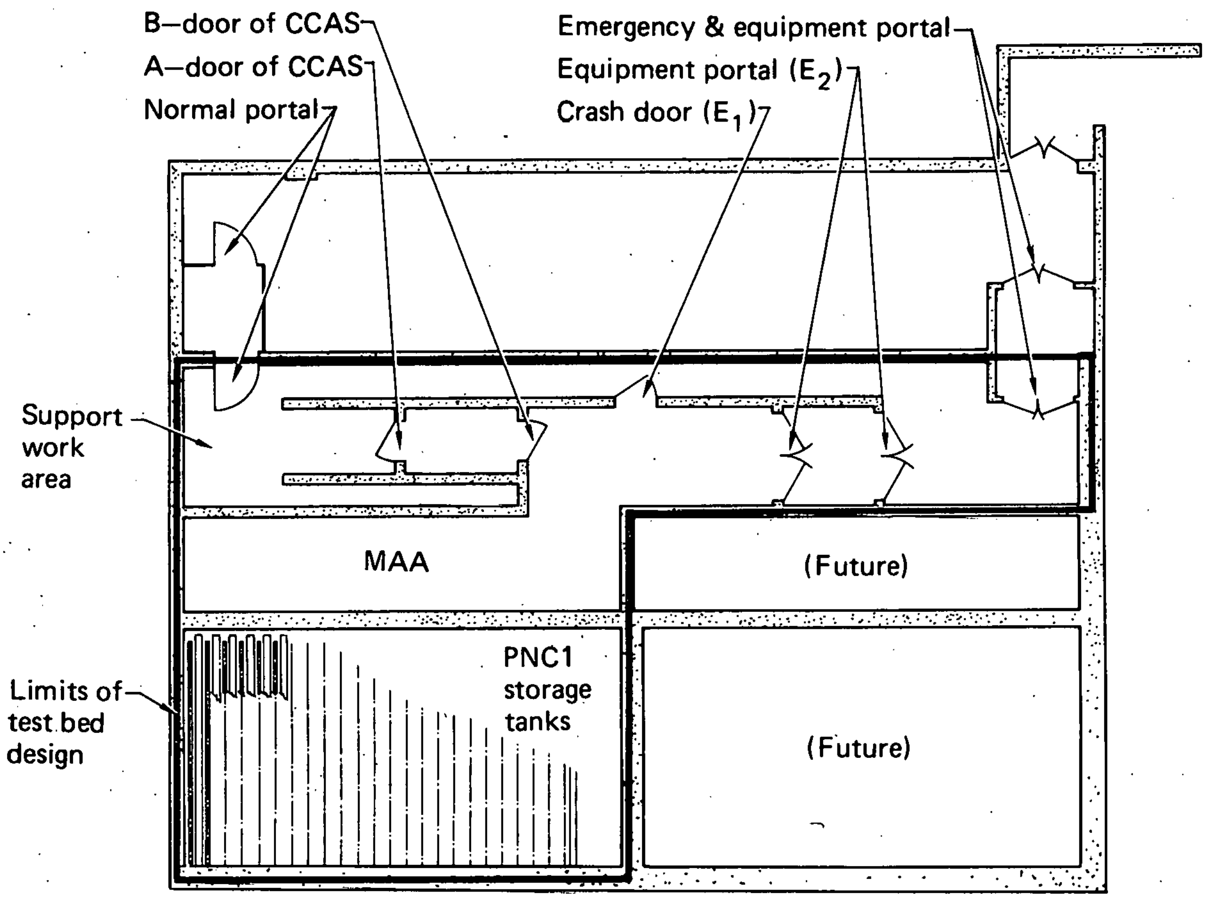
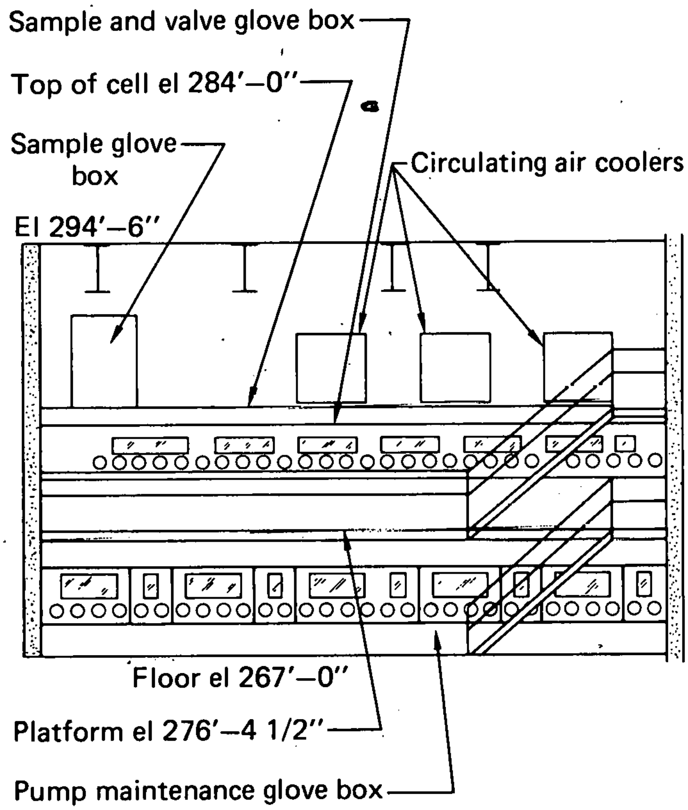
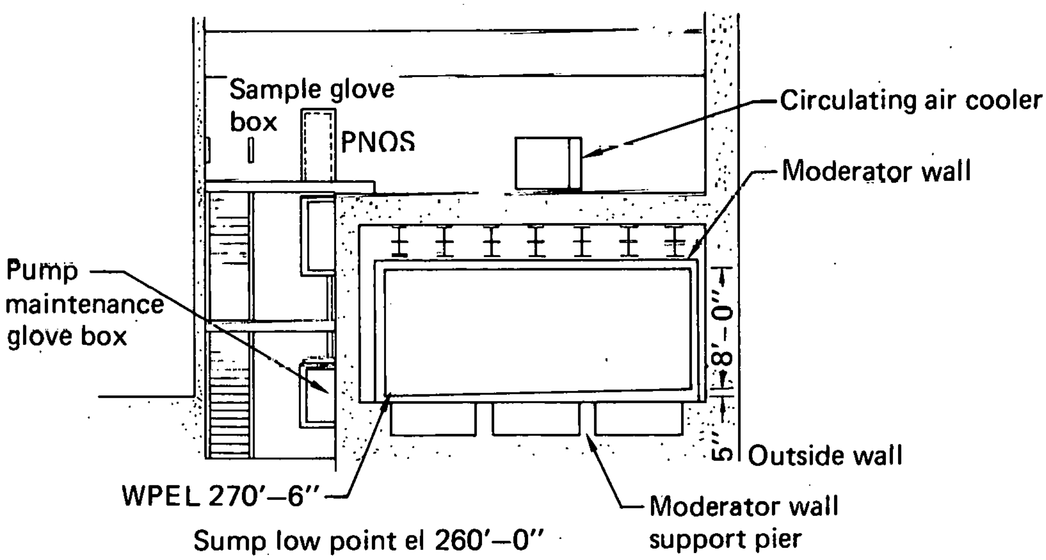


Figure 2.1-2 Plan View - Plutonium Nitrate Storage Area



Front view



Side view

Figure 2.1-3 Elevation View of Plutonium Nitrate Storage Area

2.1.1 PARTITIONS

Two-foot-thick interior walls form two cells, each 21.5 ft. x 38.3 ft. One of these cells (PNC1) is utilized for plutonium nitrate storage; the other is unused, providing space for future expansion. In addition to the cell walls, two other partitions divide the building lengthwise into areas for glove box operations, support work, and a room for mechanical equipment. A stairway provides access to a mezzanine above the storage cells where the sampling box and the air conditioning equipment are located. Figures 2.1-2 and 2.1-3 present the plan and elevation of the interior of the storage facility.

2.1.2 ACCESS TO MATERIAL ACCESS AREA

Only three doors are provided into the material access area. One in the NE corner of the equipment room for the movement of equipment, one in the NW corner of the same room for personnel entry and a third door for emergency access or egress. An airlock provides access to the support work area from the equipment area and the portal control booth connects the support work area to the glove box and mezzanine area.

Three process lines pass to the storage facility (SF) from the PPC; one to carry product in; one to permit product to be returned for rework; and one to return process off-gases to the off-gas treatment system. Only one process line leaves the SF to the conversion facility. All lines are double jacketed stainless steel as they pass through the cell walls and are free draining in their normal direction of flow.

All other penetrations of the building, (for ventilation, service piping, etc.) are adequately protected to preclude unauthorized access through these routes.

2.1.3 VENTILATION

The air flow enters the building through inlet filters into the mechanical equipment room. It passes then to the support area; thence through wall openings to the operating and mezzanine area. The glove boxes draw their air through inlet filters from the operating area. The atmosphere in the cell is drawn from the glove boxes, and recirculated through the cell and the chillers on the mezzanine to provide a controlled temperature within the cell. A small (≈10%) portion of the recirculated cell air is continuously withdrawn and passed through the airborne plutonium monitor system.

2.2 STORAGE CELL DESCRIPTION

The cell is a Q designed area which contains 24 storage tanks separated from each other and the end walls by moderator slabs. The spacing of the tanks and slabs is shown in Fig. 2.2-1. The floor of the cell is lined with stainless steel and provided with a sump designed to prevent criticality incidents in the event of a tank rupture. No provisions for man-access during regular operations is incorporated into the design of the cell.*

2.2.1 CELL WALL PENETRATIONS

Piping penetrations through the cell wall are all of stainless steel and are listed in Table 2.2.1-1.

Purpose	Size	Cell Location	Quantity	Remarks
Vent Hdr.	1"	W. wall	1	to PPC
Tank drain	1-1/2"	E. wall-low	24	into pump glove box
Tank fill	1-1/2"	E. wall-high	24	from valve glove box
Density bubbler-lo	1/4"	roof	24	to mezzanine
Density bubbler-hi	1/4"	roof	24	to mezzanine
Tank static pressure	1/4"	roof	24	to mezzanine
Tank purge	1/4"	roof	24	to mezzanine
Conduit-thermocouple	1/4"	roof	48	to mezzanine
Sump return	1"	E. wall-low	1	returns spillage
Ventilation recirc.	various	roof	10	air ducting
H_2 Analyzer inlet	1/4"	roof	1	connects to vent
H_2 Analyzer outlet	1"	roof	1	connects to vent

TABLE 2.2.1-1 Storage Cell Penetrations

*A crane-removable manhole plug is located in the roof of PNC1 near the SE corner for emergency access to the tank area. (Note: No building crane is provided so plug removal is considered a major repair incident.)

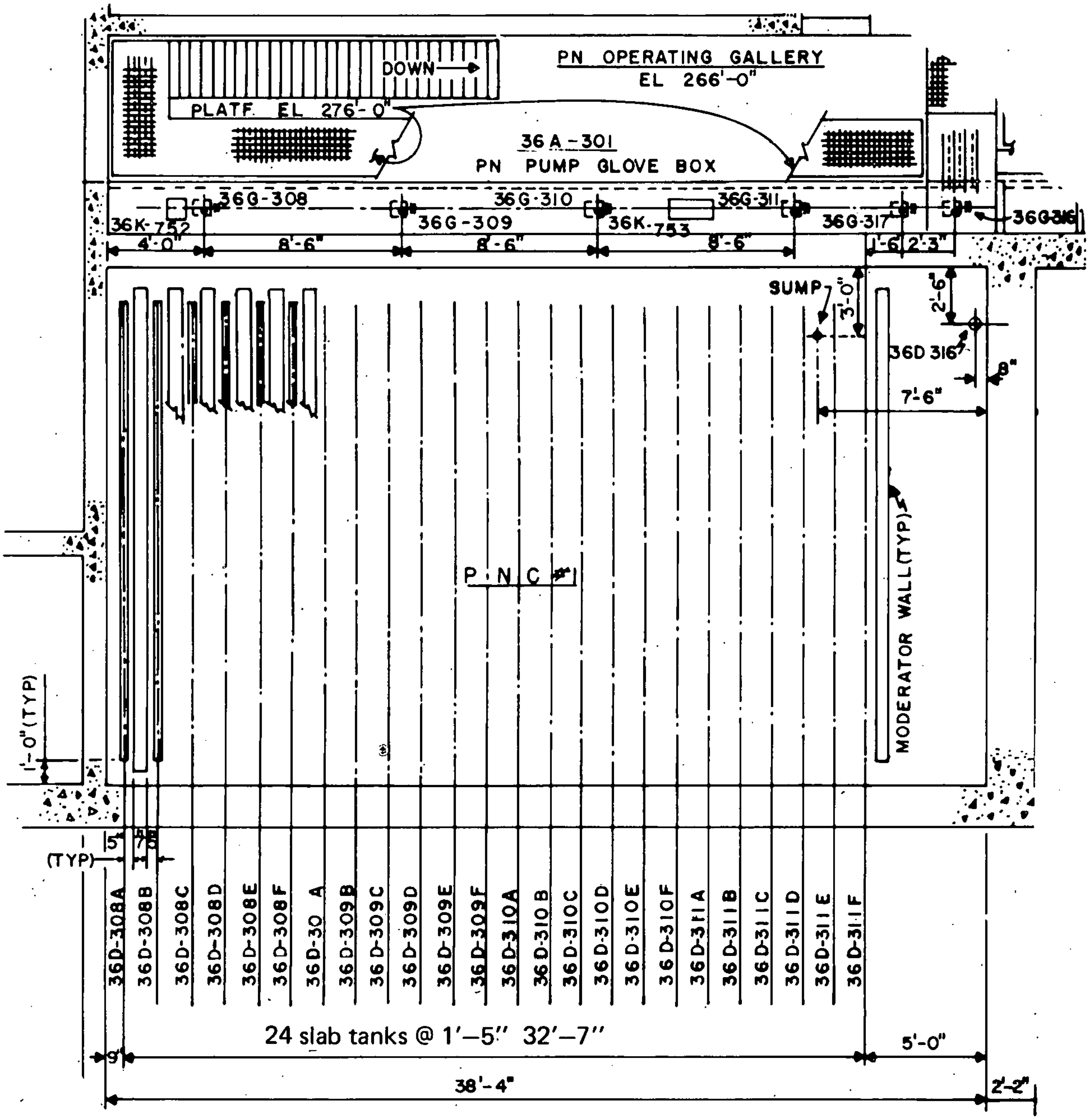


Figure 2.2-1 Storage Cell Detail

2.3 STORAGE TANK DESCRIPTION

The storage cell contains 24 titanium storage tanks separated from each other and the end walls by moderator slabs. The tank characteristics are listed in Table 2.3-1.

Length - 20'
Height - 8'
Thickness - 2-1/8"
Capacity (to overflow connections) - 756 liters (200 gal)
Nominal Pu Concentration - 240 gram/liter
Material - titanium: ASTM B265-72, Gr. 1 or 2

TABLE 2.3-1 Tank characteristics

Figure 2.3-1 presents a cross-section of a typical tank. Note that the tanks are rectangular but that a slope of 5" toward the drain is obtained by the different heights of the two supporting legs.

2.3.1 Penetrations

Each tank has 11 penetrations to provide for instrumentation, air scavenging, process liquid flow, and overflow. A description of these penetrations follows:

2.3.1.1 Product inlet

Four perforated dip tubes extend nearly to the bottom of the tank from four flanges on the top. The tubes are manifolded together to a 1" supply pipe outside the tank. The perforations, (1/4" dia. with axis parallel to walls of tank), are spaced at 6" intervals along the length of the dip tubes to insure turbulent mixing during the "stirring" mode of operations. The perforations in the dip tube are such that the uppermost perforation lies above the maximum height of the liquid in the storage tank. Thus, removal of SNM from the storage tank by use of suction on the product inlet dip tubes is unlikely.

2.3.1.2 Product Outlet

A 1-1/2" pipe leads from the lowest portion of each tank to a valve in the pump and pump maintenance glove box. This valve is a combination gate valve and check valve with the free flow direction out of the tank.

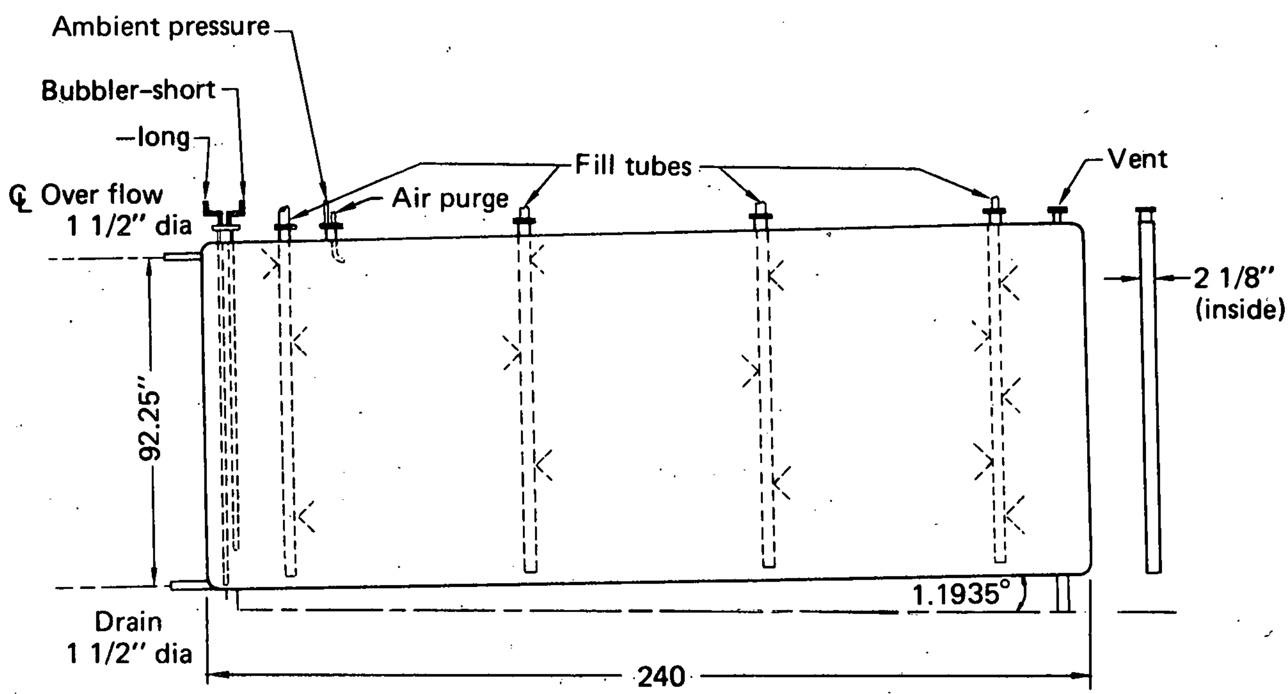


Figure 2.3-1 Typical Storage Tank

2.3.1.3 Common Overflow

A 1-1/2" pipe located 92.25" above the low part of the tank interconnects all tanks in a single module (six tanks) providing a common overflow.

2.3.1.4 Air Scavenging

A 1/4" tube enters through a flange and terminates above the highest liquid level to provide a sweep of air across the liquid surface and out a 1" vent line at the opposite end of the tank. This flow of air prevents accumulations of radiolytically produced hydrogen within the tank.

2.3.1.5 Bubbler Tubes

Two 1/4" tubes enter through a flange over the deepest portion of the tank (directly above the outlet) and dip into the liquid; one tube extending to 3/4" from the bottom of the tank, the other terminating 10" above the first. This provides a head difference to air flow through the two tubes that is a function of the density of the liquid. A third tube penetrates the flange that the scavenging air enters and provides a reference pressure above the liquid surface. The differential between this reference pressure and the lower dip tube, combined with the density measurement, provides a liquid level indication. The two tubes which dip into the liquid contain liquid check valves to prevent flow of liquid up these tubes. The check valves are located above the tank but below the cell roof.

2.3.2 TANK INTERCONNECTIONS

PNC1 consists of four modules of six tanks each. Figure 2.3.2-1 presents a schematic diagram of the interconnections between tanks and modules. The diagram makes a distinction between three levels of accessibility to the piping (the cell, the glove boxes and the manned area) but does not show their relative spatial position. All piping is 304 Stainless Steel, welded construction, with the exception of flanged and bolted connections to the pumps to facilitate their maintenance and replacement. This interconnection of tanks, valves, and pumps permits the transfer of solution between tanks and modules, the homogenizing of batches of solution, the transfer of any tank contents to the Conversion Facility, the recovery of any leakage, the sampling of any tank contents, and the return of any tank contents to the Plutonium Product Cell, PPC, for rework.

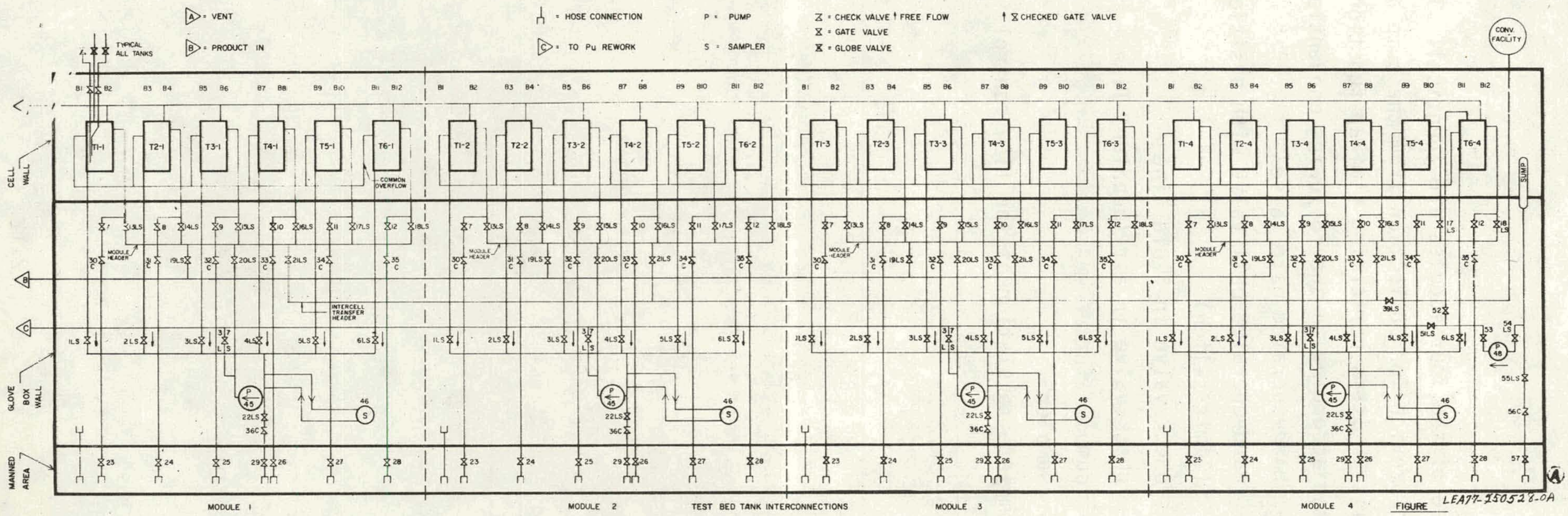


Figure 2.3.2-1 Test Bed Tank Interconnections

Three of the four modules are identical. The fourth has additional piping to provide for collection from the sump and transfer to the Conversion Facility. Items performing similar functions in each module are similarly numbered according to the following convention:

- XX - hand-operated gate valve
- XXLS - hand-operated ball valve with position monitor switch (limit switch)
- XXC - check valve in fluid line
- BXC - check valve in air (bubbler) line
- PXX - pump
- SXX - sampler

A complete tabulation of the flow control items is presented in Table 2.3.2-1.

P = Pump
S = Sampler

MODULE	ITEM	TYPE	PURPOSE
1	1	LS	Tank Drain Valves - Checked to Prevent Reverse Flow
	2	LS	
	3	LS	
	4	LS	
	5	LS	
	6	LS	
	7		Cold Chemical Addition Valves Located Closest to Tank Inlet Manifold
	8		
	9		
	10		
	11		
	12		
	13	LS	Tank Inlet Valves
	14	LS	
	15	LS	
	16	LS	
	17	LS	
	18	LS	
	19	LS	Module Header To Product Inlet Header
	20	LS	Module Header to Pump
	21	LS	Module Header to Transfer Header

MODULE	ITEM	TYPE	PURPOSE
1	22	LS	Pump Washdown Valve @ Pump
	23		Cold Chemical Addition-External Valves
	24		
	25		
	26		
	27		
	28		
	29		Pump Washdown External Valve
	30	C	Cold Chemical Addition Check Valves. (Flow towards tanks)
	31	C	
	32	C	
	33	C	
	34	C	
	35	C	
	36	C	Pump Washdown Check Valve (Flow Towards Pump)
	37	LS	Transfer Pump
	45	P	Transfer Pump
	46	S	Sampler Loop
	B1	C	Check Valves in Bubbler Lines
	B2	C	

TABLE 2.3.2-1 Tank Valving Description

MODULE	ITEM	TYPE	PURPOSE
2	1	LS	
	2	LS	
	3	LS	Tank Drain Valves. Checked to Prevent Reverse Flow
	4	LS	
	5	LS	
	6	LS	
	7		
	8		Cold Chemical Addition Valves Located Closest To Tank Inlet Manifold
	9		
	10		
	11		
	12		
	13	LS	
	14	LS	
	15	LS	Tank Inlet Valves
	16	LS	
	17	LS	
	18	LS	
	19	LS	Module Header to Product Inlet Header
	20	LS	Module Header to Pump
	21	LS	Module Header to Transfer Header

MODULE	ITEM	TYPE	PURPOSE
2	22	LS	Pump Washdown Valve @ Pump
	23		
	24		
	25		Cold Chemical Addition-External Valves
	26		
	27		
	28		
	29		Pump Washdown External Valve
	30	C	
	31	C	
	32	C	Cold Chemical Addition Check Valves. (Flow Towards Tanks)
	33	C	
	34	C	
	35	C	
	36	C	Pump Washdown Check Valvc. (Flow Towards Pump)
	37	LS	
	45	P	Transfer Pump
	46	S	Sampler Loop
	B1	C	Check Valves in Bubbler Lines
	B2	C	

TABLE 2.3.2-1 Tank Valving Description (continued)

MODULE	ITEM	TYPE	PURPOSE
3	1	LS	
	2	LS	
	3	LS	Tank Drain Valves,
			Checked To Prevent
	4	LS	Reverse Flow
	5	LS	
	6	LS	
	7		
	8		Cold Chemical
	9		Addition Valves
	10		Located Closest
	11		To Tank Inlet
	12		Manifold
	13	LS	
	14	LS	
	15	LS	Tank Inlet Valves
	16	LS	
	17	LS	
	18	LS	
	19	LS	Module Header To
			Product Inlet Header
	20	LS	Module Header to Pump
	21	LS	Module Header To
			Transfer Header

MODULE	ITEM	TYPE	PURPOSE
3	22	LS	Pump Washdown
			Valve @ Pump
	23		
	24		
	25		Cold Chemical Addi-
	26		tion-External Valves
	27		
	28		
	29		Pump Washdown
			External Valve
	30	C	
	31	C	
	32	C	Cold Chemical Addi-
	33	C	tion Check Valves.
			(Flow Towards Tanks)
	34	C	
	35	C	
	36	C	Pump Washdown Check
			Valve (Flow Towards
			Pump)
	37	LS	
	45	P	Transfer Pump
	46	S	Sampler Loop
	B1	C	Check Valves in
	B2	C	Bubbler Lines

TABLE 2.3.2-1 Tank Valving Description (continued)

MODULE	ITEM	TYPE	PURPOSE
4	1	LS	Tank Drain Valves Checked to Prevent Reverse Flow
	2	LS	
	3	LS	
	4	LS	
	5	LS	
	6	LS	
	7		Cold Chemical Addition Valves Located Closest to Tank Inlet Manifold
	8		
	9		
	10		
	11		
	12		
	13	LS	Tank Inlet Valves
	14	LS	
	15	LS	
	16	LS	
	17	LS	
	18	LS	
	19	LS	Module Header To Product Inlet Header
	20	LS	Module Header To Pump
	21	LS	Module Header To Transfer Header

MODULE	ITEM	TYPE	PURPOSE
4	22	LS	Pump Washdown Valve @ Pump
	23		Cold Chemical Addition-External Valves
	24		
	25		
	26		
	27		
	28		
	29		Pump Washdown External Valve
	30	C	Cold Chemical Addition Check Valves. (Flow Towards Tanks)
	31	C	
	32	C	
	33	C	
	34	C	
	35	C	
	36	C	Pump Washdown Check Valve. (Flow Towards Pump)
	37	LS	
	45	P	Transfer Pump
	46	S	Sampler Loop
	D1	C	Check Valves In Bubbler Lines
	B2	C	

TABLE 2.3.2-1 Tank Valving Description (continued)

MODULE	ITEM	TYPE	PURPOSE
4 (Continued)			
4	39	LS	Transfer Header To Conversion Facility
	48	P	Sump Pump
	51	LS	Sump Pump to Pu Rework Header
	52		Sump Pump to Tank #6
	53		Sump Pump Isolation (Pressure Side)
	54	LS	(Suction Side)
	55	LS	Sump Washdown Addition Line
	56	C	Sump Washdown Check-Flow Towards Sump
	57		Sump Washdown External Valve

TABLE 2.3.2-1 Tank Valving Description (continued)

2.4 SAFEGUARD COMPONENTS

Check valves have been incorporated into all potential material flow paths which penetrate the cell walls or the glove box areas. In addition, sensors which indicate a valve closed or not closed (valve position monitors) have been provided to furnish a binary signal to the Material Control System computers. In order to prevent unauthorized operation of the transfer pumps (P45), the pump controller is enabled by a signal from the MC computer; actual starting of the pump is a local operator action. For safety reasons, the sump pump has no enabling tie to the MC computer; however, any operation of the sump pump is sensed by the computer which sends an alarm signal to the MC officer.

Other safeguard features are associated with the physical arrangement of the facility components. All exposed piping is kept as short as possible and is unobscured for visual inspection. The transfer pumps are operated from the remote panel outside the Portal Control System booth. All sensitive instrumentation and electrical connections are contained within interlocked cabinets. The cell walls are assumed contiguous with the PPC on the upstream side, and the conversion facility on the downstream side.*

For the purposes of evaluating this Test Bed Storage Facility design, some estimates of reliability of check valves and limit switches have been made. It should be emphasized that these are <u>estimates</u> based on the use of check valves and switches in environments quite different than the Test Bed Storage Facility. Credible reliability data would have to be determined after the selection of the particular equipment is made. This reliability is discussed further in the sections on Material Control System instrumentation.

2.4.1 Tank Instrumentation

The following variables relating to the solution stored within the PNC1 are measured:

<u>Density</u>: measured by a differential pressure transducer between the long and short bubbler tubes of each tank. The fixed length difference of these two tubes is 10" $\pm$ 1/64".

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*This is at variance with the Barnwell arrangement where the lines between the PPC and PNC pass through a manned area.

Pressure head (a function of level for a given density): measured by differential pressure transducers between the long bubbler tubes and the static pressure tubes which terminate above the liquid level. The long bubbler tube terminates 3/4" ± 1/4" above the bottom of the low point of the tank.

Temperature: sensec by two thermocouples located at approximate 1/3 points on the external surface of the bottom of each tank. The general design philosophy of the process instrumentation system is to provide a maximum amount of physical protection against unauthorized tampering without compromising accuracy. Operational convenience is considered to be of secondary importance.

2.4.2 Control Panels

2.4.2.1 Local Panel

The local panel is an enclosed box on the mezzanine, running the full length of the cell and located directly above the low end of the tanks. The bubbler and static pressure tubes are welded to liquid check valves, penetrate the roof of the cell through grouted sleeves, and are welded to isolation valves (globe valves) at the outer surface of the roof. The base of the local panel box is approximately 1 foot above these valves; leaving only a very short length of exposed tubing between the valves and the box. All exposed connections between the local panel box and the cell roof are welded.

The local panel box is divided into four sections; one for each module. Each section is equipped with a hinged, high impact clear plastic cover that is interlocked to the MC computer to provide notification of unauthorized access. All adjustments to bubbler air flow rates, the differential pressure transmitters, connections for calibration, etc. require the opening of this cover; so, as a consequence, can be done only with the cognizance of the MC Officer. Each local panel box module contains the following pieces of equipment listed in Table 2.4.2.1-1.

ITEM	NUMBER	REMARKS
DP* Transmitter	12	Measures density & pressure head
Rotometer	12	Measures bubbler air supply
Panel Meter	12	0-100%, local readout
Power supply	12	for transmitters
Valves	18	for connections of micromanometer for calibration
Valves	24	for isolation of transmitters
Valves	12	for rotometer isolation

Table 2.4.2.1-1 Contents of Local Panel

All differential transmitters are Taylor model 1303T, force balance instruments** which measure differential pressure and transmit a proportional 4 to 20 mA dc electrical output signal. This model instrument is adjustable from 20 to 250 in. water full scale. An electrical accessory is attached to each transmitter to provide a local panel meter reading 0-100% of full scale. The output from the transmitter is a two wire system which provides the 24 V dc power as well as the output signal. The power supply, in this installation, will be located within the panel box and the transmitter output will be run in heavy wall conduit from the local panel to the remote panel.

2.4.2.2 Remote Panel

The remote panel is located in the Support Work Area (see Fig. 2.1-2). This panel is an enclosed cabinet, interlocked with the MC computer in a similar fashion to the local panel. In order to provide interlock protection, the following items are located within the cabinet.

1) terminal boards for thermocouples
2) A to D converters for differential transmitter signals
3) terminal boards for all valve limit switches
4) terminal boards for all MC computer connections
5) transfer pump interlock to MC computer
6) scale adjustments to all meters and recorders

---

*Differential Pressure

**Described in more detail in Section 8.

7) intercom system to glove box area

8) all high/low level alarm adjustments

The surface of the cabinet supports all read-out and annunciator equipment which are required for the operation of the Test-bed Storage Facility. These items include, but are not limited to, the following:

1) 24 point strip chart recorders for temperature recording
2) Indicator lights showing the position of each limit switch equipped valve
3) Two strip chart recorders for each module with a selector switch permitting the density and pressure head of any one particular tank to be recorded
4) Panel meters duplicating the 0-100% readout meters at the local Panel
5) High, low, and temperature alarm lights
6) Transfer pump operating switch
7) Sump pump operating switch
8) Sump level alarm indicator

2.4.3 GLOVE BOX DESCRIPTION

Three glove boxes are provided for radiological safety of personnel performing the manipulation of valves, pumps, and samples. Figure 2.4.3-1 is typical of these glove boxes. One box, at floor level, extends the length of the north wall of the cell and contains tank drain valves 1-6, pumps P45 and P48, and sump valves 53 and 54. (See Fig. 2.3-3). A second box, accessible from a balcony and contiguous with the pump box, provides access to the remaining valving for the tank interconnections. The third glove box is located on the mezzanine above the cells, is contiguous with the valve box, and provides an enclosure for four sampling stations and the sample bottle transfer tube to the analytical laboratory. The relative locations of these three boxes permit all piping connections between them to be contained within an enclosure and ventilation air to circulate freely between them.

2.4.3.1 Valve - Glove Position Relationship

Figures 2.4.3.1-1 and 2.3.2-1 and Table 2.4.3.1-1 give the relationship between the glove positions and the valves.

VALVE	GLOVE PAIR Module 1	2	3	4
1	16	19	22	25
2	16	19	22	25
3	17	20	23	26
4	17	20	23	26
5	18	21	24	27
6	18	21	24	27
7	2	5	8	11
8	2	6	8	11
9	3	6	9	12
10	3	6	9	12
11	4	7	10	13
12	4	7	10	13
13	2	5	8	11
14	2	5	8	11
15	3	6	9	12
16	3	6	9	12
17	4	7	10	13
18	4	7	10	13
19	2	5	8	11
20	3	6	9	12
21	3	6	9	12
22	17	20	23	26
23	0.	0.	0	0
24	0	0	0	0
25	0	0	0	0
26	0	0	0	0
27	0	0	0	0
28	0	0	0	0
29	0	0	0	0
30	2	5	8	11
31	2	5	8	11

TABLE 2.4.3.1-1 Valve/Glove Position Relationships

	GLOVE PAIR			
	Module			
VALVE	1	2	3	4
32	3	6	9	12
33	3	6	9	12
34	4	7	10	13
35	4	7	10	13
36	17	20	23	26
37	3	6	9	12
38	-	-	-	-
39	-	-	-	27
P45	17	20	23	26
P48				28
51	-	-	-	27
52	-	-	-	27
53	-	-	-	28
54	-	-	-	28
55	-	-	-	28
56	-	-	-	28
57	-	-	-	0

0 = Outside of Glove Box

TABLE 2.4.3.1-1 Valve/Glove Position Relationships (Continued)

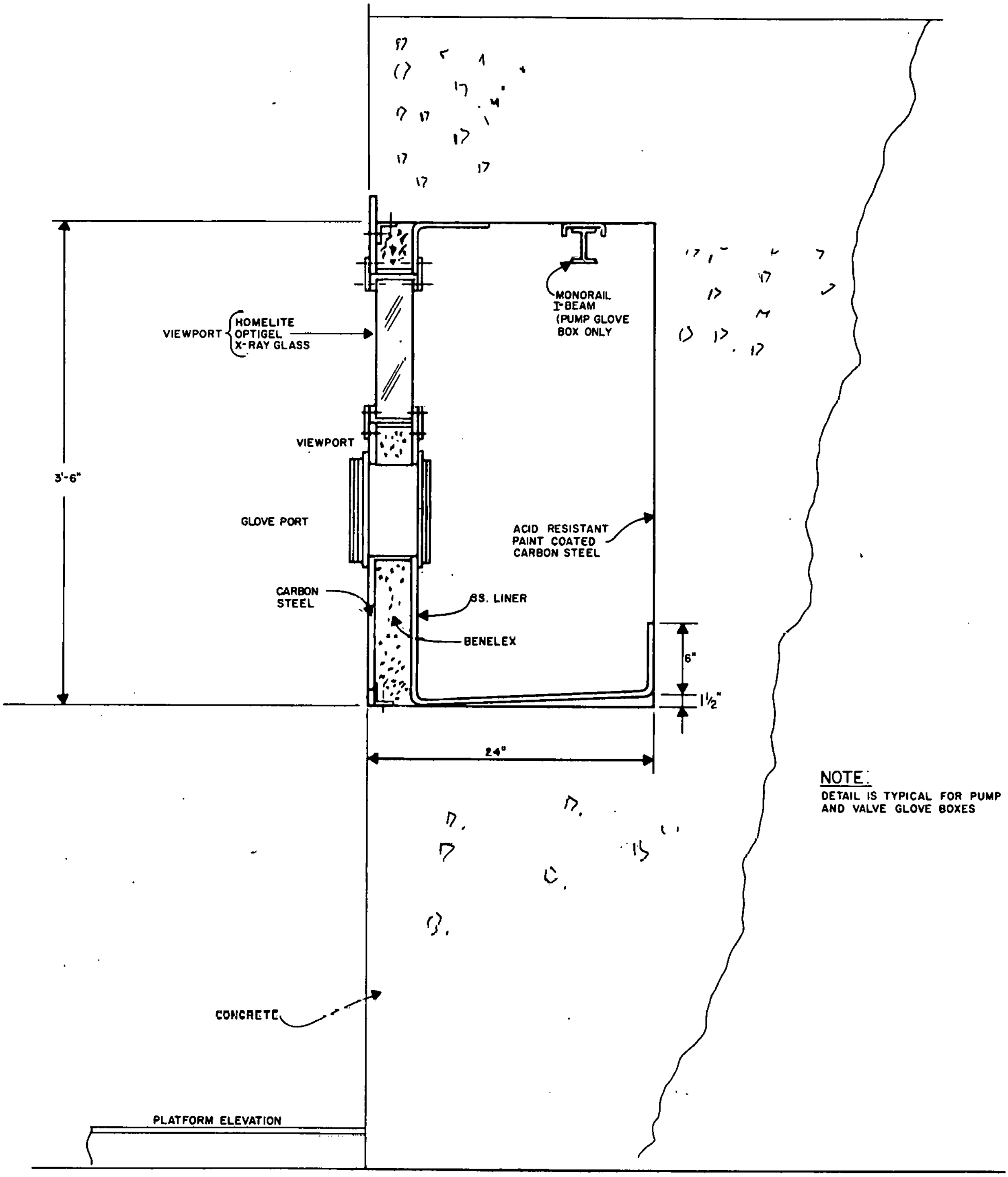

Figure 2.4.3-1 Typical Glove Box

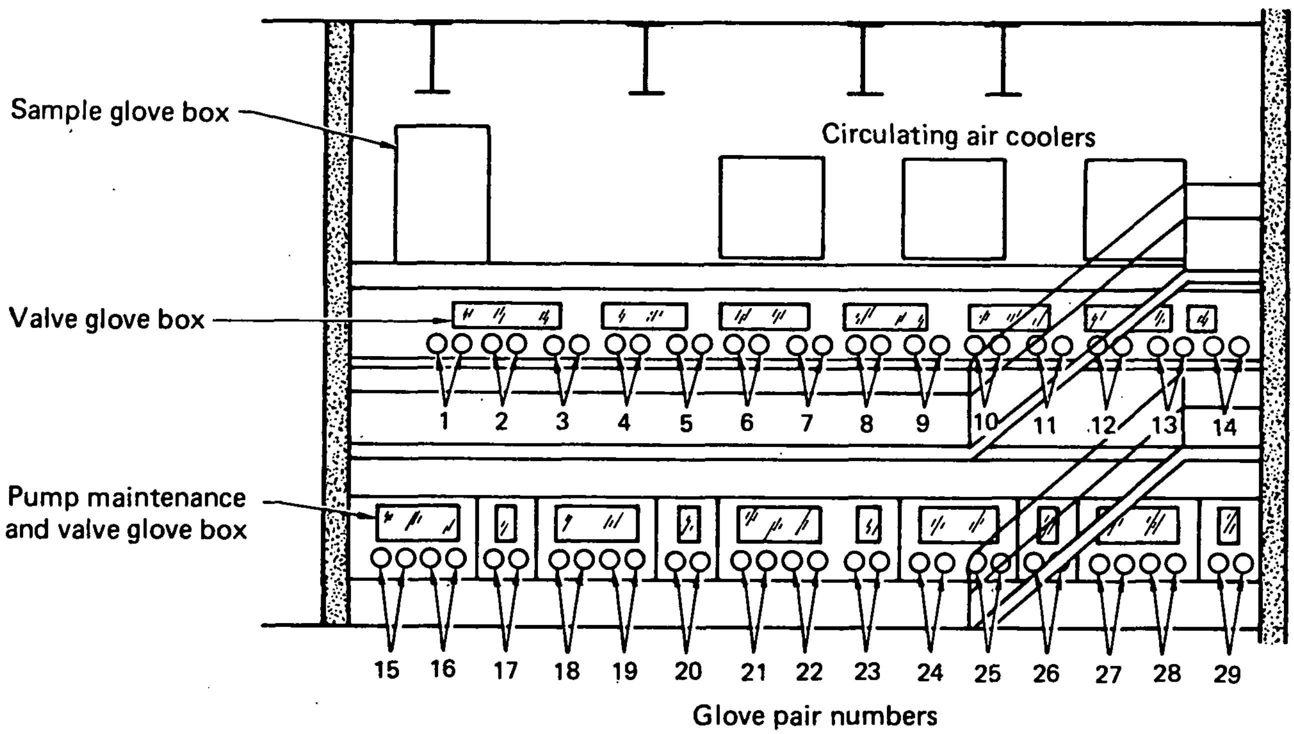

Figure 2.4.3.1-1 Glove Box Numbers

2.4.3.2 Glove Box Monitoring

The three glove boxes are maintained at negative pressure relative to the Material Access Area, MAA. Glove box internal pressure is monitored by differential pressure transducer/transmitter units. These units are mounted in enclosures attached to the box of each glove box. These instruments are capable of detecting a pressure change of 0.1 psi. The signal from these transducers is transmitted via cable through pressurized conduit to the MC System. The bag in/out ports on all glove boxes are monitored by a Form C, magnetic reed relay door switch.

The switch is polled asynchronously by the MC computer system for both the normally open (N.O.) and normally closed (N.C.) contacts. A magnet embedded in the door itself provides the actuation force for this switch.

2.4.3.3 Penetrations

In addition to the glove ports to provide manipulative access, each box is provided with bag in/out ports for the entry and removal of maintenance tools and equipment. The condition of these bag-in/out ports (i.e., closed or not closed) is monitored by the MC computer. Piping which penetrates box walls is tabulated in Table 2.4.3.3-1 below.

Purposes	Size	Box	Location	Quantity	Remarks
Tank drain	1-1/2"	Pump	S. wall	24	from PNC1
Tank fill	1"	Valve	S. wall	24	to PNC1
Product Hdr.	1"	Valve	W. wall	1	from PPC
Rework Hdr.	1"	Valve	W. wall	1	to PPC
Delivery Hdr.	1"	Valve	S. wall	1	to CF
Chem addition	1"	Valve	N. wall-high	24	from Oper. area
Pump/sump wash	1"	Pump	N. wall-high	7	from Oper. area
Rabbit	1"	Sample	top	1	to Analytical Lab.

TABLE 2.4.3.3-1 Glove Box Penetrations

2.4.4 Plutonium Nitrate Specifications

The solution stored within PNC1 is plutonium nitrate, $Pu(NO_3)_4$. The specifications of this solution are given in the table below:

Property or Impurity	Value		Unit
Plutonium concentration	100-300		g/l
Nitric acid concentration	2-10		molar
Entrained organic solvent	0.5	maximum	vol %
Insoluble residue(1)	5000	maximum	ppm Pu
Uranium	5000	maximum	ppm Pu
Americium	2800(2)	maximum	ppm Pu
Other metals	5000	maximum	ppm Pu
Sulfur (as sulfate)	1000	maximum	ppm Pu
Fluorine & chlorine	150	maximum	ppm Pu
Equivalent boron content (excluding uranium and americium)	10	maximum	ppm Pu
Fission products			
Gamma-emitting(3)	40	maximum	Ci/g Pu
Zirconium-niobium-95	5	maximum	Ci/g Pu

TABLE 2.4.4-1 Plutonium Nitrate Specifications

NOTES:

(1) The insoluble residue after filtering the plutonium nitrate solution through a 100 micron filter and washing with 8M nitric acid for one hour at 25°C.

(2) As determined within 120 days from time of separation.

(3) Gamma-emitting fission products whose parent isotopes have a half-life of 30 days or greater.

2.5 INTERFACES WITH REMAINDER OF FACILITY

For purposes of limiting the scope of this test design of a Storage Facility Material Control System, the upstream and downstream interfaces were kept as simple and straight-forward as possible. The upstream interface will be with the PPC, the downstream interface with a Conversion Facility presumed to be in the location shown in Fig. 2.1-1.

The PPC is a Material Balance Area, MBA, as are the PNC and the CF. This creates the requirement that the material balance around each area, PPC, PNC1, and CF must close.

2.5.1 Upstream Interface

The final stages of the PPC are shown in a simplified schematic* in Fig. 2.5.1-1 where six tanks are interconnected to provide concentrator surge capacity, sampling holdup, interim storage, and capability for 100-liter batch measurements. The operating plan hypothesizes transfers from any two of the interim storage tanks, in batches of approximately 730 liters, without incremental measurement in the 100 liter measuring tank. This necessitates careful calibration of the three interim storage tanks and the piping holdup, as the material will be pumped to the elevation of the 100-liter tank and will gravity-flow through the tank to the Storage Facility.

2.5.2 Downstream Interface

The Conversion Facility, that is fed on demand from the Storage Facility, is postulated to have two feed preparation tanks of 260-liter capacity each. The piping from PNC1 passes through the south wall directly into the Conversion Facility and will be free-draining between valve 4-39 LS and the feed preparation tank in use.

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*The purpose of this figure is only to show PPC Material Accountability, not to be included as a target in the test bed design.

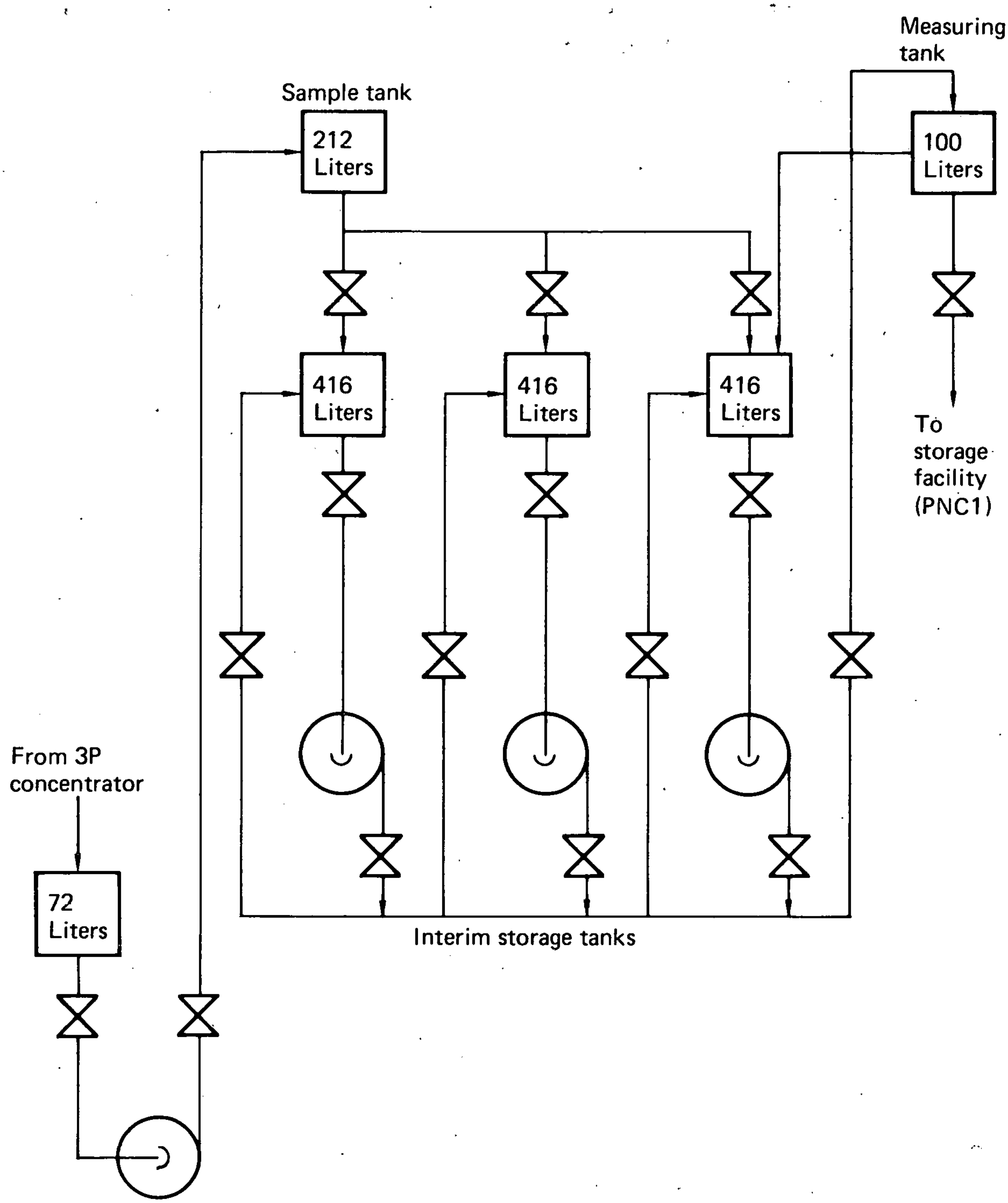

Figure 2.5.1-1 PPC Load-Out: Simplified Schematic

REFERENCES for SECTION 2

2-1 W. N. Ross, "Test Bed Design--Physical Configuration," Lawrence Livermore Laboratory, MC 77-300 July 8, 1977.

3.0 MATERIAL CONTROL SYSTEM DECISION LOGIC*

The function of the Material Control Decision Logic, MCL, is to generate compensatory responses to the loss or potential loss of SNM in the Plutonium Nitrate Storage Area. These responses are of two types: Information gathering and/or security force deployment. The response to specific situations will be decided by the MCL based on process and plant state measurements.

The decision logic is organized in a hierarchical, redundant fashion, making use of information from a variety of monitors, local-level logic subsystems, computers, and human operators. The four principal levels of this hierarchy are shown in Fig. 3-1, with the Plant Manager at the highest level and individual monitors at the lowest level. An increase in level of the hierarchy in general implies an increase in authority, an increase in the importance of each identified unit, and a decrease in the level of detailed information.

Table 3-1 defines the "Theft Danger Rating" (TDR) system which is used to indicate the level of danger** with respect to ongoing or potential theft of SNM. These levels vary from TDR-3 (greatest danger) to TDR-0 (nominal operating conditions), and each implies a unique type of response, as indicated in the last column. Subsequently in this section, responses will be indicated simply in terms of the TDR value.

Referring back to Fig. 3-1, note that three of the levels of the decision hierarchy are assigned a TDR value in the right column. A given subsystem will occasionally be described, for example, as a "TDR-1 subsystem", according to this rule. Roughly speaking, this notation is used to characterize the danger level produced by a loss of a subsystem on a particular hierarchical level.

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*This discussion is based on Reference 3-1.

**"Level of danger" may be taken to be roughly proportional to the expectation of loss of SNM, given an attempted diversion under existing conditions, in the absence of a safeguard system response. Increases in SNM proximity or availability to potential diverters and decreases in probability of detection of diversion, all add to this measure of danger. Further descriptions and examples are provided in Table 3-1.

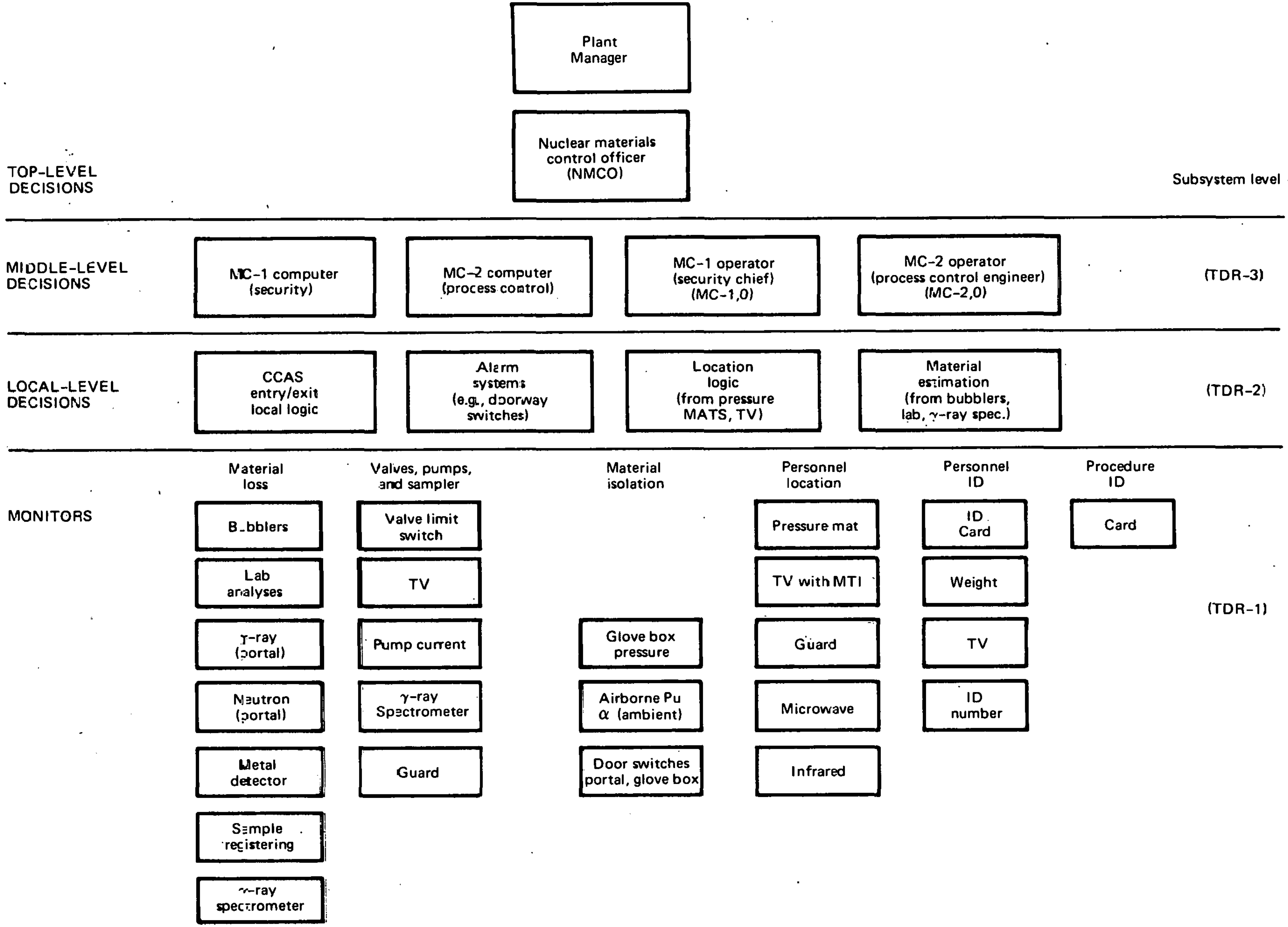


Figure 3-1 Material Control System Hierarchy

THEFT DANGER RATING	SITUATION CHARACTER	RESPONSE NATURE
TDR-3	DIRECT OPPORTUNITY FOR EXTRACTION OR EXTRACTION IS OCCURRING OR HAS OCCURRED*	. PRIMARILY CONTROL DECISION . SEND HIGH-LEVEL SECURITY FORCE (3 GUARDS), ALERT OUTSIDE AGENCIES, ADD SPECIAL PORTAL SECURITY PROCEDURES . REQUIRES PLANT MANAGER AND MC-1,0 AND MC-2,0 APPROVAL FOR REDUCTION TO TDR-2
TDR-2	POSSIBILITY OF EXTRACTION OF SNM WITH RELATIVE EASE**	. MIXED CONTROL & INFORMATION DECISION . SEND LOW-LEVEL SECURITY FORCE (1 GUARD), ALERT HIGH-LEVEL SECURITY FORCE . REQUIRES MC-1,0 AND MC-2,0 APPROVAL FOR REDUCTION TO TDR-1
TDR-1	POSSIBILITY OF EXTRACTION OF SNM WITH RELATIVE DIFFICULTY***	. PRIMARILY INFORMATION DECISION . GUARDS & OPERATORS READ MONITORS, CHECK RECORDS, COMMUNICATE WITH WORKERS, ALERT LOW-LEVEL SECURITY FORCE . REQURIES MC-1,0 APPROVAL FOR REDUCTION TO TDR-0
TDR-0	NOMINAL OPERATING CONDITIONS	

*E.G. SNM DETECTED OUTSIDE OF NORMAL CONTAINMENT, OR MATERIAL LOSS DETECTED
**E.G. SNM REMAINS INSIDE OF NORMAL CONTAINMENT, BUT PROTECTION IS SERIOUSLY DEGRADED (E.G., SAMPLING OR LOAD-OUT MODE WITH SIGNIFICANT MONITOR FAILURES)
***E.G. SNM IS WITHIN MEDIUM TO HIGH LEVELS OF CONTAINMENT (E.G. WITHIN INNER CELL WALLS WITH SOME MINOR MONITOR FAILURES)

TABLE 3-1 THEFT DANGER RATING AND RESPONSE DEFINITIONS.

In the more detailed descriptions of the decision logic which follow, unless otherwise indicated, logic functions are performed by two essentially identical cross-checking computer systems, the MC-1 computer (primary facility which is located in the security area) and the MC-2 computer (a back-up facility located in the process-control area). In case of failure of either computer, the authority for decisions is switched to the other.*

3.1 SAFEGUARDS MANAGEMENT

A management diagram for the Safeguards System is shown in Fig. 3.1-1. Directly responsible to the Plant Manager is the Nuclear Materials Control Officer (NMCO); he has charge of the entire safeguards program for the plant. Below him are managers responsible for safeguards performance assessment, personnel training, and maintenance. With respect to their safeguards functions, also responsible to the NMCO are the Security Chief (MC-1 operator, MC-1,0) and the Process Control Engineer (MC-2 operator, MC-2,0). The MC-1,0 is associated with the MC-1 computer and directs the work of security guards; the MC-2,0 is associated with the MC-2 computer and directs the process operators. Finally, the NMCO is reported to by the Health and Safety Officer, who in turn is in charge of the Health and Safety Technicians. Any of the people associated with the Safeguards function can order a security response.

For the purposes of on line detection of diversion, the important operators on a decision-making level are the NMCO, MC-1,0, and MC-2,0. The latter two are responsible for various workers including security guards, process operators, and health and safety technicians; the principal roles of these workers are information gathering, physical security, and operations execution.

Note that the management diagram of Fig. 3.1-1 describes essentially two aspects of the Safeguards System: the portion contained by the dashed lines describes the organizational structure for on-line safeguards decision functions (the major topic of this section), while the portion of the diagram to the left describes the system for evaluating and maintaining the Safeguards Systems itself.

While the humans in the system have responsibilities for executing the work, the MC computers perform the functions of monitoring, advising, scheduling operations, recording, and enabling certain operations (e.g., CCAS booth door opening, pump powering) to be performed. It is also important to emphasize that

*A discussion of computer system availability can be found in reference 3-2.

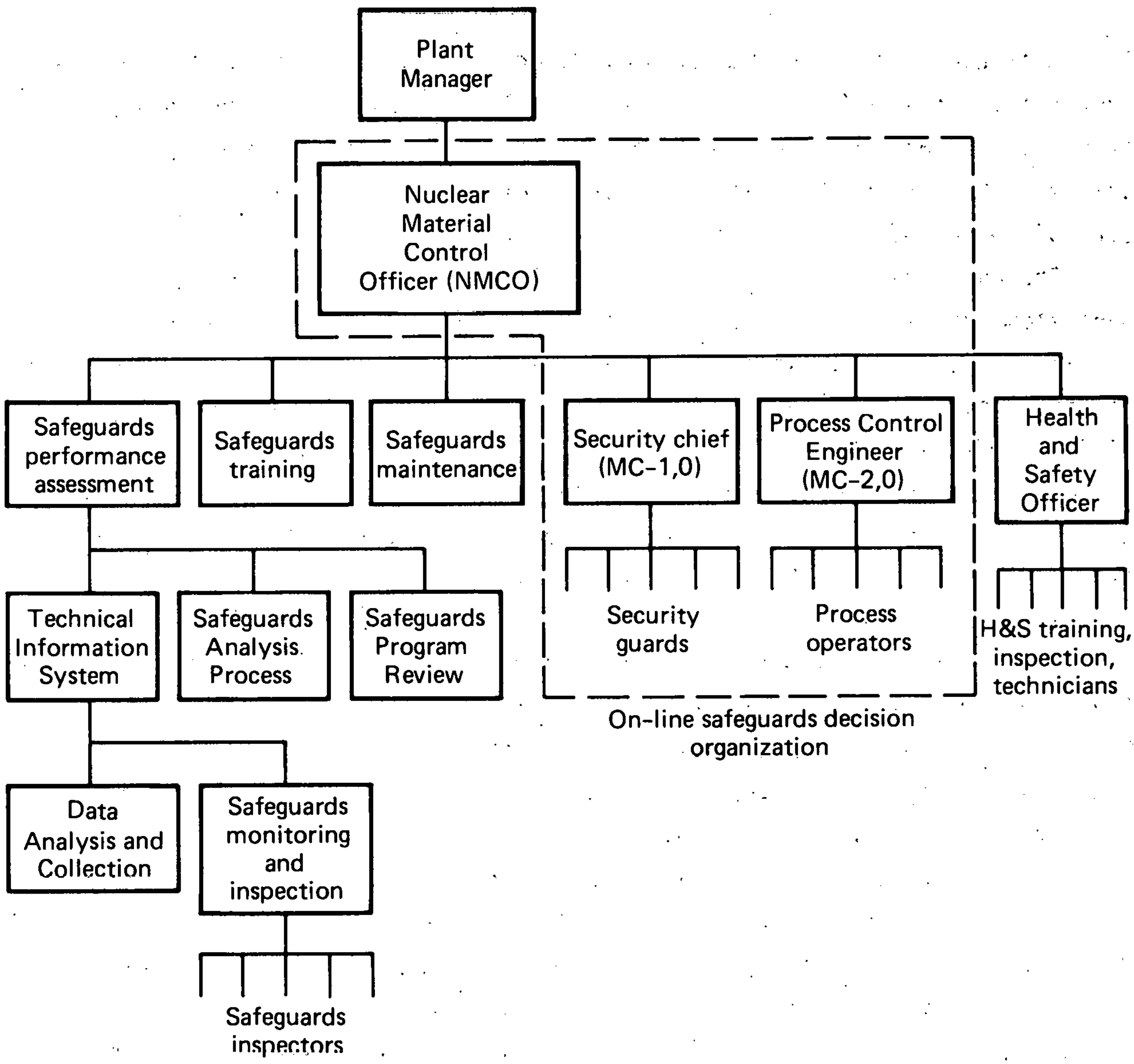


Figure 3.1-1 Safeguards Management Diagram

the human decision makers (NMCO, MC-1,0, and MC-2,0) have broad override powers over the Safeguards System, although, as will be apparent in the subsequent sections, there are certain built-in checks and inhibitions to their use of these powers. The next section describes the decision logic in detail.

3.2 DECISION LOGIC

The overview of the Decision Logic of Fig. 3.2-1 shows how major logic subsystems are interconnected. The specific generation of TDR-values (and hence via Table 3-1, of responses) occurs in the central logic subsystem, the Master Decision Logic (MDL) shown in Fig. 3.2-2.* A detailed explanation of the MDL will be deferred until a following section. All the input information to the MDL comes either directly from human operators, from other logic subsystems, or from the computer controlled access system. A typical logic subsystem, that for personnel location, is shown in Fig. 3.2-3.

TDR-values are displayed through a coded visual and audible alarm system at both the MC-1 and MC-2 stations, for the benefit of the two operators. Alarm systems also announce the TDR level in the Material Access Areas. The MC-1 operator is responsible for insuring that the appropriate responses are taken, according to the rules of Table 3-1.

Certain information is stored in computers MC-1 and MC-2 and used by the decision logic. Much of this information is organized into three tables. Table 3.2-2 represents some of the procedure information permanently stored in the MC-2 computer, relating authorized valve, pump, sampler states, workers (number and type), and procedure duration to procedure code and operating mode definition. Tables 3.2-3 and 3.2-4 indicate the formats of the Daily Work Schedule and Personnel Authorization tables, respectively.

3.3 ANOMALY VARIABLES AND TDR LEVELS

The various decision logic subsystems are connected through the use of "anomaly variables",

$$A^{i}_{cj}(\cdot) = \begin{cases} 0 \text{ (normal)} \\ 1 \text{ (non-normal)} \end{cases}$$

*Table 3.2-1 contains an explanation of the symbols used in this section.

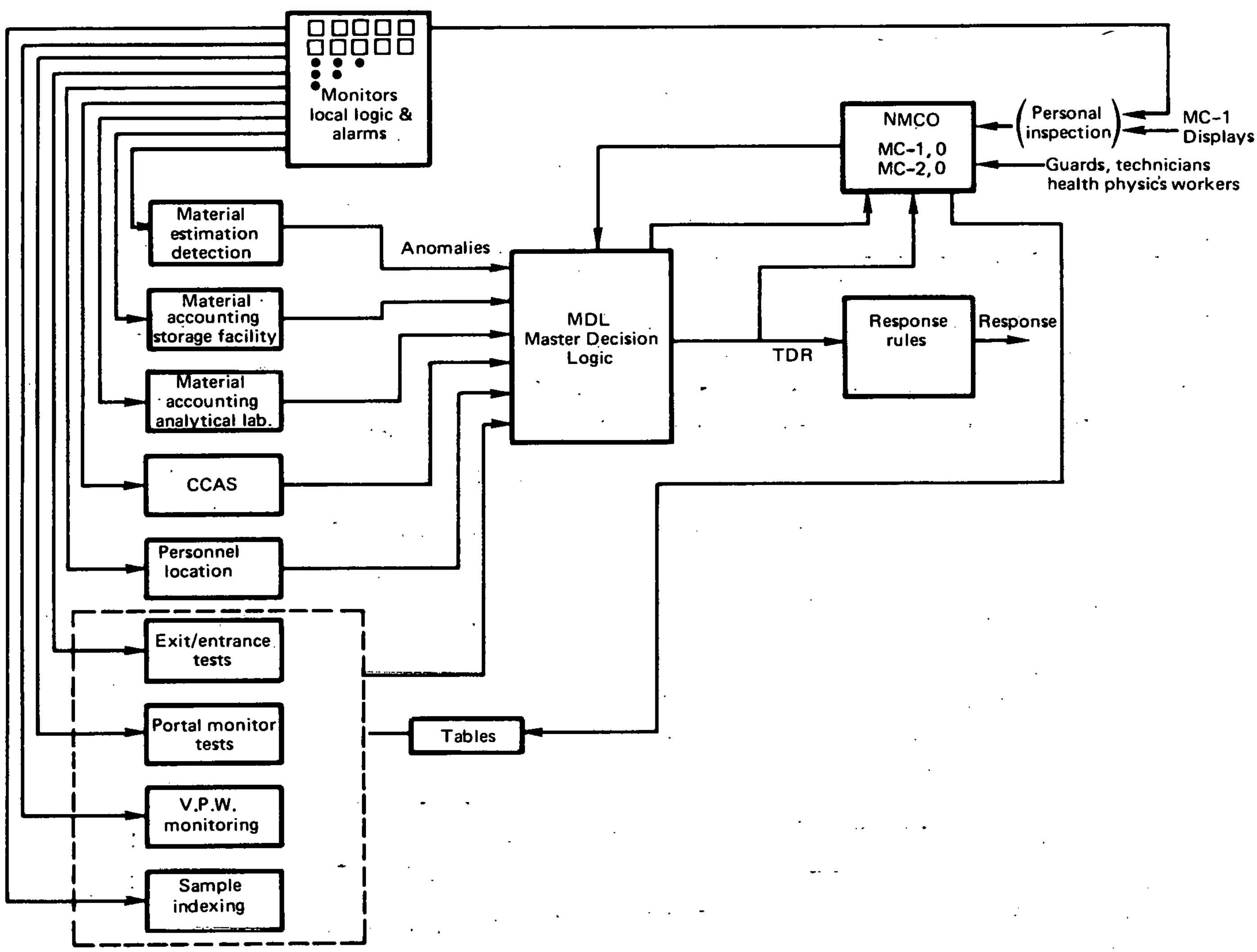


Figure 3.2-1 Decision Logic Overview

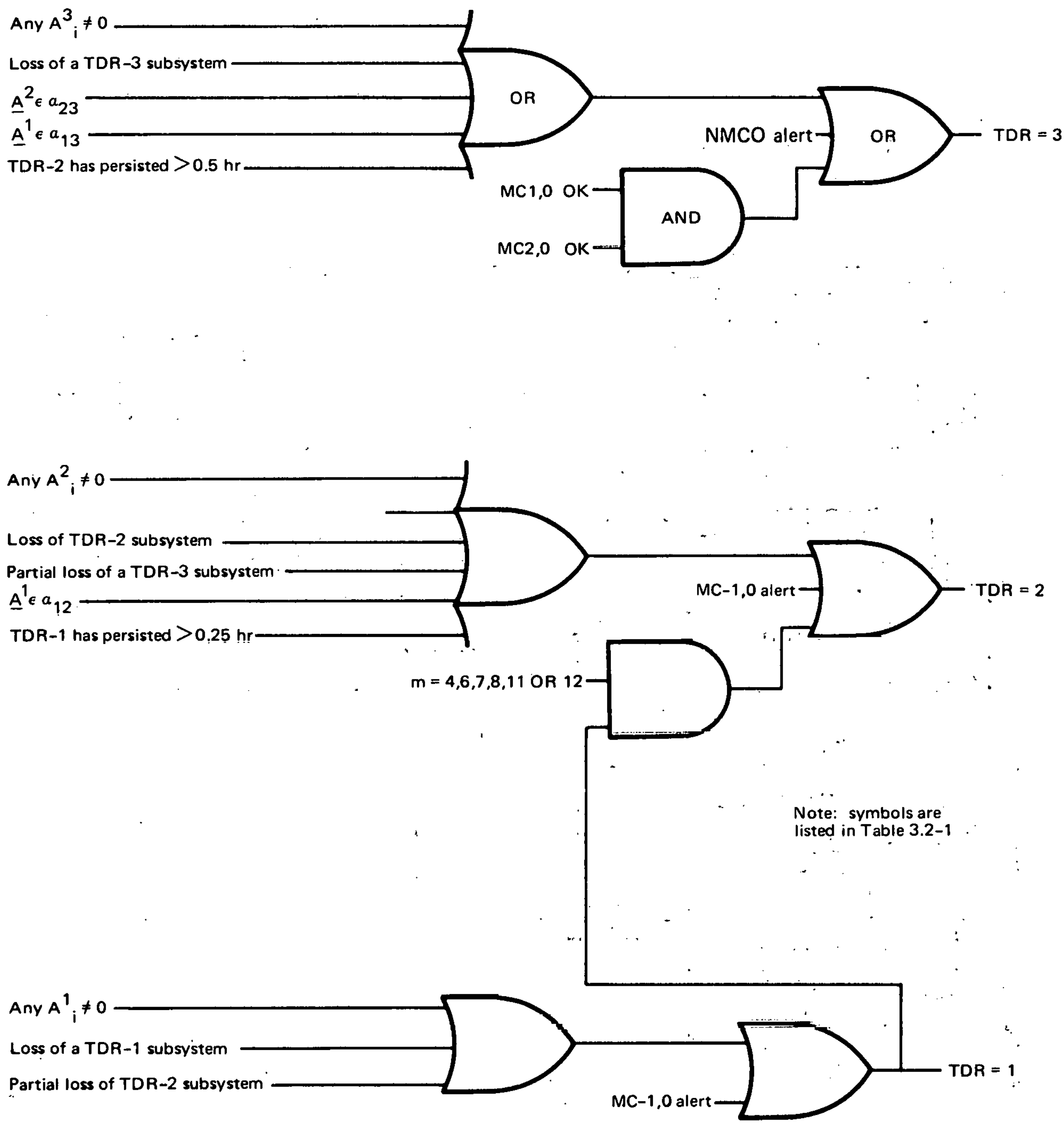
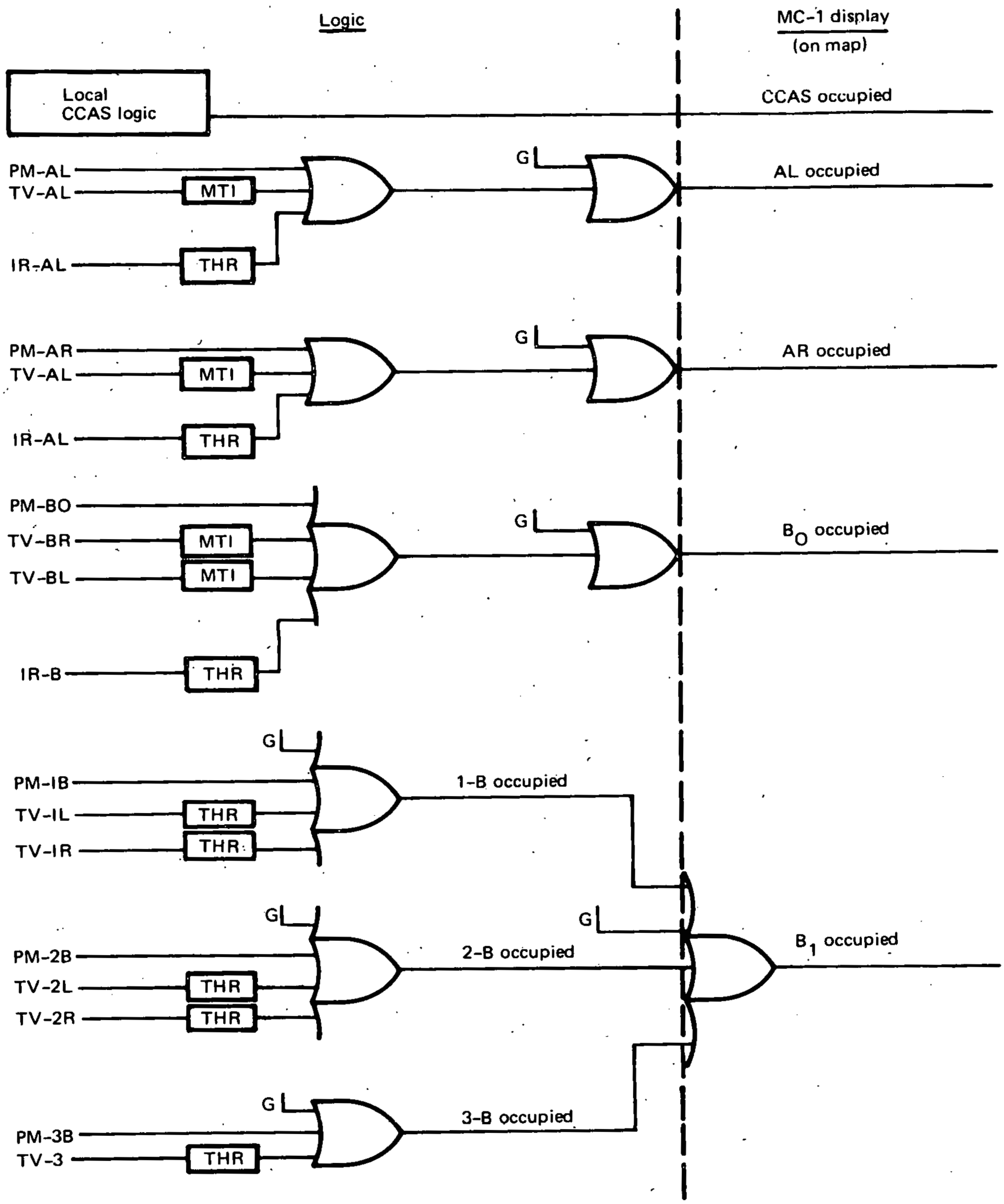


Figure 3.2-2 Master Decision Logic (MDL)



G = Guard
MTI = Moving target indicator
THR = Threshold logic

*Read, e.g., "PM-AL monitor signal"

Figure 3.2-3 Personnel Location Logic

SYMBOL	DEFINITION	VALUES (RANGE)
A	Area just outside Plutonium Product Storage Area	
$A^{i}_{Cj}(\cdot)$	An anomaly giving rise, in the absence of any other anomaly, to TDR-i, for some class C and index j, sometimes identified further with indices ()	0 (normal), 1 (abnormal)
A_V	valve anomaly	
A_P	pump anomaly	
A_W	weight anomaly	
A_E	entrance/exit anomaly	
A_T	procedure duration anomaly	
A_{GB}	glove box presence anomaly	
A_S	sample transmission anomaly	
A_{MW}	portal metal anomaly (weak)	
A_{MS}	portal metal anomaly (strong)	
A_A	alarm anomaly	
A_B	B area α particle detection anomaly	
A_G	portal area γ-ray detection anomaly	
A_{VP}	valve glove box pressure anomaly	
A_{SP}	sample glove box pressure anomaly	
A_L	material loss (accountability or material estimate checks) anomaly	

Table 3.2-1 Decision Logic Notation

SYMBOL	DEFINITION	VALUES (RANGE)
A_{LA}	laboratory analysis anomaly	
A_{BC}	bar code present	See Section 5
A_{BCC}	bar code consistent	See Section 5
A_B	bag-in schedule anomaly	
$\underset{\sim}{A}^i$	vector of all level-i anomaly variables	
A_{ij}	set of vectors of anomaly level i which raise TDR to level j	
B	Plutonium Product Storage Area	
B_0, B_1	Subdivisions of B area	
CCAS	Computer Controlled Access System (used to indicate area as well as system)	
D	Dummy variable	
I	Set of samples sent but not received by lab	set of non-negative integers
I	Set of samples overdue at lab	set of non-negative integers
m	Mode index	
M=(m,i,j,k,l)	Procedure code	5-tuple of integers (each one not always used)
MC-1 computer	security station computer	
MC-2 computer	process control station computer	
MC-1,0	MC-1 operator (Security Chief)	
MC-2,0	MC-2 operator (Process Control Engineer)	
NMCO	Nuclear Materials Control Officer	

Table 3.2-1 Decision Logic Notation (continued)

SYMBOL	DEFINITION	VALUES (RANGE)
n(T), n(H), n(G)	Number of workers of type T, H, G (see below)	Integers 1-12
P(k)	Pump state for pump 45 in module #k	0 (off), 1 (on)
S	Authorized <u>and</u> sensed index set	set of non-negative integers
S_a	Authorized index set	set of non-negative integers
S_c	Authorized <u>and</u> sensed <u>and</u> constant index set	set of non-negative integers
S_s = (i,j,k,l)	Index set of sensed valves (i,j), pumps (k), and sampler flows (l)	set of non-negative integers
t	Present value of time	
t_{start}	Procedure start time (associated with first worker's entrance)	real number
t_{end}	Procedure end time (associated with last worker's exit)	
t_{Bi}, t_{Li}	Time of sending (from B area) & receipt (at analytical laboratory), respectively, of sample i	real number
T,H,G	Indicators of technician, health and safety, guard type workers	
V(i,j)	Valve setting for valve #i in module #j	0 (closed), 1 (open)
[t]	Authorized range of procedure durations	
[t_1, t_2]	Authorized range of procedure starting times	

Table 3.2-1 Decision Logic Notation (continued)

SYMBOL	DEFINITION	VALUES (RANGE)
$(\cdot)$	Sensed value	
$(\cdot)_a$	Authorized value	
1-B, 2-B, 3-B	First, second, and third-floors of B_1-area	

Table 3.2-1 Decision Logic Notation (continued)

(m,i,j,k,l) CODE	OPERATING MODE	Specified Valves OPEN	CLOSED*	P(PUMP 45) [on(1) OFF (0)]	W Flow in Sampler Line [YES(1) NO (0)]	Unauthorized Worker Locations	Number of Workers n(T),n(H)	Authorized Duration (Interval) t
0	Static		39-4	0	0	B	0,0	-
1-(i-j)	Filling single tank (i.j) from PPC	(13,14,15,16,17 or 18-i) and (19-i)	13-18 V_i except for one open	0	0	3-3,1-B 1-3	2.1	.3-.7 hr.
2-(i,j,k,l)	Transfer within same module (tank (i,j) to (k,l))	(1-6)(one),(20), (13-18) (one)	39-4	1	0	3-B, 1-B	"	.3-.7 hr
11-(i,j,k,l)	Transfer within same module & sample		37	1	1	1-B	"	.3-7 hr
3-(i,j,k,l)	Transfer between modules (tank (i,j) to (k,l))	(1-6)-i (one), (20)-j,(13-18) j (one)	39-4	1	0	3-B,1-B 1R,L	"	.3-.7 hr.
12-(i,j,k,l)	Transfer between modules & sample			1	1	1-B	"	
4-(i)	Stir module & sample		39-4	1	1	1-B	"	8-11 hrs.
5-(i,j)	Return tank (i,j) to Pu rework tank		39-4	1	0	1-B	"	.3-.7 hr.
6-(i,j)	Load-out	39 -4 and 21-i and (13-i or 14-i or 15-i... or 18-i)	21-j (j) and all from set of not used	1	0	3B,1-B	"	.3-.7 hr.
7-( )*	Maintenance		39-4	0	0	(to be specified)	(to be specified)	(to be specified)
8-( )*	Emergency		39-4	0	0	-	-	-
9-( )*	Chemical Addition		39-4	0	0	3-B	"	3-5 hrs.
10-( )*	H & S Check		39-4	0	0	-	0,2	1-2 hr.

*Indicated items are not complete.

Table 3.2-2 Typical Procedure Table (TDR = 0 or 1)

(t_1, t_2)	m,i,j,k,l	Authorized ID's
.	.	.
.	.	.
.	.	.

Table 3.2-3 Format of Daily Work Schedule Table

TDR-2,3 PERSONNEL AUTHORIZATION TABLE

Authorized ID's	Number of Guards in Area $N_a(G)$	Number of Health Workers $N_a(H)$
TDR=2	1	1
TDR=3	3	2

Table 3.2-4 Personnel Authorization Table (TDR=2 or 3)

to indicate anomalous conditions; the superscript index i = 1, 2, 3 indicates the TDR level the particular anomaly would produce in the absence of any other anomaly given certain "low risk" operating modes; the subscript notation c_j and the argument (•) are further used to identify the physical origin of the anomaly* (see Table 3.2-2, under "A", for definitions of the subscript notations and see Table 3.3-1 for a classification of anomaly levels by source). In general, the setting of an anomaly variable to the one state is caused by a signal received from a sensor.

Values of the anomaly variables influence the decision logic in the ways indicated in Fig. 3.2-2; in general, a level i anomaly gives rise by itself to a TDR of level i. Anomaly signals also affect various display systems in the MC-1 and MC-2 rooms. Not shown in any logic diagram is the important "latching" effect on each anomaly variable: having once been set to a value of unity, an anomaly variable cannot return to zero by the simple removal of the physical signal which produced it but must be reset by the appropriate operators, as specified by the logic described in Section 3.5. Note that the logic does not require the nulling of the physical signal, but only the relevant operator approval; thus operators in fact have the power (provided the correct combination of approvals is obtained) to override any anomalous signal. A discussion of the procedures used to minimize erroneous overrides will be given in a following section.

TDR levels are generated according to the logic of Fig. 3.2-2. They are either generated automatically through electrical signals from sensors or subsystems, as received by the MC-1 and MC-2 computers, or by the direct action of human operators. For example, a definite indication of material loss** in tank 4-2 generates an anomaly signal $A^3_{L4-2} = 1$; this immediately causes a TDR of level 3, independent of other logic inputs. Alternatively, in the absence of a material loss signal from the tank level estimator/detector ($A^3_{L4-2} = 0$), a TDR of 3 could be produced through the sole approval of the NMCO.***

In addition to the direct influence of operators and the effects of

*In order to simplify the notation, in many places a single subscript is used to indicate the entire set of anomalies of a given level.

**See Section 7 for discussion of material loss detection

***The next subsection describes the exact mechanism of all such operator inputs to the computer.

Anomaly Level	Origin	Symbol
1		
2		
3		

TABLE 3.3-1 Format of Anomaly Level* Source Table

*Anomaly level = TDR level which this anomaly would produce under nominal conditions, and under least sensitive operating mode conditions.

single anomalies, there are two other principal methods of generating TDR levels, according to Fig. 3.3-1. Special combinations of anomalies also produce TDR levels; in Fig. 3.3-1 these relations are

$$\underline{A}^1 \in A_{12} \rightarrow \text{TDR}=2,$$
$$\underline{A}^1 \in A_{13} \rightarrow \text{TDR}=3,$$
$$\underline{A}^2 \in A_{23} \rightarrow \text{TDR}=3,$$

where $\underline{A}^i$ is a vector of all anomaly variables of level i, and A_{ij} is the set of vectors of anomaly level i which raise the TDR to level j. Normally, the sets A_{ij} will be constructed from linear combinations of the anomaly variables as

$$A_{12} = \left\{ \underline{A}^1 : \sum_i C_{12i} A_i^1 > N_{12} \right\}$$

$$A_{13} = \left\{ \underline{A}^1 : \sum_i C_{13i} A_i^1 > N_{13} \right\}$$

$$A_{23} = \left\{ \underline{A}^2 : \sum_i C_{23i} A_i^2 > N_{23} \right\}$$

As the simplest case, the weighting coefficients, C_{jki} may be all taken as unity, so that the criteria become simply thresholds on the number of nonzero anomaly variables of level i permitted before the TDR level is automatically raised to level j.

The second method shown in Fig. 3.2-2 for raising the TDR level automatically, arises from a test on the <u>time</u> in which the system has remained at a certain level. Fig. 3.2-2 shows the following particular rules:

TDR = 1 has persisted $\geq$ .25 hr. $\rightarrow$ TDR = 2
TDR = 2 has persisted $\geq$ .5 hr. $\rightarrow$ TDR = 3

Thus, threshold times are chosen according to judgments on the normal times to decrease TDR levels (via subsequently described procedures) when actual diversion is not taking place; times in excess of these thresholds are in effect taken as evidence of a higher state of danger. These thresholds are also a protection mechanism against collusion on the part of some operators and guards to permit lower levels of TDR to persist indefinitely while diversion is taking place.

Also note that one further method for producing a TDR level is made

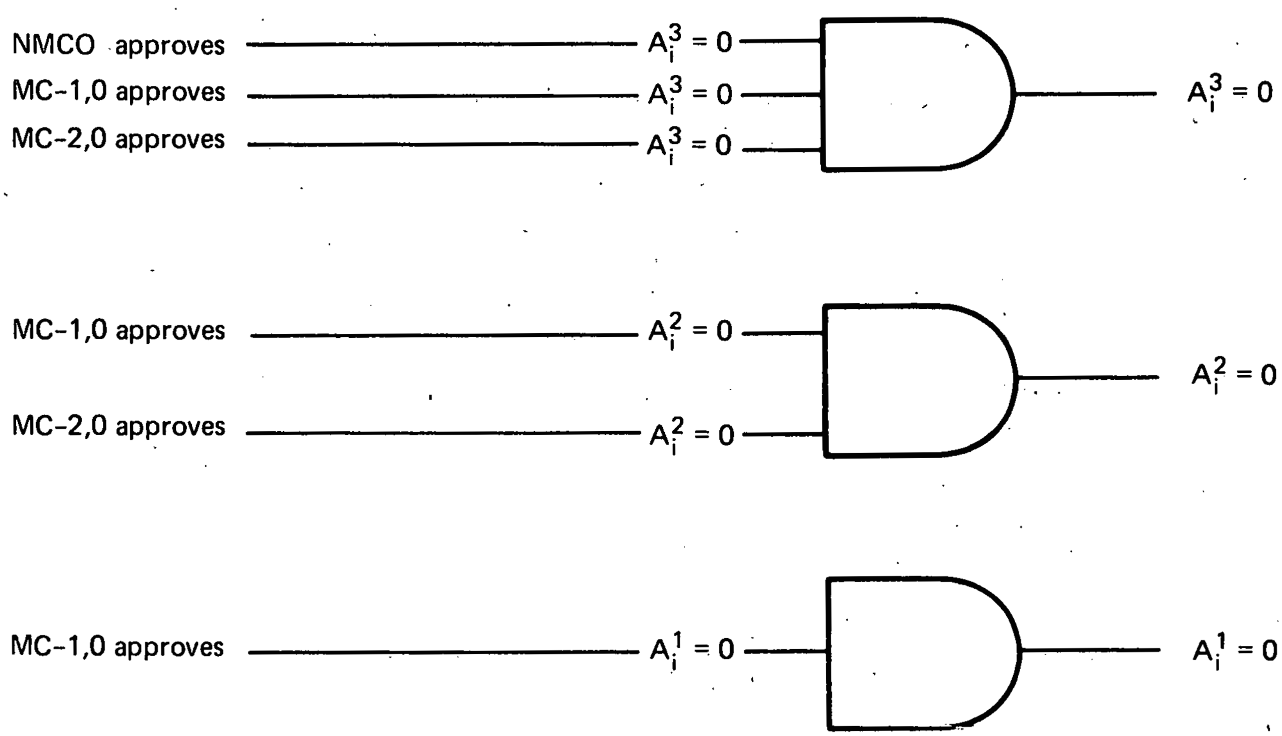


Figure 3.3-1 Anomaly Reduction Logic

explicit in the Master Decision Logic of Fig. 3.2-1, without reference to anomaly variables: the partial loss* of a subsystem of level i produces a TDR level of (i-1), while the complete loss of a level i subsystem produces a TDR level of i. "Partial loss" is taken to mean either significantly degraded (but not totally lost) functioning of the subsystem, e.g. increasing noise on a signal, loss of subsystem back-up, or loss of auxiliary power supply.

3.4 REDUCTION OF TDR LEVELS

The procedure for reducing a TDR level is indicated in Fig. 3.4-1 and requires the following actions:

a) The appropriate MC supervisors must approve any reduction in TDR level; each reduction can occur only one step at a time.

b) Three supervisors (NMCO, MC-1,0, MC-2,0) are required for the reduction TDR-3 to TDR-2, two (MC-1,0, MC-2,0) for TDR-2 to TDR-1, and one (MC-1,0) for TDR-1 to TDR-0.

c) In addition to the approval of the indicated supervisors, a TDR reduction requires the cancellation of each anomaly alarm at the given TDR level. In turn, the zeroing of each anomaly also requires the explicit approval of a relevant group of supervisors, even when the initiating stimuli have returned to a normal state. (See Fig. 3.3-1 and Section 3.5 for the anomaly reduction rules, which are analogous to those for TDR levels themselves.)

The effect of these procedures is that responsible supervisors are required to investigate the detailed causes of a TDR level, and to make explicit judgments on whether these causes have been removed; furthermore, they must make a separate, global judgment on whether the overall situation merits a reduction in a TDR level. With higher TDR levels, greater security is achieved through the requirement of greater redundancy in decision-makers and in the participation of a higher level of authority. Since neither detailed measures of danger (A's) nor global measures (TDR's) can be automatically re-set to lower levels, i.e., because the decision logic has <u>memory</u>, the process is protected against various forms of diversion and tampering which would produce only transitory anomalous signals.

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*In many cases, monitor subsystems are equipped with tamper detection circuits and may also be wired in a supervisory mode.

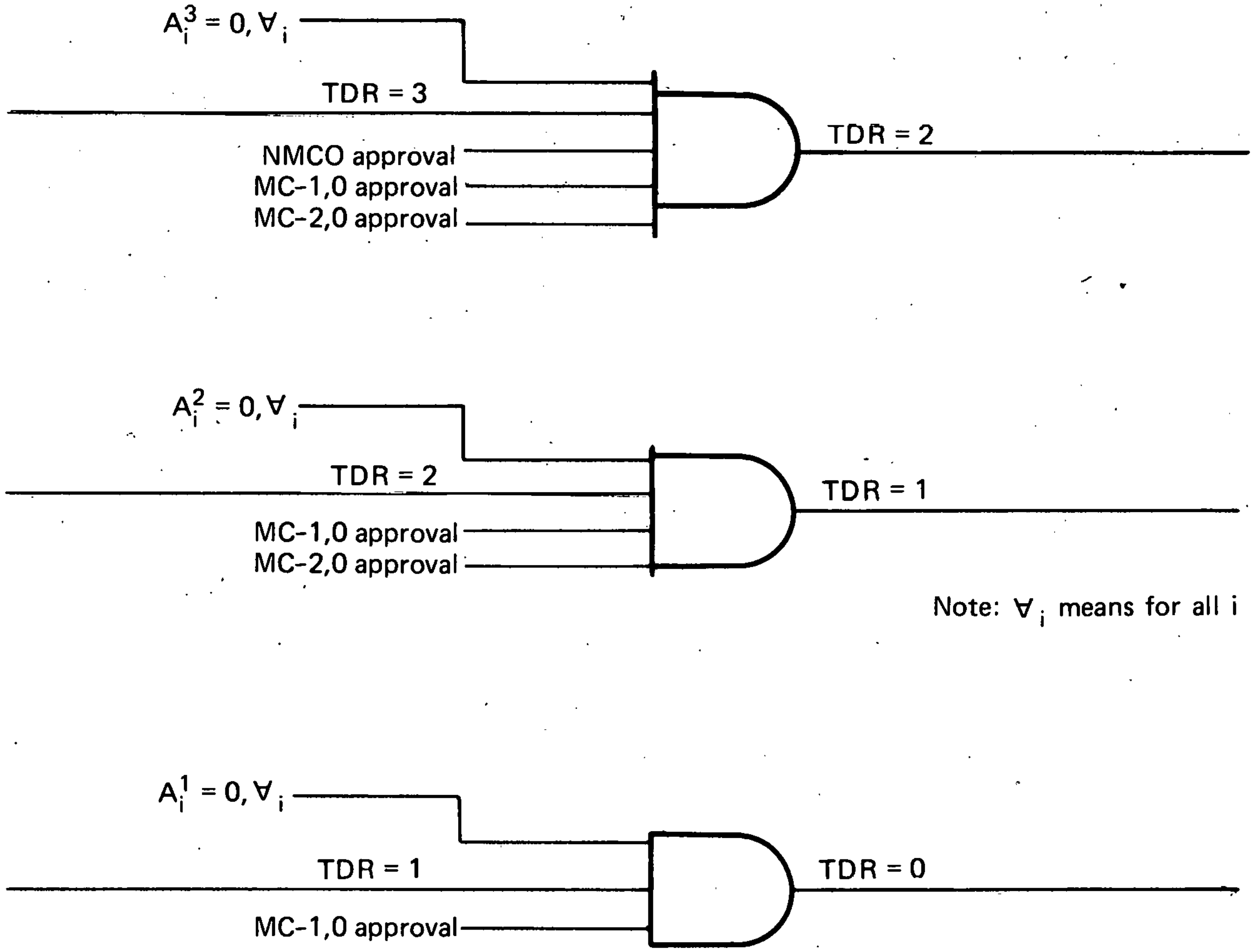

Figure 3.4-1 TDR Reduction Logic

To reduce erroneous reductions in TDR and anomaly levels by operators, certain procedures are required to be followed in addition to those indicated in Figs. 3.4-1 and 3.3-2. Each participating operator must enter his ID card and number in the computer, which allows his input upon verification by the computer that he is authorized for this action. A record is kept of this action.

In addition, the computer may require a statement regarding the reason for the reduction; when required, the operator's response is recorded and stored. All anomaly reductions are reviewed by the NMCO at the end of each shift.

Finally, every reduction in anomaly level or TDR level requires the operator to follow a check list which is specific to the circumstances; the purpose of the check list is to provide redundancy as well to utilize a trained operator's ability to recognize unforeseen patterns and extract useful information from unanticipated origins. The next section gives an example of an operator check list.

3.5 OPERATOR CHECK LIST: EXAMPLE*

The following is an example of a typical check list procedure which will be used to aid the NMCO, MC-1,0, or MC-2,0 in their decisions regarding the lowering of a TDR level. In general, a check list be presented to each person involved in the decision on a cathode ray tube (CRT) display and he will be required to input answers to check list questions correctly before the computer allows a reduction in TDR state.

Sample Check List

A simple incident which is likely to happen frequently is used as a basis for the checklist example presented here. There are seven television cameras in the MC design. There will be motion detectors for each CCTV camera. Whenever one of these "sees" a change of light intensity, it signals movement. If this occurs and no one is seen on the CCTV monitors to be in the area, an investigation is in order.

In this scenario, it is assumed that one of the motion detectors viewing one of the monitored areas, A-1 detects motion.** When this happens, the system

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*This is discussed more fully in Reference 3-3.

**If a scheduled procedure requires the presence of an operator in the field of view of a particular TV camera, there will be no anomaly situation and hence no anomaly called. The location of operators during operations is a variable monitored by the MC system.

is placed immediately by the MC-1 computer into state TDR-1, unless certain activities are being carried out, e.g., plutonium product sampling, in which case, the system goes to TDR-2. For the purposes of this example it is assumed that there is no scheduled activity going on and the system is placed in TDR-1 by computer MC-1.

When the MC system goes to the TDR-1 state, both the MC-2,0 (Process operator) at the MC-2 computer and the MC-2,0 (Security Guard) at the MC-1 computer survey all signal and television inputs to their individual stations as to the apparent reason for the change in state. They will also gather any additional information which would indicate a need for going to an even higher TDR state. This is all done as quickly as possible without any check lists being used. Then each operator will begin his check list procedure. The first group of questions or commands on each check list is that set which will require raising the TDR state if answered affirmatively.

The first several questions or commands remind the Security Guard and the SFO of the actions each should take immediately upon entering state TDR1. It should be noted that the above scenario eventually starts the MC-1 Guard going through his check list. But the same check list will be used no matter what caused the transition to state TDR-2. It is generally applicable.

The check lists used by the three decision makers include some checking of information and situations not otherwise included in the Master Decision Logic (MDL). The intelligence, adaptability, and pattern recognition talent of human operators will make possible some improvements over the fixed, less flexible design logic.

Upon any change of TDR state upwards, the first concern of anyone in the system is to ascertain that there is no indication of additional threat which should cause the TDR state to be raised even higher. This is the purpose of the A check list. Only after this set of questions has been answered negatively does a second set, the B set, get attention allowing the lowering of the state.

Table 3.5-1 gives the A check list for this example scenario. After this A check list has been completed, the MC-1,0 will then be presented the B check list on his CRT display. Table 3.5-2 gives the B check list.

Step A-2 in the first check list requires the investigation of each anomaly. A sample anomaly reduction check list for the unauthorized motion as detected by the CCTV system is given in Table 3.5-3. A list such as this

For this level of check list, the format of the questions dictates that upon the first answer of YES the system will be raised to TDR-2 and a TDR-2 check list will be used.

STEP	ACTION	REACTION
A-1	Have you failed to find at least one guard available for dispatch if necessary?	YES - Go to TDR-2 NO - Proceed
A-2*	Have you failed to identify the anomalies which raised the system to TDR-1?	YES - Go to TDR-2 NO - Proceed
A-3	Does a survey of signals and television screens show anything that increases the threat? (Review video recording)	YES - Go to TDR-2 NO - Proceed
A-4	Can you see any unauthorized personnel in: Area A_R ? A_L ? CCAS? B_O ? 1-B ? 2-B ? 3-B ?	YES - for any area Go to TDR-2 NO - Proceed
A-5	Has State TDR-1 existed for more than 0.5 hours?	YES - Go to State TDR-2** NO - Proceed
A-6	Has Emergency Exit Mode been used and not reset?	YES - Go to State TDR-2 NO - Proceed
A-7	Does the computer show existing anomaly sum exceeds limit for TDR-1?	YES - Go to State TDR-2** NO - Proceed
A-8	Is any radiation monitor indicating the passage of nuclear material through a CCAS?	YES - Go to State TDR-3 NO - Proceed
A-9	Is any metal detector indicating the passage of metal through a CCAS?	YES - Go to State TDR-2 NO - Proceed

TABLE 3.5-1. Checklist A for MC-1,0: Security

*An anomaly list, in chronological order of appearance (most recent first will be displayed to the MC-1,0).
**This is automatic.

STEP	ACTION	REACTION
A-10	Is there any indication of unauthorized attempt to modify data or program?	YES - Go to State TDR-2 NO - Proceed
A-11	Is the Alpha Air Monitor indicating airborne nuclear material presence?	YES - Go to State TDR-3 NO - Proceed
A-12	Is the computer indicating excessive time to complete any recent task?	YES - Go to State TDR-2 NO - Proceed
A-13	Is there indication of passage through CCAS with weight outside limits?	YES - Go to State TDR-2 NO - Proceed
A-14	Is the last inventory outside acceptable limits?	YES - Go to State TDR-3 NO - Proceed
A-15	Have you any evidence that might indicate unauthorized movement of nuclear material?	YES - Go to State TDR-3 NO - Proceed
A-16	Go to the anomaly check lists* for the anomalies identified in Step A-2. Return here when anomaly list is cleared.	

TABLE 3.5-1. Checklist A for MC-1,0; Security (continued)

*Check lists similar to those shown here for TDR levels exist for each anomaly. For this example, a single specific anomaly was assumed to have occurred. An anomaly reduction check list for this example is presented in Table 3.5-3.

For the next level of check list, upon the first answer of YES, take remedial action and start again at the beginning of Section B.

STEP	ACTION	REACTION
B-1	Have you failed to cancel any anomaly?	YES - Continue attempts to cancel NO - Proceed
B-2	If repair is needed, have you failed to initiate a repair order?	YES - Order Repair NO - Proceed
B-3	Have you any evidence that a reduction to TDR-0 is possibly unwise?	YES NO - Proceed
B-4	Lower state to TDR-0.	

TABLE 3.5-2. Checklist B; Reduction of TDR Level

STEP	ACTION	REACTION
1.	Review playback of CCTV camera; are there any unauthorized personnel?	YES - Go to TDR-2 NO - Proceed
2.	Dispatch Guard to anomaly location	
3.	Has the Guard failed to report on the area?	YES - Wait NO - Proceed
4.	Has the Guard found any unauthorized personnel in the area?	YES - Go to TDR-3 NO - Proceed
5.	Has the television system degraded so much that it should be considered failed?	YES - Initiate Repair Order NO - Proceed
6.	Is the cause for the anomaly likely to cause others as well?	YES - Check for existence of these NO - Proceed
7.	Has the MC-1 computer omitted reporting any anomalies which exist?	YES - Go to TDR-2 NO - Proceed
8.	Have you any evidence that the anomaly signal should not be cancelled?	YES - Go to TDR-2 NO - Proceed
9.	Cancel anomaly signal. Proceed through check lists for other anomalies existing and return to TDR-1 Checklist at B.	

TABLE 3.5-3. Checklist for Anomaly Caused by Unauthorized Movement Detection

will be available for each potential anomaly.

Follow the sequence of questions and actions as required by the answers.

3.6 PROCEDURE MONITORING

Procedure monitoring is an important element of the Test-Bed MC System. The monitoring of operating procedures is described in this section. The steps in each operating procedure are given in another section of this report.

The fundamental indicators of procedure performance are:

- worker number, ID, and classification
- worker location
- event times
- event character

Procedures are authorized and carried out according to rules described in Section 4 of this report. Several procedure monitoring functions are indicated there; the parallel procedure monitoring system is described here in more detail, and shown in Fig. 3.3-1.

Sections A and B of this figure show the personnel screening part of the procedure logic. Identities are checked upon entry of ID cards into the card reader in the CCAS booth; comparisons are made with the MC-1 based authorization as to number, identity, and classification (e.g., technician (T) or health and safety worker (H)). Another card designating the procedure is also entered, and the procedure ID is compared against that authorized by the computer; starting time is also compared against the authorized one for the given procedure. Upon satisfaction of all tests, entry is permitted, at which point the official procedure start time is defined to begin (it begins upon the entry of the first person of a team).

Next, the computer defines, for the authorized procedure, sets of authorized valve, pump, and flow conditions (Section C of Fig. 3.6-1). Then the logic begins two monitoring tasks for the procedure: in part D of the figure, tests are made continuously and reported continuously for indications of valve, pump, or flow states which are unauthorized to occur at any time during the procedure. In part E of the Fig. 3.6-1, tests are made continuously and reported at the termination of the procedure of indications of states which should have occurred by the end time but did not. Finally, certain tests are made on monitors continuously during all procedures, independent of time and activity, as indicated in part F of the figure.

The end-time of a procedure is determined by the exit time of the last worker (workers exit in complementary fashion to their entrance: by a removal of the procedure card which they inserted upon entrance; ID cards are simply read, but kept in their possession). This end time is required by procedure tests in Part E of the figure. The time is of course an important measurement itself; overall time comparisons are not shown explicitly in Fig. 3.6-1; they appear in various places in Section 4 on Operating Procedures.

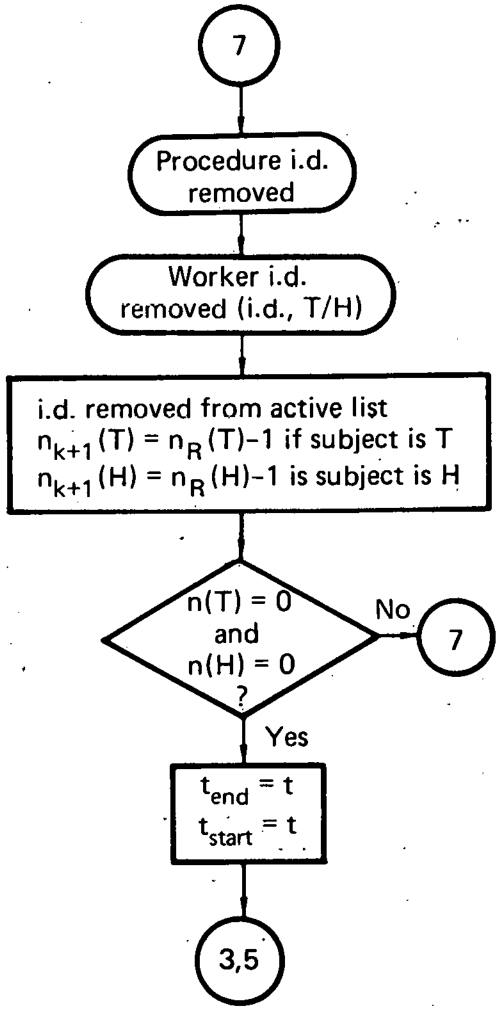


Figure 3.6-1A Procedure Completion Monitoring

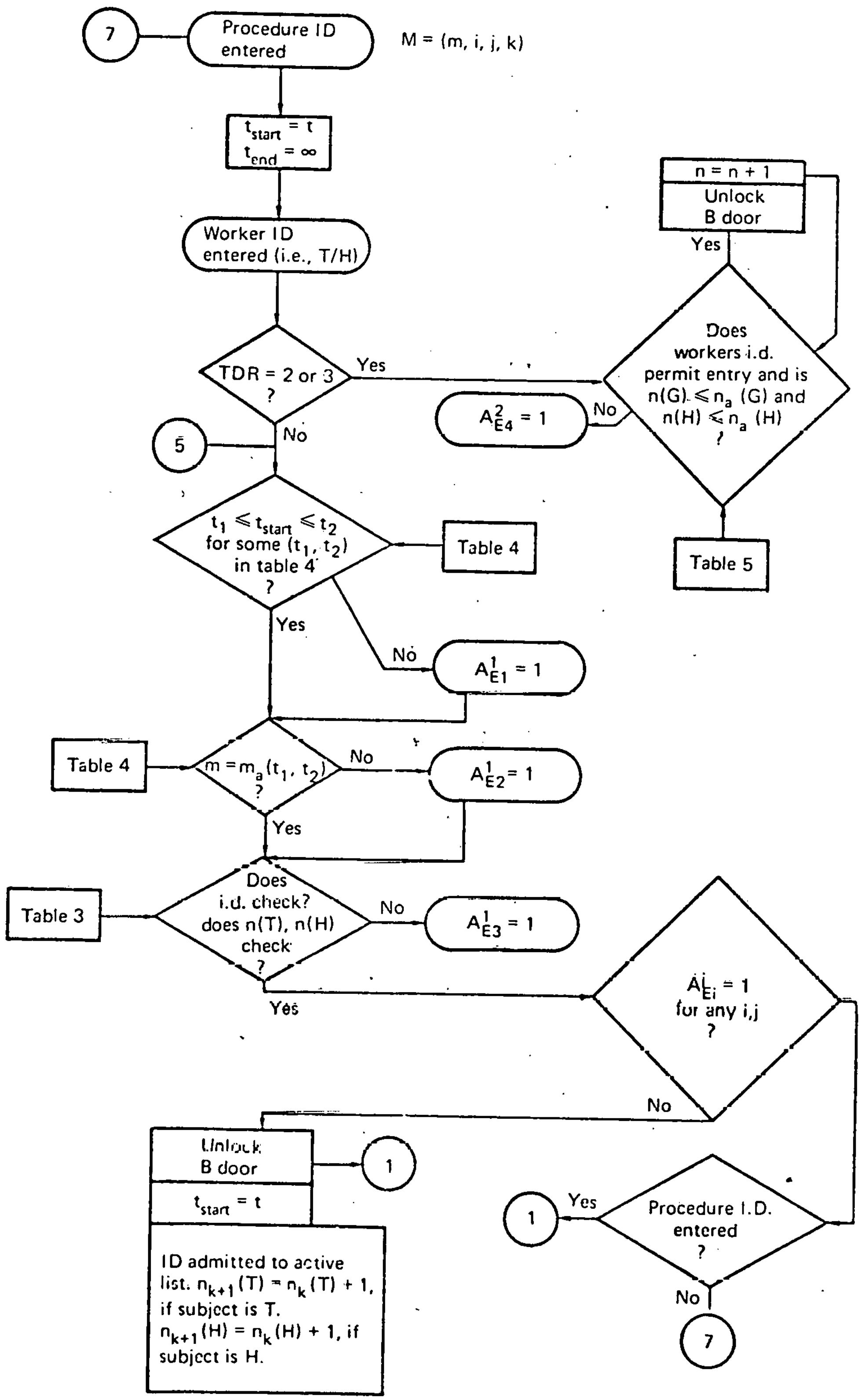
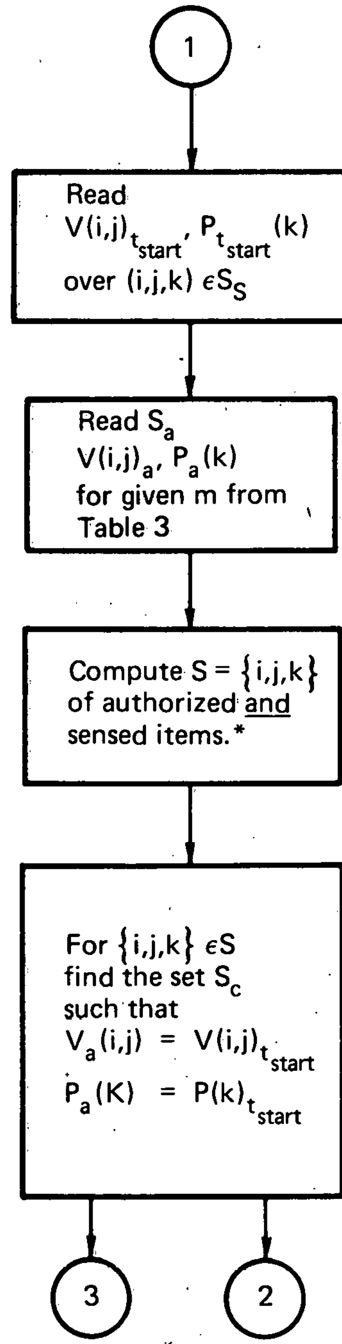


Figure 3.6-1B Procedure Initiation Monitoring



*The set S consists of these items which are both authorized and sensed, i.e., there is a possibility that some authorized items are not sensed, and such items are not in S.

Figure 3.6-1C Definition of Authorized and Sensed Valve and Pump Conditions.

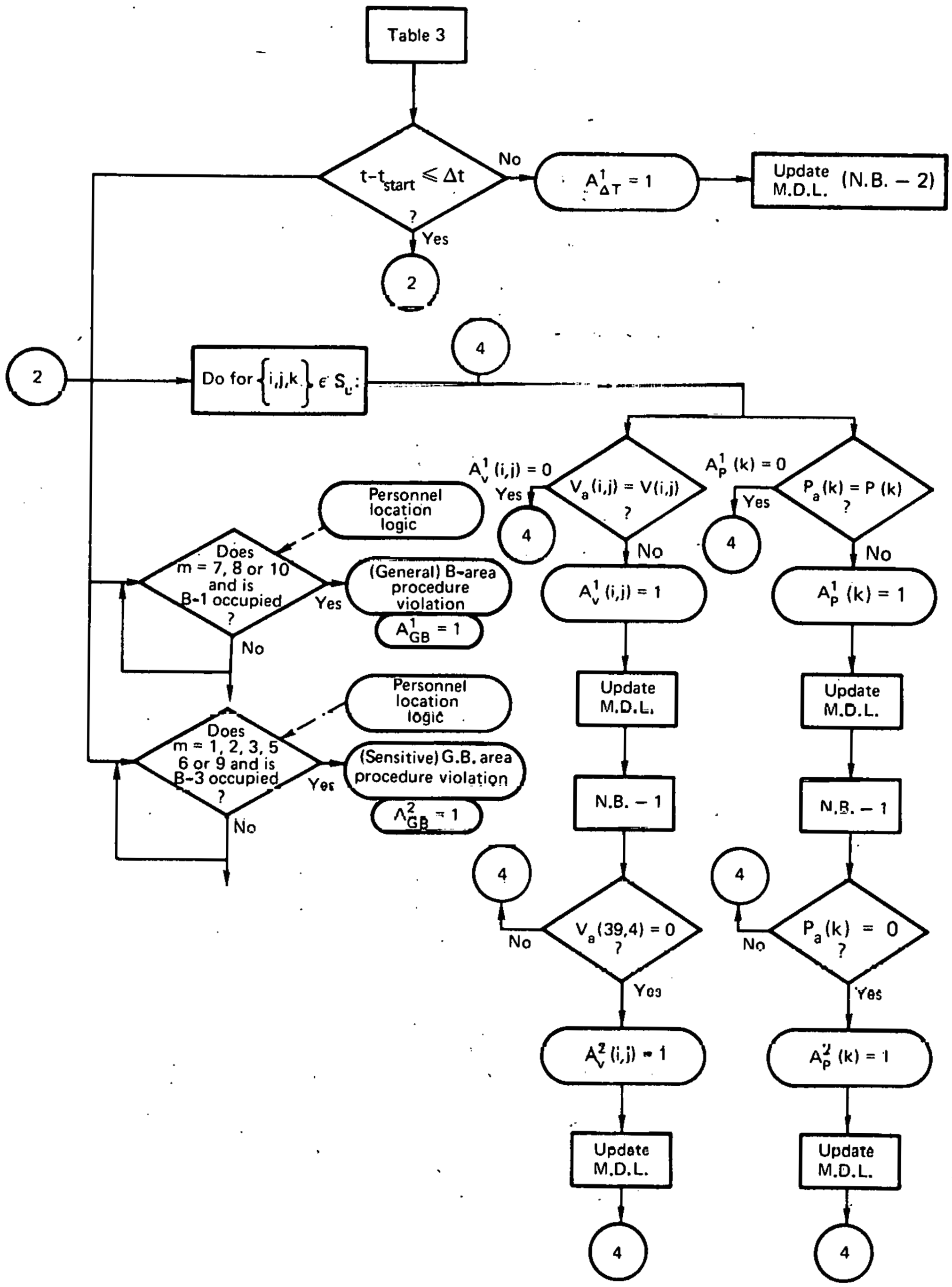


Figure 3.6-1D Continuous Test over $[t_{start}, t_{end}]$

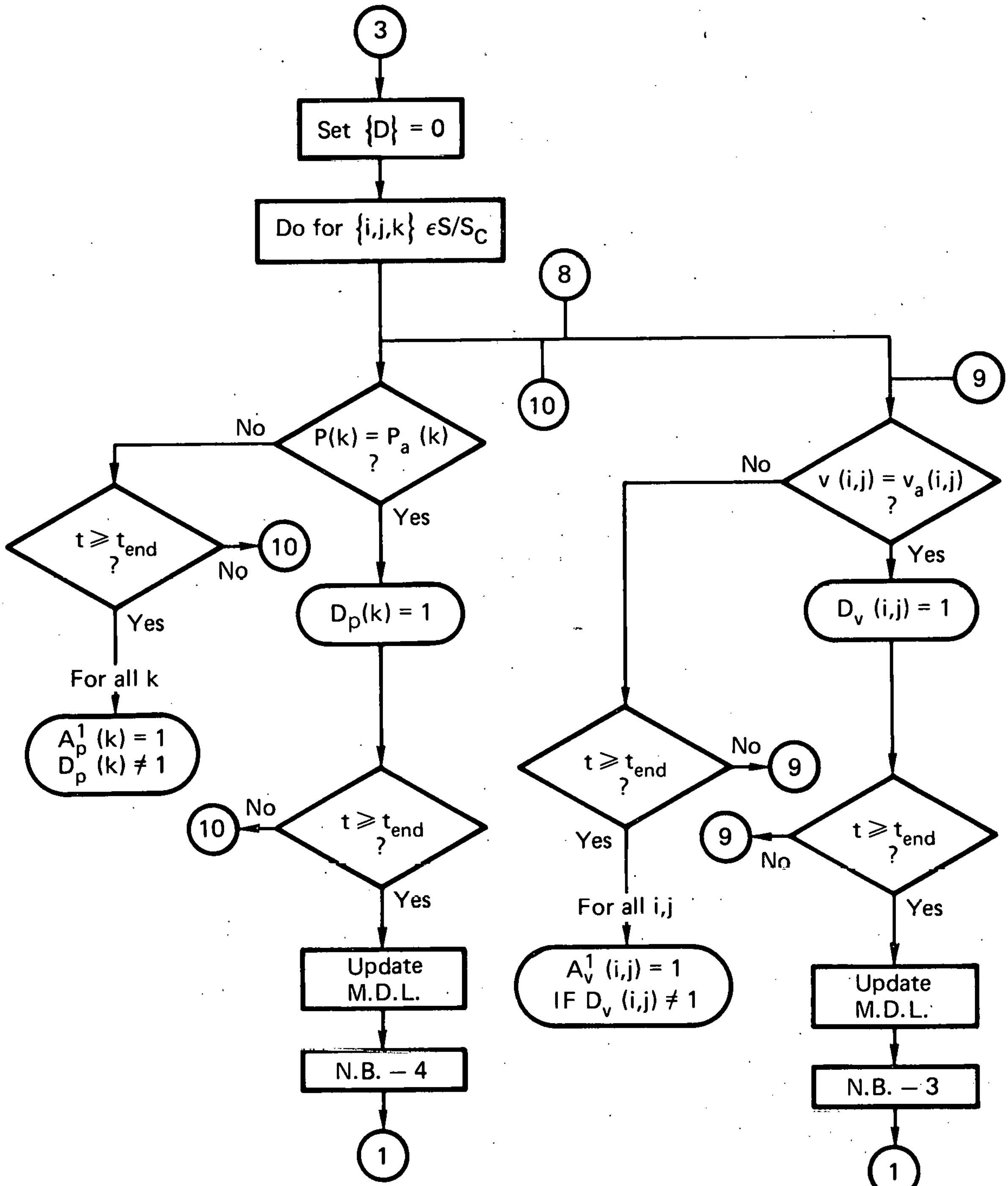
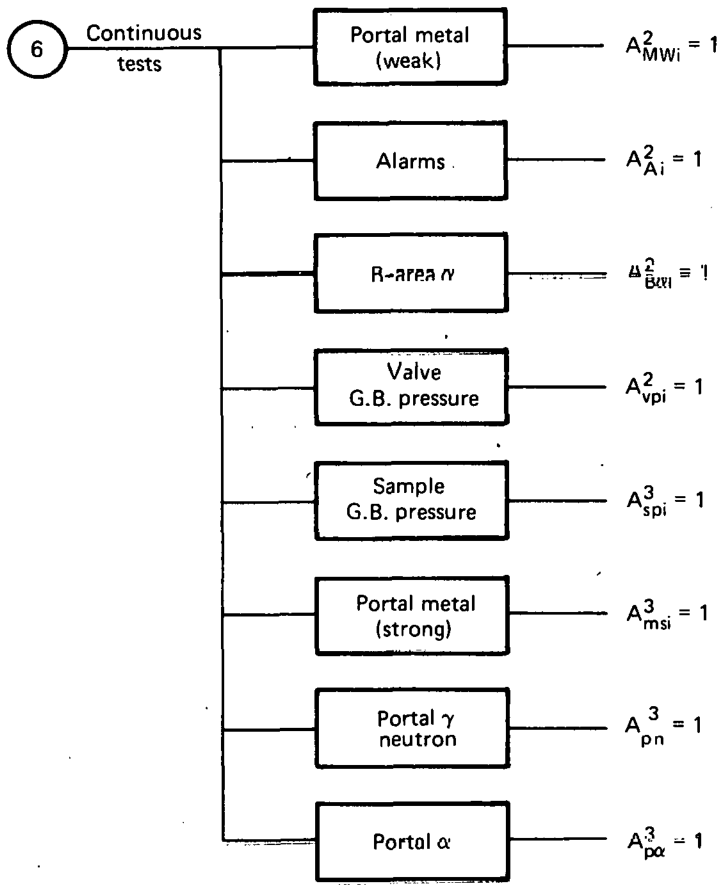


Figure 3.6-1E - Tests Reported at $t = t_{end}$ (N.B.-7)



CODE

N.B.-1 "and do not repeat 4 on this index until TDR=0"

N.B.-2 "and do not repeat 7 until $A^1_\Delta = 0$."

N.B.-3 "and do not repeat 9 on this index until $t \geq t_{end}$ and 3 do-loop complete."

N.B.-4 "and do not repeat 10 on this index until $t \geq t_{end}$ and 3 do-loop complete."

N.B.-5 "and do not repeat 11 on this index until $t \geq t_{end}$ and 3 do-loop complete."

N.B.-6 Exit CCAS logic not shown

N.B.-7 Tests insure that specified changes have occurred by t_{end}. Authorized values in this case are authorized changed values.

(i,j) = Valve-module indices;

k = Pump module index

S_s = i,j,k,ℓ, index set of sensed values, pumps and flows.

S_a = i,j,k,ℓ, authorized index set.

S = i,j,k,ℓ, authorized and sensed index set.

S_C = Set of indices of authorized, sensed and constant items.

M.D.L. Master decision logic.

Figure 3.6-1F Continuous Monitoring Independent of Time and Procedure Status

REFERENCES for Section 3

3-1. S. Weissenberger, "Decision Logic: Exemplary Design for Plutonium Product Storage Area," Lawrence Livermore Laboratory, MC 77-725, June 9, 1977.

3-2. E. P. Schelonka, "Availability Analysis for High Reliability Computer Systems in Nuclear Facilities", Presented at The Institute for Nuclear Materials Management Eighteenth Annual Meeting, June 29 - July 1, 1977, Washington, D.C.

3-3. D. E. Morgan, "Redo of Sample Checklist," Lawrence Livermore Laboratory, MC 77-372, August 4, 1977.

4.0 OPERATING PROCEDURES*

This section outlines the operation procedures which must be utilized to permit the maintenance of a running inventory of the total plutonium in the Test Bed Design Pu Nitrate Storage Facility. A significant portion of the protection provided by this safeguard system is derived from adherence to these operating procedures. Details on the accountability procedures are provided in section 7.4.

4.1 FACILITY DESCRIPTION

The facility consists of one cell, made up of four modules, each module consisting of six tanks of 756 liters capacity each. Under steady state operation, transfers will be made from the Plutonium Product Cell (PPC) twice weekly at a rate of 730 liters/transfer. By directing each filling to a particular tank, one module will take three weeks to fill. At which time it will be stirred, analyzed, inventoried, and sealed off.

The module will then remain in the storage mode for approximately six weeks, during which time no laboratory analyses will be made. Following the six weeks of storage, the module will then provide the feed for the conversion facility over the next three week period. Laboratory analyses will be repeated on material after it is received at the conversion facility; consequently, the only laboratory analysis considered in this Test-Bed Design is that done upon the completion of filling a module. It should be noted that Tank 6 of Module 4 has been designated as a "slop tank" and incorporates some unique plumbing to permit collection of any spillage to the sump. (See Fig. 2.3.2-1.) In order to keep this tank available at all times for any emergency that arises, Module 4 will utilize only five tanks (rather than the six of the other three modules) for normal process operations.

The "normal" modes of operations of PNC1 are treated separately below. Temperature, level, and density measurements are recorded continuously although the precision of any given reading may be affected by the specific operations being performed at that time. These modes are:

---

*This discussion is based on material contained in Reference 4-1.

STATIC STORAGE

Plutonium product is not moved and is found solely in the storage tanks and those lines which had previously been used and are not free draining. An estimate of the length of the pipe runs and locations was made and an evaluation of possible trapped volumes indicates that the holdup outside of tankage might be as much as 72 liters and probably will not be less than 18 liters for PNC1. The volume uncertainty in the holdup, due to normal piping manufacturing tolerances is about 12 ml/foot of pipe. Valves 19, 20, 21, and 1 through 6 of each module will be sealed.

PRODUCT RECEIVAL MODE (Accountability Procedures are described in Section 7.4)

Product is received as a gravity flow from the PPC and is directed to a specific tank in PNC1. The change in inventory in PNC1 is that change of volume indicated by the liquid level change of the tank designated to receive the flow. For purposes of modeling PNC1 the assumption is made that "normal" operations will constitute two transfer operations of 730 liters every week.

STIRRING MODE

Utilized to either homogenize the contents of any given module of six tanks to provide a uniform batch of Pu product for future conversion to oxide, or to homogenize the product in a single tank for accountability measurements after product has been received. When being stirred, product is drawn off from the lowest portion of the six tanks in the module (or specific tank), pumped by the module pump and returned, via the module header, to the same module (or specific tank). It is estimated that nine hours will be required for three complete exchanges of a full module. The valves will be adjusted to obtain approximately the same flows to all six tanks.

During this time, a side stream of approximately 0.25 liter/min is circulated through the sample glove box and returned to the pumped stream. Periodic samples may be withdrawn from this stream and sent to the laboratory for analysis. Continuous on-line analysis is made with a γ-ray spectrometer. This spectrometer is connected in series with the sampler loop and consequently samples a small portion of the same 0.25 liter/min flow.

TRANSFER MODE

Product from any one tank can be pumped to any other, either within the same module or between modules. The module header is utilized for intra-module transfers; the inter-cell transfer header for inter-module transfers. It is estimated that 30 minutes of pumping time is required for transfer of a full tank. Sampling may be conducted during this period.

CHEMICAL ADDITION MODE

Provision has been made for the addition of cold chemicals in premeasured amounts (i.e., nitric acid), to each tank and for wash down and decontamination of the pumping system. The chemical connections to the tanks are made to hose connections outside of the glove boxes located above the high liquid level of the tanks. These lines are protected by check valves which permit inward flow only. All flush and addition line inlets are at the same level, approximately at the 284' 2" elevation.

LOAD-OUT MODE

Plutonium Nitrate from PNC1 is transferred directly to the CF via a pipe connected to valve #39, Module 4.

An appropriate steady state operating cycle for PNC1 is shown in Fig. 4.1-1. This figure shows the pattern and approximate duration of each mode within the normal (non-emergency) operational cycle.

4.2 ROLE OF THE MATERIAL CONTROL COMPUTER SYSTEM

All operating procedures are designed to be highly interactive with the MC computer. Section 2, summarizing the functions of the Material Control System, presents a much more global view of the total computer-facility interactions. The computer has three identifiable functions as relates to process operating procedures. These are described below.

4.2.1 Operation Monitoring

Operations in the Storage Facility are paced by the MC computer which provides instructions on required valve positions (obtained from its internal data bank) and follows through by monitoring the actual position of crucial valves. It also compares actual times for process operations with "normal" times; providing a flag upon recognition of anomolies.

4.2.2 Safety Monitoring

The MC computer provides a safety function by enabling particular operations only when certain preset conditions are met; and it provides warning alarms of various levels upon detection of procedural anomolies.

4.2.3 Material Accountability

It provides a real-time best estimate of plutonium inventory, regardless

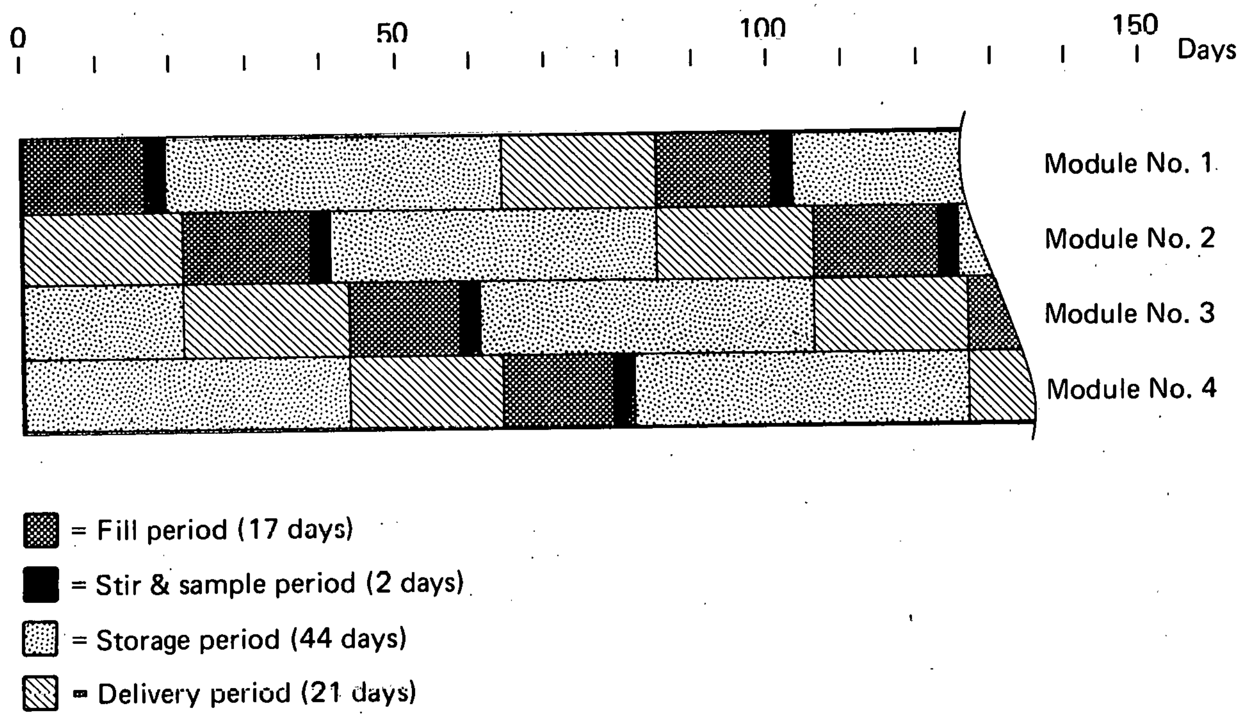


Figure 4.1-1 Approximate Steady State Operations Cycle

of the operating mode of the facility. To accomplish this, the computer has hard-wired ties to crucial function transducers; it contains a data base of models, holdups, calibrations, etc; and it plays an interactive role with the Laboratory Data System (LDS).

4.3 COMPUTER/FACILITY TIES

Real-time information on the operational status and the inventory of the Storage Facility is provided by a number of both digital and analog ties (Table 4.3-1.) and described below.

ITEM	TYPE OF SIGNAL	NUMBER OF CHANNELS	INDEPENDENT* LOCAL** RECORDING	INDEPENDENT LOCAL SIGNAL (ALARM)
Valve Position	Binary	72	NO	NO
Density	Digital	24	YES	NO
Liquid Head	Digital	24	YES	YES
Static Head	Digital	24	YES	NO
Temperature	Digital	48	YES	YES
Sampler	Binary	4	NO	YES
Pump	Binary	4	NO	YES
Spectrometer	Digital	1-4	YES	YES

TABLE 4.3-1 COMPUTER/FACILITY TIES

*"Independent" refers to a lack of dependency on the availability or condition of the MC computer.

**"Local" implies accessibility to the floor of the storage facility but also includes a process alarm to the central room for safety purposes.

4.3.1 Valve Position Indicator - a binary signal which indicates that any limit switch equipped valve is either closed or not closed.

4.3.2 Density and Level Measurements on Each Tank - the differential pressure between the two density measuring bubbler tubes will be converted to a digital signal at the pressure transducer and tied to the MC computer. In addition, the pressure head on the longer of the two bubbler tubes will also undergo A to D conversion and be tied to the MC computer.

4.3.3 Static Head Measurement - A transducer with A to D conversion will continuously monitor the static head above the liquid level in each tank and be similarly tied to the MC computer.

4.3.4 Temperature Measurement - Each of the two tank skin thermocouples are similarly tied to the MC computer.

4.3.5 Sampler - Each of the four samplers will be interlocked to provide the MC computer with a binary signal when material could be flowing through the needle block.

4.3.6 Pumps - Each of the four module pumps and the sump pump will similarly provide a binary signal to record actual running times. In addition, the four module pumps require an enabling signal from the MC computer system.

4.3.7 The γ-ray Spectrometer - A bypass stream from each sampler will be directed (at the time that sampler is operating) through a γ-ray spectrometer. The spectrometer will supply a digital signal to the MC computer proportional to the ^{239}Pu concentration of the stream. This device provides indication of when stirring is complete and provides a check on the analytic laboratory measurements.

4.3.8 Interlocks - Position switches are located on each local and remote panel door and on the cover of the bag in/out ports of the glove boxes. These switches will provide an alarm in the event of an unpreprogrammed entry to either the panels or a glove box.

4.4 PRE-OPERATIONAL CALIBRATIONS

4.4.1 TANKS

Each tank shall be calibrated by NBS Standard calibration techniques with both density 1.0 material and density 1.5 material. The results of this calibration will be a curve for each tank of liters vs. bubbler system indicated head, for each of the two density fluids. (By using fluids of two densities it is presumed that an approximation that would account for possible varying density - dependent mechanical deflections of the tank could be made.) The reduced data from this calibration forms part of the permanent data base for the MC computer.

4.4.2 PIPING

The holdup of material in the piping system (for each module) will be experimentally determined to provide data on entrapped volumes under these conditions:

a) Holdup in fill lines from PPC following a material transfer episode,

b) Holdup in lines and valves following a "stir" mode,

c) Holdup in lines and valves following a "transfer out" mode,

d) Holdup in lines and valves following a "send-to-rework" episode.

The above data is a part of the MC computer permanent data base.

4.5 OPERATIONS FLOW CHARTS

At any given time (under steady state operations) the plutonium inventory of the Storage Facility will consist of the sum of the inventories of each module and the appropriate pre-operational calibrations of pipe holdup. Inasmuch as any one module cycles from filling through storage, delivery, and back to filling in a 12-week period it should suffice to follow a single module through this sequence.

Four periods are identifiable in the cycle life of a module (Fig. 4.1-1): a fill period of about three weeks; a stir and sample period of two days; a storage period of about six weeks; and a delivery period of three weeks. The running inventory of the module during these periods is computed in the following manner:

a) Fill and Stir/Sample Period - Inventory is based on real-time estimated volumes and analyses from the preceeding material balance area (the PPC). (See Section 7.4 for Accountability Procedures.)

b) Storage Period - Inventory is based on real-time estimated volumes and laboratory analyses of the homogenized module contents.

c) Delivery Period - Inventory is calculated by the sum of the storage period inventory of sealed tanks and the real-time estimated volumes of unsealed tanks following each delivery.

The flow of information between the MC computer, the PPC Operator, the SF Operator, and the MC Officer is graphically presented in Figs. 4.5.1-1 through 4.5.3-1. These charts, in general terms, define the time steps during the 12-week history of a "typical" module cycle. The interface with the MC Computer Safeguards logic occurs at those points labeled "alarm" and is further expanded in Section 3, "MC System Decision Logic." The sampling mode is described in Section 5 of this report.

4.5.1 PRODUCT RECEIVAL MODE

The procedure for the product receival mode is shown in Fig. 4.5.1-1. This procedure is used by the Pu Product Cell (PPC) operator and the storage

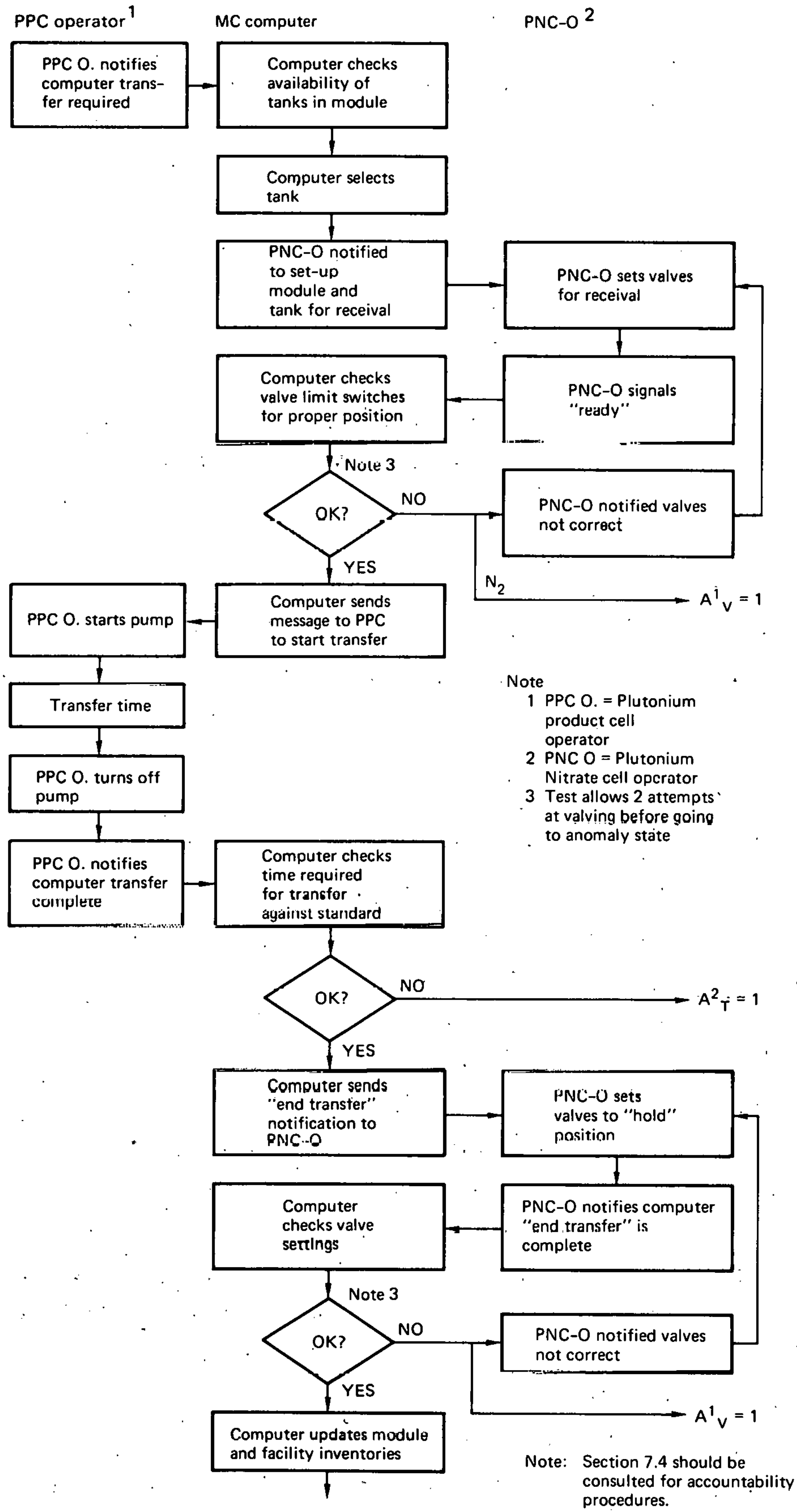


Figure 4.5.1-1 Procedure for Product Receival Node

facility (SF) operator to transfer concentrated $Pu(NO_3)_4$ into the storage tanks. The operations are performed at the direction of the MC computer system. The primary parameters monitored by the MC computer system are positions of the valves in the storage area.

4.5.2 PRODUCT STIRRING MODE

The procedure for the stirring mode is shown in Fig. 4.5.2-1. The stirring mode procedure involves the MC computer system and the Storage Facility Operator. The Product Sampling mode shown on the figure is discussed in Section 5. The product stirring mode is used at the following times:

a) At the end of product receival

b) Prior to product load out

In the product receival mode, the tank which receives the $Pu(No_3)_4$ is stirred and samples are taken. This information is used for accountability purposes, that is, to verify the receival of material as specified from the PPC.

In the product transfer mode, the entire module is circulated as a unit in order to provide uniform isotopic concentration of the Pu product.

4.5.3 PRODUCT LOADOUT MODE

The procedure for transfer of the $Pu(NO_3)_4$ from the PNC to the Conversion Facility (CF) is shown in Fig. 4.5.3-1. These steps in this procedure require the SF operator, the CF operator and the MC Computer System.

Laboratory analysis is expanded in Section 6 of this report. This section also includes flow charts depicting the information interchange with the Laboratory Data System (LDS).

4.6. MAINTENANCE PROCEDURES

The following maintenance procedure is typical of procedures to be implemented for removal or repair of the equipment associated with the Plutonium Nitrate Storage Area. It is directed toward the replacement of a failed module pump located in the floor level glove box. The procedure may be divided into the following six subprocedures: Preparation for Pump Changeout, Pump Changeout, Washdown, Sump Transfer and Inventory, Transfer to Rework, and Resume Normal Operation.

The flow of information between the MC computer, SF Operator and the MC Officer is shown graphically in Figs. 4.6.1-1 through 4.6.6-1. These charts define, from start to finish, thc "proper" maintenance procedure to be implemented for a pump changeout in a module of the test-bed storage facility. Each

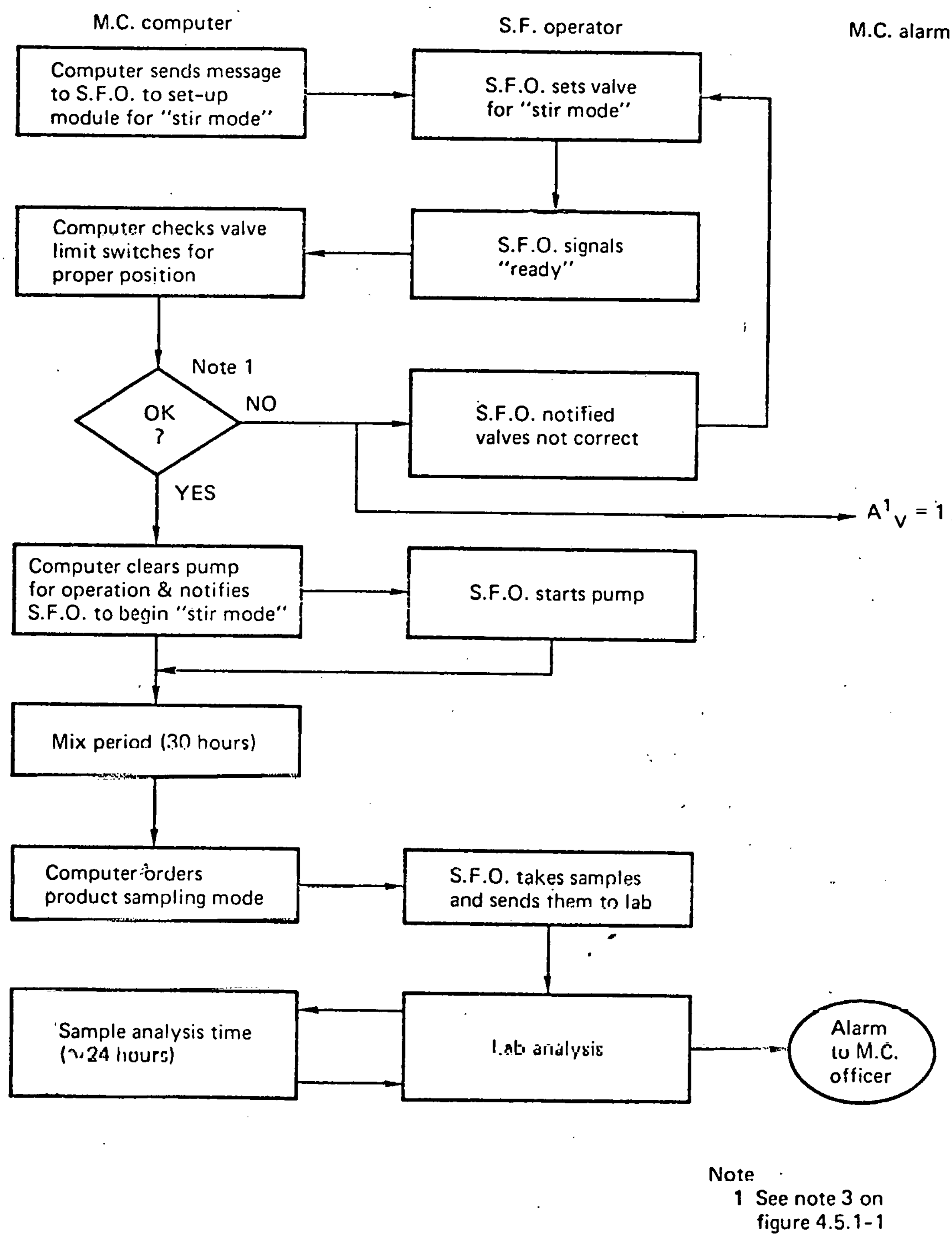


Figure 4.5.2-1 Procedure for Product Stirring Node

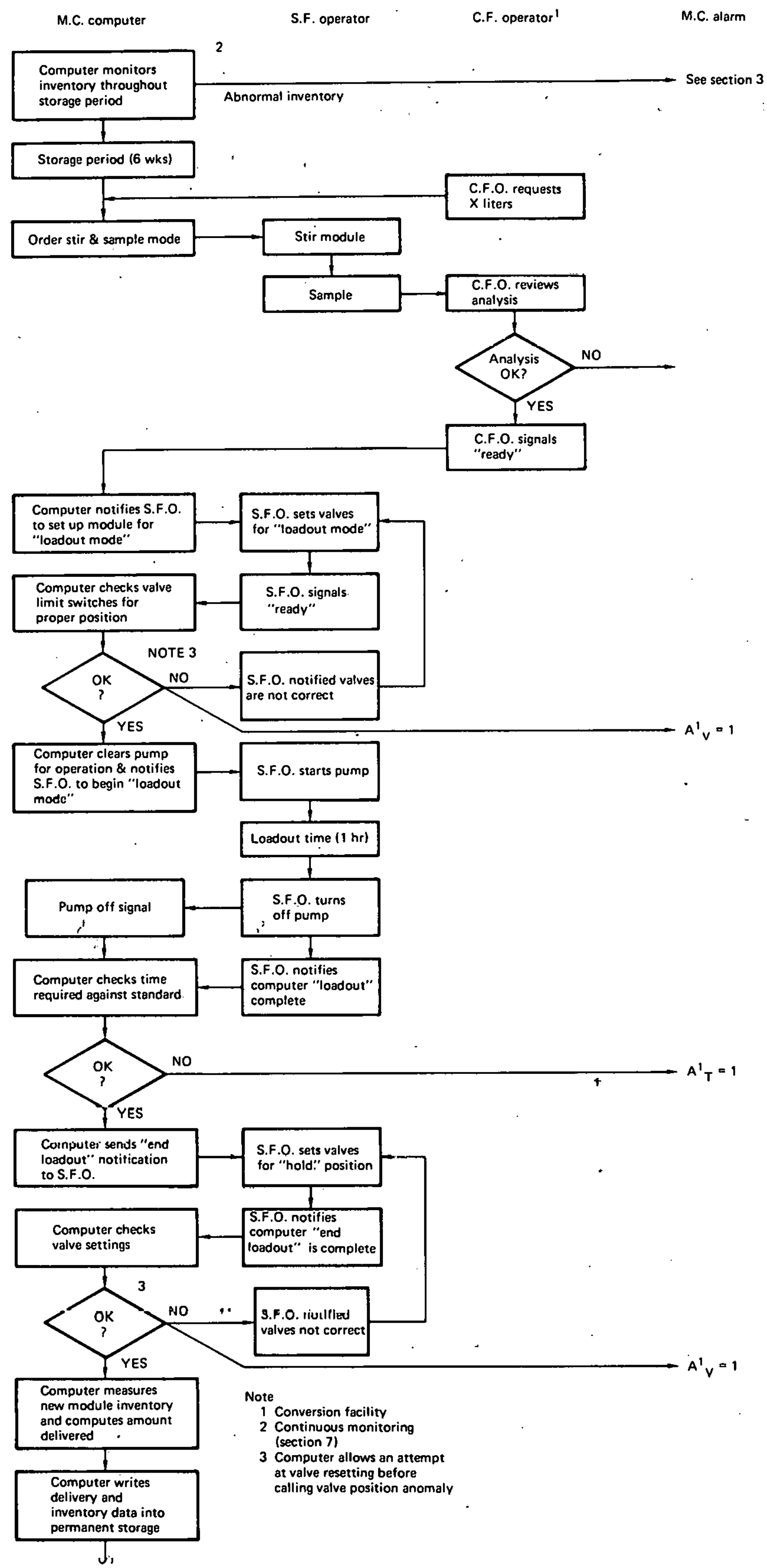


Figure 4.5.3-1 Procedure for Product Load-out Node

step of the procedure is described below.

4.6.1 PREPARATION FOR PUMP CHANGEOUT (Fig. 4.6.1-1)

Upon detection of a pump failure, the Storage Facility Operator, SFO, relays a "pump # - failure" notification to the Material Control computer. The MC computer instructs the SFO to halt any standard operating procedure in progress. Power to the pump is switched off, valves are set to the "hold" (off) position and valve settings are checked by the MC computer.

The MC computer notifies the SFO to open those valves necessary to transfer the SNM in the failed pump to the slop tank (Module 4, Tank 6). The specific combination of valves and piping depends upon which module's pump failed. After checking the valve limit switches for the proper position, the MC computer will notify the SFO to open the valves to the pump cold chemical addition lines. A premeasured amount of pressurized nitric acid will force the plutonium nitrate solution out of the failed pump to the slop tank. Upon completion of this "pump-wash" procedure, all valves are reset to the "hold" position, the limit switches are checked by the MC computer and the SFO notifies the MC computer of the volume of HNO_3 used for the wash.

4.6.2 PUMP CHANGEOUT (Fig. 4.6.2-1)

At this point, the MC computer permits the glove box bag-in-out cover plate limit switch to be actuated without an alarm and notifies the SFO to begin pump replacement procedures.

The new pump and all tools are bagged-in together. The failed pump is disconnected and all residue is drained onto the glove box floor. The new pump is then connected to the pipe fittings. The old pump and used tools are bagged-out in one operation by a special transportation team. The maintenance crew leaves the equipment and tools in the MAA.

4.6.3 WASHDOWN

Removal of the failed pump permits hold-up plutonium nitrate solution in the pump inlet and exit piping to spill out onto the glove box floor. This spillage is washed down into the sump, by the SFO, with a premeasured amount of nitric acid supplied via a hose bulkhead connection through the wall of the pump maintenance glove box. The SFO notifies the MC computer of the total volume of HNO_3 utilized.

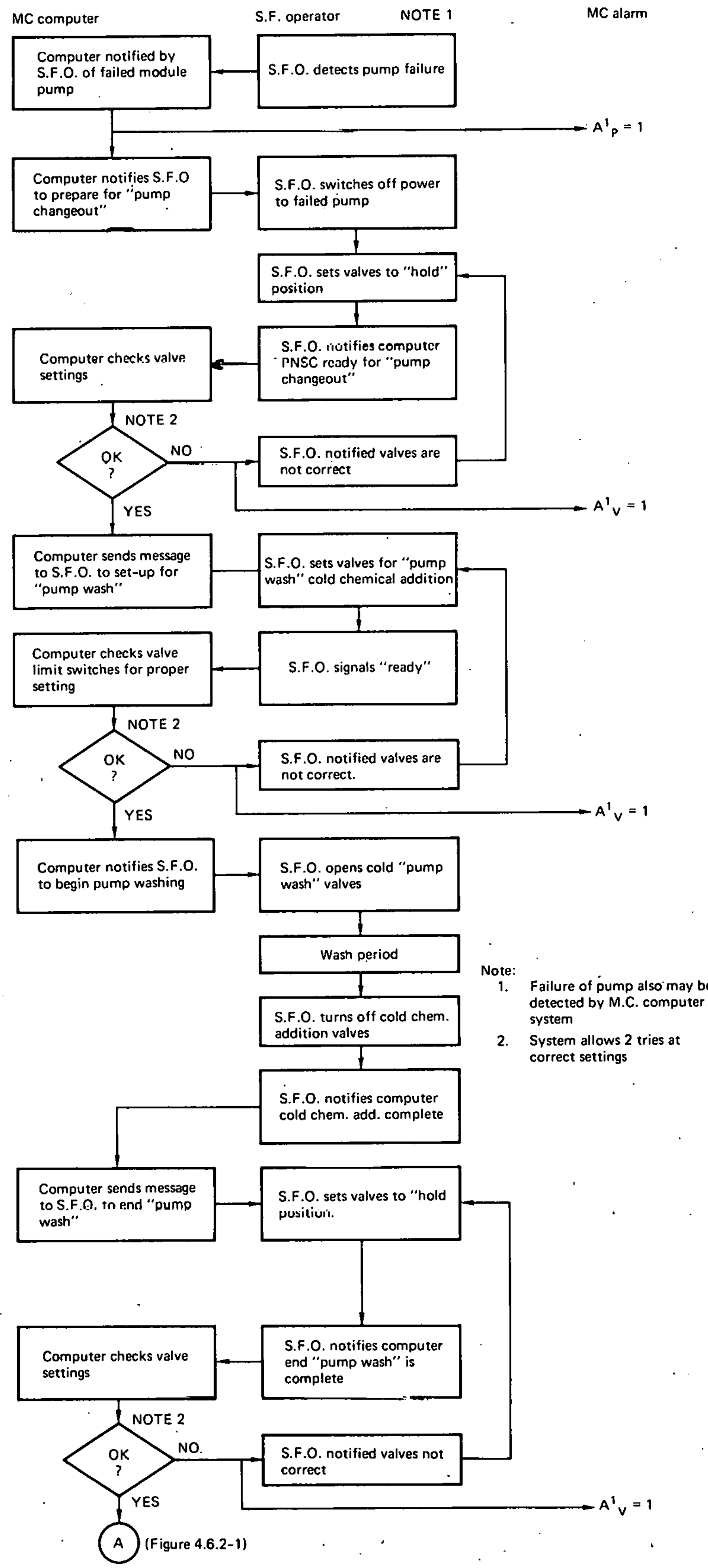


Figure 4.6.1-1 Preparation For Pump Changeout (Washdown)

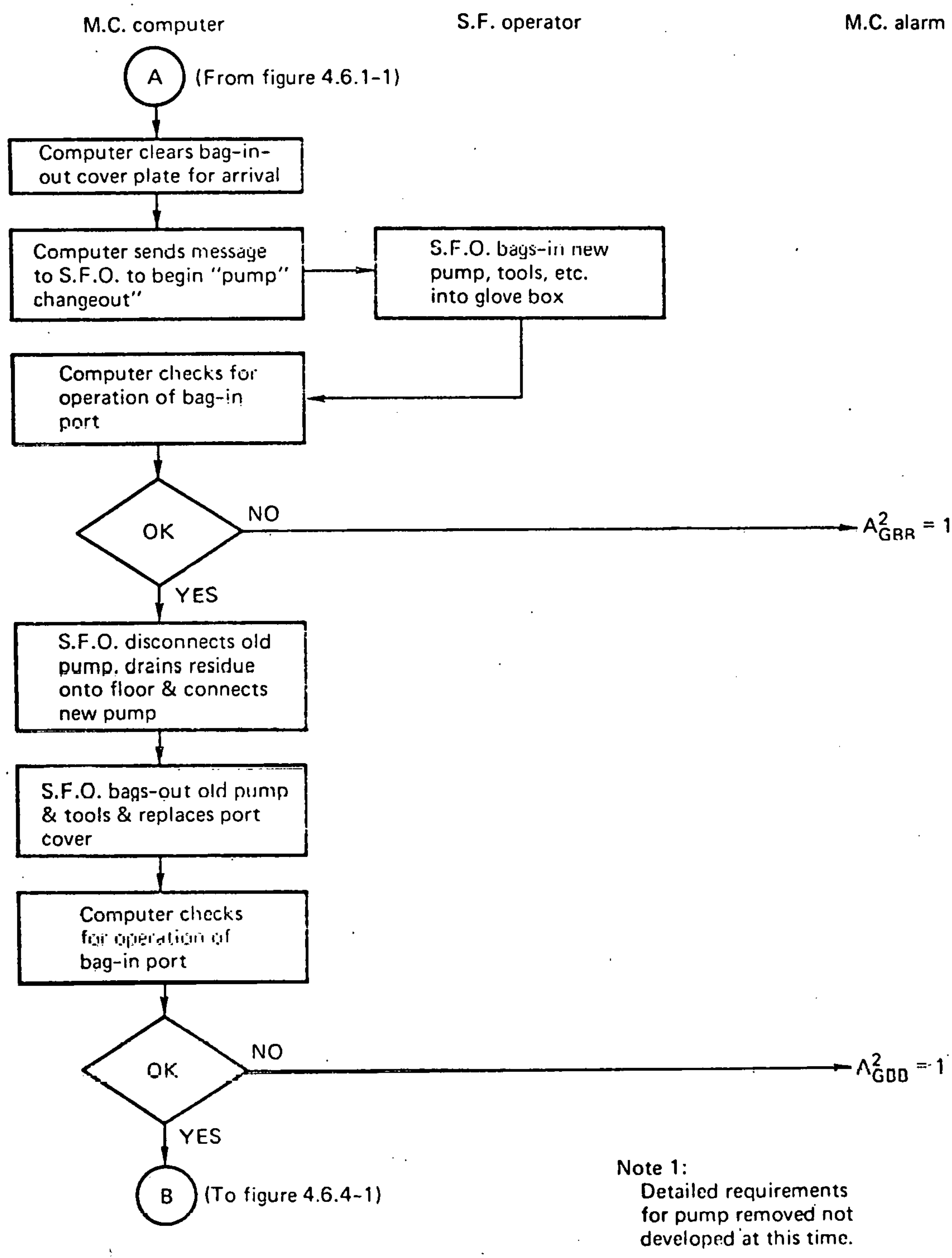


Figure 4.6.2-1 Procedure for Pump Changeout

4.6.4 TRANSFER SUMP (Fig. 4.6.4-1)

The MC computer notifies the SFO to prepare for the transfer of the sump contents to the slop tank. The appropriate valves are opened (limit switch positions are checked by the MC computer) and the sump pump sends the solution to the slop tank. Three times the sump is washed with a premeasured amount of nitric acid. Each time, the solution is sent to the slop tank and the SFO notifies the MC computer of the volume of HNO_3 used in the wash. The MC computer determines the slop tank volume by signals received from the bubbler system and compares this value to the expected value; namely, the sum of the pump holdup, pump inlet and exit piping hold-up and the total of all premeasured washing with nitric acid. An alarm is sent to the MC Officer in charge of material accountability in the event of too large a discrepancy in the volumes alone. The SFO returns valves to the "hold" position and the MC computer checks their positions.

4.6.5 INVENTORY SLOP TANK (Fig. 4.6.5-1)

The SFO is notified by the MC computer to set up Module 4 for stirring and sampling of the slop tank. The contents of the slop tanks are mixed for six to eight hours. The SFO next takes samples and sends them to the Analytical Laboratory for analysis. A higher level alarm than the previous one is sent to the MC Officer if the actual plutonium inventory of the slop tank differs significantly from the expected losses due to a pump failure. The MC computer then recalculates the inventory of the entire cell (module by module) and updates records in memory. The SFO resets all valves to the "hold" position and the MC computer checks the limit switches positions.

4.6.6 TRANSFER TO REWORK (Fig. 4.6.6-1)

The contents of the slop tank, by nature of the nitric acid washings and possible contamination, are not of sufficient quality for loadout to the conversion facility. The dilute solution is sent to the Plutonium Rework Tank by the SFO after proper notification by the MC computer. The valves are set for transfer to rework and their positions are checked by the MC computer. The total transfer time is checked against the expected interval based upon the MC computer's knowledge of the slop tank inventory and normal tank transfer rates. A time discrepancy in excess of the allowable error triggers an alarm to the MC Officer. Upon completion of transfer, the valves are reset to the "hold" position by the SFO and their positions are checked by the MC computer.

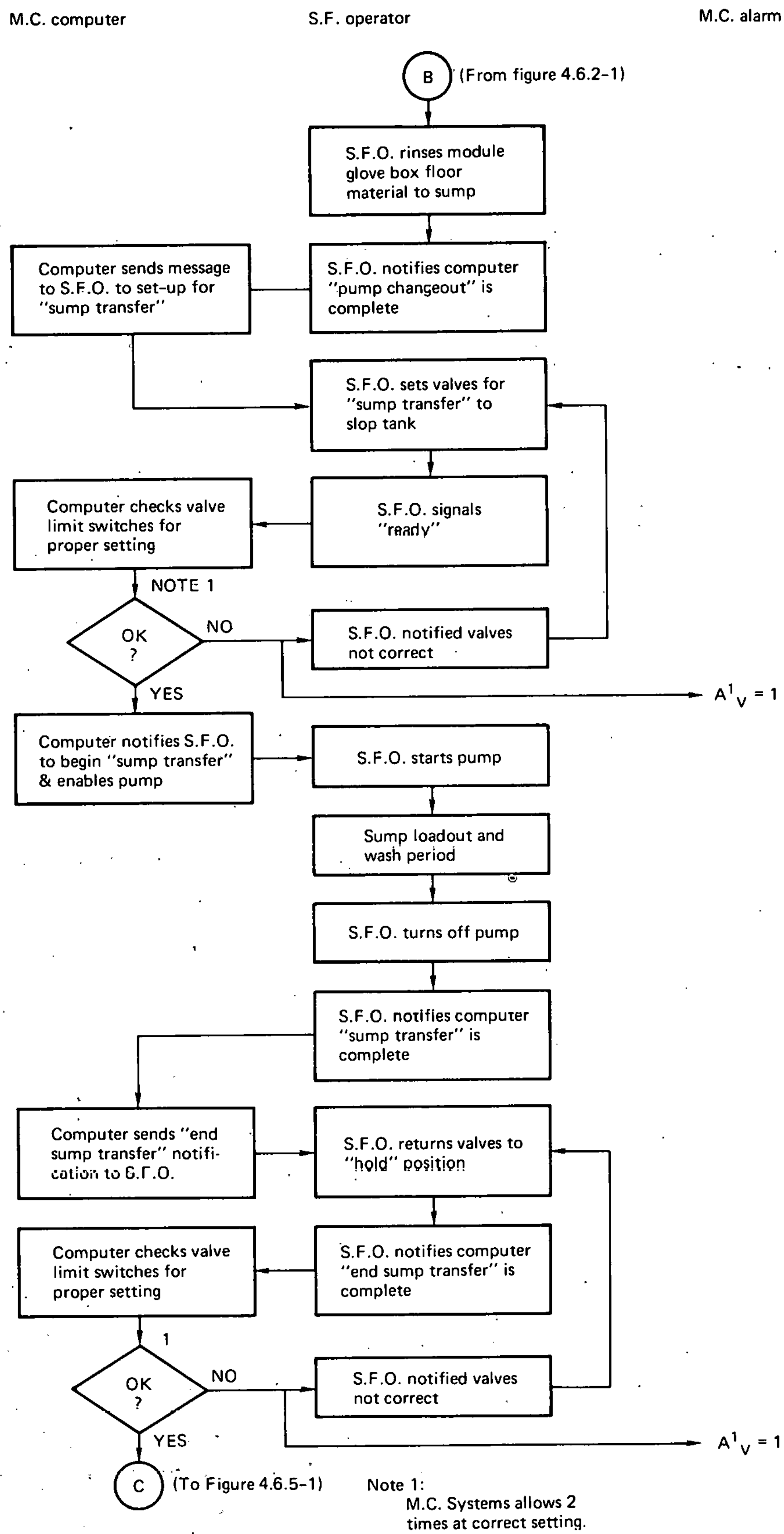


Figure 4.6.4-1 Procedure for Sump Transfer

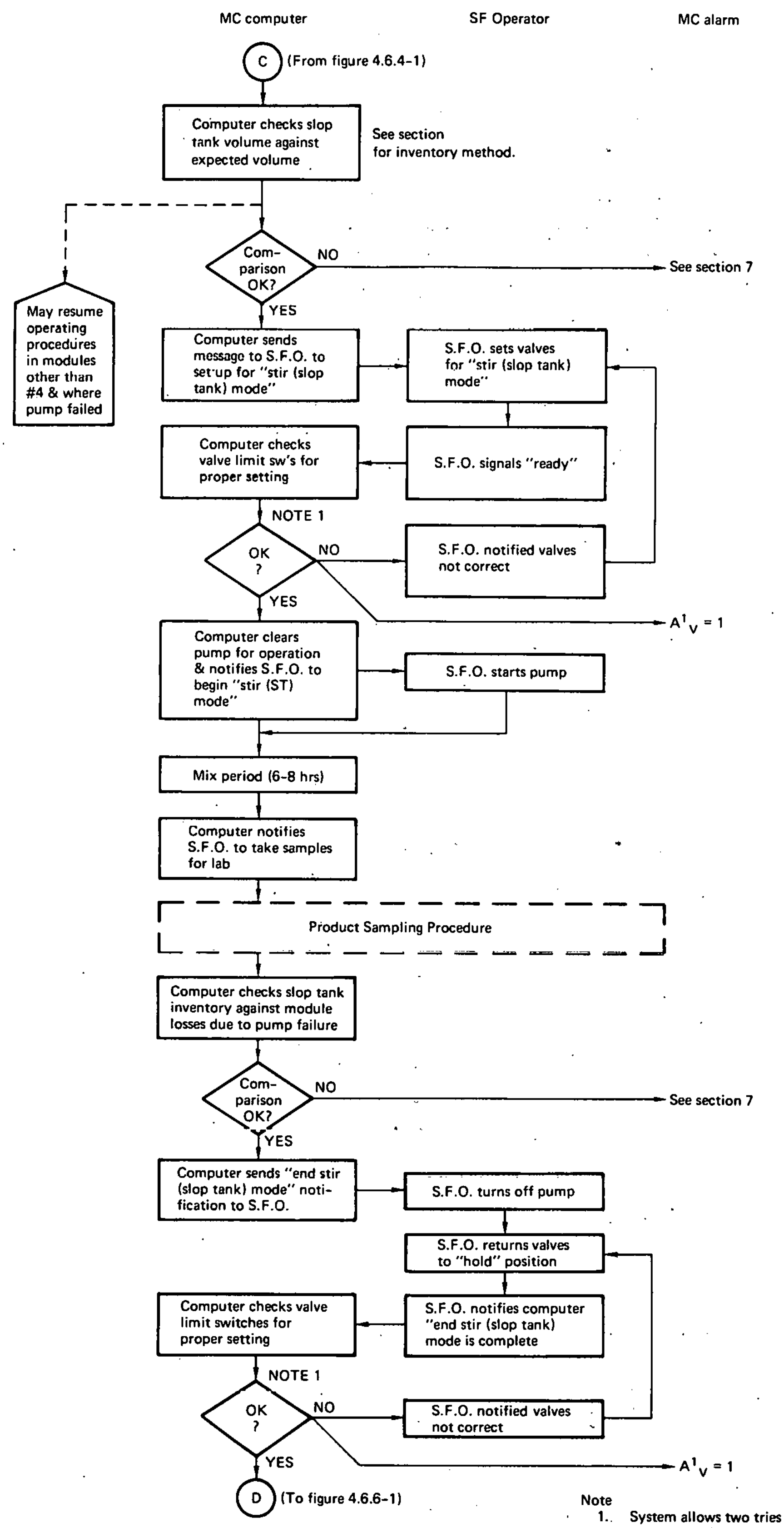


Figure 4.6.5-1 Procedure for Inventory of Slop Tank

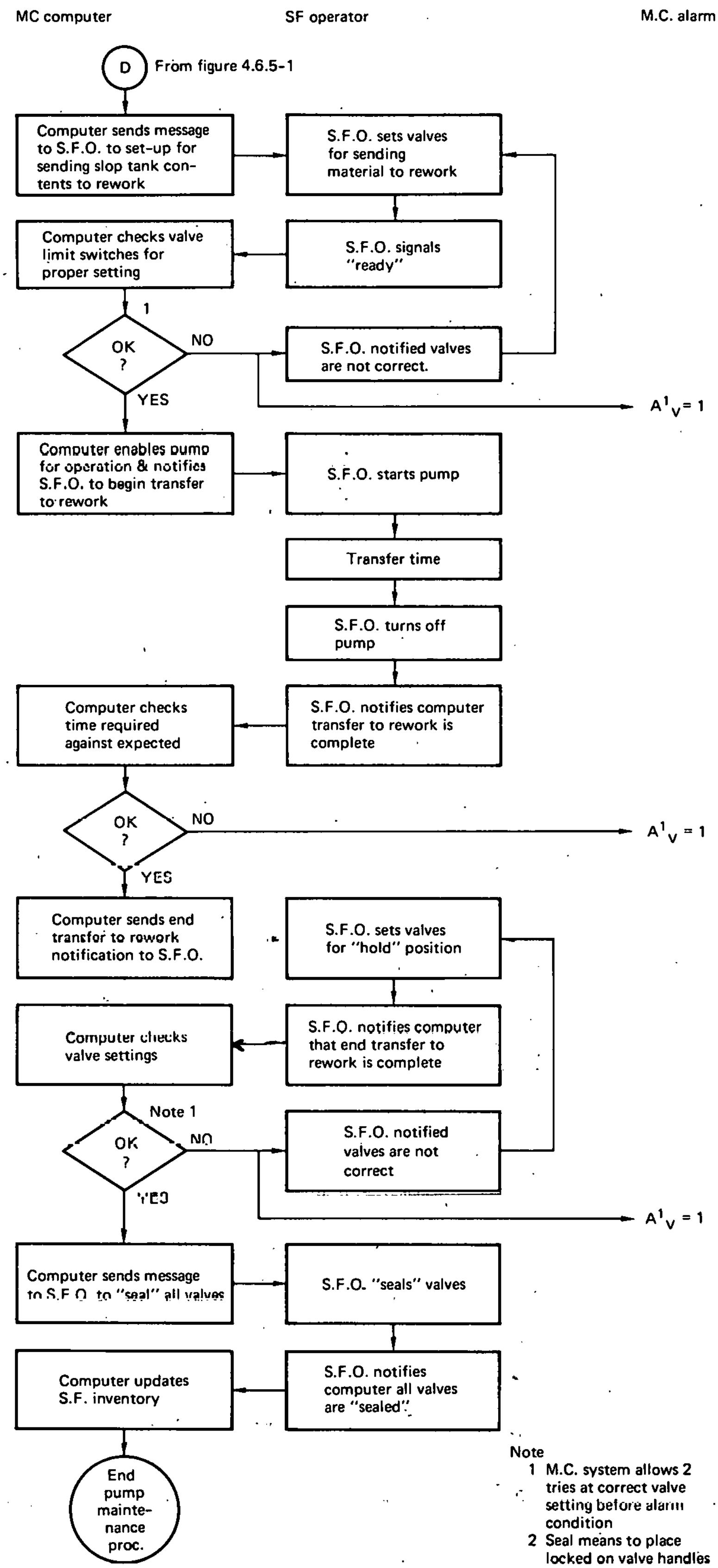


Figure 4.6.6-1 Procedure for Transfer to Rework

The MC Computer notifies the SFO to "seal" all valves involved in the sump and rework transfers. Tagging, dating, etc., procedures required to "seal" a valve that will be implemented will not be discussed here.

4.6.7 RESUME NORMAL OPERATION

Technically, the pump maintenance procedure is complete at this point. However, if the module whose pump failed was in the "load out" mode prior to the failure, the MC computer will instruct the SFO to complete the delivery from that tank and module, providing the balance has not already been made up by another tank and module. If the module, whose pump failed, was in the "stirring and sampling" mode prior to the failure, the MC Computer will send a resume "stirring and sampling" mode notification to the SFO. The command will be to set up the valves for stirring and sampling of the module. It is assumed that if the pump failed while not in operation, the module was in the "storage" or "receive product" mode and will resume such until time for the succeeding operating procedure to commence.

REFERENCES for Section 4

4-1. W. E. Harrison, "Section on Inventory Methods," Lawrence Livermore Laboratory, MC 77-320, July 13, 1977.

5.0 PLUTONIUM PRODUCT SAMPLING

Precise determination of the composition of the material stored in the PNC1 is made via analytical laboratory analysis. Samples are drawn from the storage tanks and transported via a pneumatic air tube system to the laboratory. Various chemical analyses (described in Section 6) are performed on these samples. The results of the analyses are directly entered into the Laboratory Data System computer (LDS) and are available through communication links to the Material Control System computers. The use of the data gathered by the LDS in conjunction with the continuous tank solution volume (mass) estimates provides a real time material accountability capability.

5.1 SAMPLING HARDWARE*

Samples are drawn from individual Glove Box Sample Stations operated directly by the operator.

For accountability purposes four (4) sample vials will be filled from a tank. Three of these are for triplicate analyses and one is a spare. The sample vials are tared in the Analytical Laboratory to $\pm$0.1 mg. The vials are transported to the sampling glove box by hand carry. Each sample vial is placed in turn on the sampling needle block (Fig. 5.1-1) and the solution allowed to circulate through the vial for 5-20 minutes. The correct circulation time will be experimentally determined and also determined from the variance of the ^{239}Pu concentration measurement from the in-line γ spectrometer. The sampling stream is split so that only 10% of the solution goes through the vial. This increases the circulation of the sampling stream. When the vials are removed from the needle block they are placed in rabbit containers. The pneumatic transfer system transports the rabbit containers from the glove box to the Sample Receiving Area of the Analytical Laboratory. Both sender and receiver must push buttons to activate the system. In the Sample Receiving Laboratory the loaded sample vials are weighed, and the log number, tare weight and loaded weight entered

*Portions of this section have been taken from Reference 5-1.

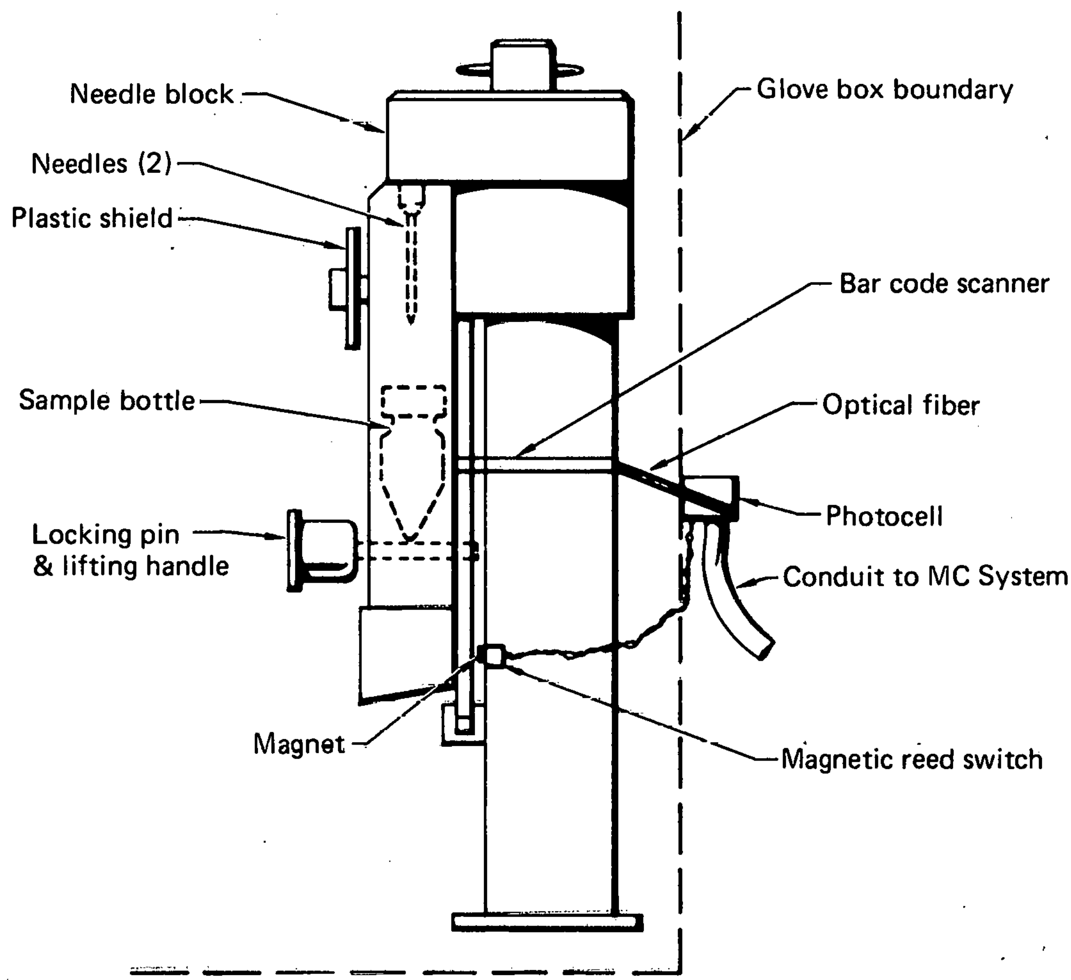


Figure 5.1-1 Sample Needle Block and Lift

automatically into the Laboratory Data System (LDS). These data are echoed to the laboratory data terminal along with the date and time and net weight for a written record that is initialled by the laboratory technician.

5.1.1 Glove Box Sample Stations (Fig, 5.1-1)

The bottle raising mechanisms located in the glove box sample stations are operated manually by the operator. There is one sampler for each of the four modules.

The operator can raise or lower the sample bottle by pulling the lifting handle toward the face of the sample station and moving the bottle in the desired direction. A locking pin is incorporated into the lifting handle which maintains the bottle in the upper or lower positions. An independent raising mechanism is provided for each sampler in the station. A magnetic reed switch provides an indication of the lift mechanism position. (Down or Not Down).

The sample station lifts contain optical bar code readers which scan the vial identification permanently etched into the sample bottles. The scanner heads are connected by means of fiber-optic cables to the scanner photoelectric sensor which is located outside of the glove box. The communication links from the lifting mechanism position switches and the optical scanners pass through pressurized conduit to the Material Control System computers.

5.1.2 Sample Vial (Fig. 5.1.2-1)

Each 10-ml sample vial has a unique sample number which is encoded into the surface of the vial in the form of a bar code. This code is read by sensors at each sampling station, the analytical laboratory tare weighing station, and at each location a sample transfer is made. The MC computer system retains the master listing and history of each vial and can be queried by the LDS* to obtain information as required for the laboratory analyses.

The sample bottle is a 10-ml glass bottle fitted with a plastic cap. The cap has the center punched out and an elastomeric diaphragm placed into the cap to provide access for the sample needles.

5.1.3 Needle Block and Needles

The needle blocks sit on top of the sample manifold and are positioned with the needles directly above the sample bottle. The blocks have a machined

*Laboratory Data System Computer

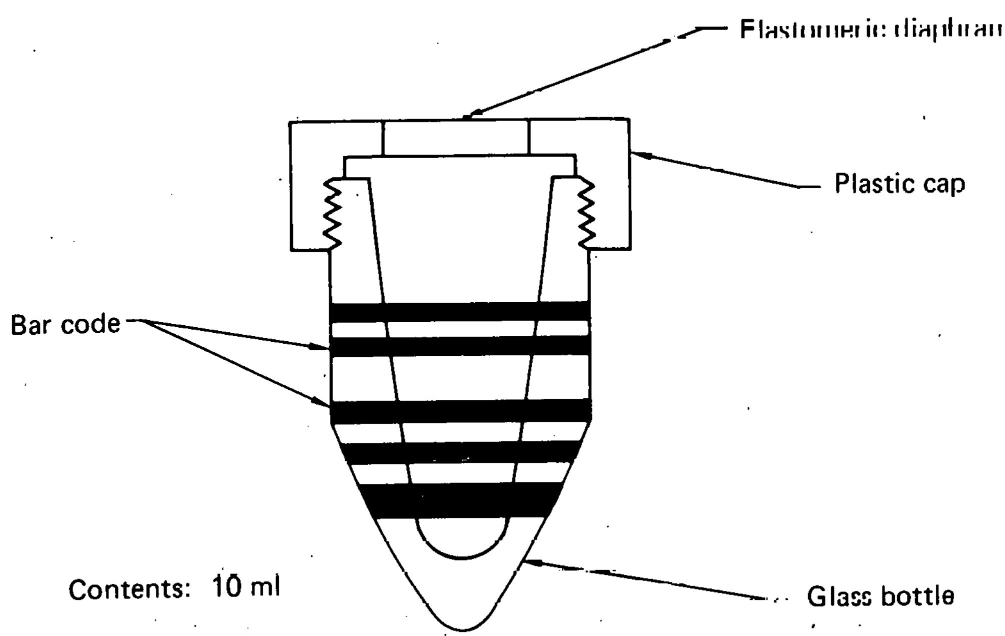


Figure 5.1.2-1 Sample Vial

port for the sample and return lines and a by-pass between the two ports which enables approximately 90 percent of the liquid to by-pass the sample bottle. A hold-down bolt holds the needle blocks in position.

The sample needles are stainless steel with Luer-Lok adaptors. The shorter needle is placed on the left (vacuum) side of the needle block. The longer needle is placed on the right (supply) side of the needle block.

5.1.4 Sample Loops (Fig. 5.1.4-1)

The sample loop consists of the lines from the sample point to the needle block (supply) and back to the sample point (return), and the air supply lines to the ejector and air lift. This loop contains an in-line ^{239}Pu γ spectrometer. The liquid and gasses are separated and the liquid flows through the monitor loop prior to returning to the sample point.

The in-line monitor sampler loops can be valved to by-pass the γ-spectrometer portion of the sample loop. However, loops which have active monitors should always have liquid recirculating with the monitor lines valved in.

The sample loops require four criteria to be met before liquid can be circulated through the loop: (1) a liquid seal is established on the supply and return lines at the sample point, (2) a sample bottle is in position on the sample needles (an air tight seal is required), (3) sufficient submergence, i.e., liquid head above the air lift, must be established with the vacuum created at the ejector, and (4) sufficient air flow must be provided through the air lift to raise the liquid to the needle block.

The air supply for the ejector and air lift is filtered utility air. Each sample station has a common supply header from which air is diverted to each of the sample loops located in the station.

A Whitey toggle operated shut-off valve (Valve 1) is the primary block valve for each sample loop. Valve 1 is monitored by means of a limit switch. The closed/not closed output from this switch is sent to the MC computer system. The air supply is divided after Valve 1 into two independent streams; (1) the air lift supply system and (2) the ejector supply system.

The air lift supply is regulated by the Hand Control Valve (HCV) which is an integral part of the Flow Indicator (FI). The FI has a range of 0-4.0 SCFM.

The ejector supply is regulated by the Flow Orifice (FO) which is a

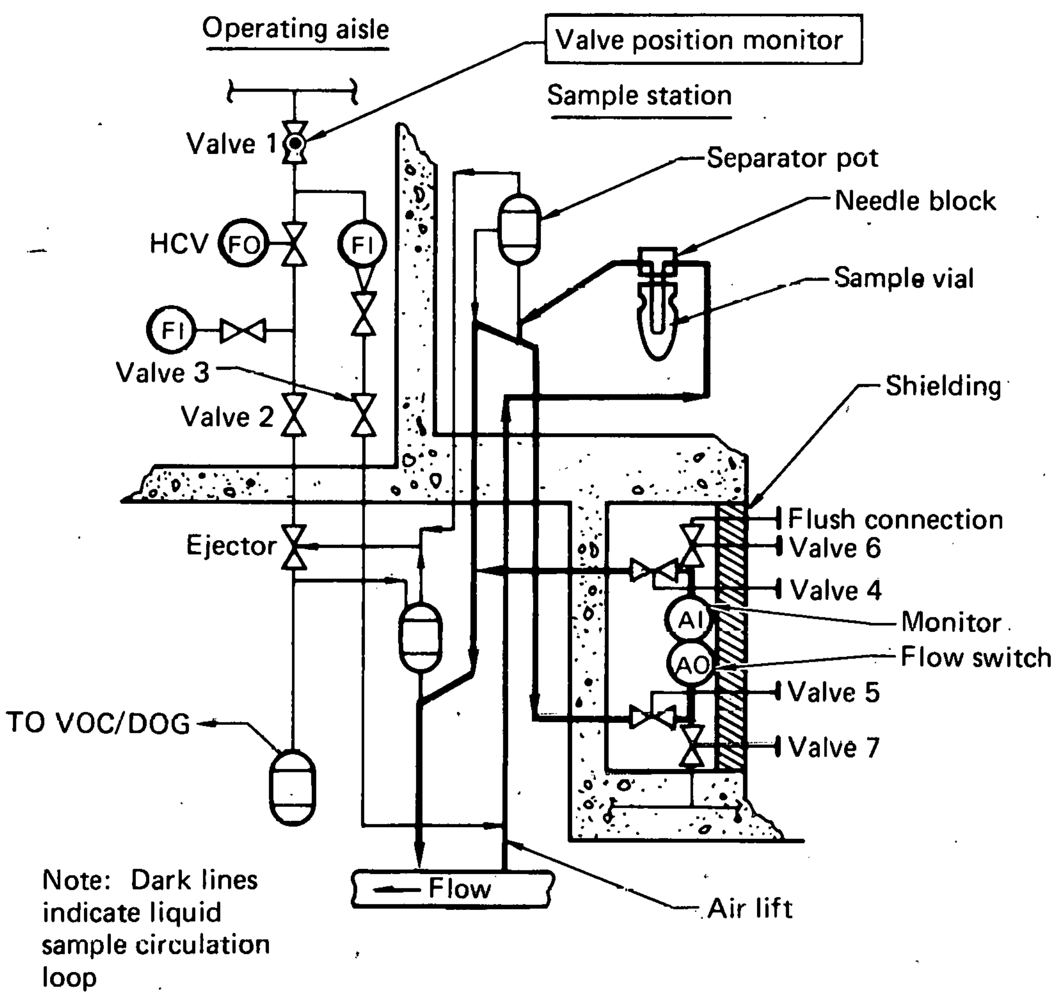


Figure 5.1.4-1 Sample Loop with in-line ^{239}Pu γ Spectrometer

Whitey regulating valve. The pressure indicator isolation valve is used during maintenance procedures and is left open during normal sampling operations.

Stainless steel Hoke block valves, Valves 2 and 3, are located on each air supply line prior to exiting the operating aisle.

5.2 SAMPLING PROCEDURE (Fig. 5.2-1)

The procedure for sampling from the storage tanks in PNC1 is given in the following pages and figures. Interactions with the SFO and the MC computer system are shown in Fig. 5.2-1. A running estimate of the solution mass stored within PNC1 is made by the MC System through the use of data collected from the tank bubbler instrumentation. This mass estimate (described in Section 7), is combined with the Pu concentration determined by the analytical laboratory to produce an estimate of the mass of Pu stored in each tank in PNC1. The steps in the sampling procedure proceed at the direction of the MC computer system. That is, the SFO must wait until the MC System authorizes the next step in the procedure. Failure to do so results in an MC alarm condition.

The steps in the sampling procedure are as follows:

5.2.1 PREPARE the number of sample bottles required. These bottles will be tared (weighed) in the analytic laboratory to ± 0.1 mg. Each vial has a unique log number. The LDS computer automatically records the sample bottle ID and its weight. In some cases, there will be preweighed vials in the sampler glove box. These bottles may be used for sampling. The MC computer system will compare the bottle ID with previously stored ID/weight combinations to verify that authorized bottles are being used.

5.2.2 TRANSFER the sample bottles into the sample station by bagging in for the glove box stations, through the bag in/out port. The opening of the bag in/out port is monitored by the MC computer system. Unauthorized use of this port triggers an MC alarm condition.

5.2.3 POSITION the sample bottle in the bottle raising mechanism beneath the needle block from which the sample is to be taken.

> <u>CAUTION</u>: The sample needles will penetrate gloves. The operator should never place his gloved hand behind the plexiglass shields which are located in front of the needle points.

5.2.4 ELEVATE the bottle raising mechanism until both of the needles penetrate the bottle diaphragm. As the lift mechanism is elevated, the magnetic reed

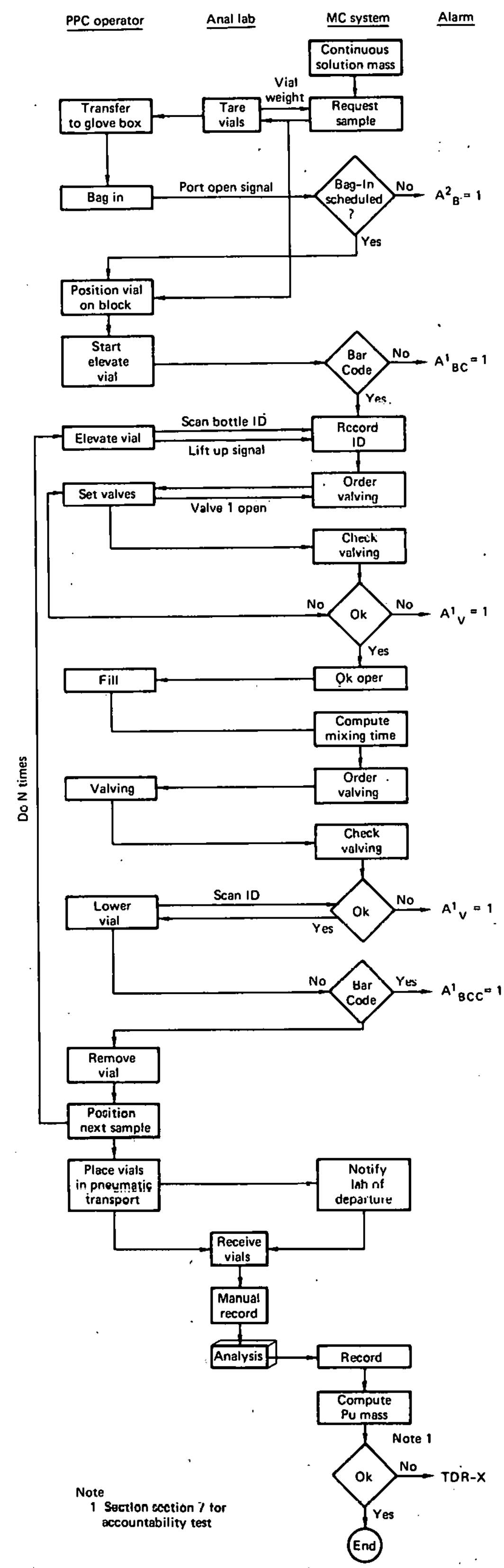


Figure 5.2-1 Procedure for Product Sampling

switch at the down position will indicate a "lift not-down" condition to the MC computer system. As the lift is manually raised, the bar code scanner mounted in the lift support bracket will read the bottle I.D. and transfer this information to the MC computer system.

5.2.5 SET VALVING. The valving sequence required to establish or stop liquid circulation is the same for all samplers. The opening of valve 1 (Fig. 5.1.4-1) alerts the MC System to the use of the sample loops.

5.2.6 FILL VIAL. Allow the liquid to circulate through the first sample bottle for a period of time specified by the MC computer system and as indicated by the MC control panel lights.

5.2.7 CLOSE VALVE 1.

5.2.8 LOWER THE BOTTLE raising mechanism. Bar code is scanned a second time.

5.2.9 REMOVE THE BOTTLE.

5.2.10 POSITION the next sample bottle in the bottle raising mechanism.

5.2.11 REPEAT steps 4 through 9 for each additional bottle required.

5.2.12 PLACE VIAL in rabbit for pneumatic transport system.

5.2.13 RECEIVE VIALS at analytical laboratory.

REFERENCES for Section 5

5-1. Procedure S-ACLOP-805-1, Remote Samplers Operating Procedure (Needle Block Samplers), L. F. Sears, AGNS-BNFP, Feb. 20, 1976.

6.0 ANALYTIC LABORATORY

The Analytic Laboratory is used for the precision determination of the composition of material stored in PCN1. All laboratory instrumentation involved with plutonium accountability is automated so that the Laboratory Data System (LDS) computer can perform the measurements via a stored program once the prompt has been given by the operator at a data terminal. The data entries are echoed to the data terminal for transcription into written records that are initialled and dated by the laboratory technician. Records of all laboratory measurements are stored on magnetic tape via the LDS computer.

6.1 ANALYTIC LABORATORY OPERATING PROCEDURE

Figure 6.1-1 gives the time sequence of the laboratory work associated with analyzing samples from the Plutonium Nitrate Storage Facility. It should be noted that the calculations of tank volume and preliminary densities are functions of the MC Computer; all other operations shown interact with the LDS. Each sample vial is scanned for ID and weighed when received from the sample glove box via the pneumatic transport system. This information is automatically placed into the LDS. Nonarrival of a vial, the arrival of an empty vial, or the arrival of a non-ID'd vial causes an alert to the MC computer system.

6.2 ANALYTIC MEASUREMENTS

Figure 6.2-1 shows the sequence of analyses which is performed on the plutonium product samples. These analyses are described in the following subsections.

6.2.1 Spectrographic Analysis

The plutonium nitrate solutions are assayed for elements that would interfere with the analytical measurements if present in sufficient concentration. These interferring elements are primarily iron, chromium, manganese and vanadium. One version of the method involves treatment of the plutonium with oxalic acid, evaporation and ignition to plutonium dioxide. Alternatively the plutonium can be separated from the impurities by an ion exchange method. In either case, the residue is blended with a $AgC\ell$-LiF carrier and the blend placed in special graphite electrodes for excitation with a direct current arc. The emission

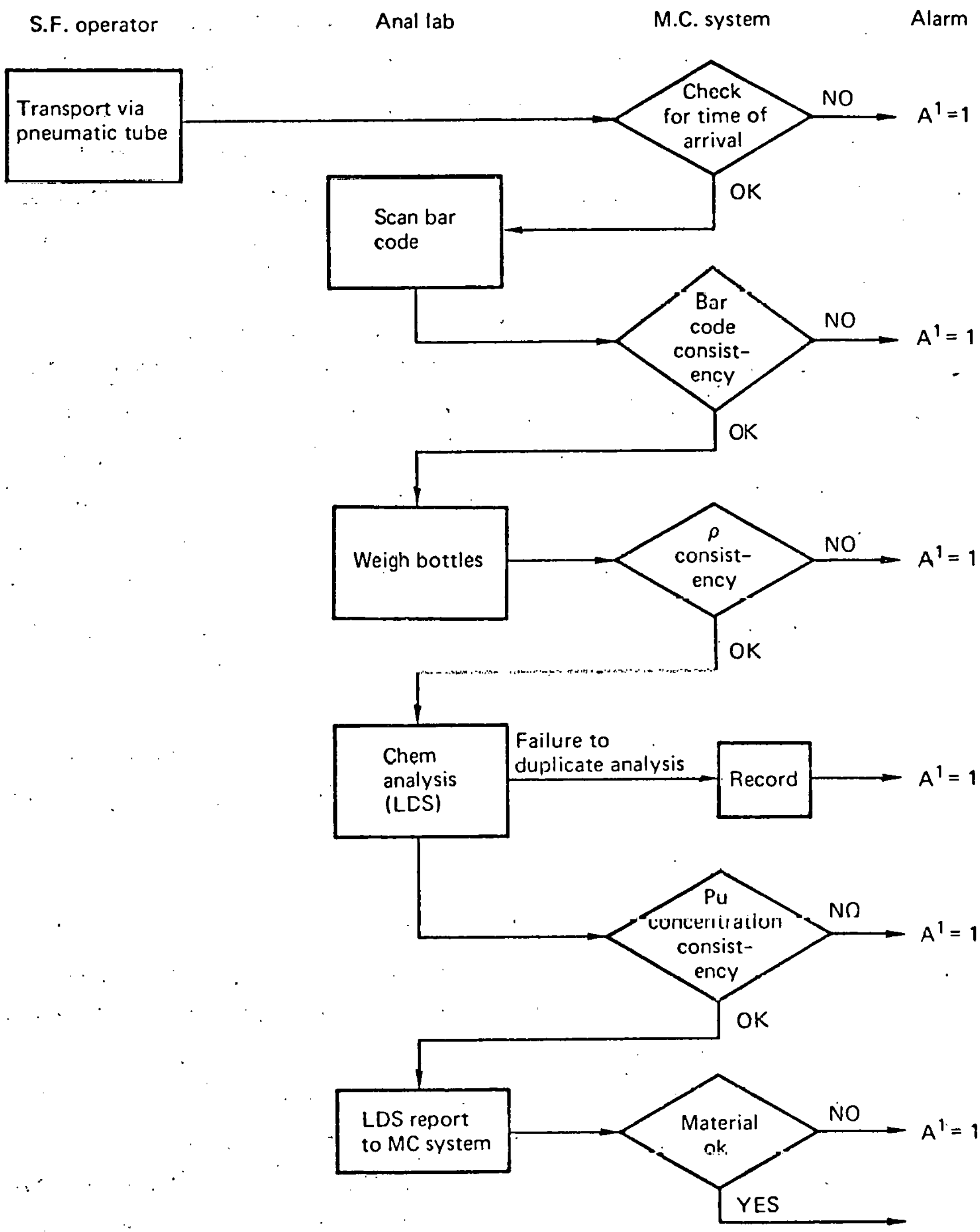


Figure 6.1-1 Analytic Laboratory/Material Control System Interactions

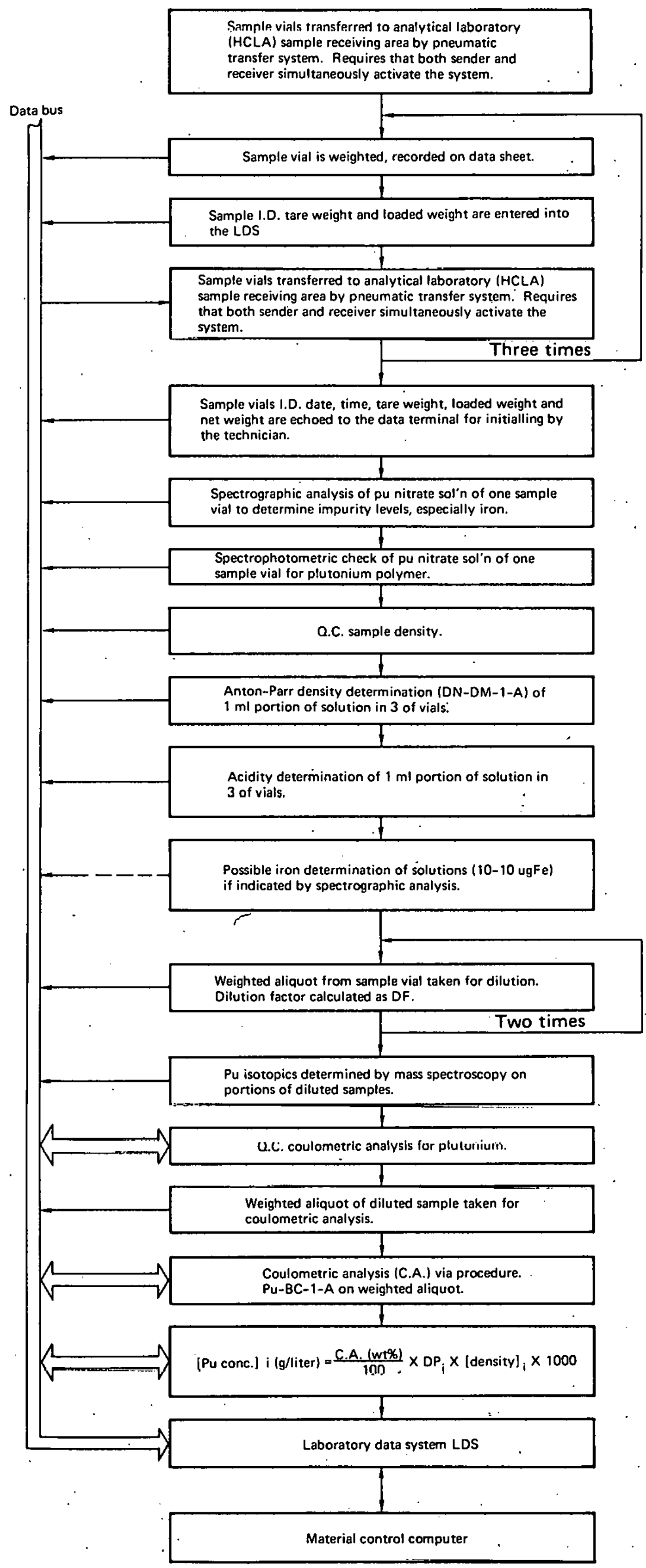


Figure 6.2-1 Analytic Laboratory Measurement Sequence

spectrum is recorded with both a direct-reading or a photographically recording spectrograph. The emission lines of interest are compared to those from standards of known composition.

6.2.2 Plutonium Polymer

A polymer of Pu(IV) can form in solutions less than 4 M in HNO_3. The rate of polymer formation is proportional to the Pu(IV) concentration and inversely proportional to the square of the acid concentration. The rate increases with temperature. Until a history of plant operations is obtained, many of the plutonium nitrate samples will be checked for the polymer. The method involves the extraction of monomeric $Pu(NO_3)_4$ into tributyl phosphate (TBP) and the measurement of the visible spectrum of the remaining aqueous phase for the presence of polymer.

6.2.3 Anton-Parr Density Determination

Densities can be determined with the Anton-Parr DMA 10 Densimeter to a precision of 0.0003 g/ml at a rate of six (6) samples per hour. The densimeter operates on the principle of measuring the change in the resonant frequency of a hollow mechanical oscillator when it is filled with substances of different mass. Only 0.6 ml of solution is required.

6.2.4 Acidity Determination

The acidity of the Pu nitrate solutions must be controlled to prevent polymer formation. In the method used, plutonium is precipitated with iodate and filtered out. The filtrate is titrated for acid potentiometrically with sodium hydroxide solution. The accuracy will be $\pm$10% (2 σ).

6.2.5 Iron Determination

If spectrographic analysis indicates that iron content of the Pu nitrate solutions is greater than 100 micrograms per gram of Pu, the actual iron content will have to be determined and allowed for in the coulometric determination, or some other means of eliminating the interference will have to be followed. The corrosion rate of the stainless steel tanks and piping is unknown at present for concentrated plutonium nitrate solutions. When iron is present in the range 100-1000 micrograms per gram of Pu, it can be determined spectrophotometrically and corrected for in the coulometric analysis. Iron does not interfere in the amperometric determination of Pu(IV) with iron(II) as a titrant but this is a more lengthy procedure. Complexing of iron with bathophenanthroline sulphonate allows plutonium to be determined by the standard coulometric analysis with no interference from the iron at levels up to 1 mg of iron per 1-10 mg of Pu (Reference 6-1).

6.2.6 Dilution of PU Nitrate Solutions

The samples of plutonium product have a concentration (250 g Pu/liter) that is too high for accurate coulometric analysis since only 5-10 mg Pu are required for each determination. A dilution of 1:25 brings the concentration into the appropriate range for accurate weighed aliquots.

6.2.7 Mass Spectroscopy

The atomic weight of plutonium is a function of the abundances of the several isotopes. Mass spectroscopy of purified plutonium samples provides the isotope ratios so that an accurate equivalent weight of Pu can be used in the coulometric analysis. Only microgram amounts of Pu are required.

6.2.8 Coulometric Analysis

Plutonium in samples is determined by coulometric analysis which consists of the selective oxidation of Pu(III) to Pu(IV) at a fixed potential in 0.5 $\underline{M}$ H_2SO_4. The integrated current required for the oxidation is a measure of the Pu quantity. All the plutonium in the sample is reduced to Pu(III) electrochemically prior to the oxidation step. The solution must be purged with flowing argon prior to the electrochemical steps to remove all the dissolved oxygen. If the presence of iron is indicated by spectrographic analysis, a correction can be made if it is in the range 100-1000 micrograms per gram of Pu. Reference 6-1 indicates that complexing the iron with bathophenanthroline sulphonate will shift the potential of the ferrous-ferric couple enough so that the iron would not interfere with the plutonium analysis. The estimated precision for a single determination by coulometric analysis is 0.15% (1σ). Plutonium polymer is not electrolyzed with this method and would have to be depolymerized with HF prior to analysis and the fluoride removed by fuming with concentrated H_2SO_4.

6.3 QUALITY CONTROL (QC)

The requirement of analyzing QC samples before plutonium samples is used for the certifying of technicians and analysts. The correct results are unknown to the operator, who must reproduce the correct answer to within a tolerance before proceeding to production samples. The procedure also checks on whether or not the method itself is out of control through faulty equipment or materials.

Quality control samples will be ordered on a random basis by the MC computer system. These samples will be transported to the glove boxes by the SFO as if they were empty vials. They will be passed through the entire analytic laboratory procedure as normal samples. Communication, via the intercom system, will be monitored to prevent collusion between the SFO and the laboratory technicians.

6.4 MATERIAL CONTROL SYSTEM INTERACTION

Data gathered by the analytical laboratory instruments is automatically entered into the separate Laboratory Data System (LDS) computer. Results of the Pu concentration determination and any abnormalities are relayed to the MC computer. Calculation of the mass of plutonium stored in each tank of PNC1 is made by the MC computer system. Any discrepancies with inventory causes an MC System alert.

The interaction of the analytical laboratory with the MC System for normal (non-quality control) samples is shown in Fig. 6.1-1. The analytical laboratory is notified by the Storage Facility Operator that a sample is being transported via the pneumatic transport system. At this time, the MC computer system checks for the arrival of the sample. Non-arrival of the sample within a specified time causes a MC system alert. Once the bottle has been received in the analytical laboratory, its bar code is scanned. This code is checked for inconsistency with the code stored in the MC system for the sampling operation. An inconsistent code leads to an MC system alert. After the bottle is logged in, the bottle is weighed, and the MC computer system compares this weight to a estimated weight based on the bubbler system measured solution density.* An inconsistent test result again leads to an MC alarm condition. The chemical analyses are then performed. An MC alarm condition arises if there is a failure to duplicate analyses on samples taken from the same tank. The analytic laboratory ^{239}Pu concentration is compared to the in-line γ spectrometer measurement and inconsistency causes an MC alert condition. After processing of the analytic laboratory data, the LDS transfers the data to the MC computers. This is used to update the inventory and is explained in Section 7. In addition, other laboratory conditions can lead to an MC system alert. These include:

*This provides a preliminary rough test on the sample bottle contents.

6.4.1 Failure to Correctly Analyze Quality Control Samples

Failure to duplicate correct results on densities, coulometric analysis or mass spectroscopic analysis causes the MC System to request the analyst to run additional QC samples. Failure twice is reported to the Manager, Analytical Services, as an indication that the method is out-of-control and requires his authority to reduce the MC System Theft Danger Rating (A^1).*

6.4.2 Failure to Correctly Analyze Product Sample

Results out of standard range or outside of the γ spectrometer measured values requires a duplicate to be measured. Failure twice is reported to the Manager, Analytical Services, for possible assignment of a new sample and to the MC computer system. If the average standard deviation of triplicate samples is greater than allowed, a fourth sample is analyzed. Failure to obtain the allowable standard deviation on three values from four samples is reported to the Manager, Analytical Services, and causes a MC System alert (A^1).

*These symbols refer to MC Decision Logic Anomaly Levels (Section 3).

REFERENCES for Section 6

6-1. Stokely, J. R. and Shults, W. D., Analytic Chemistry, 1971, 43(4) p 603.

7.0 MATERIAL ACCOUNTING SYSTEM

The "material accounting system" is that part of the material control and accounting system which includes the measurement of material, documentation of the identity, quantity, location, and transfer of all material, and which, in conjunction with the MC Logic, evaluates material discrepancies. The accounting system (Fig. 7-1) is composed of on-line process instrumentation, analytic laboratory instrumentation, accounting and operating procedures, and inventory calculations. Real-time estimation of storage tank contents is combined with analytical laboratory quality information to produce a continuous accurate estimate of the storage facility inventory. The following sections discuss the components of this system.

7.1 INSTRUMENTATION*

The contents of each storage tank in the PNC are continuously monitored by pneumatic bubblers. Measurements are available from this system at approximately 10-second intervals. This data is processed by a real-time estimator/detector described in a following section. The basic PNC bubbler instrumentation accuracy has been arbitrarily set to 0.75% of full scale** (3 σ) corresponding to an uncertainty of 0.609 cm in solution height. The estimator/detector smooths these measurements thereby increasing the height change detection sensitivity.

Analytic laboratory measurements are used in conjunction with the solution mass estimates to produce an estimate of the quantity of plutonium stored in the PNC. The laboratory measurements provide the plutonium quantity in an analytic laboratory sample to an accuracy of $\pm$ .15% (1 σ).

A gamma-ray spectrometer is used on the sampling lines to provide real-time measurements of the Pu concentration and isotopic composition. In addition, it provides a quality control check against which the more precise analytical laboratory measurements are compared. It also allows the determination of adequate tank stirring during the sampling mode.

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*There are two sets of instrumentation discussed in this section; the higher accuracy differential pressure transducers in the PPC, and the lower accuracy (0.75%) DP transducers of the PNC described here.

**Instrumentation (differential pressure transducers) of higher accuracy are available.

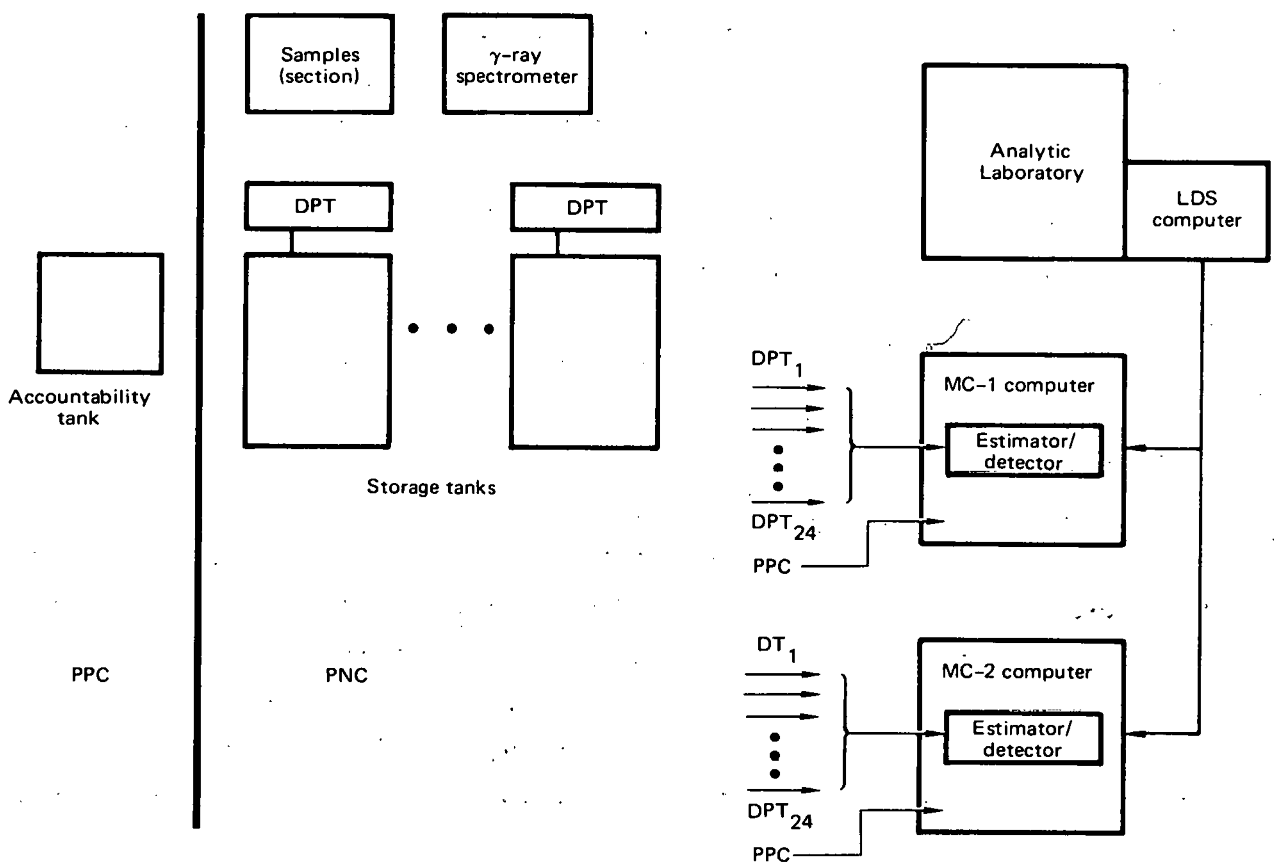

Figure 7-1 Material Accountability Components

7.2 OPERATING MODES

Several operating modes for the storage facility have been identified. These include:

1) Product Receival
2) Stirring
3) Static Storage
4) Chemical Addition
5) Transfer
6) Load-out

The operating procedures relevant to each of these modes are described in another section of this report. Accountability procedures for each of these modes will be discussed here.

7.2.1 ACCOUNTABILITY FOR PRODUCT RECEIVAL MODE

Product is received by gravity flow from the PPC and is directed to a specific tank in PNC1. There will be two 730-liter transfers per week. The product will be measured and sampled prior to transfer. Figure 7.2.1-1 is a schematic representation of the accountability aspects of the PPC. The detailed accountability procedure for product receival is given in Section 7.4.

Product from the 3P concentrator is pumped to one of the 416-liter interim storage tanks.* When the tank is filled to approximately 365 liters, the flow is diverted to a second tank. The first tank is sealed and a long continuous measurement period (data smoothed for 30 minutes) using the material estimator is begun. The second tank is filled to approximately 365 liters and the flow is diverted to the third tank. Samples are taken from the two filled tanks and an analytic laboratory analysis is performed. The data from this analysis, along with the material estimator outputs, are transferred to the MC Computer system and will be used to verify the product received in the storage facility. The accuracy of the individual bubbler measurements** on the PPC interim storage tanks was taken to be:

a bias of $\pm$ .005% Full Scale (2σ)
and a random error of 0.010% of the reading (2σ)

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*Pu Interim Storage Tank Dimensions: 7' 6" x 11' 4" x 2 1/4", sloped.

**The selection of an instrument with this accuracy was arbitrarily chosen for this Test Bed Design.

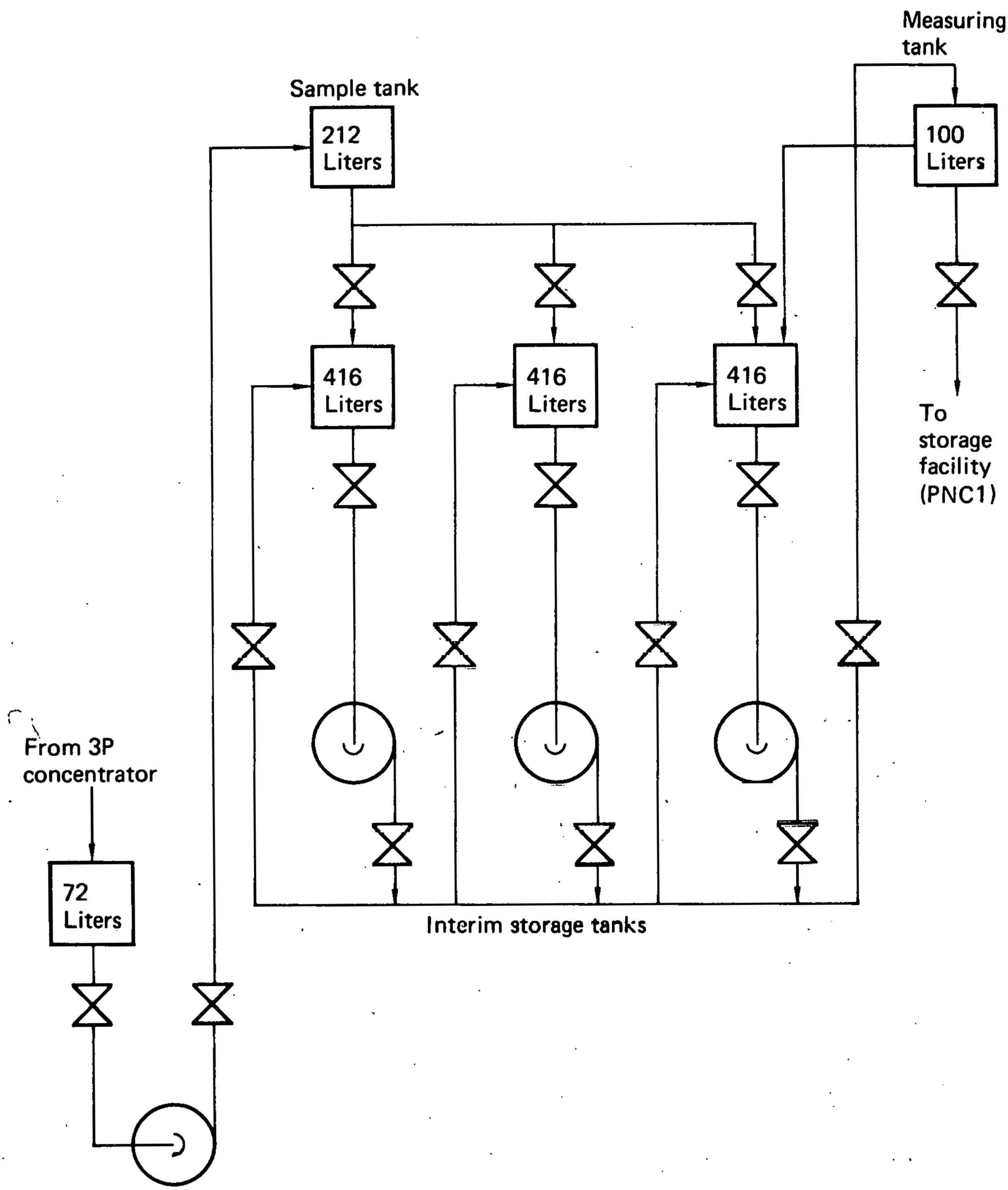

Figure 7.2.1-1 PPC load-out; simplified schematic

The bubbler measurements are taken every 10 seconds. These measurements are sent to a material estimator and processed to yield an estimate of the mass of solution in the interim storage tanks. The solution mass in each tank will be estimated to a standard deviation of 5.112 grams.* The concentration of Pu and isotopic composition will be determined by the analytic laboratory. These composition measurements will be accurate to 0.15% (1σ).

The accuracy of the solution mass estimate in the two interim PPC storage tanks is given by

$$\sigma^2_{PPC} = \sigma_{T_1}^2 + \sigma_{T_2}^2$$

where $\sigma_{T_1}^2$ is the variance of solution mass estimate for tank 1

$\sigma_{T_2}^2$ is the variance of solution mass estimate for tank 2.

Assuming the two tank estimates have equal variance, the overall estimated solution mass standard deviation for the two interim storage tanks will be

$$\sigma = \sqrt{\sigma^2_{PPC}} = \sqrt{2\sigma_{T_1}^2} = 7.229 \text{ gram}$$

The product from the two interim storage tanks will then be transferred (by gravity flow) to the $Pu(No_3)_4$ storage facility. The product received in the storage area will be directed to specific tanks, stirred, sampled, and the quantity estimated by use of the single tank estimation filter described in a following section.

The transferred solution mass is then compared to the estimate of solution mass in the PNC. The standard deviation of the PNC solution mass estimate is 236.9 grams. The total variance is then the sum of the two variances and it yields a standard deviation of 237.0 grams of solution. This corresponds to a plutonium mass uncertainity of about 40.9 grams (1σ). This is a LEMUF of 81.8 grams of Pu on transfer.**

7.2.2 ACCOUNTABILITY FOR STIRRING MODE

There are two stirring modes. These are: stirring of one tank prior to tank solution sampling; and stirring (mixing) of an entire module prior to load-out. Bubbler system measurements will not be made during the stirring (mixing) procedure.

*This assumes an uncertainity in the solution evaporation and radiolysis rate of 2 to 1.

**For nominal 250 gram/liter solution.

7.2.3 ACCOUNTABILITY FOR STATIC STORAGE MODE

After a tank has been filled and sampled, it will be sealed off from the rest of the module. Continuous measurements via the bubblers of density and solution mass will be made. Samples from a filled tank will be taken at 4 week intervals.* The tank will be stirred (mixed) prior to the sampling procedure.

7.2.4 ACCOUNTABILITY FOR CHEMICAL ADDITION MODE

If the estimate of solution density and mass falls outside of certain thresholds, nitric acid will be added to the tank to 1) replace the solution and 2) restore the solution pH and nitrate content so as to prevent formation of plutonium polymer. The procedure to be followed is as follows:

A measured amount of 4M HNO_3 will be added via the chemical addition lines. The tank solution will be stirred and sampled and a mass estimate will be made after stirring. The new mass, density, and Pu concentration will be compared to the added solution and old solution values. Estimates below 2.33σ of the mass estimate, density estimate, or pH measurement will trigger an MC alarm.

7.2.5 ACCOUNTABILITY FOR TRANSFER MODE

The intermodule and intramodule transfers will be handled by a procedure similar to product receival with the same bubbler and analytic measurements made.

7.2.6 ACCOUNTABILITY FOR LOAD-OUT MODE

Load-out to the conversion facility will be monitored by a procedure similar to product receival with one exception; the blending of all six** tanks in the module. This blending assures a homogeneous product for the conversion facility. The six tanks will be mixed and sampled and bubbler measurements taken for 30 minutes. The uncertainity of the solution mass to be transferred will be

$$\sigma_{TOT} = \sigma\sqrt{N}$$

and the total mass transferred is

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*See Section 4 for Projected Operating Plan for Storage Area.

**With the exception of module 4. The 6th tank in this module is product to be sent back for rework.

$$M_T = \sum_{i=1}^{N} M_i$$

where N = the number of tanks in the module (6 or 5)

M_i = mass in tank i

σ = standard deviation of mass measurement for any tank.

Once the analytical laboratory analysis is complete (≈24 hrs), the solution will be transferred to the conversion facility.

7.3 ESTIMATOR AND DETECTOR PERFORMANCE

The mass and density of the solution in the PNC storage tanks is continuously monitored by the bubbler system. Measurements from this system are fed to a Kalman filter to produce mass and density estimates and then to a detector to diversion (Fig. 7.3-1). The following sections describe the operation and performance of the estimator and subsequent detector.

7.3.1 ESTIMATOR MODEL (Reference 7-2)

This section describes the dynamic model for the solution in a $Pu(NO_3)_4$ storage tank. The dynamics of the solution in the tank arise through evaporation of H_2O and HNO_3 and by radiolytic effects. These effects are complex functions of several process variables including molarity of HNO_3, Pu concentration, temperature, and air circulation rate.

Dynamic equations for the solution mass can be expressed in terms of the above effects and in terms of solution volume and density. The relation between solution mass rate of change, and the radiolysis, evaporation, and potential diversion activities is:

$$\dot{M}_s(t) \triangleq \frac{d}{dt} M_s(t) = -\lambda(t) - \lambda_{H_2O} - \lambda_{HNO_3} - \lambda_r' M_s(t)P(t)$$

where $M_s(t)$ = the solution mass as a function of time

$\lambda(t)$ = diversion rate

λ_{H_2O} = evaporation rate for water

λ_{HNO_3} = evaporation rate for HNO_3

λ_r' = radiolysis rate coefficient

$P(t)$ = Plutonium concentration.

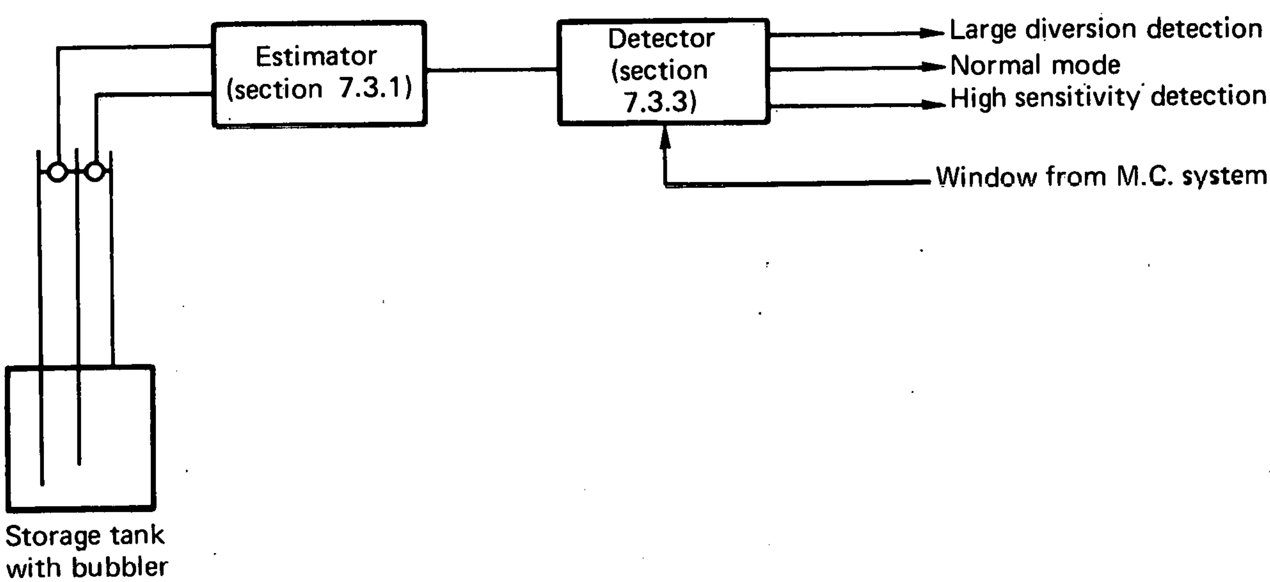

Figure 7.3-1 PPC Product Monitoring

The mass of solution in the tank is also determined by the physical configuration of the tank. That is,

$$M_s(t) = [\alpha + \beta h(t)]\rho(t)$$

where α is the tank heel

β is cross sectional area of the tank

$\rho(t)$ is the the solution density.

Combining these equations yields an equation relating the density and height of solution in the tank to the solution dynamics.

$$\alpha \dot{\rho}(t) + \beta \frac{d}{dt}\left\{\rho(t)\, h(t)\right\} = -\left\{\lambda(t) + \lambda_{H_2O} + \lambda_{HNO_3}\right\} - \lambda_r' P(t) \left\{\alpha \rho(t) + \beta\rho(t)\, h(t)\right\}$$

The estimator uses a state vector X with the following states:

$$X = \begin{bmatrix} \rho(t)h(t) \\ \rho(t) \\ \lambda(t) \end{bmatrix}$$

This set of states was chosen to make the estimation problem linear. The solution density and the potential adversary activity variables have been modeled as Wiener processes; i.e., $\dot{\rho}(t) = w_\rho(t)$, $E[\dot{\rho}_t] = 0$, $\dot{\lambda}(t) = w_d(t)$, $E[\dot{\lambda}_t] = 0$, where E is the expectation operator and w_ρ and w_d are white Gaussian processes with variances: $E[w_\rho(t)w_\rho(t)] = q_{11}\delta(t - \tau)$, $E[w_d(t)w_d(\tau)] = q_{22}\,(t - \tau)$, and $E[w_\rho(t)w_d(\tau)] = 0$. The process model is then

$$\underbrace{\begin{bmatrix} \dot{\nu}_t \\ \dot{\rho}_t \\ \dot{\lambda}_t \end{bmatrix}}_{\dot{x}_t} = \underbrace{\begin{bmatrix} -\lambda_r' P_t & -\lambda_r' P_t \frac{\alpha}{\beta} & -\frac{1}{\beta} \\ \hline & 0 & \end{bmatrix}}_{F_t} \underbrace{\begin{bmatrix} \nu_t \\ \rho_t \\ \lambda_t \end{bmatrix}}_{x_t} + \underbrace{\begin{bmatrix} -\frac{1}{\beta} \\ 0 \\ 0 \end{bmatrix}}_{g u'} \lambda_H$$

$$+ \underbrace{\begin{bmatrix} -\frac{\alpha}{\beta} & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix}}_{\Gamma} \underbrace{\begin{bmatrix} w_\rho(t) \\ w_d(t) \end{bmatrix}}_{w_t}$$

where $\lambda_H = \lambda_{H_2O} + \lambda_{HNO_3}$

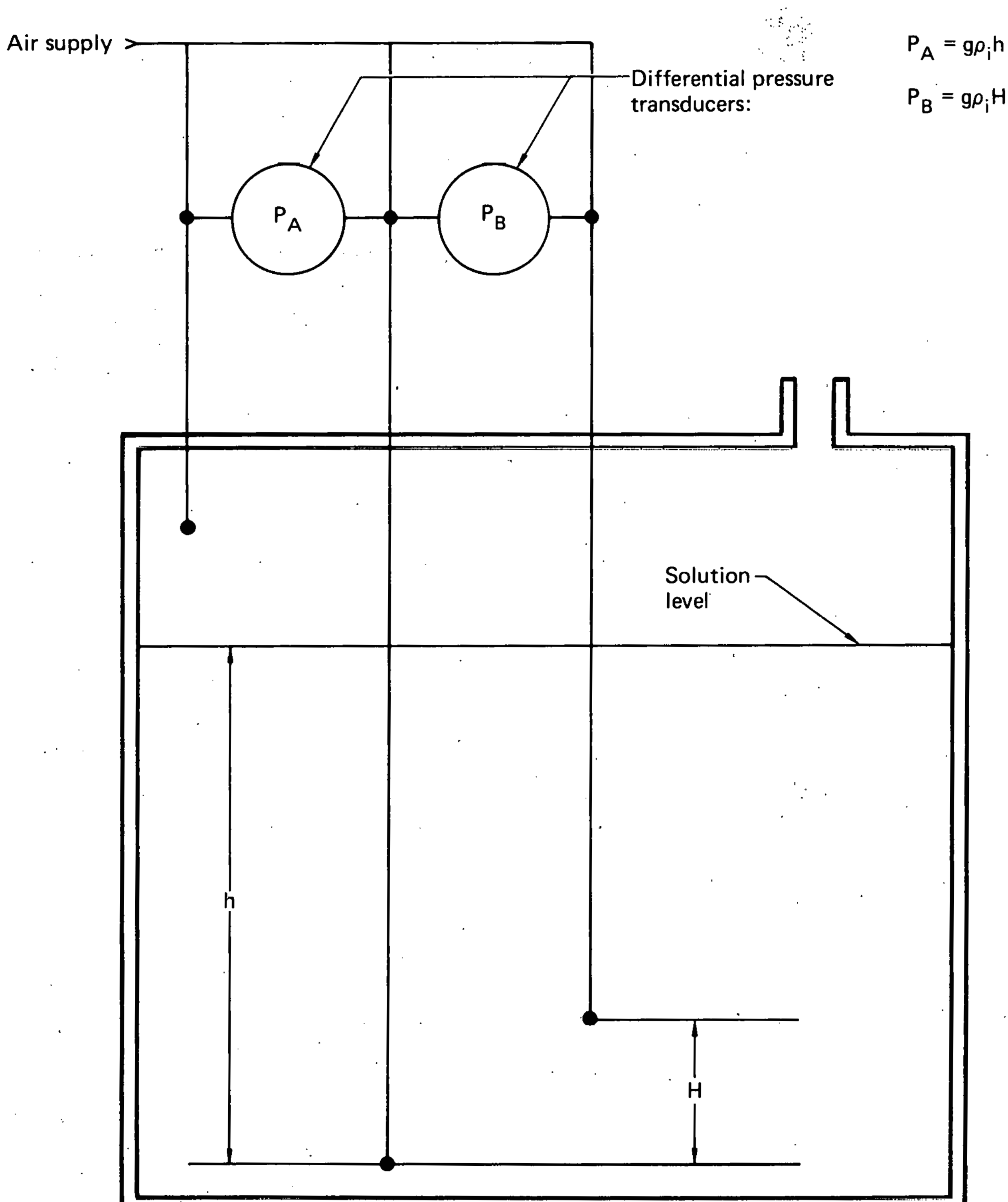

Figure 7.3.1-1 Storage Tank Air-Bubbler Measurement System

The measurements available to the estimator, $\gamma(k)$, are the discrete time measurements of differential pressures between the bubbler tubes (Fig. 7.3.1-1). These are

$$\underbrace{\begin{bmatrix} y_1(k) \\ y_2(k) \end{bmatrix}}_{y_k} = \underbrace{\begin{bmatrix} g & 0 & 0 \\ 0 & gH & 0 \end{bmatrix}}_{H} \underbrace{\begin{bmatrix} \nu_k \\ \rho_k \\ \lambda_k \end{bmatrix}}_{X_K} + \underbrace{\begin{bmatrix} v_1(k) \\ V_2(k) \end{bmatrix}}_{v_k} \qquad k = 1,\ldots.n$$

where k is the discrete-time variable, g' is the gravitational constant and H is the vertical separation distance of the density bubbler tubes. The $\underset{\sim}{V}(k)$ are noise terms with $E[\underset{\sim}{V}(k)] = 0$ and covariance $E[V(k)V(j)] = R\delta_{kj}$.

During static storage, Pu-concentration, P(t) is not measured. As a result, the above measurement strategy does not allow both $\lambda(t)$ and P(t) to be tracked during static storage. P(t) can be related to $\lambda(t)$ and HNO_3 molarity, but this relationship would only be valid as long as the density was not compromised. Pu concentration has been treated as time invariant for this analysis.

7.3.2 ESTIMATOR

The system described above is stochastic due to the random driving terms (process and measurement noise terms). A Kalman filter algorithm is used to give estimates of the process variables based on linear combinations of the measurement data. The filter is optimum in the least-squares sense and incorporates a recursive structure. The continuous-discrete filter equations, using the abbreviated notation introduced earlier, are (where $\hat{X}$ denotes linear-least squares estimates):

$$\hat{X}(t) = F\hat{X}(t) + gu \qquad \hat{\underset{\sim}{X}}(t_o) = \underset{\sim}{X}_o$$

$$\dot{\psi}(t) = F\psi(t) + \psi(t)F^T + \Gamma Q\Gamma^T \qquad \psi(t_o) = \psi_o$$

$$K(k) = \psi(k^-)H^T\ H_k\psi(k^-)H_k^T + R_k{}^{-1}$$

$$\psi(k^+) = I - K(k)H_k\ \psi(k^-)$$

$$\hat{X}(k^+) = \hat{X}(k^-) + K(k)\ Y(k) - H_k\hat{X}(k^-)$$

where $\psi(t) \triangleq E\ [X(t) - \hat{X}(t)][X(t) - \hat{X}(t)]^T$ is the error covariance matrix and where the (k^-) and (k^+) refer to times just before and after the k^{th} measurement.

The error covariance provides an indication of the mean-square error of the estimates relative to their true values - subject to correct implementation of dynamics and measurements.

7.3.3 PERFORMANCE

The process and measurement models have been used in a computer simulation code to produce a set of noisy measurements which simulated Pu-loss from a nitrate storage tank. The parameters in Table 7.3.3-1 were used and $\psi_{11}(\infty) = 1\ kg^2/m^4$ was chosen. Typical estimator outputs are shown in Fig. 7.3.3-3 through 7.3.3-6 for $\hat{X}_1(t)$ and $\hat{X}_3(t)$ for simulated Pu-losses of 150 gm and 500 gm. The rate of solution loss was 0.4 ℓ/min for a period of 1.5 and 5 minutes, respectively. The dashed line in Figs. 7.3.3-3 and 7.3.3-5 indicate the true value of $X_1(t)$.

In Fig. 7.3.3-3, the signal change due to the 150 gm diversion is embedded in the uncertainty of the estimate and makes detection difficult. Figure 7.3.3-5 shows the estimate $\hat{X}_3(t) = \hat{\lambda}(t)$ where the true value is a narrow rectangular pulse defined by:

$$\lambda(t)\begin{cases} = 100 \text{ gm/min} & 10 \le t \le 11.5 \text{ min} \\ = 0 & \text{all other } t \end{cases}$$

Without diversion the time average of $\hat{\lambda}(t)$ should equal zero. With diversion the time average is an indication of the amount of solution mass diverted.

The response time of the estimator is of the order of the pulse width of the positive peak in Fig. 7.3.3-3 (roughly 25 minutes). The long response time is commensurate with the estimator error covariance term $\psi_{11}(\infty) = 1\ kg^2/m^4$.

The estimator outputs for the case of 500 gm being diverted are shown for purposes of comparison in Figs. 7.3.3-5 and 7.3.3-6. The signal changes due to diversion in this case are substantially greater than the uncertainty of the estimates. Because of the increased signal level, detection capability for 500 gm of diversion is very good.

The instrumentation accuracy and the tank radiolysis and evaporation rate uncertainties are the limiting factors in the ability to determine tank level changes due to diversion. Only one class of diversion is considered here, that of theft without replacement. This type of theft causes a drop in the solution level in the tank.

The diversion detection logic is shown in Fig. 7.3.3-7. There are three

SYMBOL	VALUE	UNITS
3M HNO_3	0.189	kg HNO_3/ℓ
ρ_o	1448	gm/ℓ
P_o	0.173	kg Pu/kg Soln
λ_r' λ	$.94 \times 10^{-9}$	kg H_2O/sec per kg Pu
λ_H	0.5	kg Soln/day
g	9.8	m/sec^2
α	0.0209	m^3
β	0.329	m^2
h	0.254	m
q_{11}	10^{-4}	kg/m^3 sec
q_{22}	10^{-10}	kg^2/sec^3
q_{12}, q_{21}	0	
r_{11}	2641	kg/m sec^2
r_{22}	81	kg/m sec^2
r_{12}, r_{21}	0	

Table 7.3.3-1. Nominal Values for Process and Measurement Model Parameters

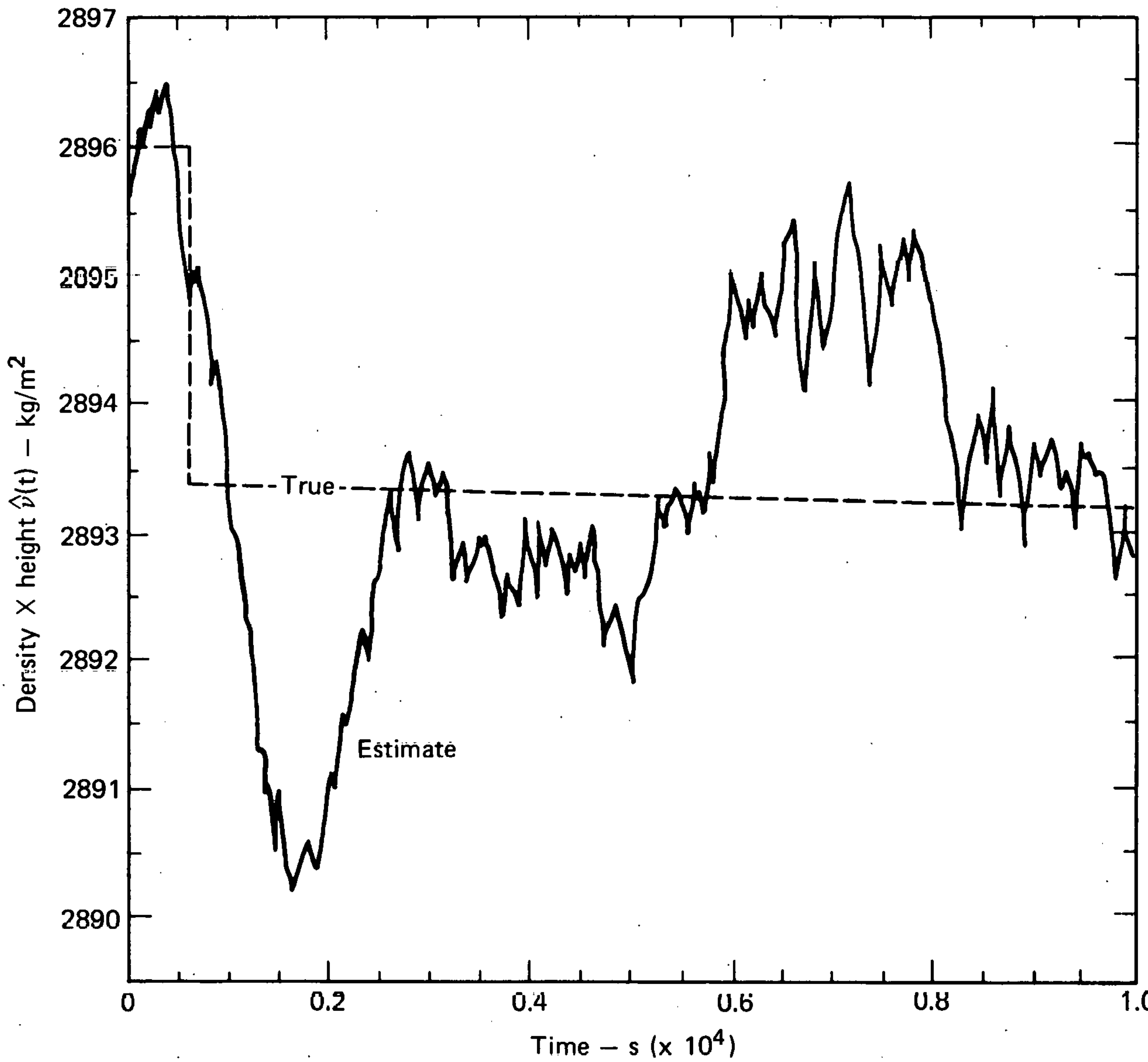

Figure 7.3.3-3 Density x Height Estimate for a Simulated Pu-Loss of 150 gm ($\lambda(t)$ = 0.4ℓ/min. for 1.5 min.)

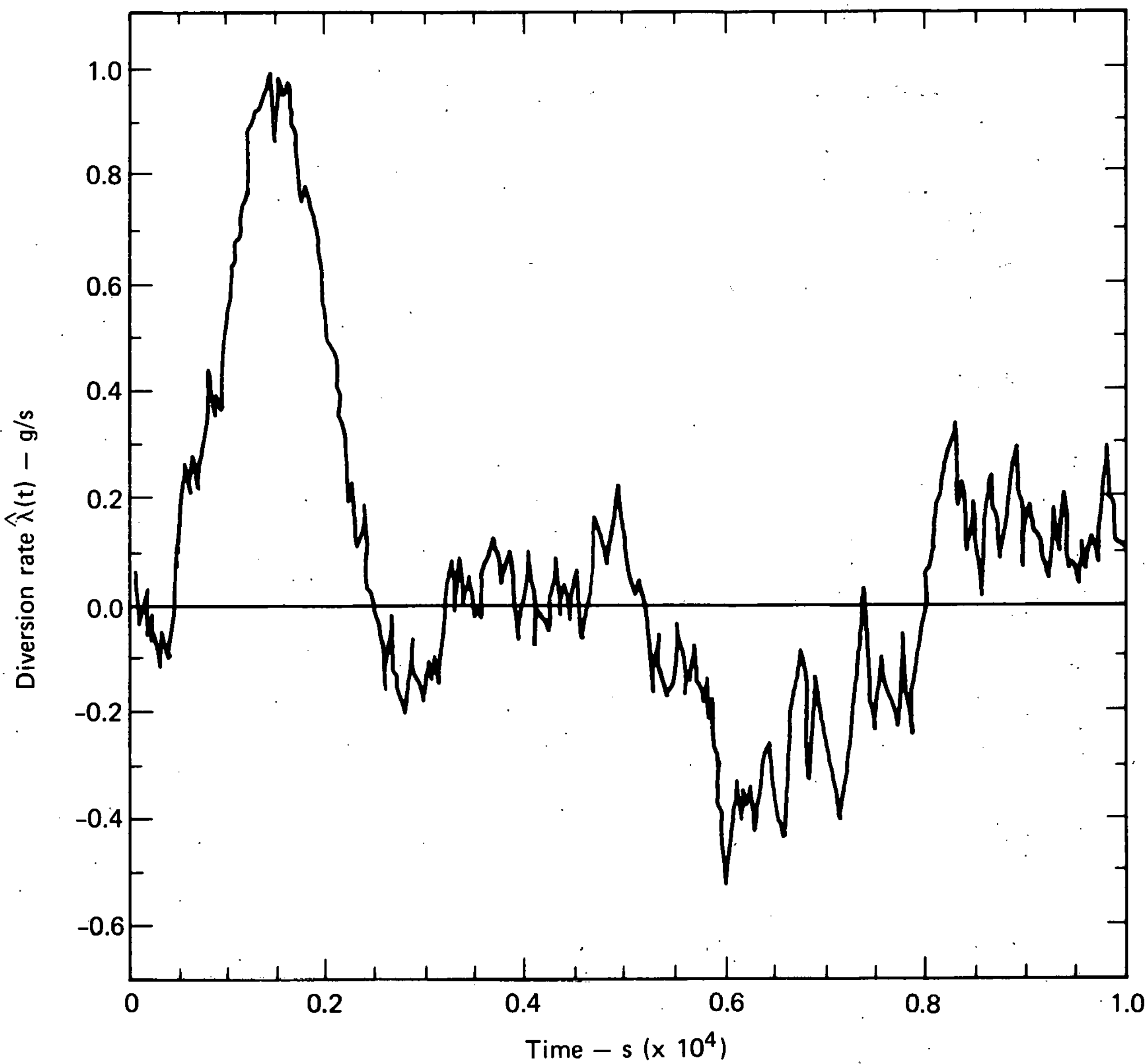

Figure 7.3.3-4 Estimate of Diversion Rate for a Simulated Pu-Loss of 150 gm

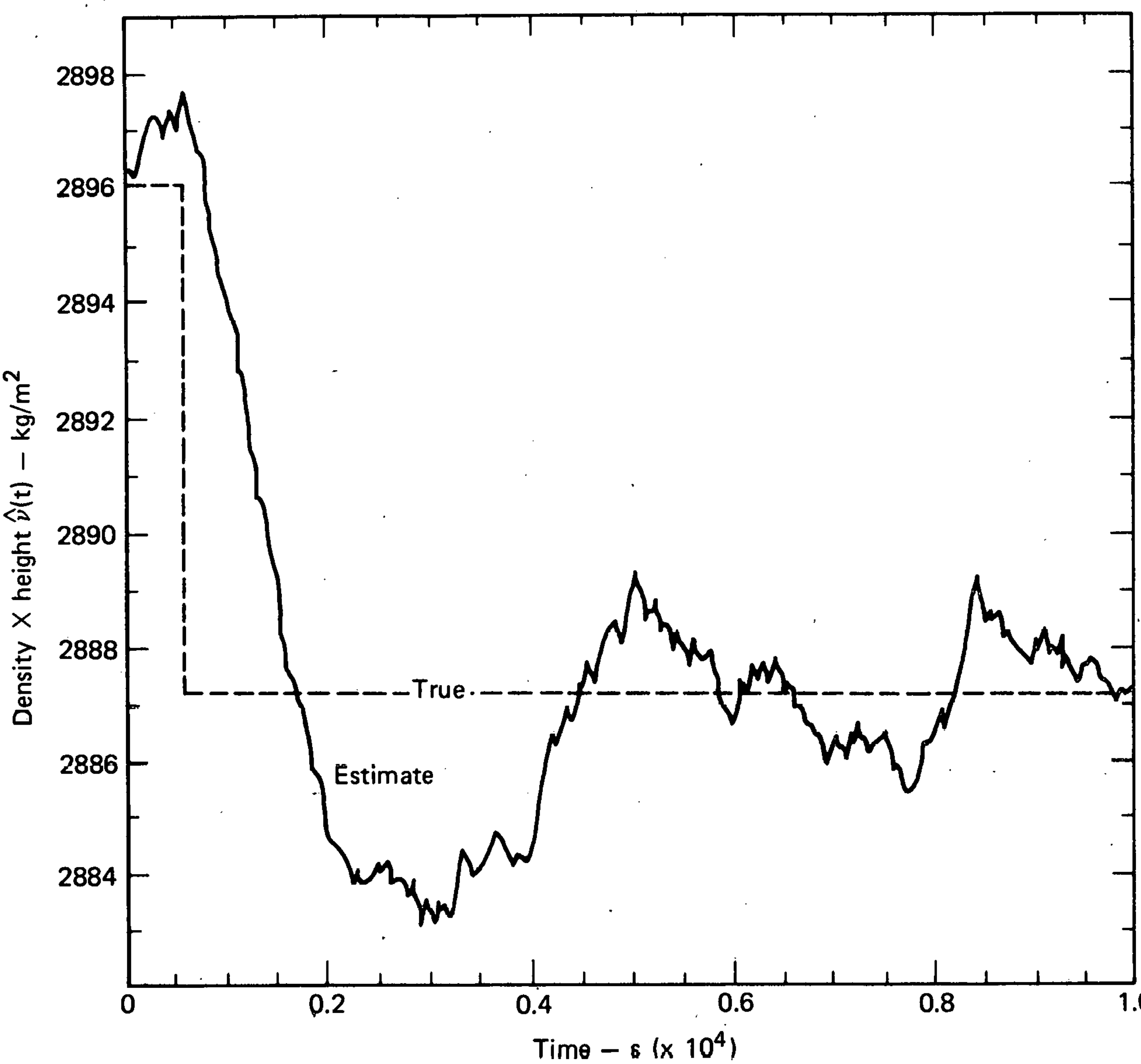

Figure 7.3.3-5 Density x Height Estimate for a Simulated Pu-Loss of 500 gm ($\lambda(t)$ = 0.4ℓ/min. for 5 min.)

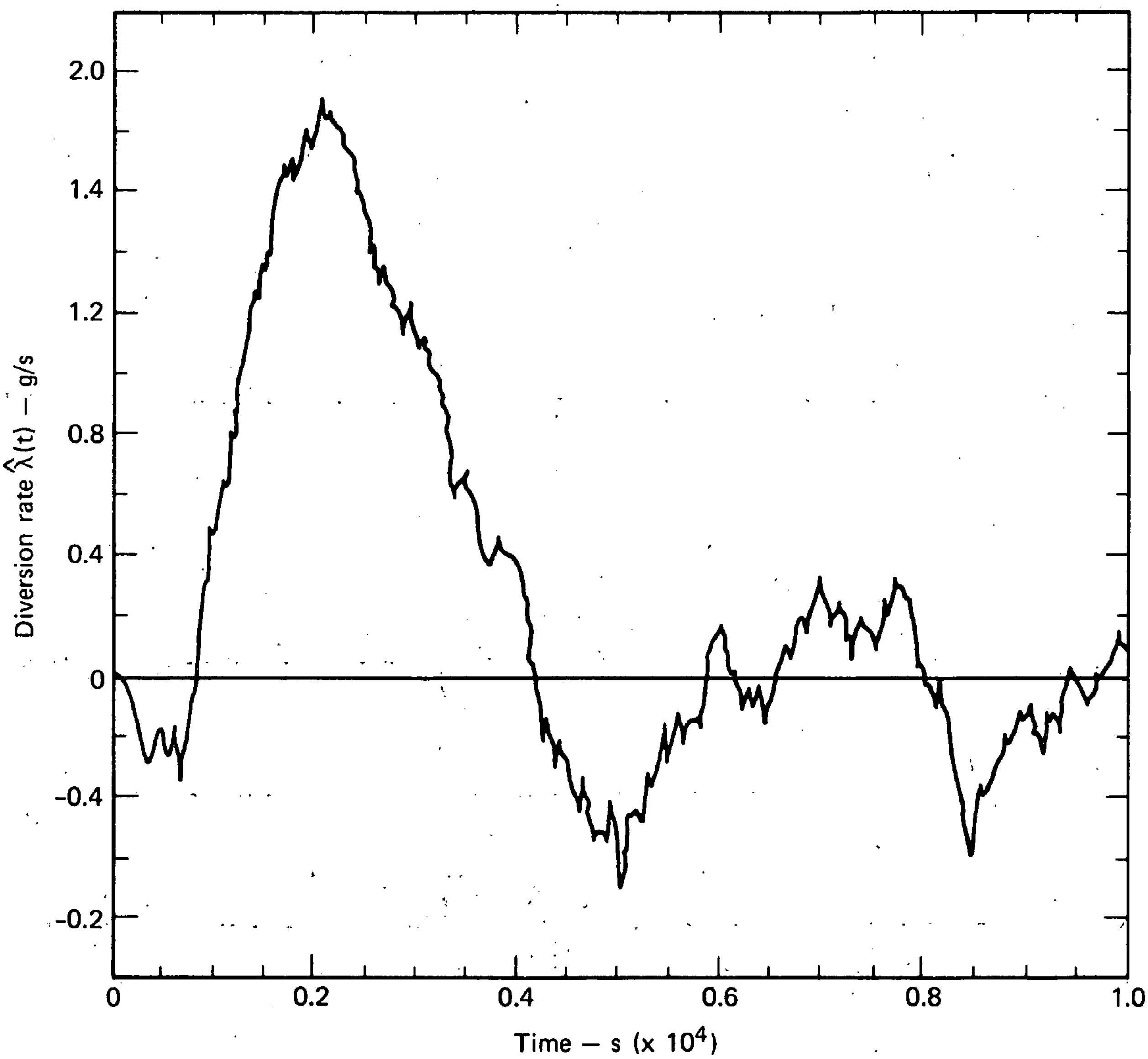

Figure 7.3.3-6 Estimate of Diversion Rate for Simulated Pu-Loss of 500 gm.

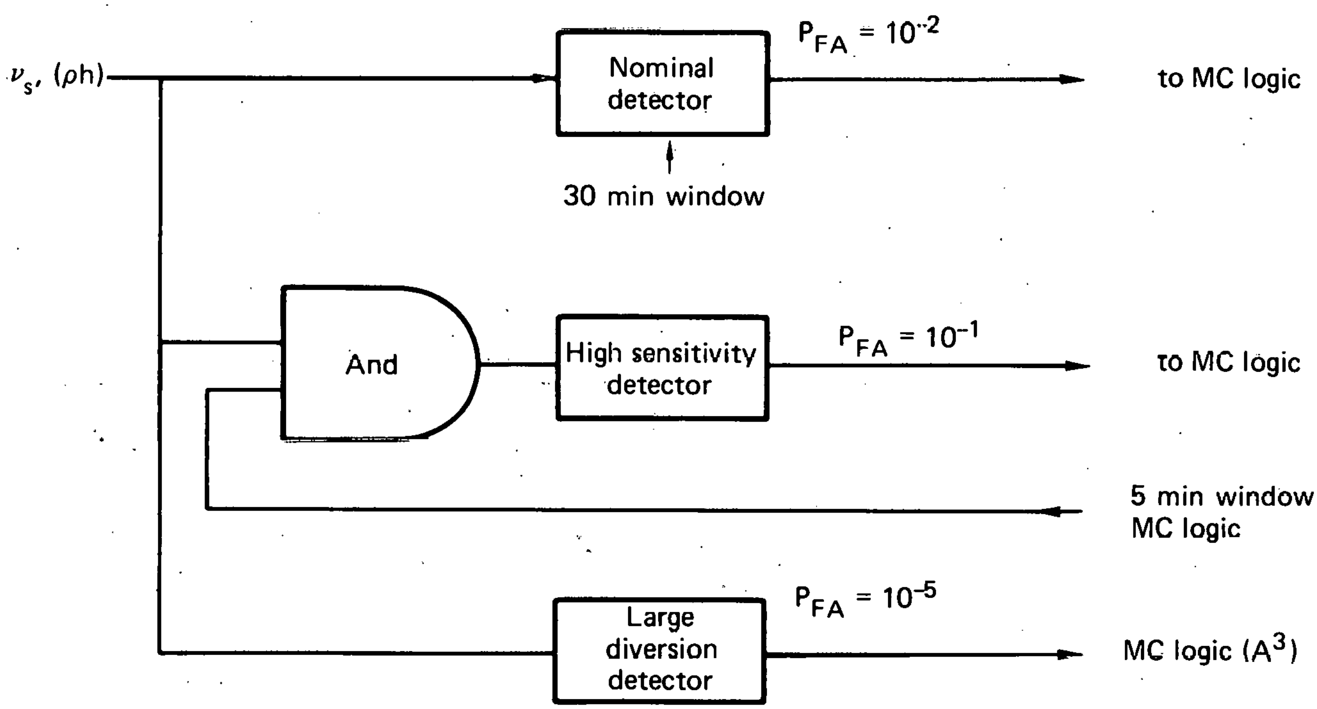

Figure 7.3.3-7 Diversion Detection Logic

separate detector systems. These are:

1. Nominal Detector
   This detector has a low false alarm rate and operates on a 30-minute smoothing interval. A detection from this system causes a A^2 anomaly level in the MC system.
2. High Sensitivity Detector
   When the MC logic is in a TDR-1, TDR-2 or TDR-3 state, a detector with a higher false alarm rate is used to provide a fast detection response.
3. Large Diversion Detector
   A continuously operating very low false alarm rate detector is used to alarm on the detection of gross diversion.

The performance of each of these detectors is discussed below.

NOMINAL DETECTOR LOGIC

All three detection filters process the estimator outputs and perform a classical hypothesis test as shown in Fig. 7.3.3-8. The smoothing window for the nominal detector on this filter combination is such that a new test is performed every 25 minutes.

The performance of the tank estimator/detector system is shown in Fig. 7.3.3-9. The detection probability is the probability that a theft of X grams of plutonium will produce a "one" output from the filter. The false alarm probability is the probability that the filter will produce a "one" output for no theft. A false alarm probability of 10^{-2} corresponds to approximately one false diversion detection per two days. Verification of the diversion alarm can then be achieved by the MC-2 operator using the data gathered and processed in the next interval.

HIGH SENSITIVITY/FAST RESPONSE DETECTOR

In certain situations* it may be desirable to have a faster time response than the 25 minute detection time discussed above. Reduction of the smoothing interval would ordinarily reduce the detection sensitivity. However, in the alert mode, the time window of interest is short duration, allowing the use of a detection threshold corresponding to an increased false alarm probability. The detection performance for this situation for

*Automatic on MC System State of TDR-1

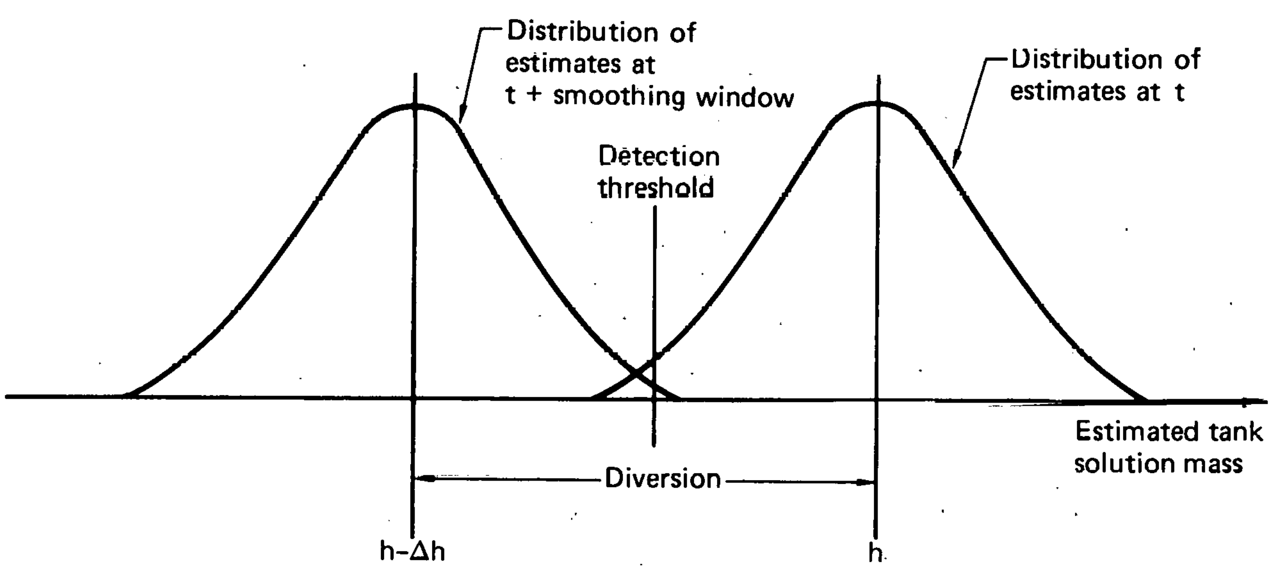

Figure 7.3.3-8 Hypothesis Test for Diversion Detection

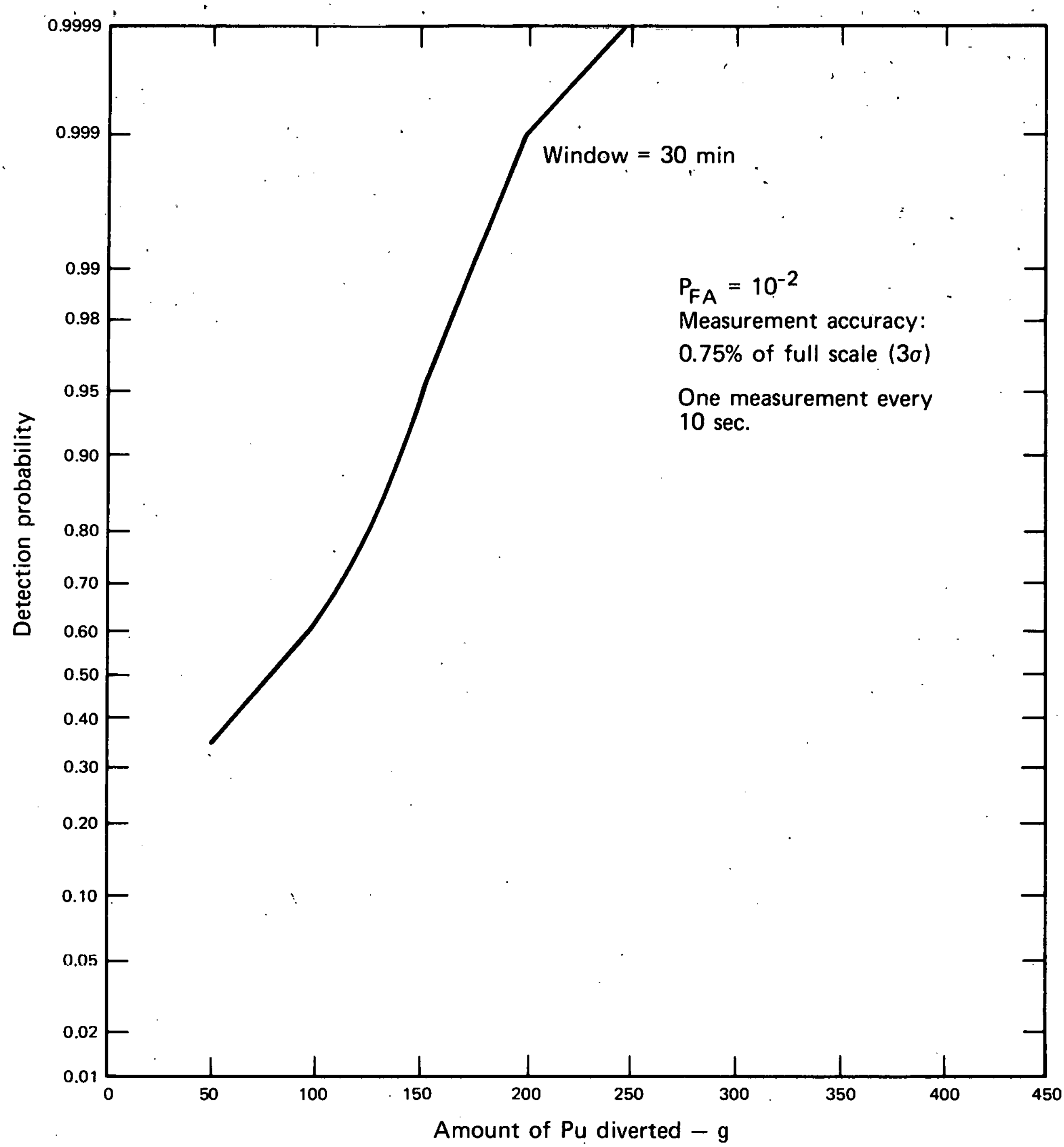

Figure 7.3.3-9 Single PNC Tank Diversion Detection Performance

a 5 minute alert window is shown in Fig. 7.3.3-10. The probability of a false alarm for this alert situation has been chosen to be 0.10.

LARGE DIVERSION DETECTION MODE

The estimator/detector is also designed to produce an alert on the detection of a large diversion of Pu. A threshold which yields a very low false alarm probability is used for this test (10^{-5} corresponding to approximately one false alarm per 9 years). Figure 7.3.3-11 gives the time to detect a diversion for various amounts of diversion for the large diversion detection mode.

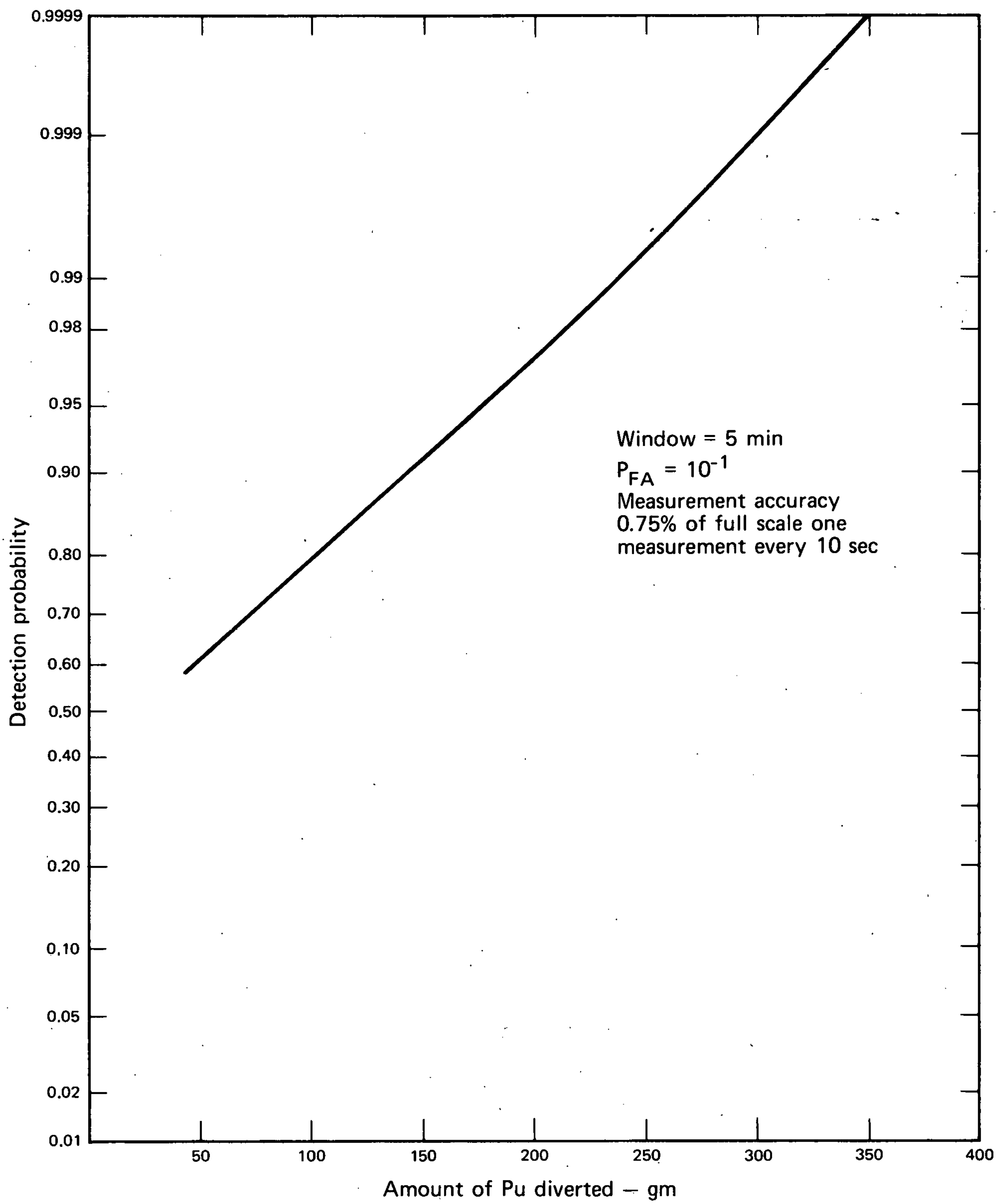

Figure 7.3.3-10 Fast Response Mode Detector Performance

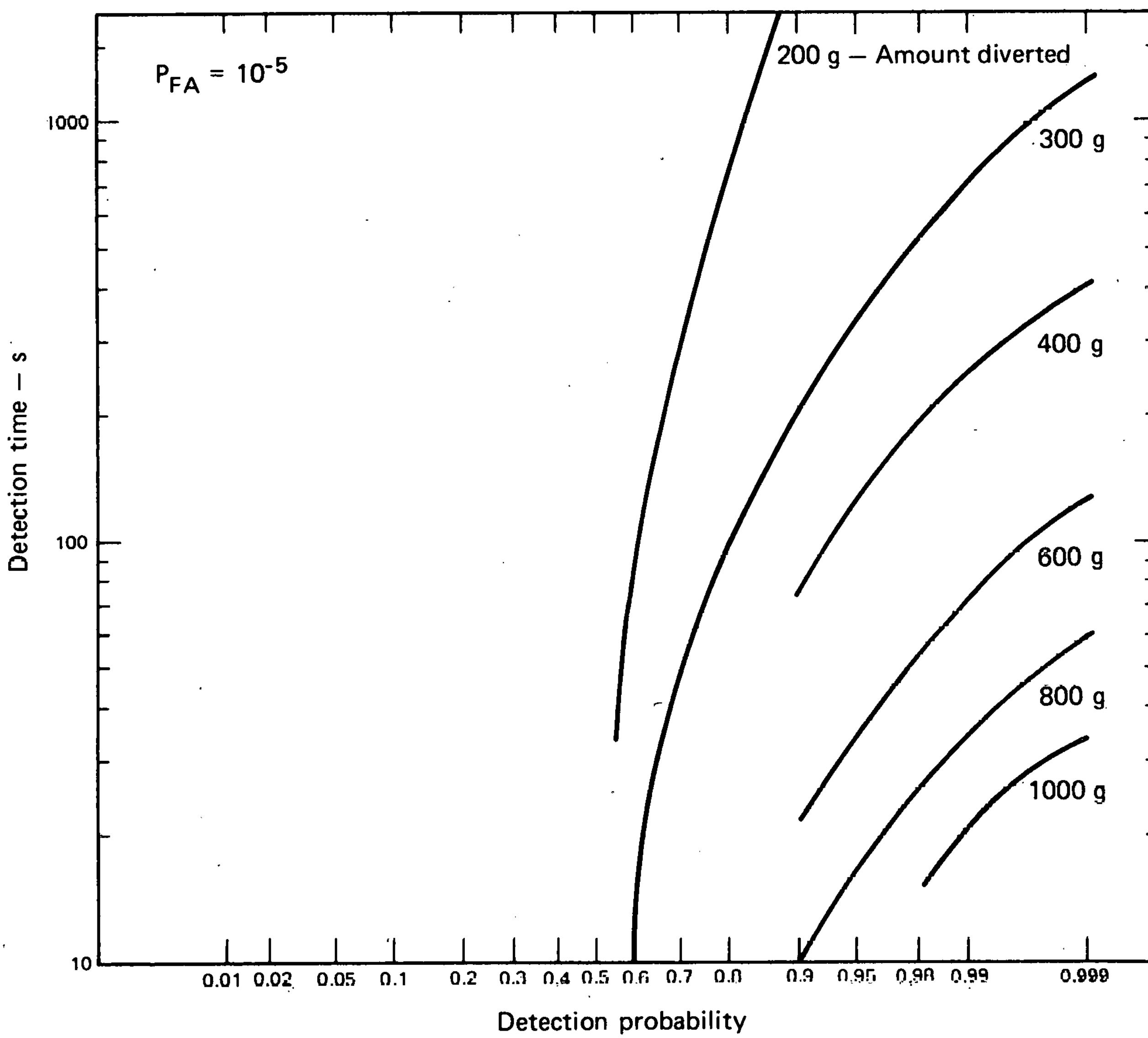

Figure 7.3.3-11 Large Diversion Detector Performance

7.4 Material Accountability Procedure

This section presents, in detail, the accountability procedures for the transfer of plutonium nitrate from the concentrator area, PPC, to the storage area, PNC. The responsibility for the material is as follows: Plutonium Product Cell: PPC-Operator; Plutonium Nitrate Cell: PNC-Operator. Authority for any transfer from any material balance area, MBA, to any other lies with the Nuclear Materials Control Officer, NMCO, with the computer enablement of the transfer performed by the Process Operator, MC-2,0. The accountability procedure described in this section produces two independent trails of transfer documentation. These are:

(1) The computer accountability records.

(2) The written and signed control of Material Transfer Forms.

The computer-generated records are tape recorded with a hard copy of all transactions printed out at the end of each day. A backup tape containing each day's transactions is retained in a vault. Loss of the active tape would therefore result in the loss of one day's records. The paper documentation is retained by the originator of each document and the Nuclear Materials Control Officer. The following sections contain the accountability related procedures for the transfer of special nuclear material.

7.4.1 Accountability Procedure for SNM Transfer

The accountability procedure for the transfer of special nuclear material is described in this section. THe important process steps in the transfer of the plutonium product from the PPC to the PNC are:

(1) Filling the accountability tanks in the PPC.

(2) Measuring the quantity of solution in the PPC accountability tanks.

(3) Drawing samples and assaying the material in these tanks.

(4) Pumping the material to the PNC receiving tank.

(5) Holding the material in the PNC receiving tank.

(6) Measuring the quantity of solution in this tank.

(7) Assaying the material in the tank.

(8) Transfering the assayed material to general storage in the PNC.

A schematic flow of the information required for a PPC/PNC transfer is shown in Figures 7.4.1-1 and 7.4.1-2. The first of these figures shows the flows of documents and material between the NMCO, MC-2,0, PPC-0 and Analytical Laboratory Technician for the material assay which is required prior to transfer. The second figure shows the document and material flows required for the actual SNM transfer.

The accountability procedure is shown in detail in Figure 7.4.3-1 and is now described. (Heading numbers correspond to those of Figure 7.4.3-1.)

7.4.1.1 Fill Accountability Tanks (Figure 7.4.3-1a)

Material from the concentrator is directed into two of three PPC accountability tanks (Figure 2.5.1-1). When the PPC-0 determines by the bubbler instrumentation readings that these tanks are filled (to a total of 730 liters) the material is directed to the third accountability tank.

7.4.1.2 Request Assay (Figure 7.4.3-1a)

The PPC-0 at this point sends an Assay Request Form to the Nuclear Materials Control Officer. This Assay Request Form is shown in Figure 7.4.1.2-1. As with all the manually generated documents, a copy of this form is kept by the originator (in this case, PPC-0).

7.4.1.3 NMCO Authorization for Assay (Figure 7.4.3-1a)

The Nuclear Materials Control Officer, NMCO, authorizes a sampling procedure by filling out a Controlled Material Transfer Form, CMTF, (Figure 7.4.1.3-1). Copies of this form are sent to the PPC-0; the Process Operator, MC-2,0; the Analytical Laboratory Technician and a copy is retained for NMCO file. The CMTF's are sequentially numbered and all numbers must be accounted for.

7.4.1.4 Computer Sampling Enablement (Figure 7.4.3-1a)

The Process Operator, MC-2,0 on receiving the Controlled Material Transfer Form, instructs the Material Control computer system to allow the sampling for material to be assayed. This enablement is accomplished by typing into the Process Operator, MC-2,0, computer terminal the information contained on the Controlled Material Transfer Form.

After the computer has been instructed to enable the sampling operation, the computer prints out to MC-2,0 the Sampling Enablement Form shown in Figure 7.4.1.4-1. This form is also printed out at the MC System terminal in the NMCO office and at the PPC-0 area.

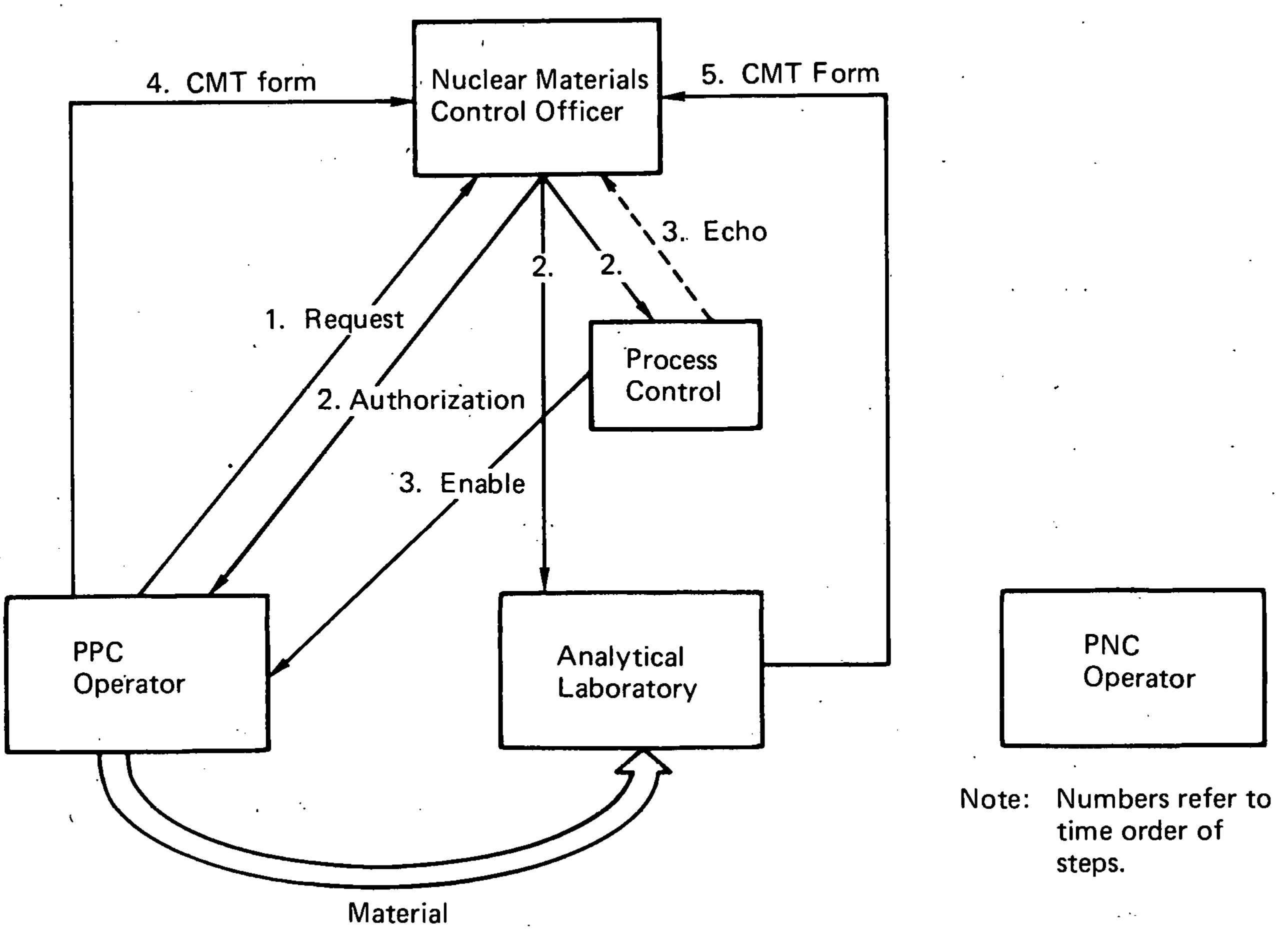

Figure 7.4.1-1 Material Transfer Control: Pre PPC/PNC Transfer

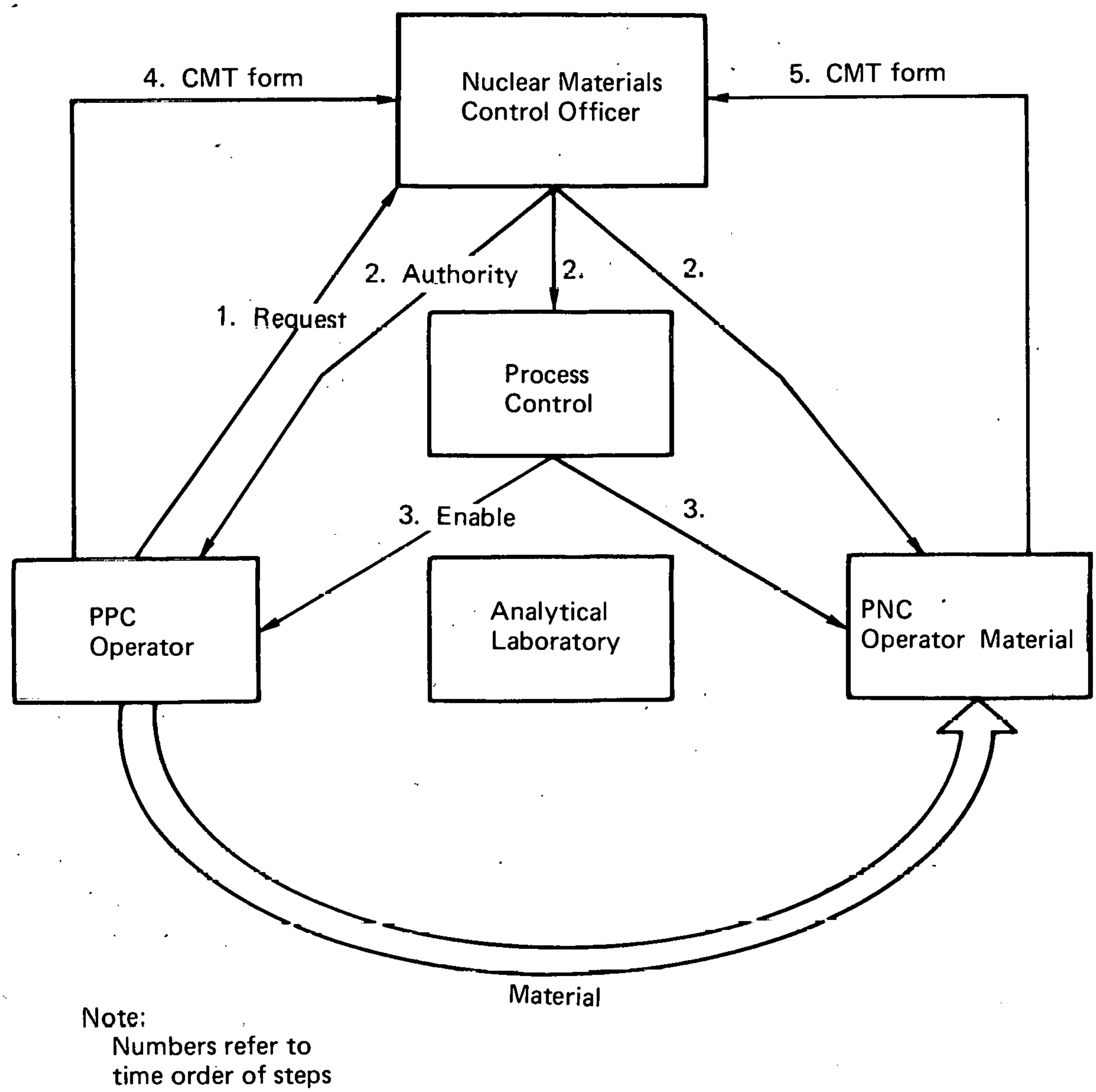

Figure 7.4.1-2 Material Transfer Control: PPC/PNC Transfer

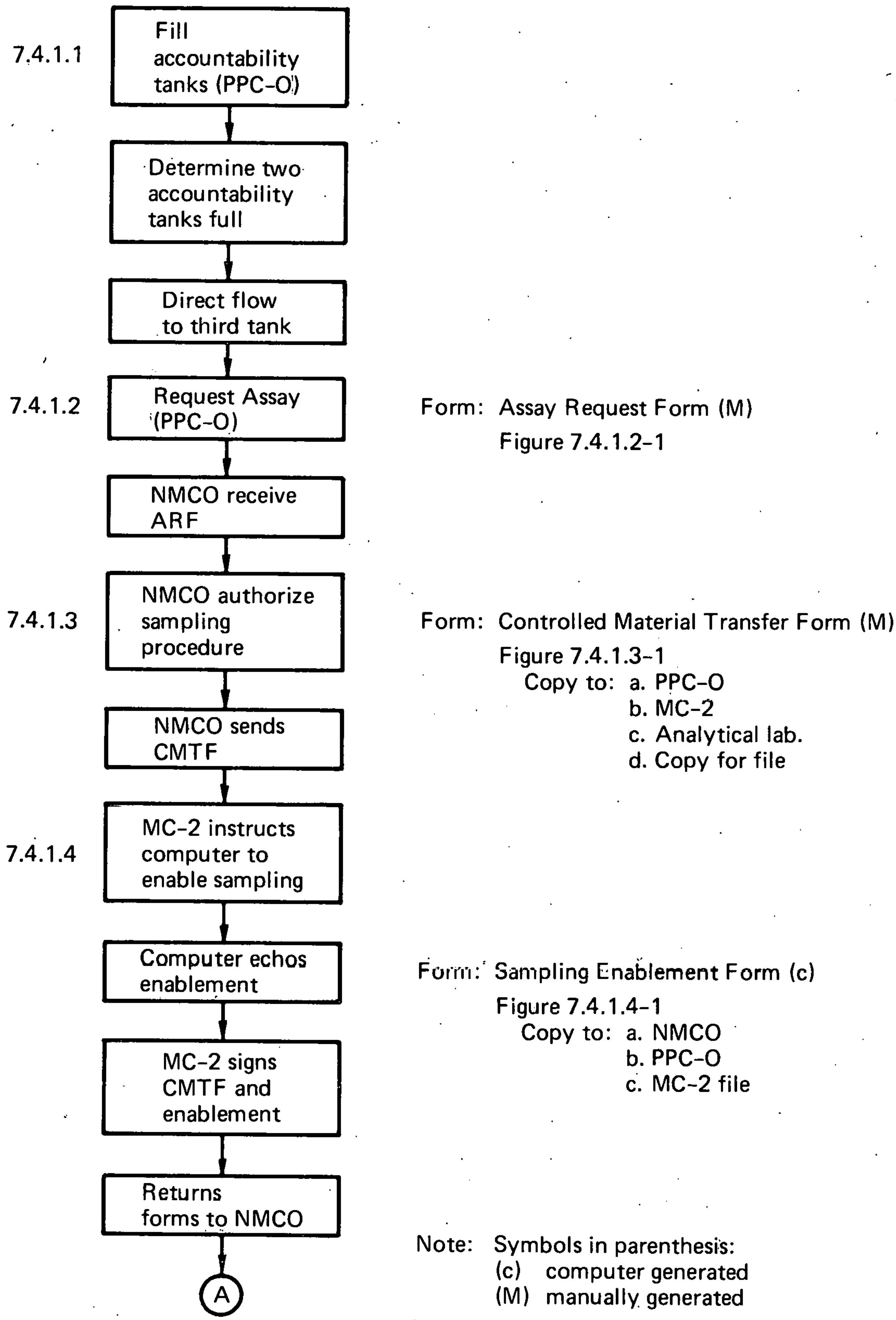

Figure 7.4.1-3a Accountability Procedure

ASSAY REQUEST FORM ARF 11281

☐ MATERIAL TO BE TRANSFERRED

☐ ROUTINE ACCOUNTABILITY

☐ MATERIAL TO BE ACCEPTED

REQUESTED ASSAY TIME: ____________ DATE ____________ TIME

MATERIAL TYPE: ____________

COMMENTS: ____________

APPROXIMATE QUANTITY TO BE DRAWN: ____________

NUMBER OF SAMPLES TO BE DRAWN: ____________

REFERENCE: ____________

FROM MBA: ____________ TO MBA: ____________

REQUESTED BY: ____________ SIGNATURE ____________ DATE

RECEIPT SIGNATURE:

Copy one to NMCO; copy two to Requestor file

ARF-1 (Rev. 02/03/78)

Fig. 7.4.1.2-1 Assay Request Form

CMT 11117

CONTROLLED MATERIAL TRANSFER FORM

☐ MATERIAL FOR ASSAY ☐ QUALITY CONTROL SAMPLE

☐ PROCESS TRANSFER

MATERIAL TYPE: ______________________

COMMENTS: ______________________

ALLOWED GROSS QUANTITY: ______________________

ITEM COUNT: ______________________

AUTHORIZED TRANSFER PERIOD: __________ DATE __________ TIME to __________ HOURS

FROM MBA: ______________ TO MBA: ______________

REFERENCE: ______________________

REQUESTED BY: ______________________

AUTHORIZED BY: ______________________
NAME TITLE DATE

COMPUTER TRANSFER ENABLEMENT: __________ SIGNATURE __________ DATE __________ TIME

RELEASE CONTROL: __________ SIGNATURE __________ DATE __________ TIME

RECEIVE CONTROL: __________ SIGNATURE __________ DATE __________ TIME

CMTF-1 (Rev. 02/03/78)

Fig. 7.4.1.3-1 Controlled Material Transfer Form

* *

```
     SAMPLING ENABLE VERIFICATION              3 FEB 78  1305

SAMPLING REQUEST APPROVED: JACK NMCOBOSS

TIME OF SAMPLE: 3 FEB 78    1310 TO 1630

NUMBER OF SAMPLES: 4

REFERENCE: ASSAY REQUEST FORM NUMBER: ARF23549
           CONTROLLED MATERIAL TRANSFER FORM NUMBER: CMT78943

SAMPLING ENABLE VERIFIED BY: CHUCK MCICOOLY

SIGNED:
```

* *

Figure 7.4.1.4-1 Sampling Enablement Form

The MC-2,0 signs the computer generated Sampling Enablement Form and his copy of the CMTF. These forms are then stapled together and returned to the NMCO.

7.4.1.5 Receives Work Orders (Figure 7.4.1-3b)

The PPC-0 receives the Sampling Enablement Form from MC-2,0 and the CMTF from the NMCO.

7.4.1.6 Begin Sampling Operation (Figure 7.4.1-3b)

The PPC-0 instructs the Material Control computer system via his terminal when he is ready to begin sampling. The Material Control computer verifies the sampling authorization from the daily work roster which was entered by the MC-2,0. If verification is not obtained a Material Control System alarm of level TDR-1 is called. If verification is obtained, the PPC-0 is instructed via his computer terminal to begin the sampling operation.

7.4.1.7 Sampling Operation (Figure 7.4.1-3b)

The PPC-0 begins the sampling operation after receiving authorization via the MC computer terminal. The sampling operation is described in more detail in Section 3. As each vial is lifted to the sampling needles the optical scanner built into the sampling lift scans the identity of the sampling bottles.

7.4.1.8 Sample Identification (Figure 7.4.1-3b)

At the end of the sampling operation when all four bottles have been drawn, the computer then prints out the Sample Identification Form. A copy of this form is printed at the Plutonium Product Cell Operator's location and also at the Nuclear Material Control Officer's terminal. This form is shown in Figure 7.4.1.8-1. The PPC-0 sends the sample vials to the Analytical Laboratory through the pneumatic transport system. At this point the PPC-0 signs the CMTF in the space labeled release control and also signs the Sample Identification Form. He then mails these forms to the Nuclear Materials Control Officer.

7.4.1.9 Receipt of Samples at Analytical Laboratory (Figure 7.4.1-3c)

The samples for assay are received at the Analytical Laboratory. Upon receipt bar code on the sample vials are scanned by an optical reader. The Material Control computer system then prints out the Sample Receipt Form on the Analytical Laboratory terminal. This form is shown in Figure 7.4.1.9-1. The Analytical Laboratory technician signs the Sample Receipt Form printed out by the Material Control computer and the CMTF which he has received from the

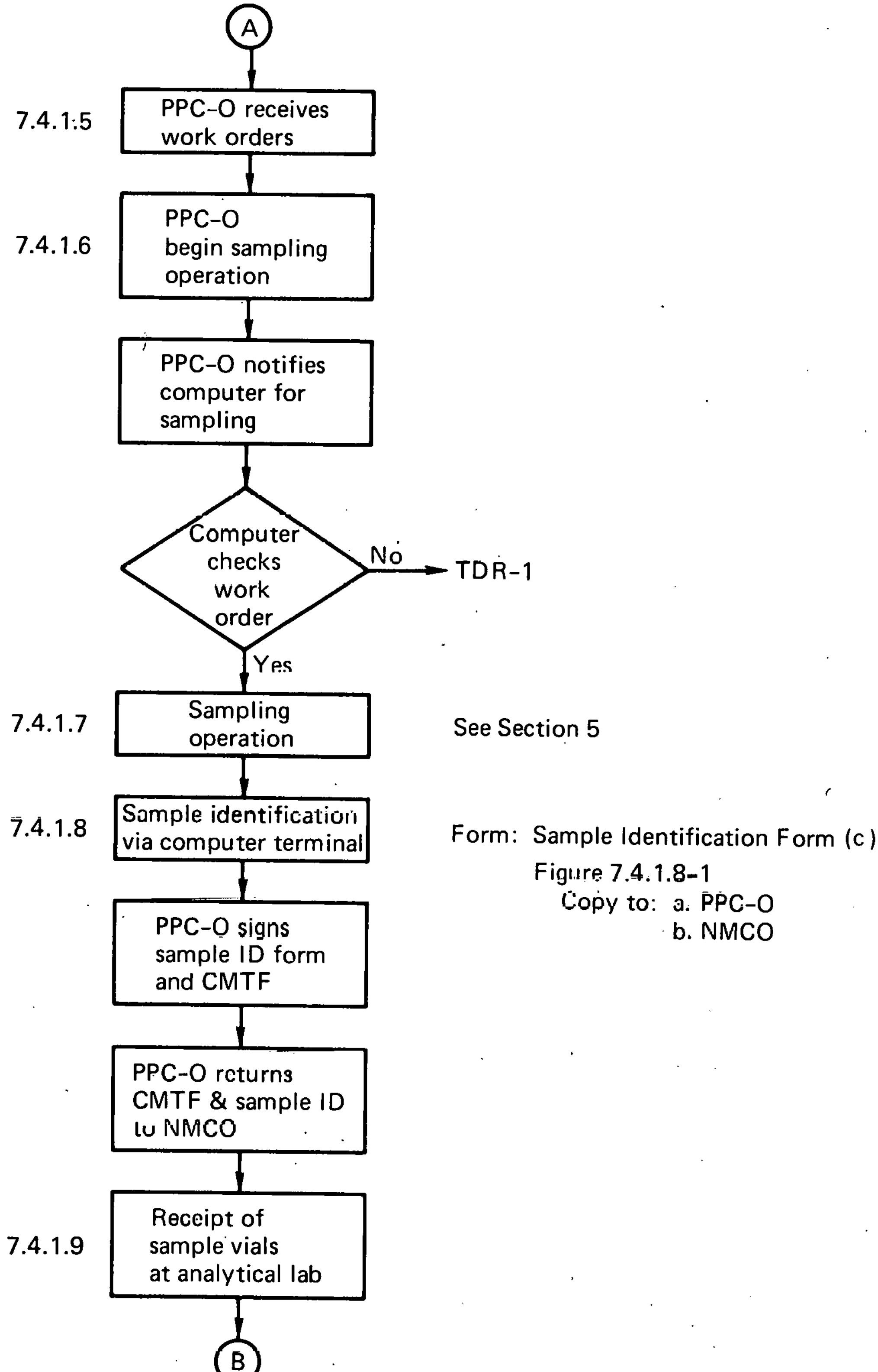

Figure 7.4.1-3b Accountability Procedure (continued)

```
SAMPLE IDENTIFICATION                      REFERENCE: CMT78943

TIME: 1410          DATE: 3 FEB 78

SAMPLING AUTHORITY: JACK NMCOBOSS
ENABLE VARIFICATION: CHUCK MC2COOLY

NUMBER OF SAMPLES TAKEN: 4

SAMPLE VIAL I.D.  1) 2221
                  2) 2224
                  3) 1212
                  4) 0001
```

Figure 7.4.1.8-1 Sample Identification Form

```
SAMPLE RECEIVAL                          REFERENCE: CMT78943

TIME: 1505        DATE: 3 FEB 78

SAMPLING AUTHORITY: JACK NMCOBOSS
ENABLE VARIFICATION: CHUCK MC2COOLY

NUMBER OF SAMPLES RECEIVED: 4

SAMPLE VIAL ID NUMBERS 1) 2221       PPC
                       2) 0001       PPC
                       3) 1212       PPC
                       4) 2224       PPC

SIGNED:
```

Figure 7.4.1.9-1 Sample Receipt Form

Nuclear Materials Control Officer. He then staples these forms together and mails them to the Nuclear Materials Control Officer.

7.4.1.10 Perform Assay (Figure 7.4.1-3c)

The laboratory assay is performed as discussed in Section 6. The Laboratory Data System (LDS), automatically enters the results into the Material Control System Computer assay suspense file. The contents of this file relating to the composition of the assayed material will not be released into the permanent computer accounting records without the authority of the Nuclear Materials Control Officer as will be discussed in the next section.

The results of the Analytical Laboratory measurements are printed out by the Material Control computer from the suspense file to Nuclear Materials Control Officer and to the Process Operator MC-2,0. The Material Assay Results Form is shown in Figure 7.4.1.10-2.

7.4.1.11 Approve Assay Results (Figures 7.4.1-3c and 7.4.1-3d)

The Nuclear Materials Control Officer and the Process Operator, MC-2,0, both must approve the results of the Anlytical Laboratory assay. The Nuclear Materials Control Officer signs the Material Assay Results Form and attaches it to the CMTF and files these copies. The Process Operator, MC-2,0, must also approve the results of the assay. Upon his approval, he signs the Material Assay Results Form and mails his copy to the Nuclear Materials Control Officer. The Process Operator also instructs the Material Control computer to release the results of quantity and quality of material. The PPC-0 is then informed that the results of the assay are consistent with the expected results.

7.4.1.12 Request for Product Transfer (Figure 7.4.1-3d)

The Plutonium Products Cell Operator requests material transfer from the PPC to the PNC from the Nuclear Materials Control Officer.

7.4.1.13 Product Transfer Authorization (Figure 7.4.1-3d)

The Nuclear Material Control Officer fills out a CMTF and sends this form along with the Material Assay Results Form generated by the computer to the PPC-0, the Process Operator, MC-2,0, the Plutonium Nitrate Cell Operator, PNC-0, and retains a copy for file. The Process Operator, MC-2,0, upon receipt of this form adds the transfer to the daily work roster. The MC-2,0 signs the CMTF after he has entered the enablement into the computer. The computer echoed Transfer Enablement Form (Figure 7.4.1.13-1) is generated, signed, and returned with the CMTF to the Nuclear Materials Control Officer.

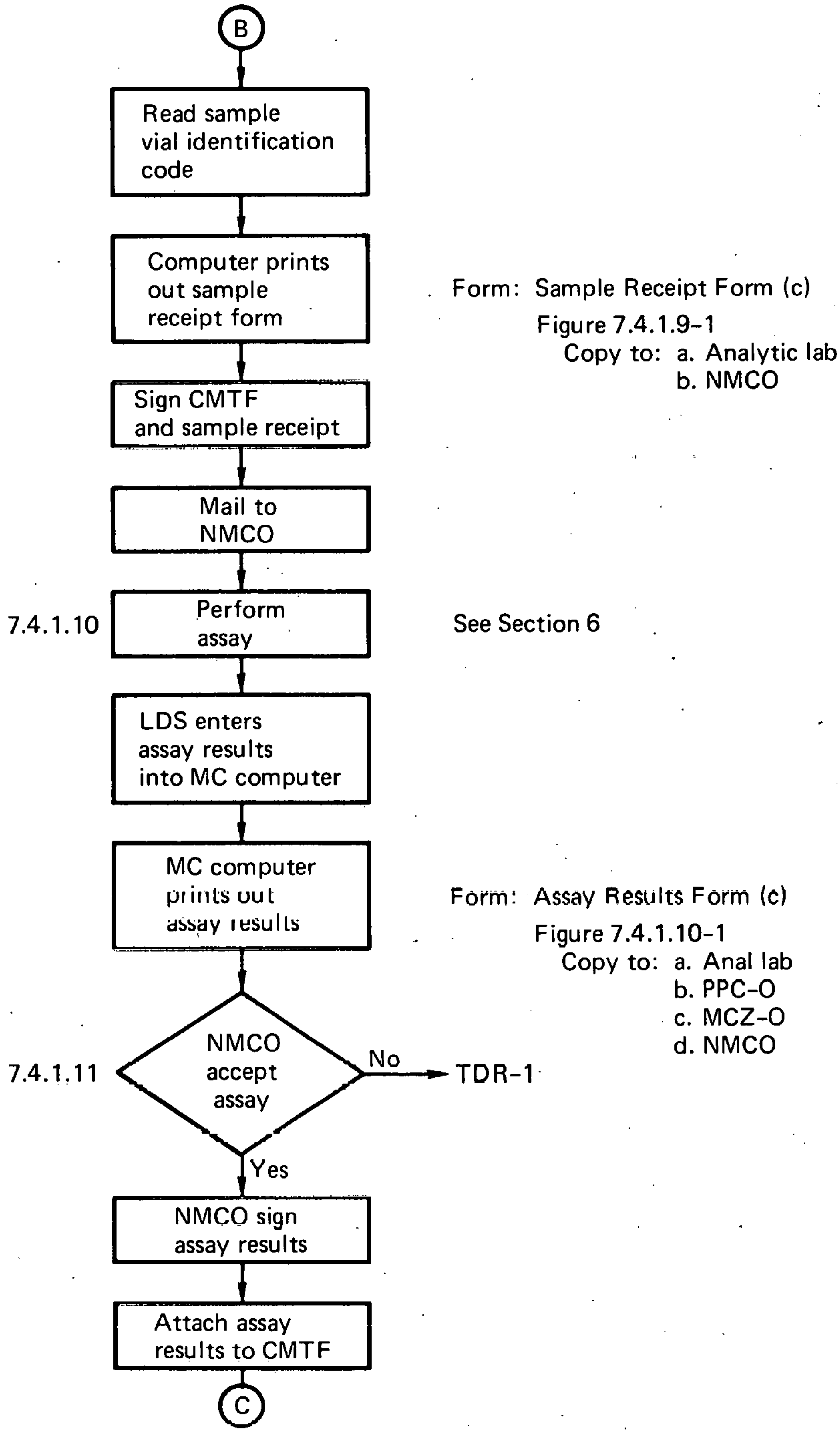

Figure 7.4.1-3c Accountability Procedure (continued)

* *

MATERIAL ASSAY RESULTS FORM 3 FEB 78. 2217

SAMPLING AUTHORITY: NMCOBOSS

REFERENCE: CMT78943

ASSAY PERFORMED BY: L. TECH

SAMPLE DRAWN FROM: PPC TANK2 & TANK 3

ASSAY RESULTS

SAMPLE ID	DENSITY (G/L)	ACIDITY (M)	PU CONC. (G/L)	U CONC. (G/L)	FISSION PROD. (CI/G)
1) 2221					
2) 0001					
3) 1212					
4) NA.					
AVERAGE					

CALCULATED TANK CONTENTS

TANK	DENSITY (G/L)	HEIGHT (CM)	SOL. MASS (KG)	PU MASS (KG)
PPC2&3				

SIGNATURE:

* *

Figure 7.4.1.10-2 Material Assay Results Forms

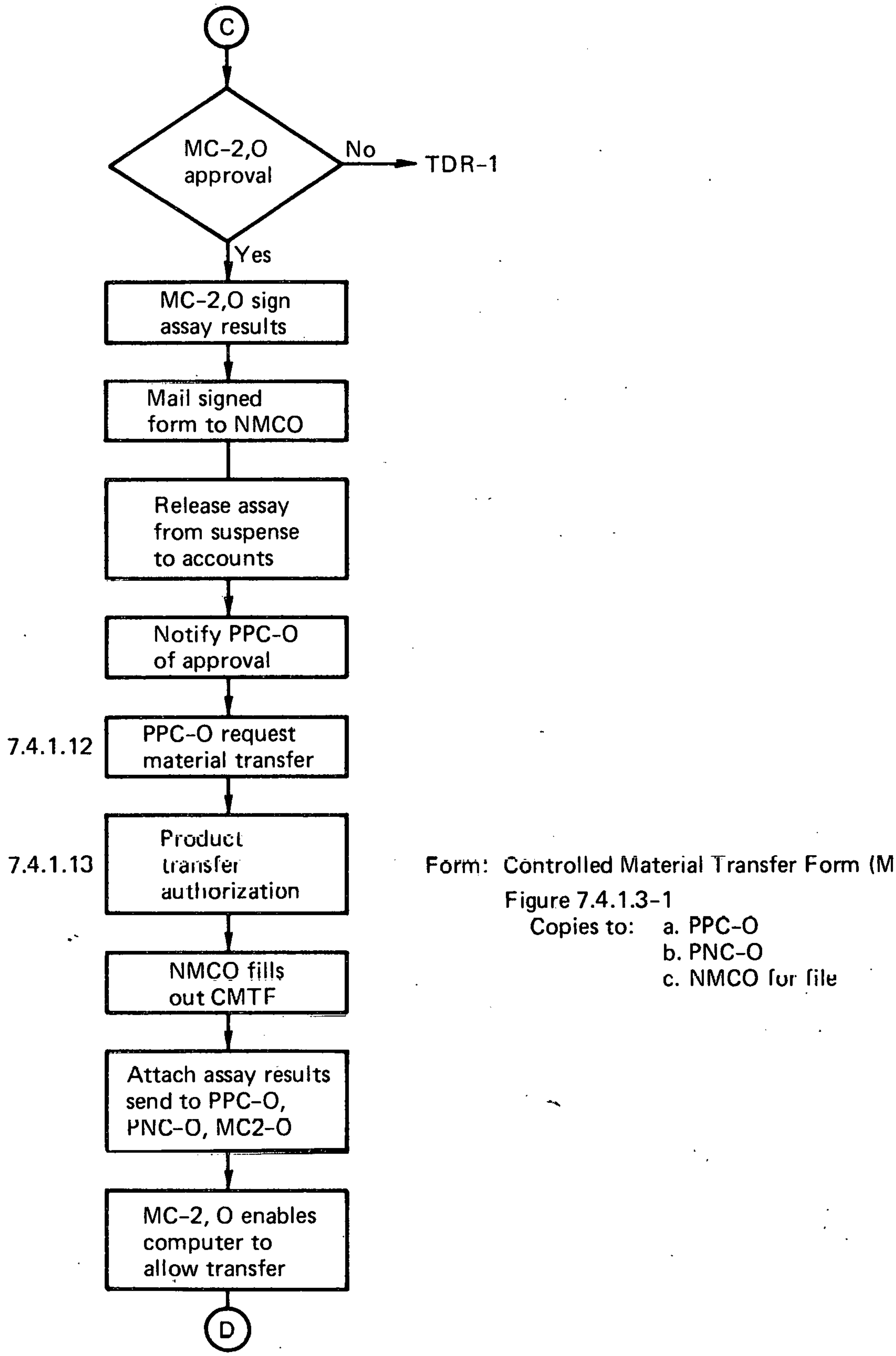

Figure 7.4.1-3d Accountability Procedure (continued)

7.4.1.14 Begin Plutonium Product Transfer Procedure (Figure 7.4.1-3e)

The PPC-O receives his daily work orders which include the CMTF signed by the Nuclear Material Control Officer and an echoed Transfer Enablement Form. At the same time the PNC-O receives his daily work orders which also contain a CMTF and a Transfer Enablement Form. When the PPC-O is ready to begin the transfer he notifies the computer system.

7.4.1.15 Computer Verification of Transfer (Figure 7.4.1-3e)

Once the PPC-O has decided to begin the transfer, the computer first checks to see if the transfer order has been entered into it. The computer then checks the availability of an accountability tank in the PNC area. This tank, as mentioned before, contains a quantity of plutonium nitrate which is sufficient to allow for readings of the initial levels in the tank. This quantity also fills the pipes and pump to allow accountability for material held up in the process piping. If the tank is not available or if the heel is not present in the tank, the Material Control System computer will inhibit the transfer and call a Material Control System alarm (TDR-1). If the conditions are correct, the computer will notify the PNC-O of the impending transfer. The PNC-O then accepts via his terminal the transfer of material. The computer then generates a list of the valving setup for the PNC-O. The PNC-O sets up his valving and the computer does a verification on the valving after notification of completion.

7.4.1.16 Final Verification of Transfer (Figure 7.4.1-3f)

The smoothed value of the material in the PPC tanks is printed out to PPC-O, MC-2,O and NMCO. (Figure 7.4.1.16-1.) The PPC-O verifies from the bubbler gauges the gross quantity of plutonium to be transferred. If the PPC-O is satisfied that the amount printed out by the computer and the gauges are consistent, he then notifies the computer to allow the transfer to begin. The computer notifies PNC-O that transfer is to begin, PNC-O notifies the computer that he is ready to accept, and the computer then renotifies the PPC-O to start the pump for transfer. At this point the computer system enables the pump in the PPC so the transfer can occur. The solution is now flowing from the plutonium product tank into the accountability tank in the PNC. At the end of the transfer, the PPC-O turns off the pump and notifies the computer system that the transfer is complete. At this point, the computer notifies the PNC-O to turn off the valving, notifies the PPC-O to close the valving and verifies the valve settings in both cells. The Material Control computer then writes out, on line two of the computer generated

```
TRANSFER ENABLE FORM                    3 FEB 78     1708

TRANSFER REQUEST APPROVED:   JACK NMCOBOSS

TIME OF TRANSFER: 3 FEB 78          1320

REFERENCE: ASSAY REQUEST FORM ARF23549
           CONTROLLED MATERIAL TRANSFER FORM NUMBERR CMT78943

TRANSFER FORM:

           TO:

SIGNED:
```

Figure 7.4.1.13-1 Transfer Enablement Form

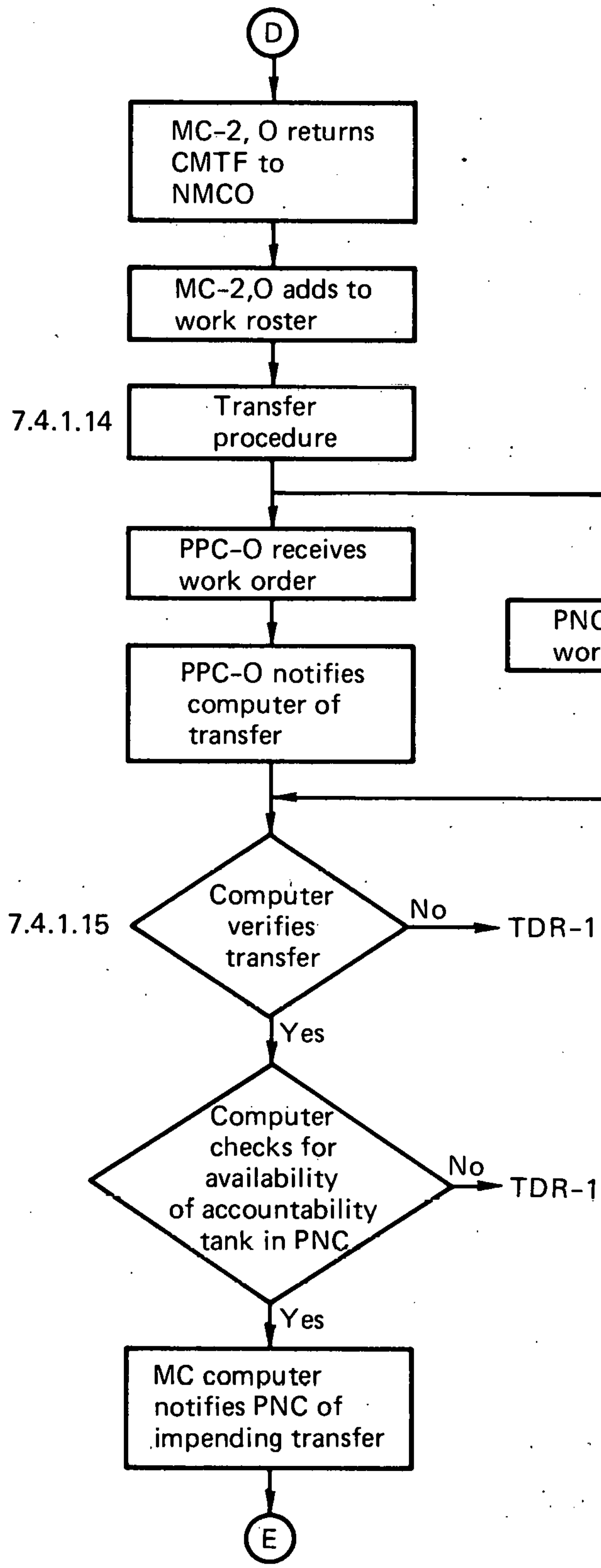

Figure 7.4.1-3e Accountability Procedure (continued)

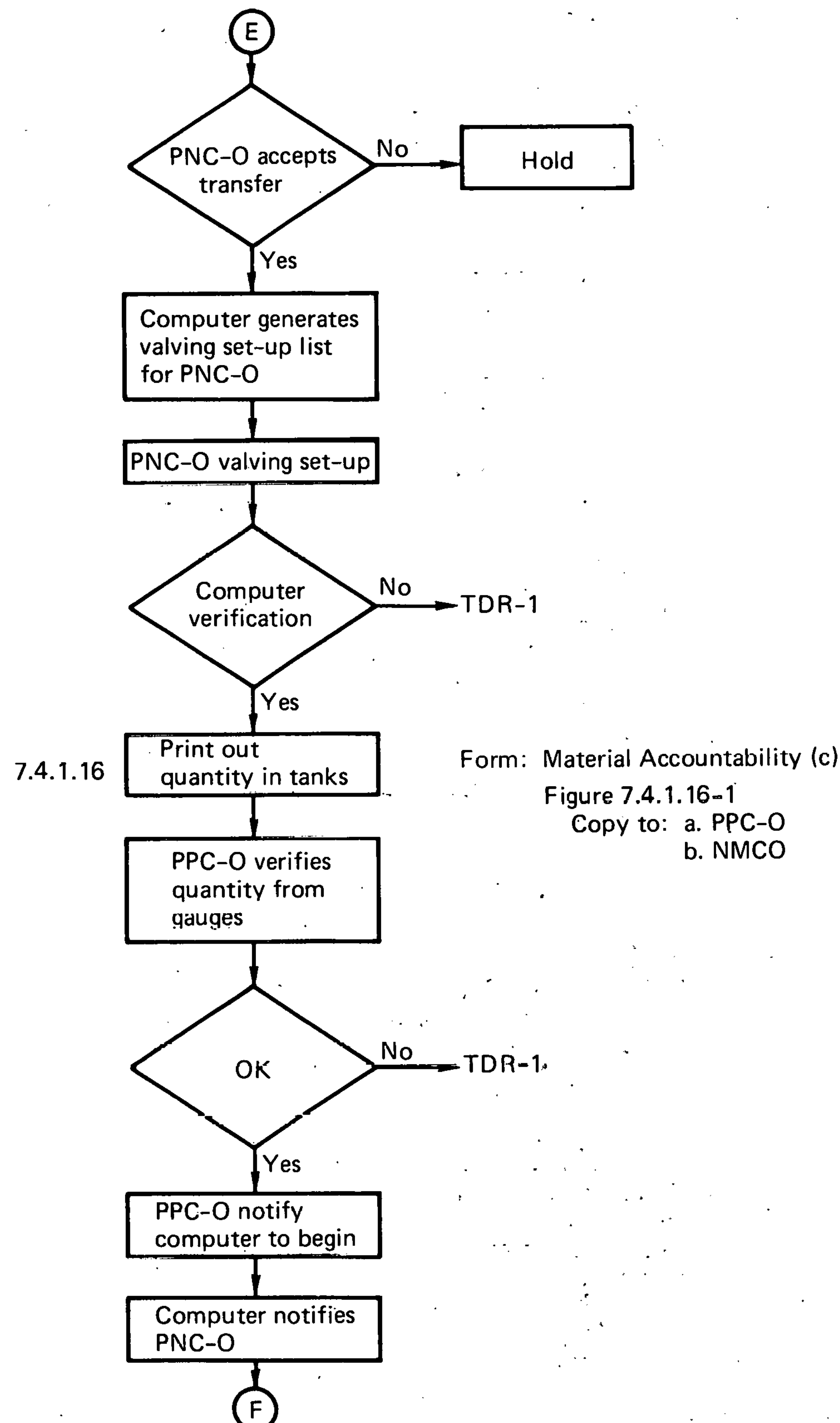

Figure 7.4.1-3f Accountability Procedure (continued)

* *

MATERIAL ACCOUNTABILITY FORM   3 FEB 78   1306

MEASURED VALUE OF TANK CONTENTS

TANK NO. 4-1	DENSITY (GRAM/LITER)	HEIGHT CM	SOLUTION MASS KG
LINE 1 INITIAL CONTENTS			
LINE 2 FINAL CONTENTS			
LINE 3 TRANSFERRED QUANTITY			

REFERENCE: CONTROLLED MATERIAL TRANSFER FORM: CMT78943

VERIFICATION BY:

* *

Figure 7.4.16-1 Material Accountability Form

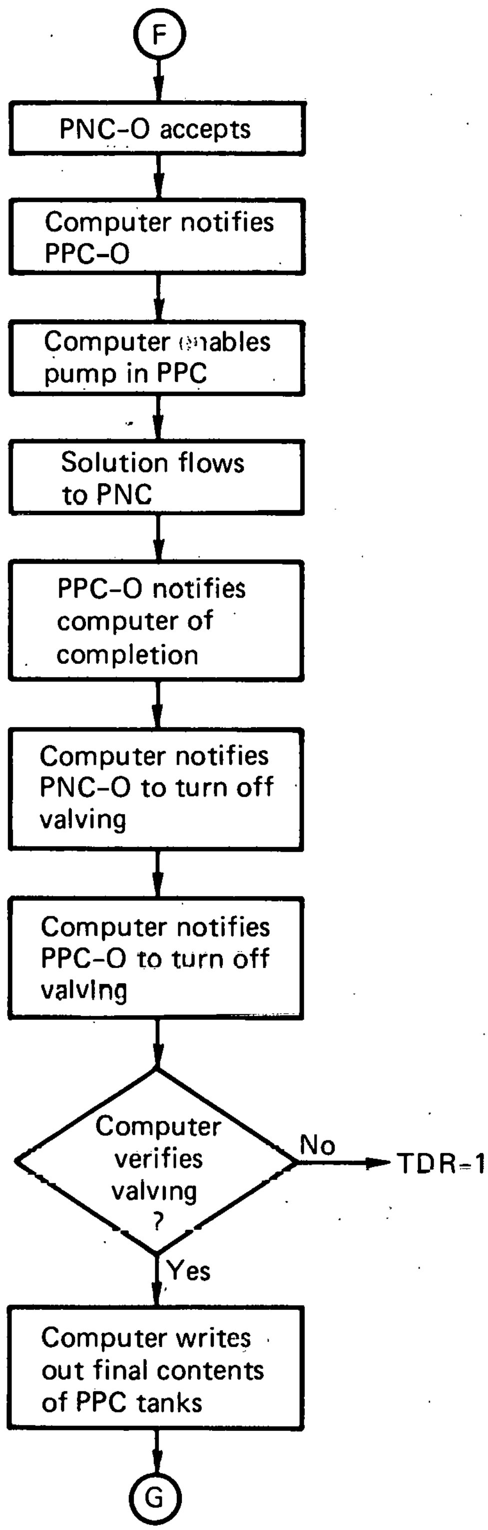

Figure 7.4.1-3f Accountability Procedure (continued)

material accountability form, the final contents of the two accountability tanks in the PPC. The PPC-O then verifies that the gauges indeed are reading zero and signs the Material Accountability Form from the computer.

7.4.1.17 Verification of Transfer (Figure 7.4.1-3g)

The PPC-O signs the CMTF, attaches the Material Accountability Form generated by the computer and sends both to the NMCO. The PPC-O has now completed his portion of the transfer procedure.

7.4.1.18 Product Receipt (Figure 7.4.1-3g)

The product is received in the calibrated and partially filled PNC accountability tank. Once the transfer is complete, the contents of the tank are monitored for thirty minutes. At the end of this thirty-minute interval the Material Control computer prints out the Material Accountability Form for the Plutonium Nitrate Cell Operator. The PNC-O then verifies the amount of received material from the gauges and either accepts or refuses the quantity subject to assay. The PNC-O signs the CMTF and the Material Accountability Form generated by the computer, staples the forms together and returns the forms to the NMCO.

7.4.1.19 Accountability Lockup (Figure 7.4.1-3g)

The computer system at this point "locks up" the accountability tank from receival or delivery of plutonium nitrate solution. This is accomplished by monitoring the valves which control flow into this tank.

7.4.1.20 Assay Report (Figure 7.4.1-3g)

The PNC-O requests an assay of the contents of the receival tank following a procedure similar to that oulined previously for assay requests for the PPC accountability tanks. Release from these tanks then is authorized by the NMCO on the CMTF into general storage. The NMCO signs off on the CMTF Form for the PPC/PNC transfer and the transfer is complete.

7.4.2 Summary of Material Transfer Accounting Procedure

The signed transfer authorization documents, together with their associated request forms, verification forms, and results forms, provide source documentation for material accounting journal entries. These forms are compiled, checked for consistency with the authorized action, and then archived by the NMCO. At the end of each day chronological journal entries are printed out by the computer detailing all computer usage for that day. In addition, account summaries are printed to conveniently convey the day's activities in selected critical accounts including

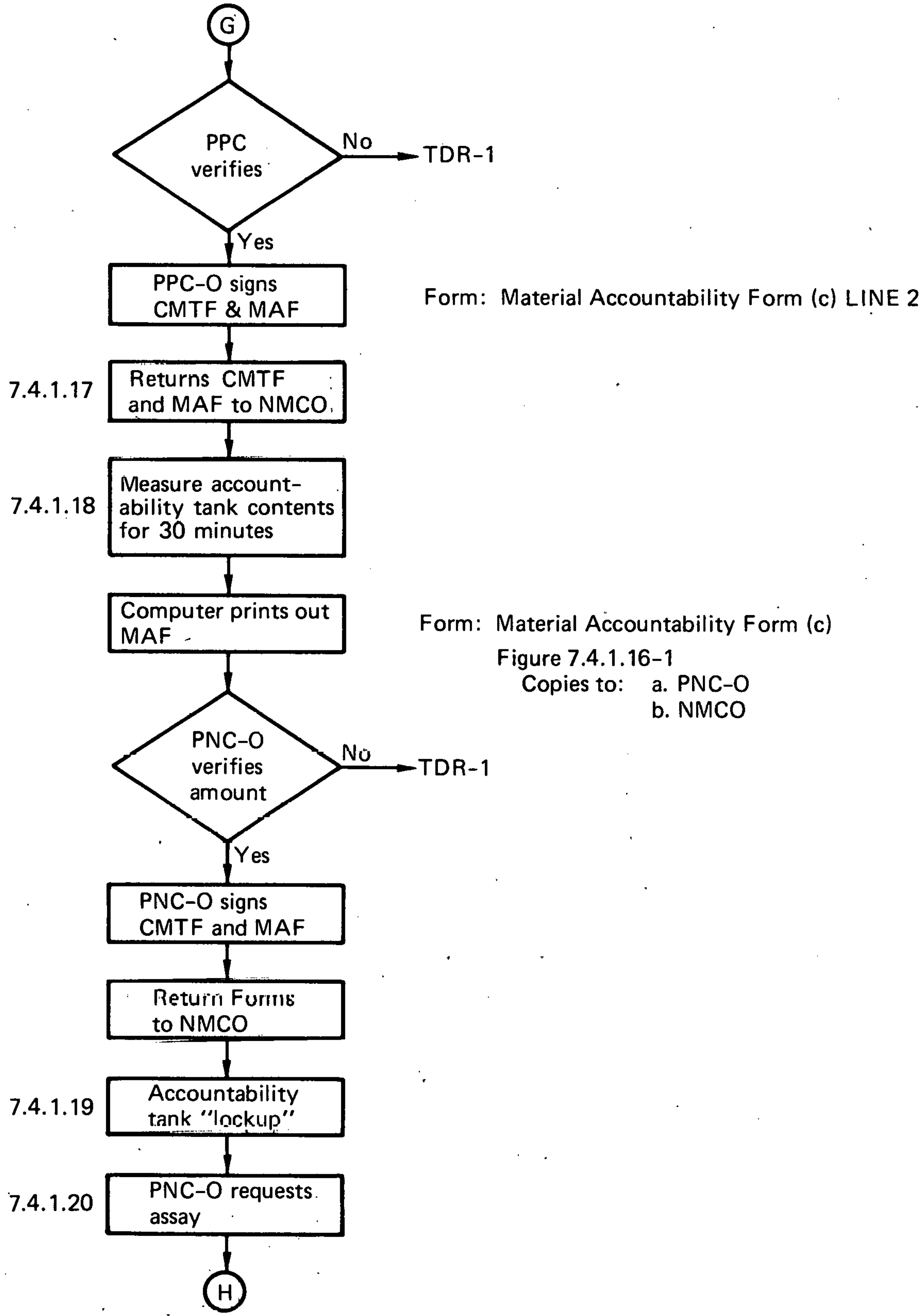

Figure 7.4.1-3g Accountability Procedure (continued)

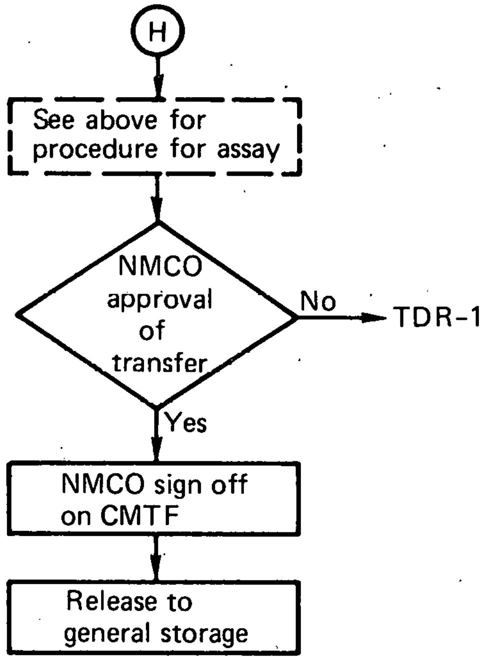

Figure 7.4.1-3g Accountability Procedure (continued)

all special nuclear material accounts. These account actions are checked against the authorization documentation, approved and archived by the NMCO.

Material transfer accounting is accomplished in a two step procedure. The first step is completed whenever the receiving MBA accepts receipt of a given gross quantity of material from the release MBA. Whenever the gross quantity received agrees within measurement uncertainties with the quantity released, the NMCO approves the gross quantity transfer. This approval must be accomplished within one work shift or the NMCO establishes an alarm state TDR-1 for the plant.

The transfer remains in the active state, and the transferred material is confined to the receiving storage tank until the material composition is confirmed by analysis. Journal entries record the transfer of SNM from the release MBA to the receiving MBA upon completion of the gross quantity transfer. These entries are based upon the release MBA assay results and the gross quantity at the time of assay sampling.

The second step in the material transfer accounting procedure is required to assess and reconcile receiver/shipper differences. The quantity of SNM received is calculated based upon the receival assay and the received quantity at the time of assay sampling. The receival MBA is held responsible for this measured received quantity of SNM. Journal entries are recorded to adjust the received quantities of material to agree with this measured quantity. These entries are balanced against transfer measurement difference accounts which are designed to keep track of both individual and cumulative shipper/receiver differences. A separate transfer measurement difference account is kept for each viable transfer path.

REFERENCES FOR SECTION 7

7-1. I. J. Sacks, "Accuracy of Material Accountability Estimates for Test Bed Design: PPC Interim Storage Tanks", Lawrence Livermore Laboratory, October, 1977.

7-2. D. R. Dunn, "Dynamic Models, Estimation and Detection Concepts for Safeguarding $Pu(NO_3)_4$ Storage Tanks", Lawrence Livermore Laboratory, UCRL-79216 presented at the Institute of Nuclear Materials Management 1977 Annual Meeting, July 1, 1977.

8.0 MATERIAL CONTROL SYSTEM INSTRUMENTATION

The instrumentation for this test bed design is divided into two major groups; material-related and personnel-related. The material-related instrumentation which includes those devices which continuously monitor the physical process variables such as the height/density bubblers and those which are used on an infrequent basis to measure the composition of the material stored within the limits of our test bed design. The personnel-related instruments are devices which monitor the human activities of the human process operators and include devices such as the closed circuit television system, the weight sensitive floor mats, and the valve position monitors.

Each of the instruments used in this test bed design has either been selected from available instrumentation or is modelled after generally available devices. The following sections describe this instrumentation.*

8.1 MATERIAL RELATED INSTRUMENTATION

As stated above, this type of instrumentation can be broken into two broad categories. The first of these is instrumentation which is used to continuously monitor the process state and is used as a part of the process control system. These instruments include:

- Height/Density Air Bubbler System
- Valve Position Monitors
- Airborne Pu particle detector

The second category includes those instruments used for precision determination of the material composition at specific discrete times. These instruments include:

- In-line γ-spectrometer
- Analytical laboratory instrumentation

8.1.1 CONTINUOUS MONITORING INSTRUMENTS

8.1.1.1 HEIGHT/DENSITY AIR BUBBLER SYSTEM

Each tank in the storage area has its own liquid density and volume measuring system based on a system commonly called a bubbler. This pneumatic system is shown in Fig. 8.1.1.1-1. The level of liquid in the tank can be

*Performance details on personnel-related monitoring instruments can be found reference 8-1.

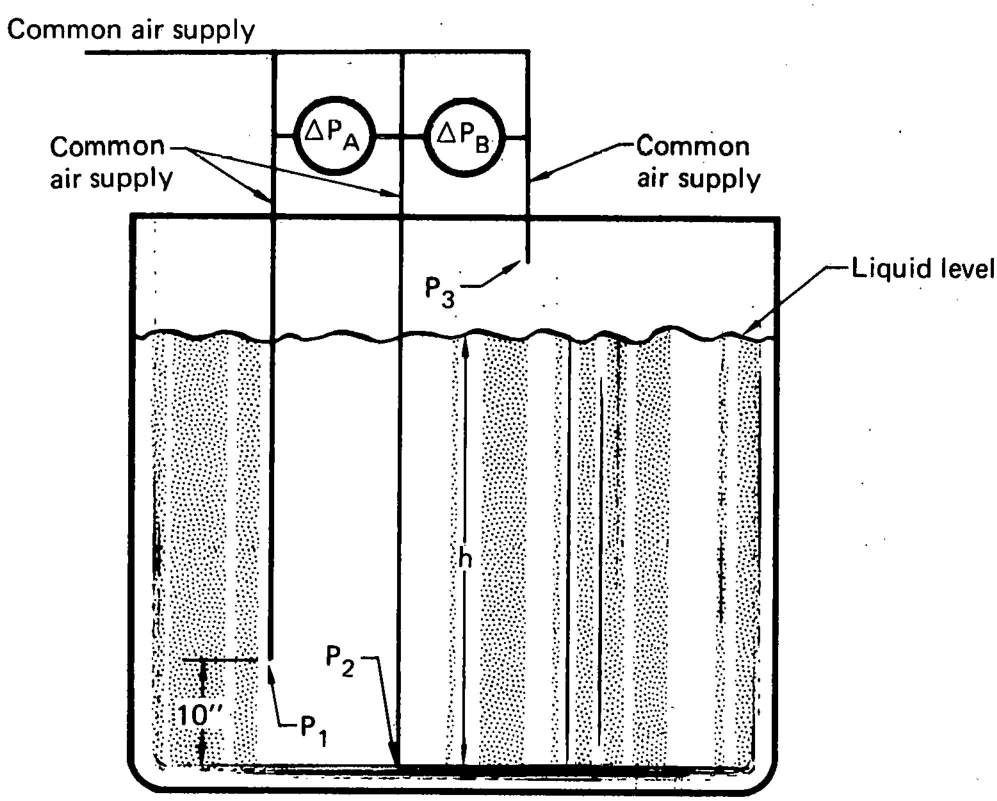

Figure 8.1.1.1-1 Pneumatic Density/Height Measurement System

determined by measuring the net pressure head (ΔP_B) and dividing it by the density (ρ_A). This can be seen by inspection of the figure and consideration of the following equations.

The pressure head at the outlet of each of the dip tubes of the bubbler system is given by

$$P_1 = g\rho(h\text{-}10'') + P_3$$
$$P_2 = g\rho h + P_3$$
$$P_3 = P_3$$

where g is the gravitational constant

ρ is the liquid density

h is the height of the liquid surface above the lowest of the bubbler tube openings.

Then, the measured variables, ΔP_A, and ΔP_B are given by

$$\Delta P_A = P_2 - P_1 = g\rho(h) - g\rho(h-10) = g\rho 10''$$
$$\Delta P_B = P_2 - P_3 = g\rho h.$$

Thus ΔP_A provides a (scaled) direct measurement of the liquid density and $\Delta P_B/\Delta P_A$ provides a (scaled) measurement of the liquid height.

The differential pressures, ΔP_A and ΔP_B, are measured by transducers of a type similar to: Taylor model 1303T, a force balance device.

This instrument transmits a dc signal in the range of 4 to 20 mA which is proportional to the differential pressure. Each instrument provides both a remote reading (connected to the Material Control system) and a local reading. The accuracy of the bubbler system is dependent on the following factors:

a. The fixed length distance between the long and short bubbler tubes is known to within $\pm$ 1/64 inches (.0397 cm).

b. The height of the lowest tube above the low point of the tank is to 3/4 $\pm$ 1/4 inches (1.91 $\pm$ .64 cm).

c. The differential pressures, ΔP_A and ΔP_B are measured to $\pm$.75% (2σ).

The transmitters of the differential pressure transducers section are powered by a 24-volt power supply contained in the local panel box.

The bubbler instrumentation is protected from unauthorized tampering in the following manner.

<u>Physical Location</u>

Figure 8.1.1.1-2 shows a schematic of the general configuration of the

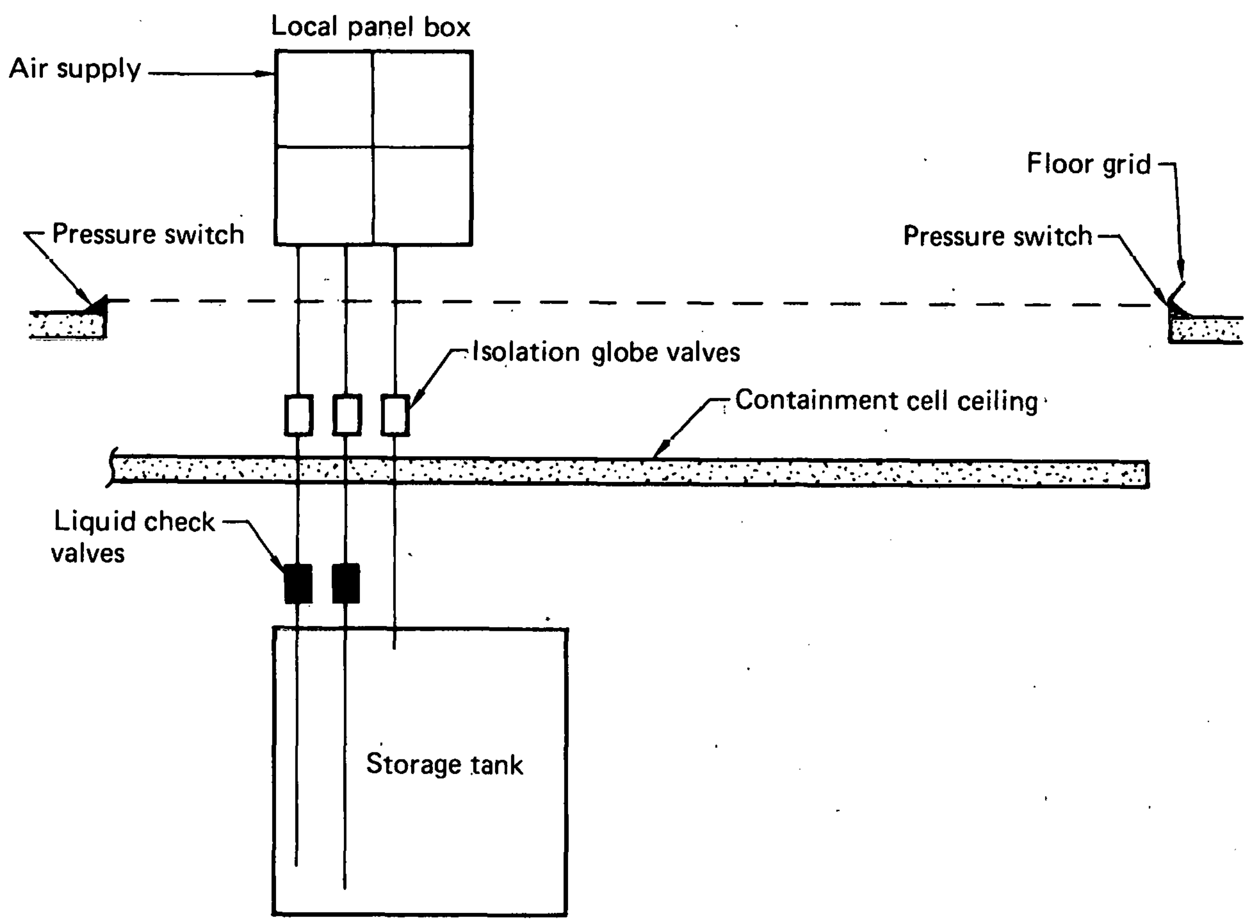

Figure 8.1.1.1-2 General Schematic of Bubbler System Protection

bubblers, valving, and pressure measuring equipment. The 1/4 inch bubbler tubes enter the tank through a flange over the deepest portion of the tank. The two tubes which dip below the liquid surface contain liquid check valves (Fig. 8.1.1.1-3) to prevent flow of liquid up these tubes. These valves are welded into the bubbler tubing. This tubing then penetrates the roof of the storage tank containment all through the grouted sleeves, and is welded to isolation valves at the outer surface of the roof.

The base of the local panel box which contains the differential pressure sensors, air supplies, etc., is approximately one foot (30 cm) above the floor grid.

The local panel box is divided into four sections; one for each module. Each section is equipped with a hinged, high impact clear plastic cover which is interlocked to the MC computer system to provide notification of access. All adjustments to air flow rates, differential pressure transducers and transmitters, connections for calibration, etc., require the removal of this cover. The contents of each module of the local control panel is given in Table 8.1.1.1-1.

ITEM	NUMBER	REMARKS
D. P. Transducer and Transmitter	12	ΔP_A, ΔP_B
Rotameter	12	Bubbler air supply flow rate
Panel Meter	12	0-100% P_A, P_B
Valves	18	For connection of micro-manometer for calibration
Valves	24	For isolation of transmitters
Valves	12	For air supply balance.

Table 8.1.1.1-1. Contents of Local Panel Box

Liquid Flow Protection

The possibility of diversion of $Pu(NO_3)_4$ through the bubbler lines is prevented by the liquid check valves in each of the bubbler lines which penetrates the liquid surface (Fig.8.1.1.1-3). The construction of these valves will cause a low density ball to float up and block the upper portion of the

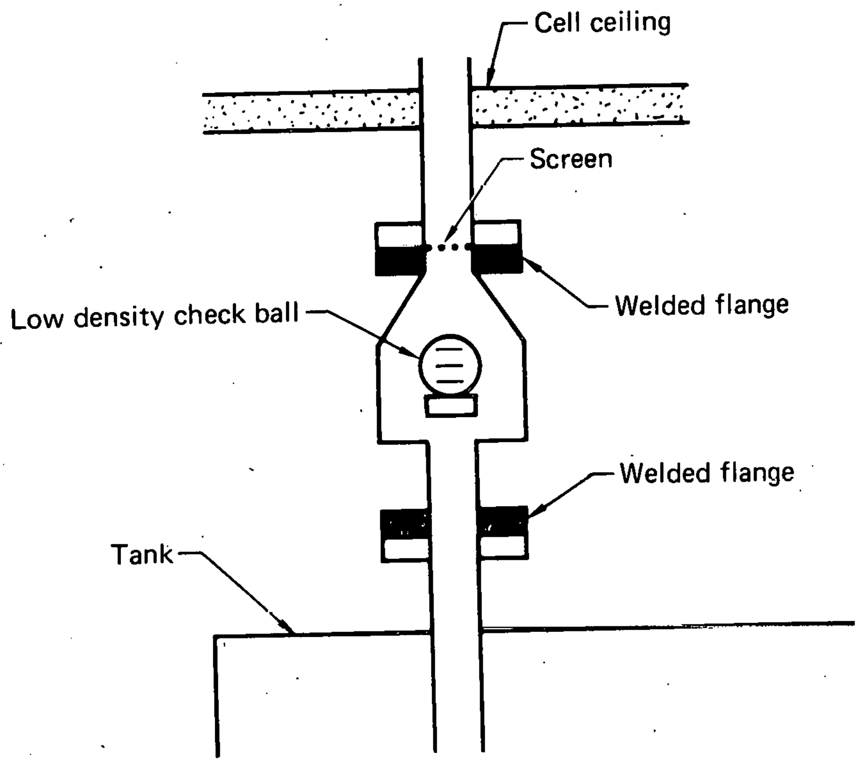

Figure 8.1.1.1-3. Bubbler Line Protection

valve if the valve becomes filled with liquid. In addition, a screen protects the valve from tampering.

Pressure Transducer Wiring

The wiring for the D.P. transmitters passes from the local control panels to the MC computer system through conduit pressurized with dry nitrogen. Pressure detectors along this conduit will notify the MC computer for any pressure changes.

8.1.1.2 VALVE POSITION MONITORS (Ref. 8-2)

Critical valves in the storage area piping are monitored by the means of valve position monitors (or limit switches). These switches are attached to the valve stem. The switch is of the SPDT type. The function of these switches is to indicate when a valve is closed. The valves themselves are of the ball type and must be rotated approximately 10° for flow to be possible. The switch itself is actuated by the movement of an arm with the radius of one inch. The 10° movement corresponds then to a linear motion at the switch of 0.174 inch. The switches trip on a motion of 0.005 inch.

Flow cannot occur until the stem has been rotated 10°. Due to the overdesign of the switch and its actuator system, the probability of detection of the condition allowing flow should be ≈ 1.0. This type of device has an inherently low false alarm rate, which will be taken to be ≈ 0.

The Rassmussen Report (WASH-1400) gives a range of reliabilities for this type of switch of 1×10^{-3} to 1×10^{-4} (failures per operation). These switches are monitored as to their performance as routine operations are performed. The limit switch cover is fastened to the switch body with screw fasteners for tamper protection. Wiring from the limit switches passes through pressurized conduit to the MC computer system. The valves which are monitored are discussed in other sections of this report.

8.1.1.3 AIRBORNE PLUTONIUM DETECTOR

The airflow through the MAA area is continuously sampled by an airborne plutonium particle detector (references 8-5, 8-6). This detector draws air from the MAA by the means of sampling tubes throughout this area. The location of the sampling tubes is shown in Fig.8.1.1.3-1. This device will detect only Pu particles which are airborne. Material which is not sprayed into the air will not be detected.

Air is sampled by the sampling tubes, drawn through transport pipes

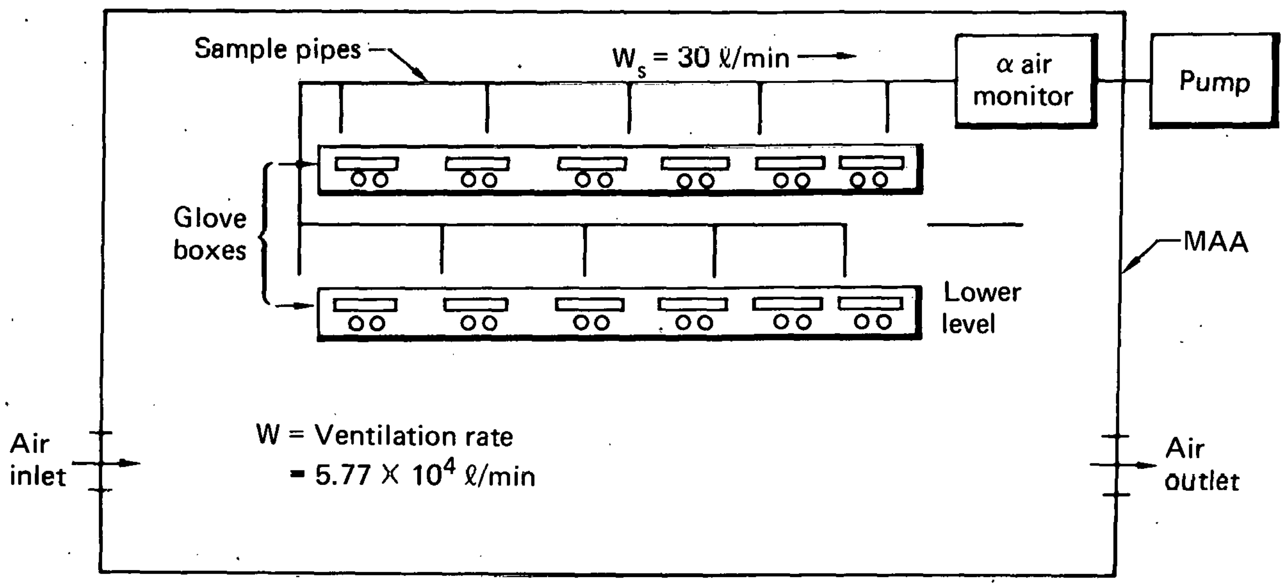

Figure 8.1.1.3-1 Airborne Particle Monitor

to a α-particle detector. This general configuration of this detector is shown in Fig. 8.1.1.3-2. Air is drawn through the monitor and airborne particles are filtered out on the filter paper. Alpha-particle emissions from these trapped particles are sensed by a detector. The resulting current pulses are shaped, amplified, and compared to a detection threshold. Count rates (pulses/min) above this detection threshold cause an alarm to be transmitted to the MC computer system. In addition, a local acoustic alarm is sounded on the detection of airborne Pu.

The airstream being sampled will contain naturally occurring α-particle emitters. These will cause a background count from the sensor. This count is about 8 counts/min. This background is the primary environmental noise source.

The probability of detecting a spray of Pu into the MAA depends on

1. the location of the spray
2. the amount of Pu which becomes airborne
3. the detection threshold of the monitor
4. the time from the spray.

The time for the airborne plutonium to travel to the monitor is composed of two times. The first of these is the time for the particles to reach the sample tubes, the second is the time for the particles to travel through the sample tube to the filter paper.

For air flow rates typical of the Test Bed Design, (MAA total flow of 5.77×10^4 ℓ/min and Monitor Flow of 30ℓ/min), upper and lower bounds for the particle time of flight to the sample tubes and then to the filter paper are

Upper bound = 604 sec.

Lower bound = 129 sec.

The probability of detection for a spray depends on the total amount of Pu dispersed into the air. A portion of this material will be sampled and will build up on the filter paper in the monitor. The rate of build-up is dependent on the air flow rate and the concentration of Pu being sampled. Higher concentrations will produce detectable levels sooner. Figure 8.1.1.3-3 presents the detection probability versus time for various initial airborne concentrations for both the airflow models discussed earlier. The threshold for this detector has been set to produce a false alarm probability of 9.4×10^{-5}.

With routine maintenance, this system will have a Mean Time Between Failure of 17500 hours. The output of the monitor is connected via a relay to

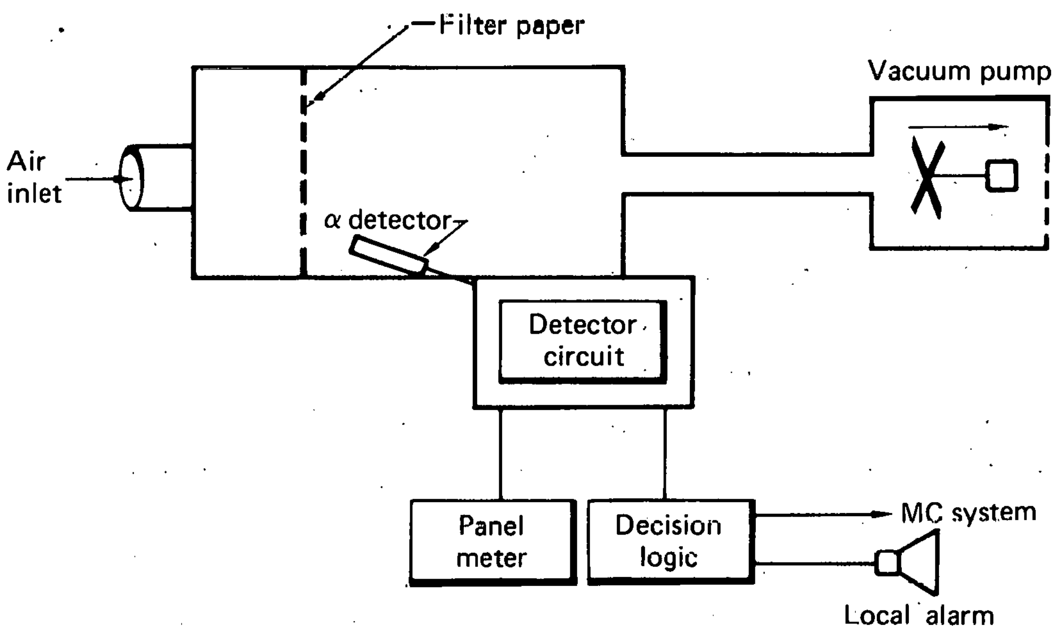

Figure 8.1.1.3-2 Air Monitor - Schematic

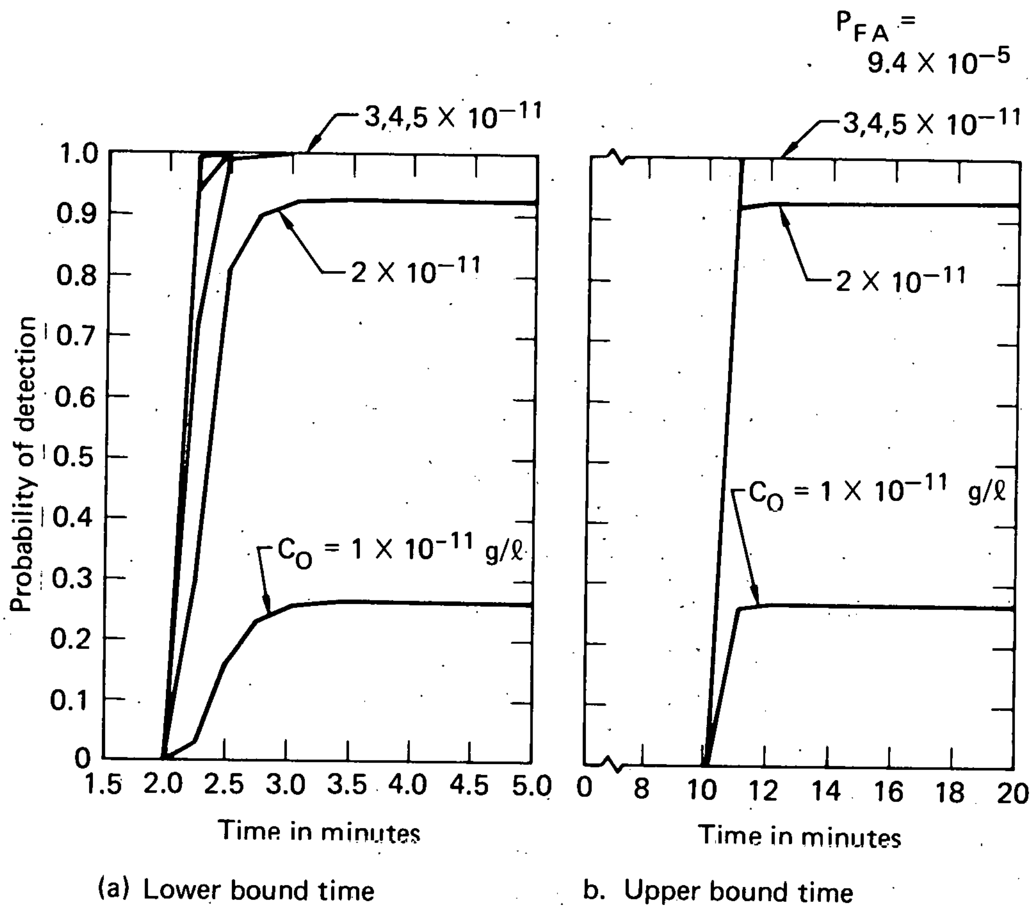

Figure 8.1.1.3-3 Detection Performance of Airborne Pu Detector

the wiring of the MC system. This relay is used in the mode of keeping held closed by the non-alarm condition. Loss of power or the detection of airborne Pu will open the circuit. The wiring conduit to the instrument is pressurized with dry nitrogen with a pressure detector to detect loss of conduit integrity.

The instrument enclosure is protected against tampering by being equipped with tamper switches. Tamper switches will cause a tamper alarm to be sounded when the access cover or cover screw is moved 6.0 mm.

8.1.2 ANALYTIC INSTRUMENTATION

This instrumentation is used to determine the precise composition of the material contained within the storage tank.

8.1.2.1 GAMMA-RAY SPECTROMETER

The γ-ray spectrometer (Ref. 8-4) is used to determine both the total Pu concentration and the ratios of the Pu isotopes and ^{241}Am which are present. A calibrated analysis cell for this instrument is located in the sampling glove box. Valving is arranged (Fig.8.1.2.1-1) so that this cell can be switched into any of the four sampler loops.

The output from the γ-ray spectrometer is used for two purposes. The first of these is to provide a measure of the homogeneity of the solution in the tank being sampled by providing data on the solution flowing in the sampling system. The MC computer system uses this information to determine when to authorize the operator to lower the sample vial. The second use of the data from the γ-ray spectrometer is as a check on the analytical laboratory measurements. The principle of operation of the γ-ray spectrometer is briefly described below.

Figure 8.1.2.1-2 shows the major components of the γ-ray spectrometer. The analysis cell is shown in more detail in Fig. 8.1.2.1-3. The GeLi detector measures the emission of the various isotopes of elements present in the Pu product solution. A typical spectrum for recently reprocessed reactor grade plutonium solution is shown in Fig. 8.1.2.1-4. The isotopic abundances can be determined from the:

43 KeV peak for ^{238}Pu
51 KeV peak for ^{239}Pu
45 KeV peak for ^{240}Pu
148 KeV peak for ^{241}Pu

The 94 KeV and 129 KeV peaks can be used to verify the results for ^{241}Pu and ^{239}Pu respectively.

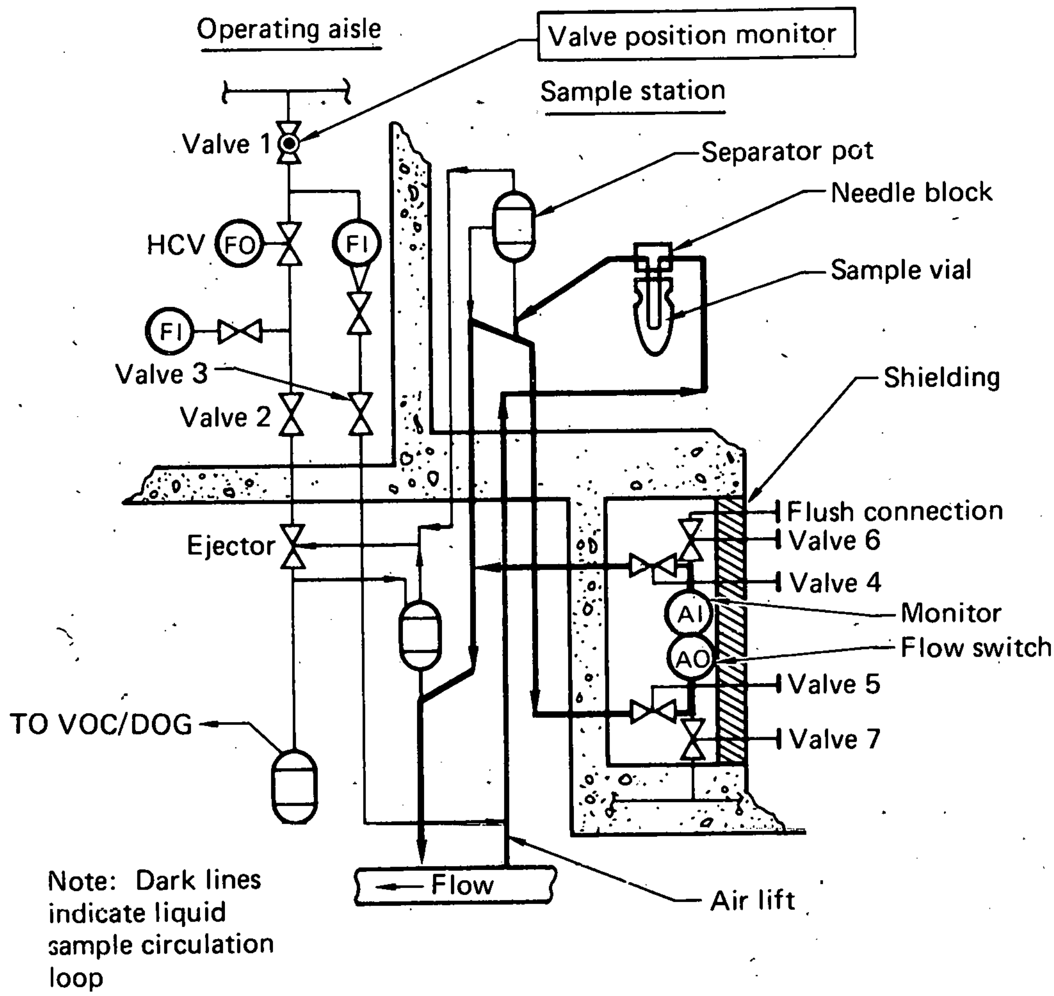

Figure 8.1.2.1-1 Sample Loop with In Line ^{239}Pu Monitor

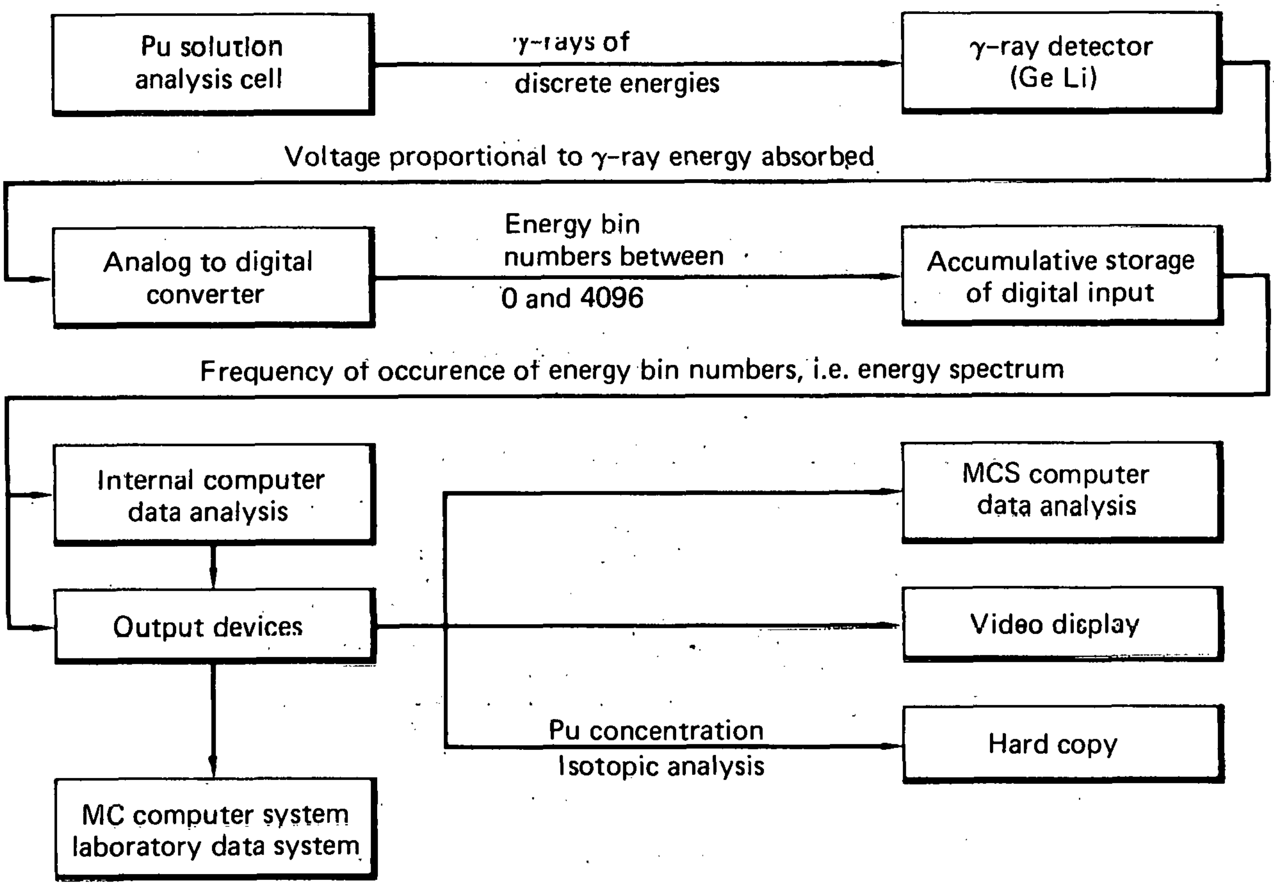

Figure 8.1.2.1-2 Schematic of γ-ray Spectrometer

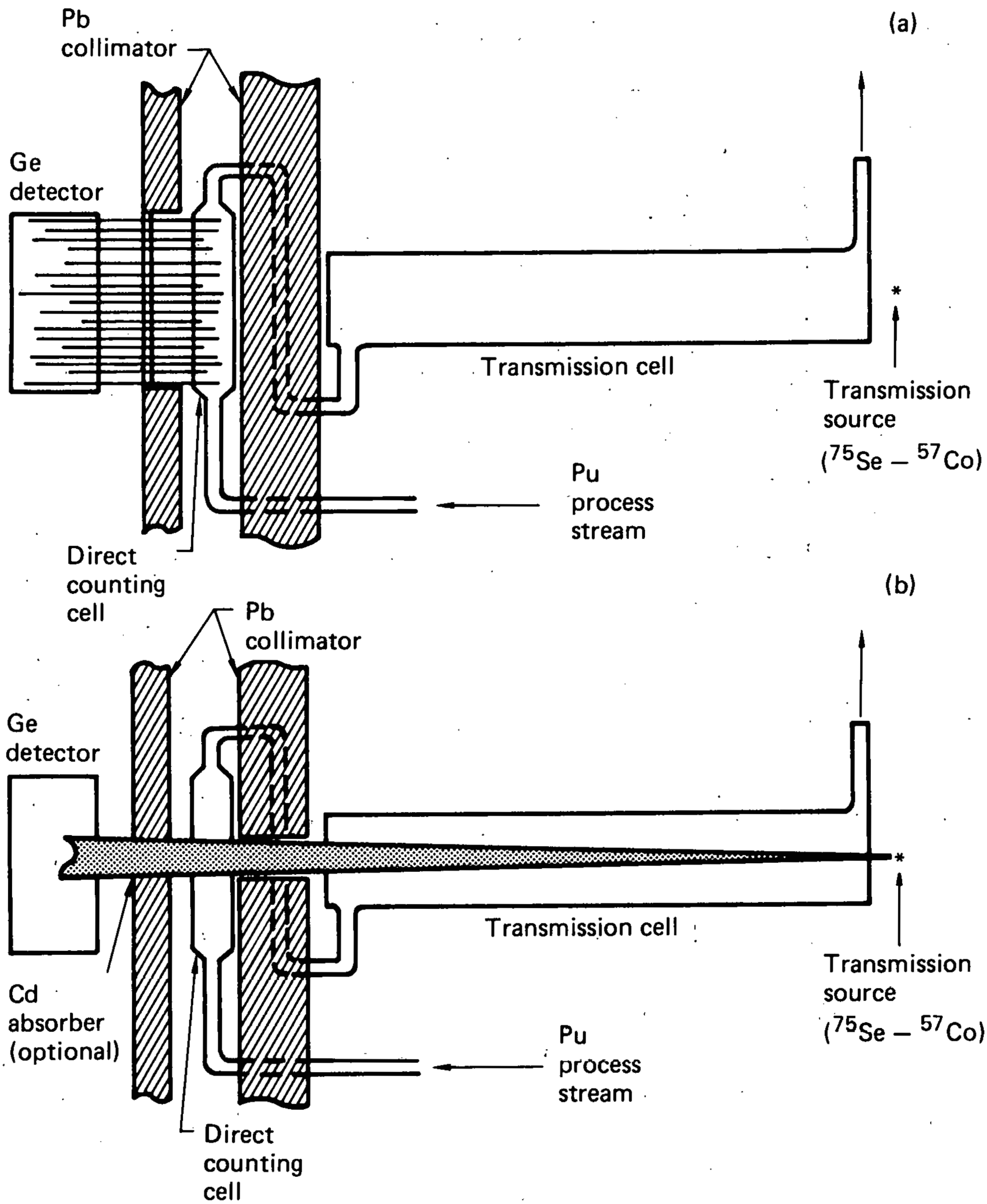

Figure 8.1.2.1-3 Schematic of the γ-ray Spectrometer Analysis Cell. (a) Shows the Direct Counting Configuration and (b) Shows the Configuration for the Transmission Measurement

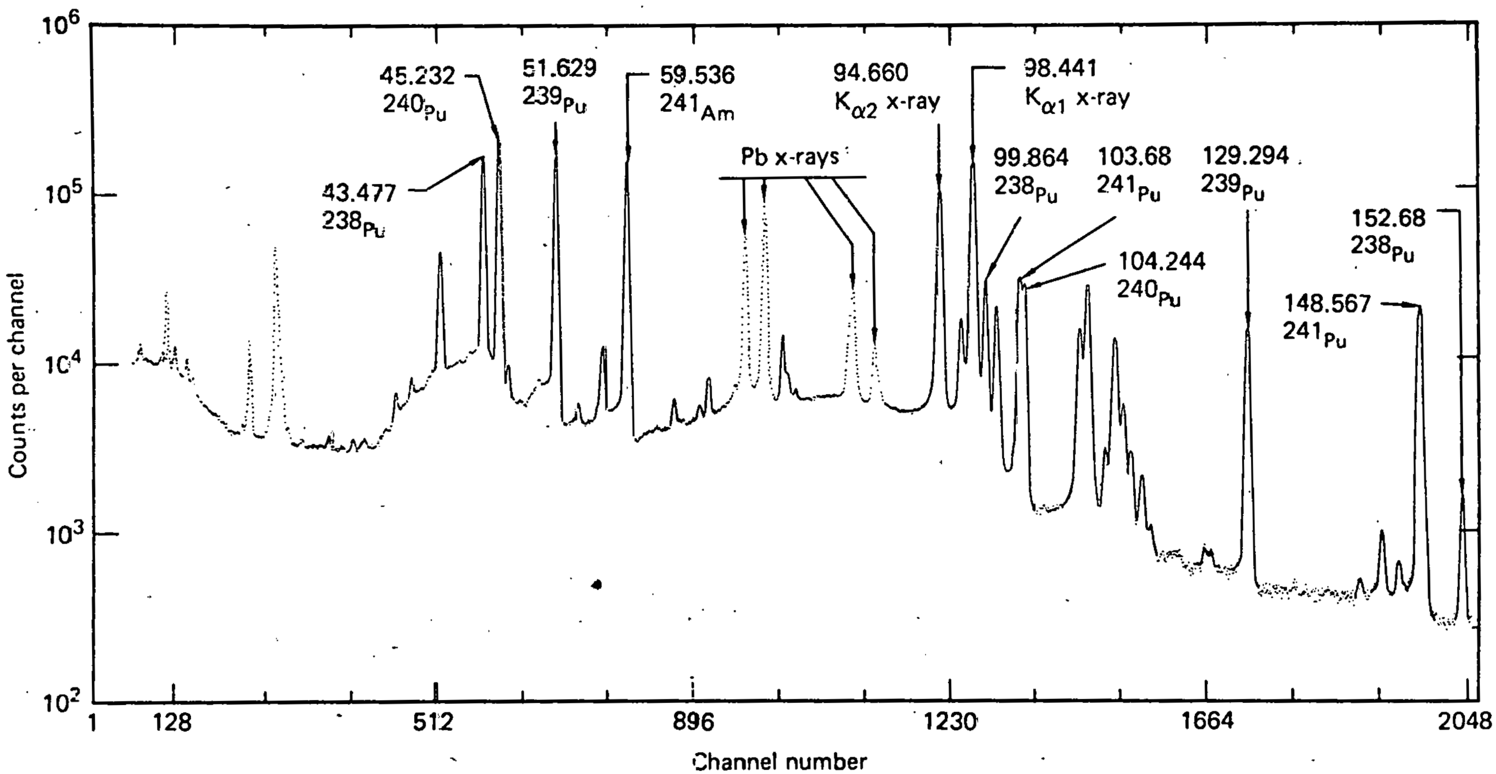

Figure 8.1.2.1-4 Low-Energy Spectrum of Recently Separated Reactor-Grade Plutonium Solution

Concentration of Pu in the solution is determined by using the transmission characteristics of the sample. An abrupt discontinutity in the solution absorbancy occurs at the K-shell binding energy of an element - for Pu at 121.80 keV. Normally two gamma rays of nearly equal energy are attenuated to the same extent since the absorption coeficients at the two energies are nearly equal. The K-shell binding energy however causes considerably different rates of absorption above and below. The logarithm of the transmission ratio at these two energies is related to the Pu concentration,

$$\text{Ln } (T_2/T_1) = -({}^1\mu_{Pu} - {}^2\mu_{Pu}) \cdot X_{Pu}$$

where T_2 is the transmission coeficient at the higher energy

T_1 is the transmission coeficient at the lower energy

${}^2\mu_{Pu}$ is the absorption coeficient at energy 2

${}^1\mu_{Pu}$ is the absorption coeficient at energy 1

X_{Pu} is the amount of Pu present.

A pair of isotopes, ^{75}Se and ^{57}Co provide the lower and upper transmission sources respectively. National Bureau of Standards traceable solutions are used to calibrate the differential transmission system.

The transmission measurement of Pu concentration on samples ranging from 130 to 360 grams/litre is accurate to 0.44%, (1σ). The isotopic determination are given in Table 8.1.2.1-1.

Isotope	Accuracy, % (1σ)
^{238}Pu	0.44
^{239}Pu	.065
^{240}Pu	.26
^{241}Pu	.23
^{241}Am	.38

Table 8.1.2.1-1. Isotopic Determination Accuracy

The abundance of ^{242}Pu is determined from analysis of the transmission and direct counting data.

The data from the GeLi detector is a series of pulses. This type of transmission does not lend itself to falsification. The wiring from the detector is routed to the MC computer system in pressurized conduit.

8.2 PERSONNEL RELATED INSTRUMENTATION

Personnel related instrumentation monitors the state of the personnel operating in the facility. This instrumentation includes

- Weight Sensitive Floor Switches
- Microwave Intrusion Detectors
- Valve Position Monitors
- Differential Pressure Alarms on 1) MAA/outer gallery 2) glove box/MAA, 3) containment cell/MAA pressure differences.
- Closed Circuit Television (CCTV)
- Computer Controlled Access System
- Hand and Foot α Detectors

The valve position monitors perform a dual function, that of both material and personnel monitoring. They were described in Section 8.1.1.2.

8.2.1 WEIGHT SENSITIVE FLOOR SWITCHES

Critical floor areas in the plutonium nitrate storage area are monitored by pressure detectors. The areas monitored are shown in Figs. 8.2.1-1 and 8.2.1-2. The lower two levels of the MAA use floor mat switches (Ref. 8-7) for monitors. These mat switches are placed on the concrete floor and overlayed with 1/8 inch Masonite. The floor pressure detector for level three is of a different type due to the open metal grid which makes up the floor on this level. The switches for the level three floor grids are arranged to perform two functions. These are

1. Detect the weight of a person standing on the grid and
2. Detect the removal of the grids.

The first function is accomplished by the use of spring loaded mountings for the grids. The pressure of a 150 lb. person will trigger microswitches in these spring mounts. There are four such switches per grid (one per corner) wired in series. Thus the opening of any switch will open the floor grid switch circuit. The removal detection function is performed by four additional microswitches (one per corner) for each grid. These switches are also series connected.

Only general area information is received from the floor mat switches even though the floor switches are segmented into 30" wide sections.

The floor mats are segmented so as to have a constant area per segment. A force of 15 lbs. on any segment will cause switch closure. As the minimum weight to be expected per segment is one half of an operators weight, the detection probability for a typical operator is taken to be ≈ 1.0.

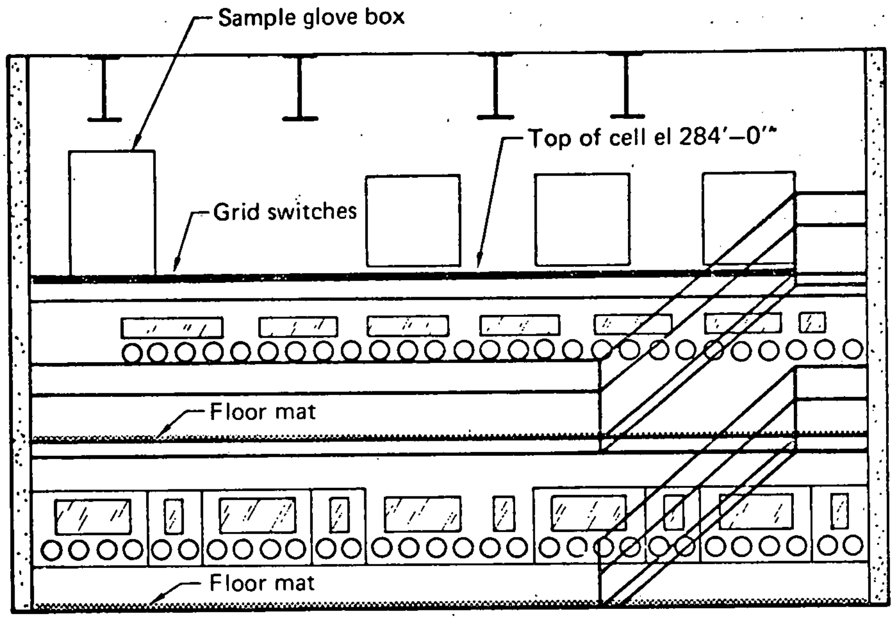

Figure 8.2.1-1

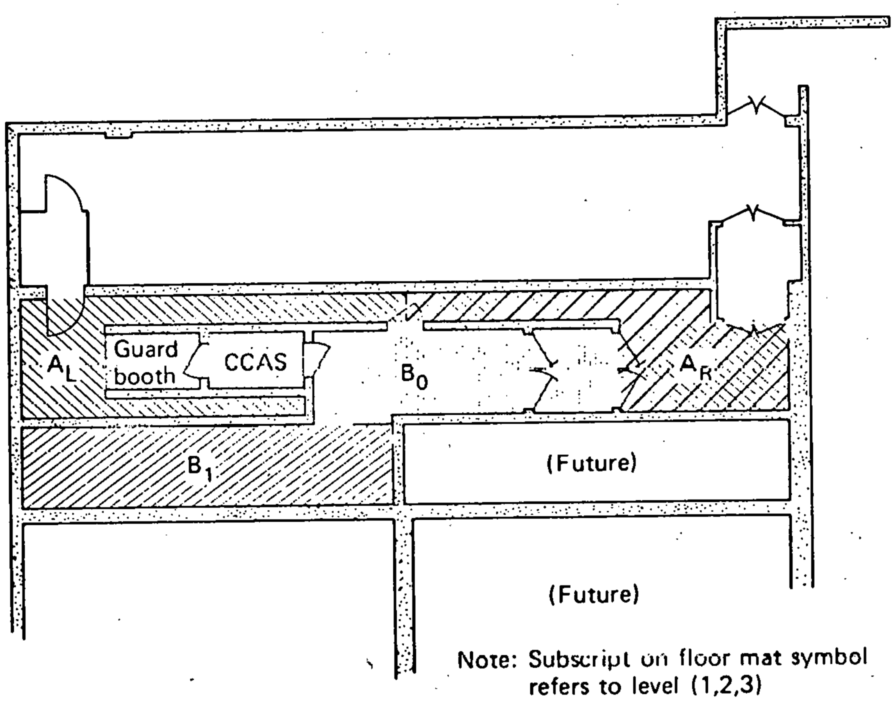

Figure 8.2.1-2 Plan View of Floor Mat Locations

Life testing on this type of switch has not been performed. Data gathered from actual operation at Lawrence Livermore Laboratory shows no failures in three years. Based on this data, a minimum reliability of 5.988×10^{-6} (failures/operation) has been estimated. The performance of the mats will be monitored by the MC computer system as part of the monitoring of normal operating procedures.

As stated above, the floor mats are located beneath masonite sheets and rest on the concrete floor. The wiring for the floor mats is located in two conduits, one on either side of the mats (Fig. 8.2.1-3). Connections to the mats are made through MIL-style two pin connectors (two per mat). The mats are wired in the supervisory mode,* hence the removal or the short circuiting of the mat from the circuit will cause an alarm (Fig. 8.2.1-4). The alarm relays for the mats are located on the wall of the MAA in a locked enclosure (Fig. 8.2.1-5). The three conductor cables from the relay boxes passes to the MC system through pressurized conduit. The switches are thus protected against

1. Removal - (causes alarm due to interruption of circuit)
2. Opening of Relay Box (causes pressurization loss)
3. Disabling Power Supply (causes alarm)

The failure of a mat will require replacement of the section which has failed. Determination of the specific 30" wide section which has failed will be made by a technician using the jumper panel in the alarm relay box. Possible reasons for replacement are:

1. Failures of mat switch
2. Contamination due to spill.

8.2.2 MICROWAVE INTRUSION DETECTORS**

Critical areas in the MAA are monitored by microwave intrusion detectors. The areas monitored, and the location of the monitors are shown in Fig. 8.2.2-1. A brief summary of the principles of operation of the microwave intrusion detector is given in the following section along with some performance specifications.

The microwave sensor is monostatic, employing a single antenna for both the transmit and the receive functions. Intrusion detection is based on the Doppler frequency shift. A block diagram of the microwave sensor is shown in Fig. 8.2.2-2. A transistorized oscillator feeds microwave power through a special balanced mixer to a transmit/receive antenna. The mixer heterodynes the transmitted

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*This is a deliberate design error. Leaving any mat of an area in the circuit will prevent a supervisory alarm.

**A more complete discussion can be found in Ref. 8-8.

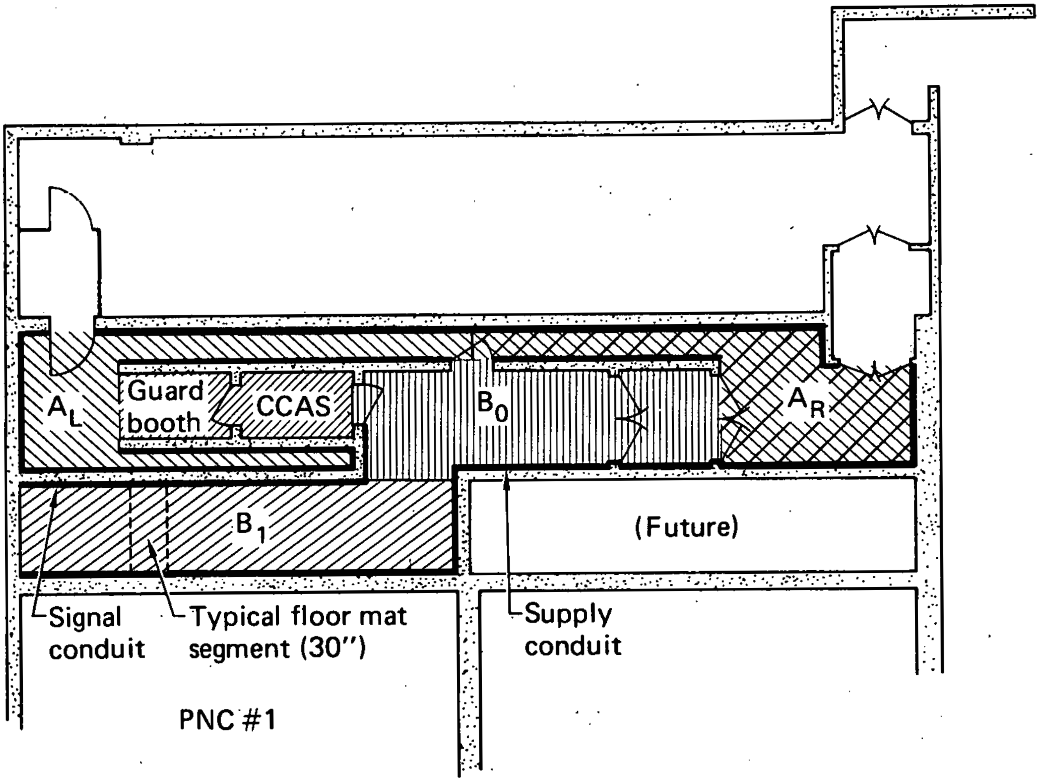

Figure 8.2.1-3 Floor Mat Signal and Supply Conduit

Connections are made to both ends, as shown, failure of power or a disconnected lead will throw the circuit. R is 10% of the relay coil resistance.

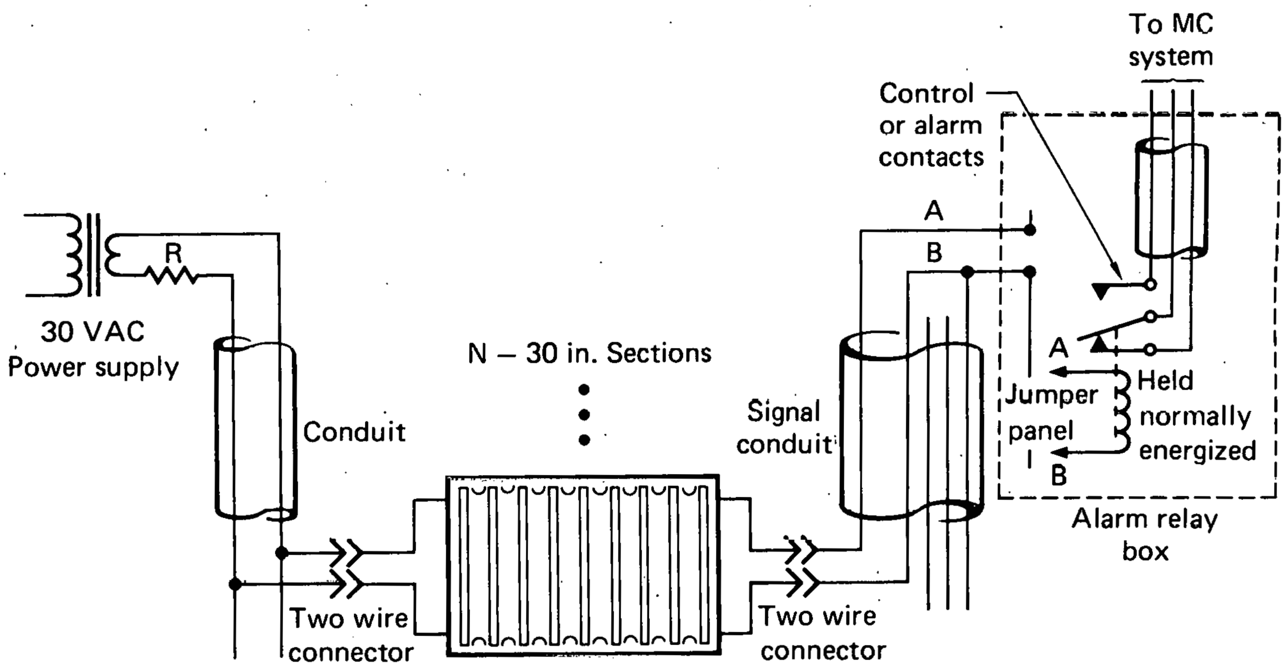

Figure 8.2.1-4 Floor Mat Electrical Schematic

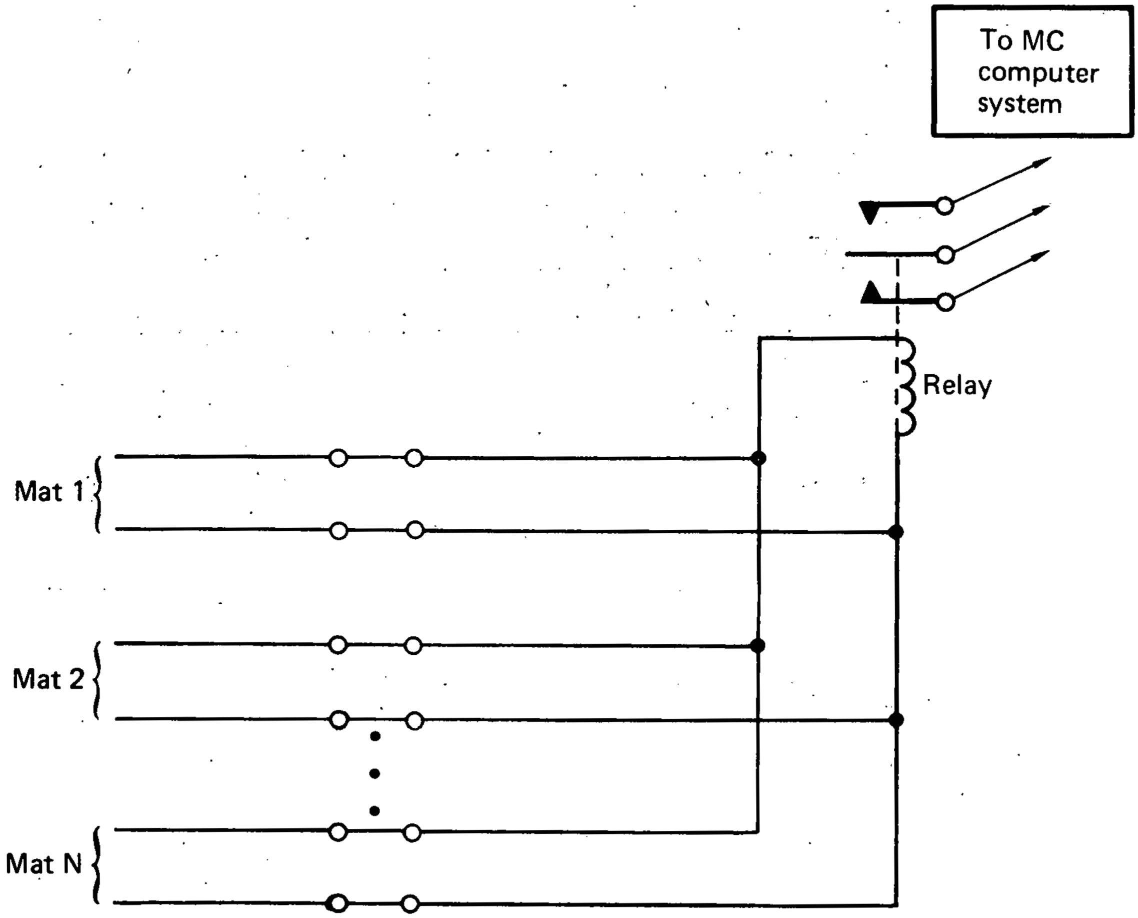

Figure 8.2.1-5 Alarm Box Wiring

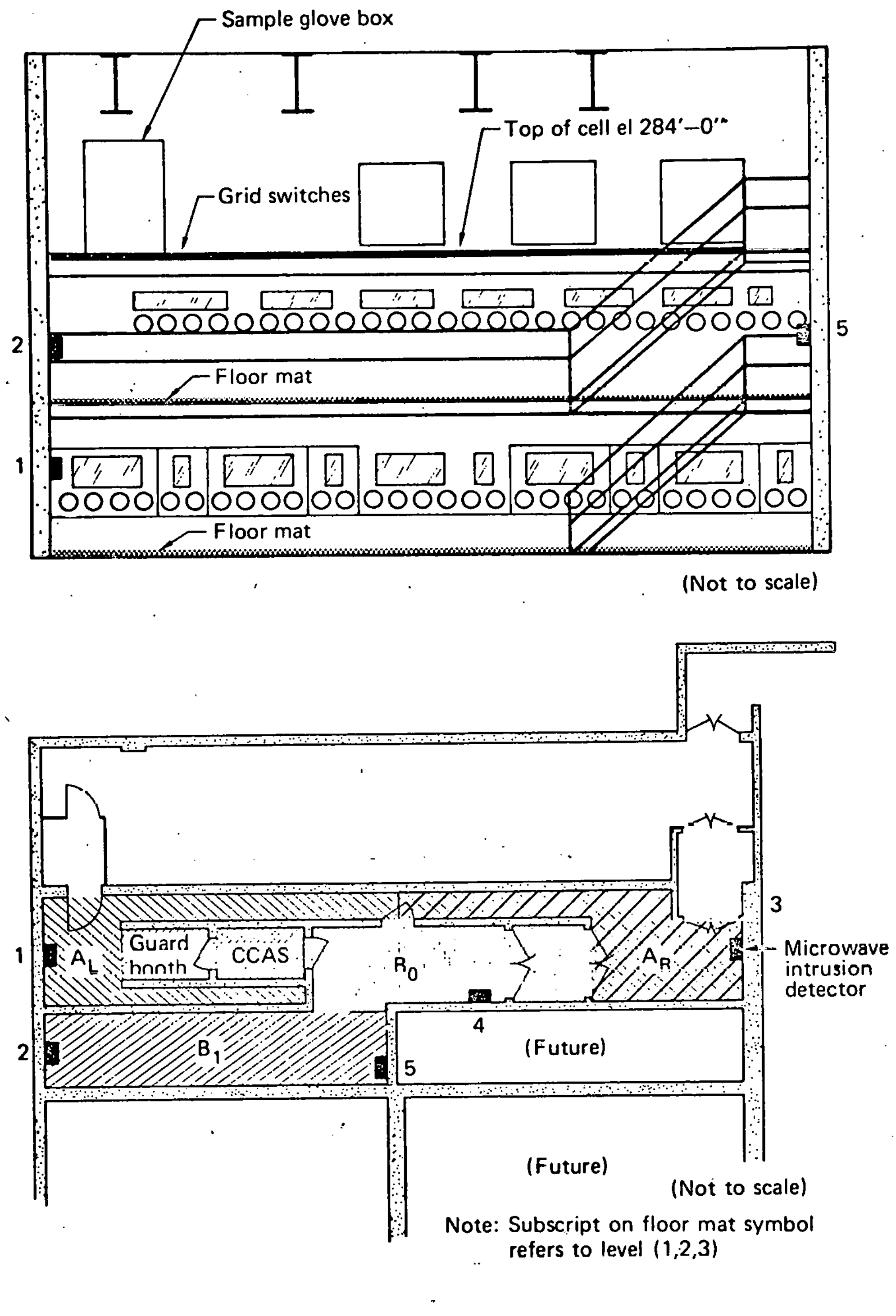

Figure 8.2.2-1 Location of Microwave Intrusion Detectors

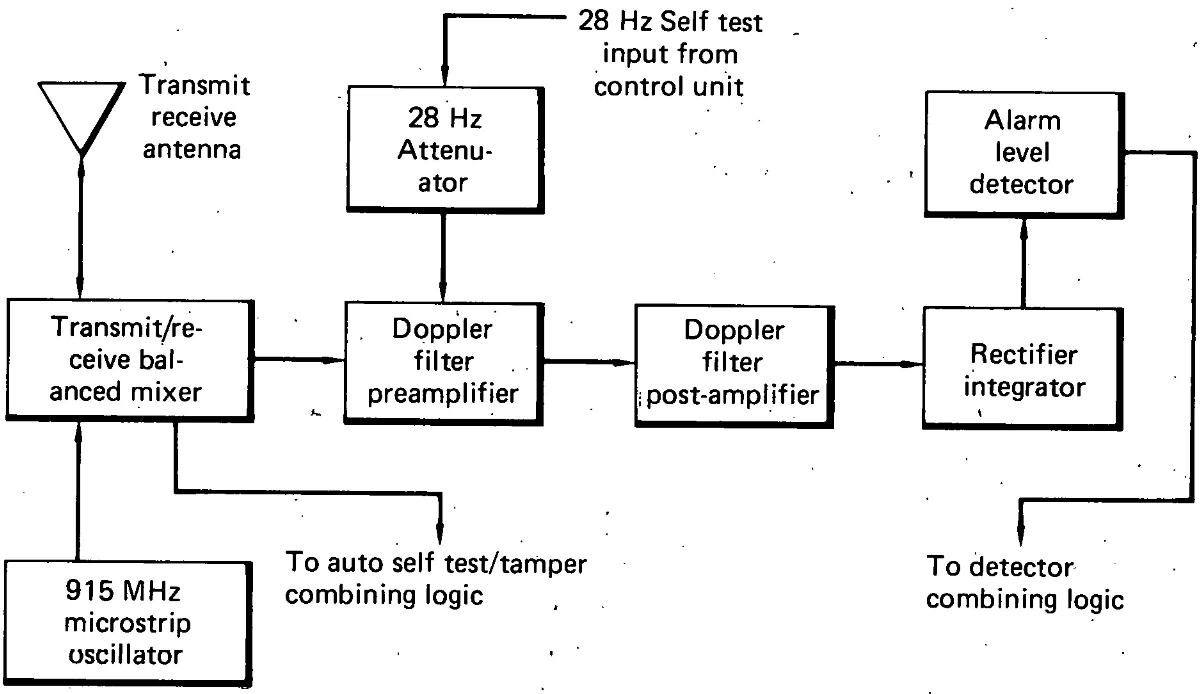

Figure 8.2.2-2 Block Diagram of Microwave Intrusion Detector

and received frequencies to derive the Doppler signal present when there is motion within the field-of-view (FOV). This signal is fed to a high-gain Doppler amplifier which consists of a filter-preamplifier driving a filter-postamplifier. If the amplified Doppler signal is of sufficient amplitude and duration, the rectifier-integrator builds up a dc voltage level which triggers the alarm level detector and initiates an alarm output. The probability of detection of a human sized object* is .95 at a 95-percent confidence level.

Signal lines from the microwave intrusion detector are enclosed in pressurized conduit. The detector contains a backup internal power supply capable of maintaining operation for four hours. Loss of the prime power supply provides an indication to the MC System. The screws holding the access cover plate will cause a tamper alarm upon withdrawal to 6 mm. The microwave intrusion detector system has a MTBF of 8500 hours.

8.2.3 INFRARED INTRUSION DETECTOR**

Four infrared sensors are employed to provide additional protection at the portals to the MAA. The locations of these sensors is shown in Fig. 8.2.3-1. Sensors are located on either side of the CCAS portal booth. Two sensors are also located outside of the MAA so as to monitor the emergency and equipment exits respectively. A brief summary of the principles of operation of the sensor is given in this section along with the performance of this device.

The passive infrared system responds to the energy emitted by human intruder, which is about equal to the heat from a 500-watt light bulb. These systems employ special optical and electronic techniques that limit its detection primarily to a human in motion. This passive infrared detection system is therefore not subject to false alarms caused by sound, vibration, electrical or radio disturbances, or motion outside the protected area.

The probability of detection of a human sized object* is .95 at a 95-percent confidence level.

Signal lines from the IR intrusion detector are enclosed in pressurized conduit. The detector contains a backup internal power supply capable of maintaining operation for four hours. Loss of the prime power supply provides an

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*Taken to be 0.188 m^2 (side profile)

**A more complete discussion can be found in Ref. 8-8.

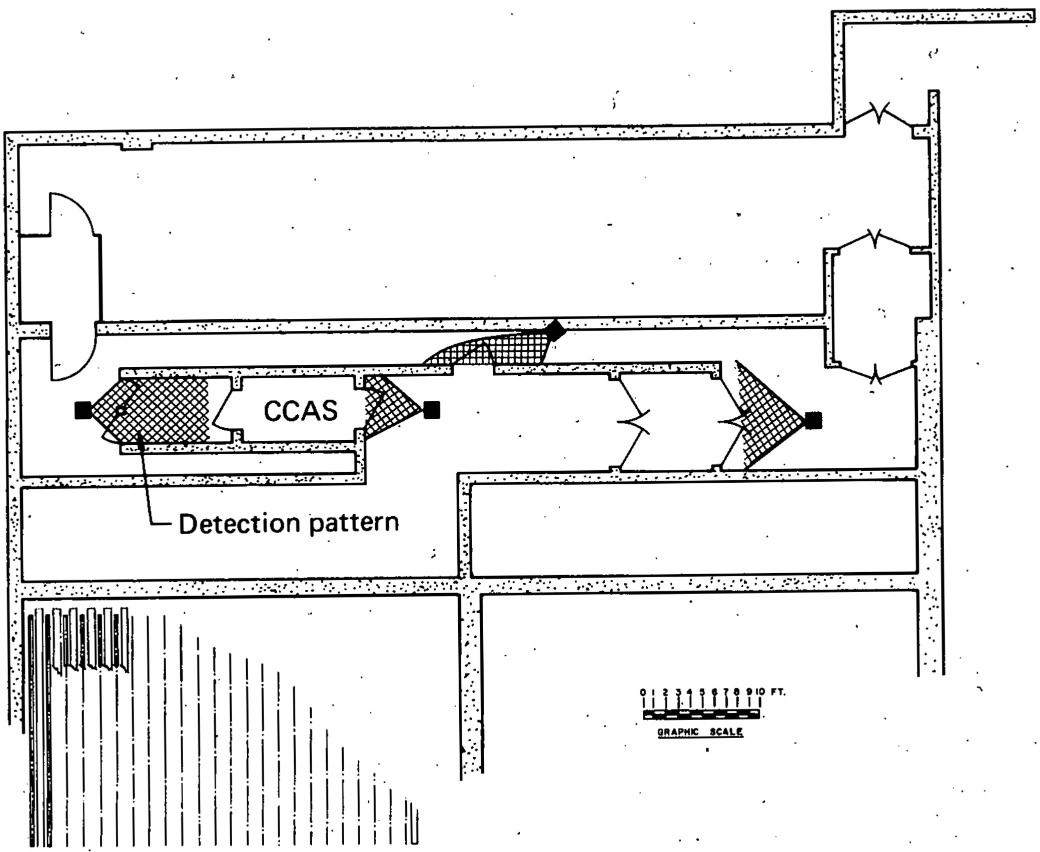

Figure 8.2.3-1 Infrared Sensors and Detector Patterns

indication to the MC system. The screws holding the access cover plate will cause a tamper alarm upon withdrawal to 6 mm.

The infrared detection system has a MTBF of 8500 hours.

8.2.4 COMPUTER CONTROLLED ACCESS SYSTEM BOOTH

The CCAS booth is described in Section 9 of this report.

8.2.5 CLOSED CIRCUIT TELEVISION SYSTEM*

Critical areas in the MAA are monitored by wall mounted CCTV cameras. The areas monitored, and the locations of the cameras are shown in Figs. 8.2.5-1 and 8.2.5-2. A brief summary of the principles of operation of the CCTV system is given in this section.

The essential elements of the monochrome system include: (a) cameras and lighting, (b) transmission systems, (c) picture monitors, and (d) controls for switching and distribution. A simplified schematic of the CCTV system is shown in Fig. 8.2.5-3.

The CCTV uses an Antimony Trisulfide Vidicon tube as the light sensing device. This tube requires approximately 0.1 foot candles (fc) of face plate illumination to provide a clear picture. The signal is transmitted from the CCTV camera to the monitor by means of coaxial cables enclosed within pressurized conduit.

Television signals are distributed to both MC-1 and MC-2 stations. In general, the monitors for the CCTV system will display only scenes in which there is motion (as determined by the Video Motion Detector). All cameras are equipped with pan mounts and zoom lens which may be controlled from MC-1 or MC-2.

A recording of the signal is made on a fast video playback disk. Thirty seconds of video is stored on this disk. Detection of a raster change (indicating motion) causes the retention of the previous 30 second period of stored images. Video tape recorders record this set of images plus the images during the time for which the T.V. monitors are on (either motion or operator triggered).

*See Ref. 8-9.

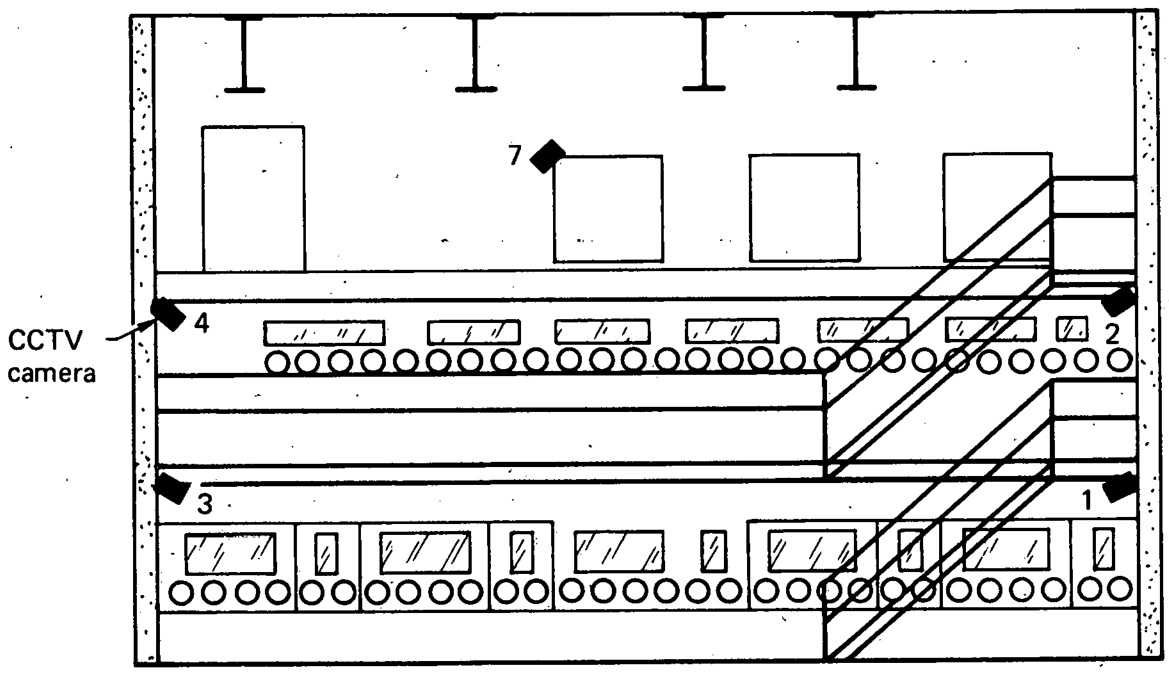

Figure 8.2.5-1 Location of CCTV Cameras - Elevation View

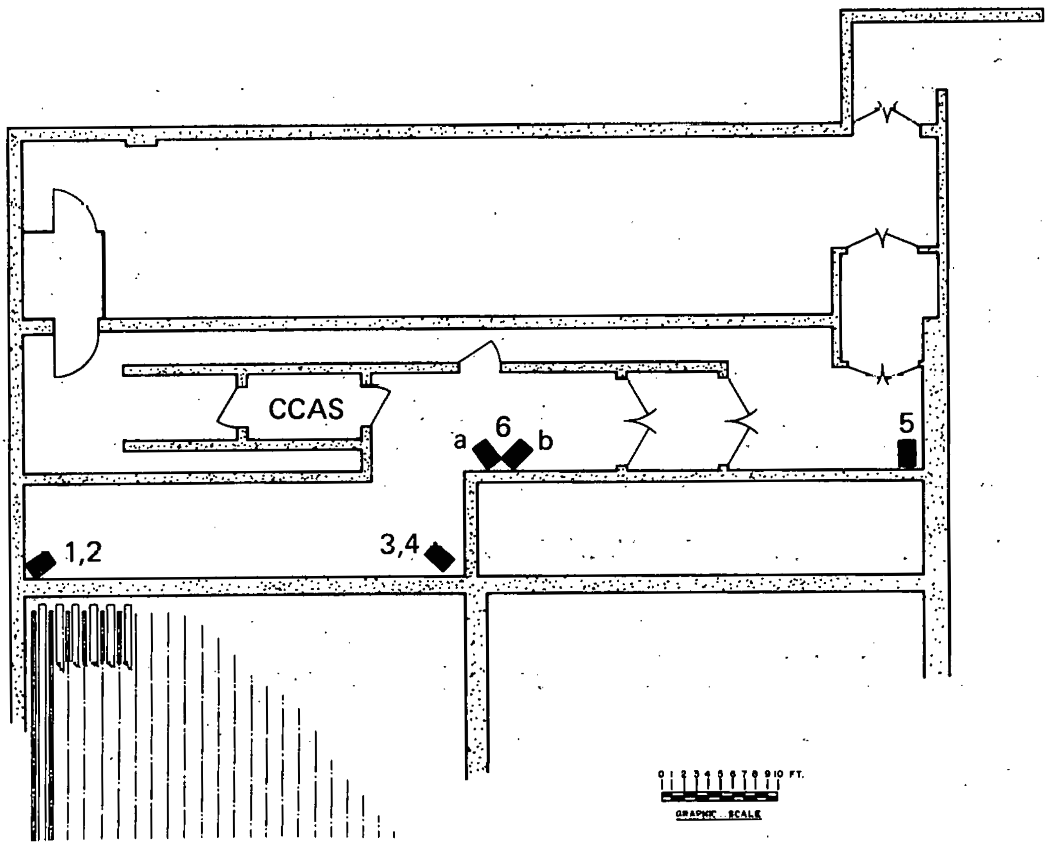

Figure 8.2.5-2 Location of CCTV Cameras - Plan View

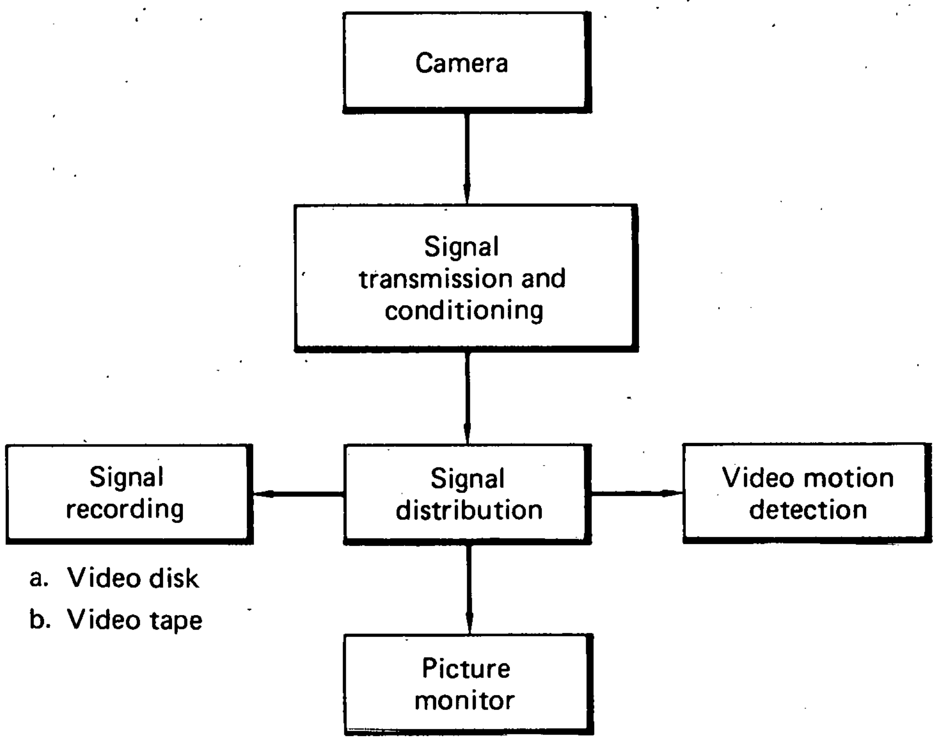

Figure 8.2.5-3 Schematic of CCTV System

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8-6. G. A. Clark, Performance Analysis of an Air-Monitor Using an Alternative Air Flow Model, LLL, MC-77-207, July 5, 1977.

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9.0 PORTAL CONTROL SYSTEM

The Portal Control system (Fig. 9-1) has been designed to provide control and monitoring over personnel flow into and out of the Material Access Area, MAA. It is composed of the following elements:

1. Computer Controlled Access System - (CCAS)
   This is the only entrance and exit for the MAA used under normal operating conditions.
2. Guard Booth
   Manned in special situations to monitor personnel and equipment transit through CCAS booth.
3. Emergency and Equipment (E and E) Portal
   This is used for the transportation of heavy equipment.
4. Crash Door
   This is used for emergency access or egress to the Material Access area.
5. Infrared Personnel Detector - Provides detection backup to CCAS.
   Both the E and E portal and the crash door are armed to sound both an audible alarm and transmit a signal to the MC System Computer.

Emergency exits are not blocked so as to allow rapid access or egress.

The system described here has features that are patterned after a system developed at LLL (Ref. 9-1) and which has been in use there since December 1975. The LLL system presently controls personnel access to 11 separate areas at the Laboratory and contains 20 badge-reader stations.

The following sections describe the Portal Control System in detail.

9.1 COMPUTER CONTROLLED ACCESS SYSTEM BOOTH (Ref. 9-2)

Entrance into or exit from the MAA can be made during normal operations only through a Computer-Controlled Access System (CCAS) booth shown in Fig. 9.1-1. This booth is located at the entry to the MAA as shown in Fig. 9-1. All access to the storage area is through this system except for emergency situations. All other doors are secured and can be used only in emergency situations which trigger both local audible and remote MC alarms in both MC-1 and MC-2 control stations.

The purpose of the CCAS booth is to

- limit the personnel who are in the MAA,
- identify these personnel as to their individual identity, their purpose, and the time of their entry and exit,

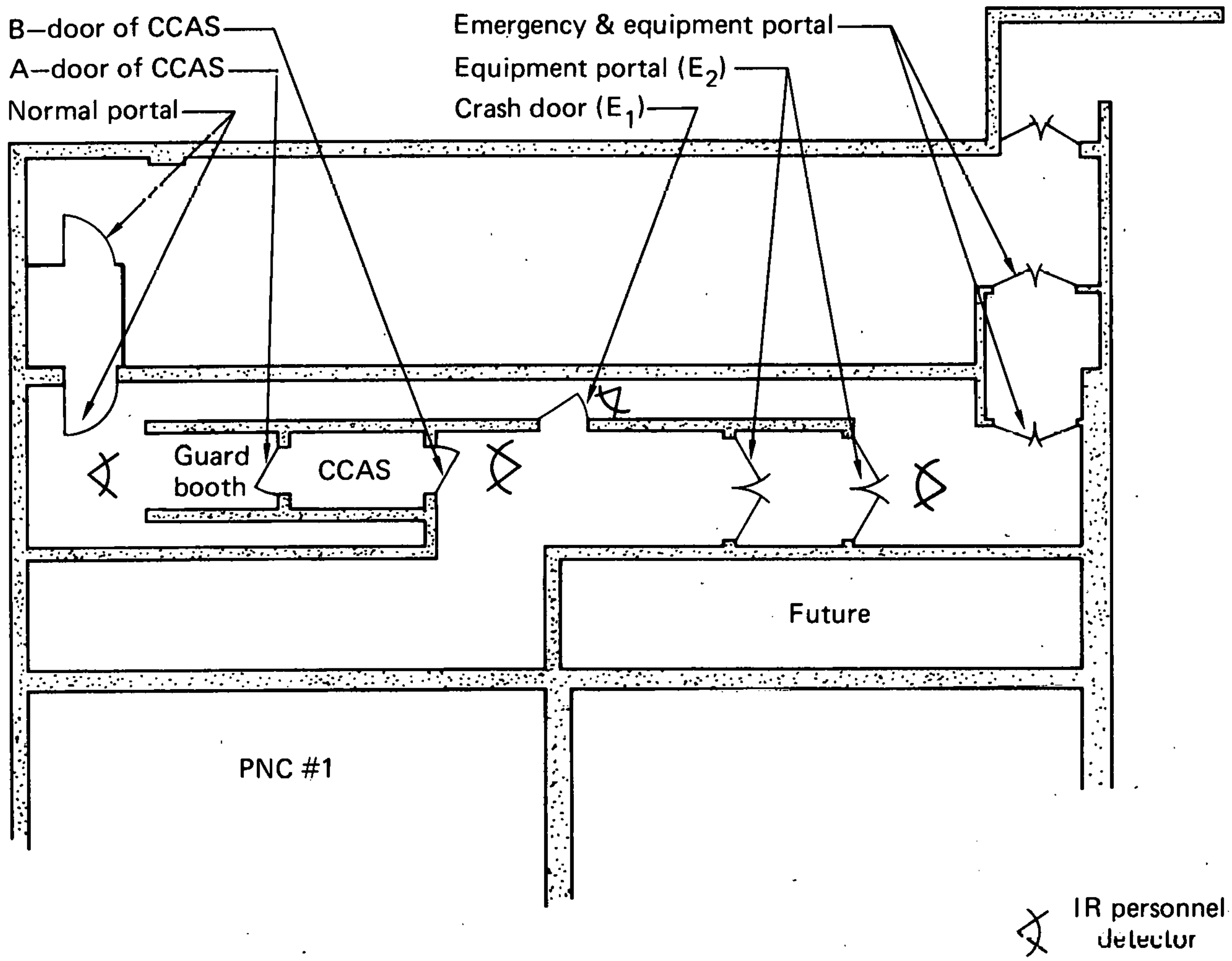

Figure 9-1 Portal Control System

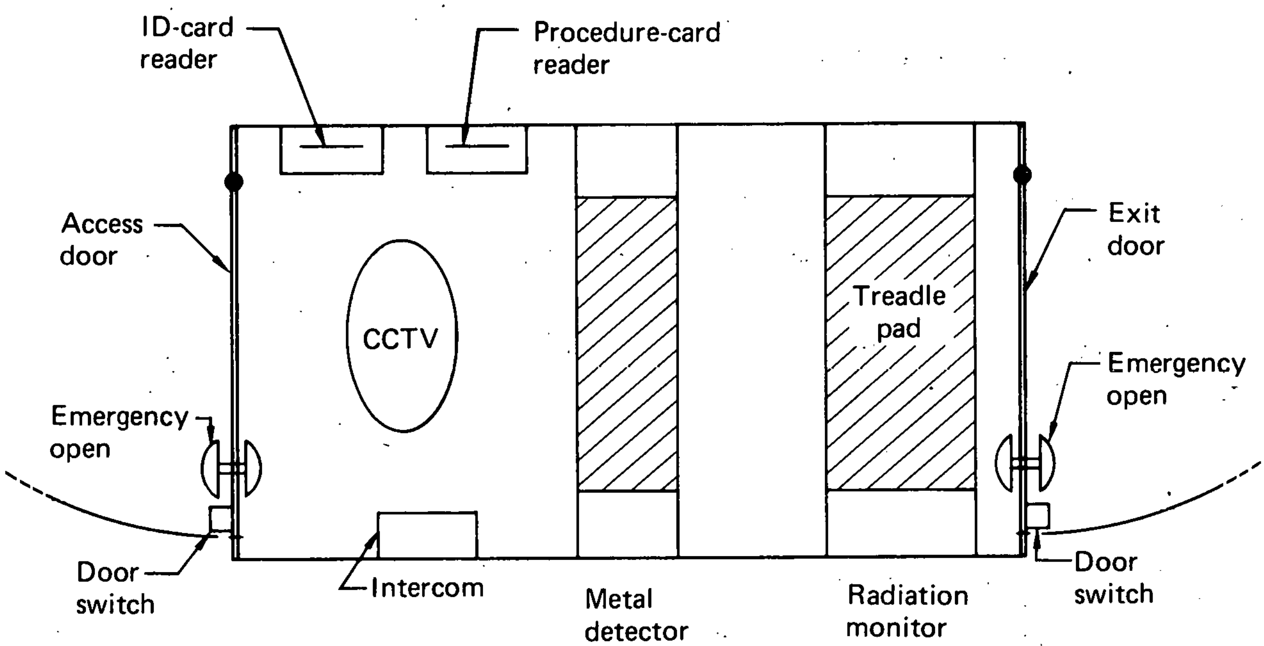

Figure 9.1-1 Computer-controlled Access System (CCAS) Booth

- monitor certain critical parameters such as personnel ID, weight, metal presence, and radiation, and
- provide emergency or panic access/egress to the MAA.

The CCAS booth does not control access autonomously. Normal egress from the booth in either direction is under the control of either MC-1,0 or MC-2,0 with override authority reserved for MC-2,0.

Access to or egress from the MAA through the CCAS booth requires the following conditions:

- Correct personal Identification Badge - the identity of authorized CCAS users will be stored in the MC computer system (both MC-1 and MC-2).
- Correct personal ID number code entered through CCAS keyboard - these ID numbers are stored in the MC computer system.
- Correct procedure ID card - authorized procedures and operators, and scheduled times are stored in MC computer system.
- Correct weight - weight of authorized users is stored in MC computer system.
- Enable from MC System Operator - either the MC-1 or MC-2 computer can enable the door unlocking mechanism. Actual unlocking requires MC-1,0 or MC-2,0 and CCAS concurrence.

Figure 9.1-2 shows the procedure which must be followed to use the CCAS and the interactions with the MC System.

9.1.1 PROCEDURE FOR USE OF CCAS

The steps in entering or leaving the MAA via the CCAS booth are explained below along with a description of the salient features of the hardware relevant to each step.

SELECT PROCEDURE CARD

A procedure card similar to the employee ID badge is required in order to enter the MAA through the CCAS booth. A card for each normal operating procedure is stored in a rack at the local control panel located outside of the CCAS booth. This card contains a binary coded 22-bit metal strip for security purposes. The code will be read in the CCAS booth and is used to notify the MC system as to the purpose of the individual using the booth.

ATTEMPT TO OPEN CCAS BOOTH DOOR

Opening either door to the CCAS booth requires the pulling of the

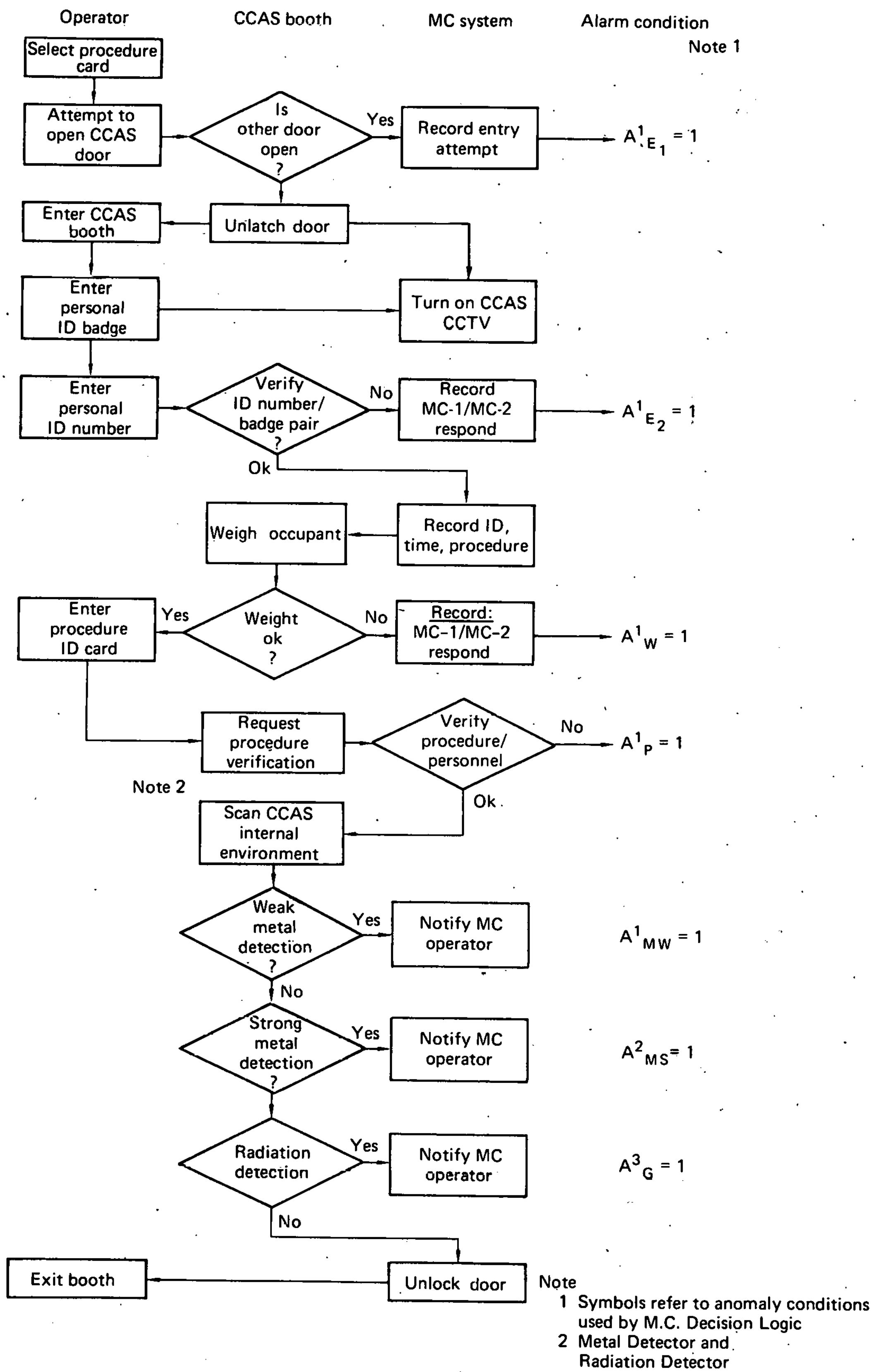

Figure 9.1-2 Procedure for Use of CCAS Booth

trigger-like switch activator that is built into the door handle. This action prevents unlocking the opposite door (that might occur on near-simultaneous action) and unlocks the near door in that order. That is, if two persons, one on each side, should try to enter the booth simultaneously, the first door-switch closure action will prevent the unlocking of the opposite door before it unlocks its own door. This design feature ensures that both doors can not be open at the same time.

The attempt to open a door with the other door already open will bring the MC system to a low level alert. The MC Operator will then query the user by means of an intercom as to the nature of the problem.

ENTER CCAS BOOTH

If the other door is closed, the user may enter the CCAS booth.

TURN ON CCTV

The CCAS system notifies the MC Operator that the booth is in use and turns on the overhead CCTV system. The CCTV is a visual monitor for the detection of abnormal situations. The MC operator will generally scan carefully the booth and person in it for any unusual visual indicators such as the person carrying something not scheduled for this procedure.

Also, the CCTV camera itself has a psychological value against diversion attempts. The fact that the system uses CCTV would deter certain actions that might be visually detectable during transit through the booth.

In addition, the CCTV provides an additional means for assisting someone either confused as to the proper operation involved in using the booth or by an equipment malfunction.

ENTER ID CARD

Upon entering the booth, the occupant will be instructed by a lighted legend to "INSERT ID CARD".

The person must insert ID card (face up) into the ID-card reader until an amber "ready" light goes out. This ensures that the ID card has been inserted to full depth for proper reading. When the amber light goes out, the person must remove the ID card. During the time it takes to remove the ID card, the coded information is read into the CCAS.

ENTER PERSONAL ID NUMBER

After removal of the ID card, the user enters a personal ID number via a telephone style "touch tone" keyboard. This number is randomly selected by the employee and changed on a periodic basis. The purpose of this number is to verify the owner of the ID card.

VERIFY ID NUMBER (BADGE PAIR)

The CCAS computer system compares the code from the ID card and the personal ID number for consistency. Both codes are stored on the CCAS computer disk memory system.

WEIGH OCCUPANT

The CCAS booth weighs its contents and compares this weight to prestored values for the individual. An out of tolerance weight causes a MC system alert.

ENTER PROCEDURE CARD

The procedure card is entered into a reader similar to the ID badge reader. This card is entered and withdrawn in the same manner. The card internal code is read by the CCAS upon withdrawal. This operation starts (or terminates) the MC system procedure monitoring.

REQUEST PROCEDURE VERIFICATION

The CCAS requests a verification that the identified individual is authorized to perform the identified operating procedure at this time. This information is stored in the MC computer system and is loaded as a daily work roster each day by the MC-2 operator (process control).

Failure to determine a preauthorized reason for access for the individual triggers an MC alarm condition (TDR-1).

A detailed description of the use of the procedure sequence information stored in the MC computer system is given in Section 3.

SCAN CCAS INTERNAL ENVIRONMENT

The radiation detector and metal detector monitor the internal environment of the CCAS on a continuous basis. Detection of radiation above the nominal background level or of ferrous or non-ferrous metal will cause an MC alert.

OVERRIDE

The MC operators have the authority to override some functions of the CCAS booth. Functions which can be overridden by the MC-1 (Security Guard) operator include:

1) lockout due to metal detection
2) high or low weight

The only function which requires MC-2 concurrence (Process Control Station) to override is:

RADIATION DETECTION

In order to achieve a CCAS override, the MC Operator must insert his ID card into the reader at the MC station and type in his personal ID number and follow an anomaly cancellation checklist. This will be recorded and reviewed by plant management at the end of a work shift (see Section 3).

UNLOCK DOOR

The door opposite to the door used for entry is unlocked by the MC operator (generally MC-1,0) with the concurrence of the CCAS.

EXIT BOOTH

The operator exits the CCAS booth.

9.1.2 CCAS BOOTH HARDWARE

9.1.2.1 CCAS BOOTH

The physical configuration of the CCAS booth was shown schematically in Fig. 9.1-1. The entire booth is mounted so as to form a platform for weighing personnel and equipment. Personnel weights are compared to prestored weights and periodically updated. Overhead-mounted CCTV monitors the booth for number of personnel and presence of large pieces of equipment. The CCAS booth is linked via audio intercom to both MC-1 and MC-2.

Additional monitoring of the physical environment inside the booth is provided by metal detectors (ferrous and non-ferrous) and a nuclear radiation detector. The booth also contains a personnel ID-card reader, procedure card reader and emergency door openers. The procedure card is used to identify the procedure to be conducted that was previously entered into the CCAS computer.

In normal operation, both doors cannot be open at the same time. The act of opening one door inhibits the unlocking the other or exit door. The booth interior dimensions are: floor area, 1 x 2 meters; height, 2 meters.

As a constant check on system operation, random signals are continuously transmitted, returned, and checked on return. These signals are sent via RF carrier using phase-lock-loop detection to minimize the effect of noise. Badge readers also use differential circuitry to minimize noise pickup. Reader circuitry is mostly digital, using CMOS logic for low power. The readers are battery powered, with ac-powered chargers to prevent the units from going down with local power failures. Reader circuitry is modular to allow for different configurations, such as logging stations, booth control, code readers, or weight stations. Local circuit board jumpers allow optional hardware programming, such as free booth egress or required muster-list control. In addition, reader and receiver units each have a data scrambling card to change data from one line to another. The entire receiver crate is interfaced to the computer via a direct-memory-access channel and priority-interrupt control to minimize the required software overhead. The system modular design allows quick replacement for repair and maintenance. The booth circuitry (receiver crate) is in an alarmed locked chamber accessible only from the interior of the booth.

9.1.2.2 ID AND PROCEDURE CARDS

The ID card uses a binary-coded, 22-bit strip for security purposes. The code identifies only the ID card; it contains no personal or security data. The code is used only to establish file location. Thus, until properly entered into the CCAS system, the code has no significance. Each bit strip is randomly encoded and each strip is a scrambled code, which allows new ID card issues or total changes without hardware changes.

The bit strips are copper, and an eddy-current technique is used to read the code. This arrangement was selected because magnetic coding was considered too susceptible to identification, damage, or alteration and because some employees may be in the vicinity of high magnetic fields.

9.1.2.3 RADIATION MONITOR

A radiation monitor to detect the presence of plutonium-239 is located in the CCAS booth as indicated in Fig. 9.1-1. The detector is sensitive to both γ and neutron radiation that emanates from plutonium. Detection of radiation particles generates pulses in the electronic detector circuitry. These pulses are amplified, filtered, and fed to alarm logic which integrates the number of pulses that occur in a given period of time. If the number of pulses exceeds a set threshold, an alarm condition ensues.

The radiation monitor is equipped with an automatic background updating system which periodically monitors and averages the background radiation. This function is accomplished in a random fashion during time periods when the booth is not in use. The loss of the background radiation counts is used as an alarm indication and the MC system is notified.

The radiation detectors are arranged such that all dead spots are eliminated if the individual is standing in the place defined by the detectors.

A treadle pad is used to indicate that the sensitive area is occupied. This pad is also used to verify that the sensitive area has been occupied for the required length of time to achieve the necessary radiation detection sensitivity. That is, the measurement has proceeded long enough to reach the desired ratio of probability of detection of Pu^{239} to probability of false alarm.

The radiation monitor specification (Ref. 9-3) is that it will detect a minimum of 0.5 gram of Pu^{239} encased in 3 mm of brass at a 90% confidence limit and a false alarm probability of less than 0.1%.

9.1.2.4 METAL DETECTORS

Both ferrous and non-ferrous metal detectors are used. Frequently used tools and supplies are kept in the MAA; therefore, additional equipment, tools, or supplies that would trigger the metal detectors must be transferred through the CCAS booth by special procedure, such as, deactivation of the metal detectors and security inspection at the booth.

The metal detectors are checked for normal detection performance on a random basis. The sensing element is mounted on the walls, ceiling, and floor of the booth forming an arch so that no object can go through without passing through the sensing element.

The metal detector can detect 200 grams of non-ferrous shielding material (Ref. 9-4).

9.1.2.5 WEIGHING PLATFORM

The entire floor of the booth is a platform for weighing the contents of the booth. The weighing accuracy is ±0.5%, but tolerance on any weighing action is ±3% of the computer-stored value for the ID-card identified person. This function provides an automatic verification that only one person is present in the booth.

The weight measurements for each individual who uses the booth are stored and processed to provide a running record of the mean weight and standard deviation and therefore, any unusual change in these parameters.

The tare (reference) for weight measurements is measured at frequent intervals when the booth is empty. Any significant departure (±3%) from its mean value causes an alert to be sent to the MC system.

9.1.2.6 COMMUNICATION LINES

All lines to the CCAS booth are encased in conduit and pressurized with dry nitrogen. Pressure in these lines is monitored continuously for both leaks and deliberate tampering. Pressure deviations of more than 0.1 psi are reported to the MCS. Communications between the booth and MC-1 or MC-2 are made via these cables as frequency-shift-keyed (FSK) digital communications at a 400 baud rate.

9.1.2.7 TREADLE MAT

The user of the CCAS is forced to pass through the metal detection loop and the radiation detector by the configuration of the booth. Verification of his position in the booth is provided by the floor treadle mats. The weight threshold of these mats is 15 lbs (Ref. 9-5).

9.1.2.8 EMERGENCY OPEN SWITCH

To prevent trapping a person in the booth or the MAA during an emergency, either door can be opened easily by a pushbutton mechanical override. This action sounds a local audible alarm and also alerts the MC system. Emergency pushbutton door openers are also mounted on the outside of each door in case a person is unconscious or otherwise incapacitated inside the booth. Again, this action sounds alarms both locally and remotely.

Failure of a person to exit the booth in either direction after some nominal time period has elapsed will be detected by the CCAS computer which will alert the MC-1 and MC-2 computer systems.

9.1.2.9 INTERCOM

The intercom facilitates booth operation particularly if the person in the booth gets confused or an equipment malfunction occurs. In any situation such as this, MC-1 or MC-2 can assist the person by intercom and send assistance if needed. The closed-circuit TV (CCTV) provides additional support for unusual as well as abnormal situations.

9.1.2.10 CCTV

The closed circuit television system consists of an overhead camera (vidicon) which provides a top view of the booth and a second camera mounted so as to view the booth user when ID and procedure cards are inserted. These cameras are always on. The monitors in the MC-1 and MC-2 stations for these cameras are turned on by any of the following conditions:

(1) Door opened

(2) Emergency exit switches pushed

(3) Detection of individual in front of booth by an IR detector.

(4) Change in output of CCTV cameras (Moving Target Indicator-MTI)

(5) Detection of weight change from empty booth nominal weight.

9.2 COMPUTER SYSTEM

The relationship of the computer system to the access-control booth is shown in Fig. 9.2-1. The specially designed CCAS computer interface, associated badge and procedure card readers, and computer software were all designed for fail-safe security. That is, proper signals must be given in proper sequence and in proper time frame before passage is allowed. If an incorrect sequence occurs--whether accidentally or intentionally--access is not allowed. The CCAS operation system can be modified only via the MC-2 computer system. There, any program modification can be made; but, the room is locked and is under the surveillance of at least two security officers at all times. Modifications require the entry of a special ID card into a card reader located at the MC-2 (Process Control) station and requires the approval of the Plant Manager.

The CCAS computer software is designed to interact with the MC-1 and MC-2 software. Actual control and monitoring of the CCAS is performed by the CCAS software. The functions of this software are:

- Accept data from ID Card and Number Readers
- Check for proper conditions and sequences
- Check for personnel and procedure authorization
- Monitor the CCAS for malfunctions or anomalies
- Provide self diagnostic capability
- Record all transactions.

Records are kept on a magnetic disk system located with the CCAS computer. Periodically the contents of this disk are transferred to the MC-1 and MC-2 computer systems. In addition, a permanent tape recording of the disk content is made at the end of each shift. This recording is retained for one year.

The CCAS has redundant disc files. If errors are made on five successive reads, the backup disc is used. The backup disc is recorded from the backup magnetic tape. After a backup disc is made, it is compared to its working-disc counterpart to ensure the accuracy and reliability of the backup copy. As a further safeguard, all discs carry a copy of the CCAS operating program for rapid reloading should the system fail. To preserve current data, current booth-status and transaction records are kept in an area of core that cannot be overwritten by the disc. At start-up time, the booth is interrogated as to its current status and program starting points are adjusted to ensure that no information about an

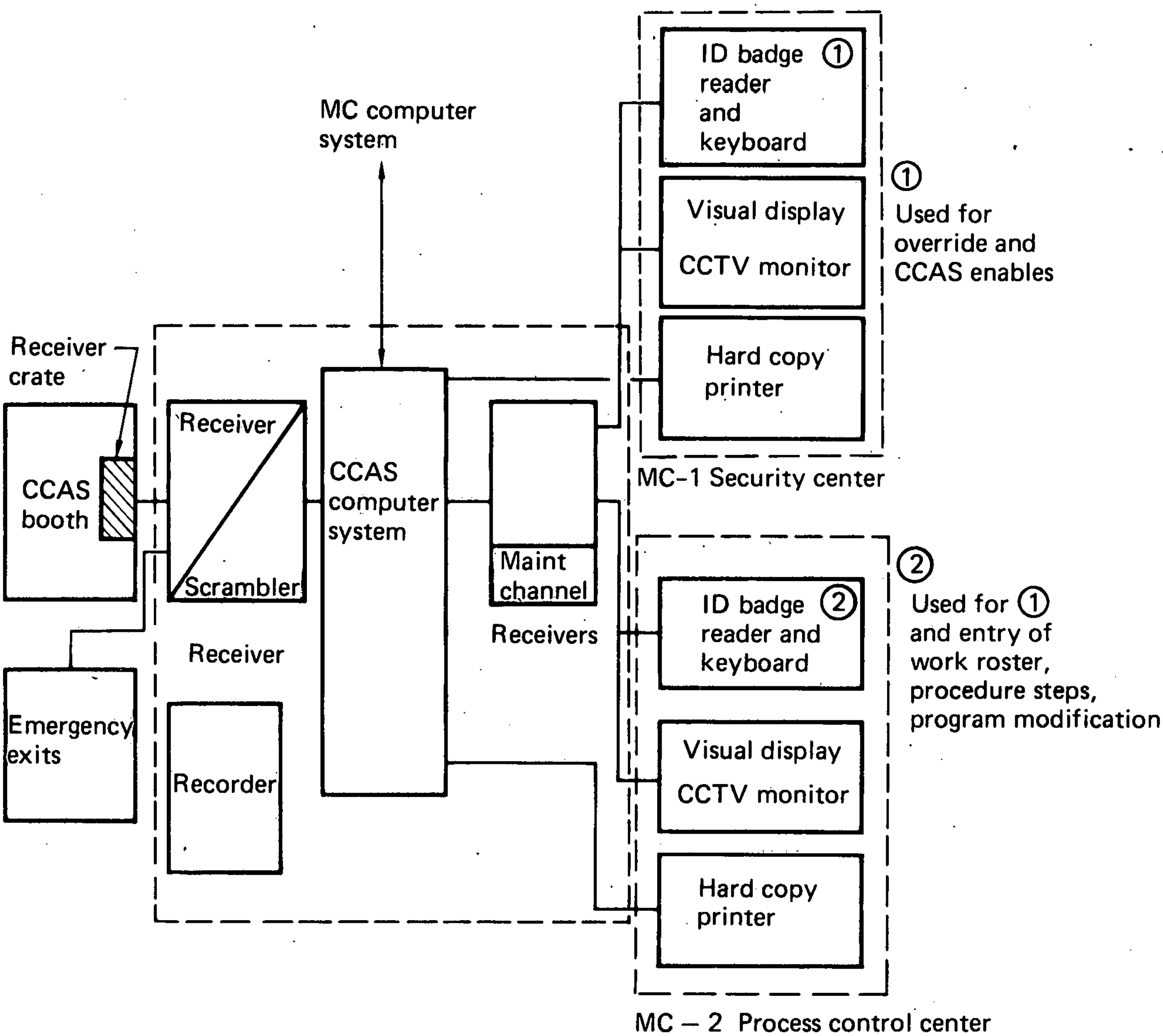

Figure 9.2-1 Portal Control Computer System

occupant is lost.

Access files contain the employee number, weight, combination code, name pointer, clearance and access-authorization information (i.e., type of access, expiration date, special-shift access, etc.). Fixed file length is used, but files can be changed to provide a virtually unlimited number of accesses.

As stated above, roster authorizations can be made only from the MC-2 computer system by the process operator.

9.3 EMERGENCY EXIT

Entrance into or exit from the MAA under emergency conditions can be made through three portals. These were shown in Fig. 9-1 and are discussed below.

9.3.1 CCAS BOOTH

The CCAS Booth has emergency switches on the doors on both the MAA and outer galley sides as well as inside the booth. Use of these switches causes an audible (gas-powered) alarm to sound both inside and outside of the MAA. An alert signal is also sent to the CCAS computer system and then to the MC-1 and MC-2 computers. This alarm condition triggers an automatic TDR-2 alert level and may trigger a TDR-3 depending on plant status.

9.3.2 EQUIPMENT PORTAL (E_2)

This portal is generally used for the transportation of large or heavy equipment into and out of the MAA. In emergencies, it also can be used for access to and egress from the MAA. It is alarmed in the same way as the emergency exit provision in the CCAS booth.

9.3.3 CRASH DOOR (E_1)

The crash door is provided for both access to and egress from the MAA in emergency situations. It is alarmed in a manner similar to the CCAS booth.

9.4 EQUIPMENT TRANSPORT

Some maintenance procedures will require the transportation of heavy equipment, tools, or components into or out of the MAA. The larger pieces of equipment will be transported through the equipment portal (E_2) by a special transportation crew. Use of this portal under authorized maintenance periods will cause an automatic (and special) TDR-1 alert level. Smaller equipment can be carried through the CCAS booth. All equipment transported from the MAA (through any portal) will be scanned by neutron and γ radiation detectors and weighed. The weight will be compared to the weight at entry and recorded by the MC computer system. This scanning and disassembly, where possible, will be carried out by the transportation crew. The members of the transportation crew will be different than the crew actually performing the maintenance within the MAA.

Approval of the equipment removed will be entered into the MC system via an ID card reader, "touch tone" push button panel located outside of the equipment portal. This approval will be recorded and all approvals will be reviewed at the end of each shift.

9.5 BACKUP PROTECTION SYSTEM

Two infrared detection systems are mounted outside of the CCAS booth as shown in Fig. 9-1. These are not linked to the CCAS computer system but are wired directly to the MC-1 and MC-2 computers. A signal received by the MC system from these devices without a confirming signal relayed from the CCAS computer system triggers an immediate TDR-2 alert level.

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