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Hanford PUREX Exercise - March 29 to 31, 1994

Special Nuclear Materials Cutoff Exercise: Issues and Lessons Learned

Volume 1 of 3: Summary of Exercise

R. A. Libby
J. E. Segal
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C. Davis

August 1995

Prepared for the Negotiations and Analysis Division Office of Arms Control and Nonproliferation
U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

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Richland, Washington 99352

(a) U.S. Department Of Energy
(b) Los Alamos National Laboratory

Executive Summary

In a September 1993 address to the United Nations General Assembly, President Clinton announced a new nonproliferation and export control policy that established a framework for U.S. efforts to prevent the proliferation of weapons of mass destruction. The new policy proposed that the U.S. undertake a comprehensive approach to the growing accumulation of fissile material. One of the key elements was for the U.S. to support a special nuclear materials (SNM) multilateral convention prohibiting the production of highly enriched uranium (HEU) or plutonium for nuclear explosives purposes or outside of international safeguards. This policy is often referred to as the President's Cutoff Initiative or the Fissile Material Cutoff Treaty (FMCT).

Because both the U.S. Department of Energy (DOE) and foreign reprocessing facilities similar to PUREX will likely to be inspected under a FMCT, the DOE Office of Arms Control and Nonproliferation, Negotiations and Analysis Division (DOE/NN-41) tasked Pacific Northwest Laboratory (PNL) to perform an information gathering exercise, the PUREX Exercise, using the Plutonium-Uranium Extraction (PUREX) Plant located on the Hanford Site in Washington State. PUREX is a former production reactor fuel reprocessing plant currently undergoing a transition to a "decontamination and decommissioning (D&D) ready" mode. The PUREX Exercise was conducted March 29-30, 1994, to examine aspects of the imposition of several possible cutoff regimes and to study verification of non-production of SNM for nuclear weapons purposes or outside of safeguards. A follow-up activity to further examine various additional verification regimes was held at Los Alamos National Laboratory (LANL) on May 10, 1994.

Specific objectives for the PUREX Exercise are listed below:

- Develop a number of **alternative safeguards approaches** for safeguarding existing reprocessing plants.
- Assist the United States Government (USG) in **understanding the problems and issues** that might be involved in allowing international inspections of existing reprocessing plants.
- Understand and **document the effects of plant operating status on inspection problems** for each of the following:
    - an operating reprocessing plant; i.e., a facility separating direct use material from fission products (spent fuel and targets).
    - a shutdown facility which is not currently separating direct use material but which is processing or stabilizing materials (without dissolution); e.g., a facility processing nuclear material for waste stabilization, plutonium cleanup, etc.
    - a shutdown plant that is still capable of operating, but which is not currently operating.

To address these objectives, the PUREX Exercise was organized in a modified form of a seminar war game or Table Top/Roundtable Discussion. The participants were divided into three teams: a Facility Team, an Inspector Team, and a Control Team. The Facility Team was generally responsible for understanding the workings of PUREX under various operating conditions and for discussing the effects of various inspection strategies on facility operations. The Inspector Team was responsible for developing a series of alternative inspection strategies that could be applied at PUREX. The Control Team was charged with facilitating the course of the exercise and capturing the results.

Input was provided by representatives from DOE Headquarters, DOE Richland Operation Office (RL), the DOE national laboratories, and Westinghouse Hanford Company (WHC) staff. The exercise included an evaluation of the application of traditional safeguards, alternative measures, and a combination of alternative safeguards measures to PUREX and similar facilities. The evaluation criteria used were effectiveness, intrusiveness and cost examined with the plant in all three operating conditions.

A summary of lessons learned from the PUREX Exercise is provided below.

- A wide range of verification strategies exist that could be applied at PUREX. The effectiveness, intrusiveness, and cost are highly dependent on the goals of the cutoff agreement and the operating status of the facility. It is easy to tell if a facility is not operating; it is harder to tell if an operating facility is violating the agreement.

- If information on materials balance is not required for verification, several attractive verification schemes are available. If information on materials balance to detect diversion is a requirement of the agreement, then no approach is available that improves on classical materials balance accounting with interim inspections of in-process inventories. However, this option can be further improved with the use of adjunctive measures.

- Verification costs are dependent on verification goals ("Confidence Costs!")

    - In the absence of significant automation, a continuous inspector presence would be required to achieve the highest levels of confidence ($\sim$1000 inspector days/year).

    - Process monitoring can be effective, but is costly to install in a facility such as PUREX ($20-$30 million in '87 dollars).

- Design verification at a large, complex, highly radioactive facility such as PUREX is <u>extremely</u> difficult. C/S measures can provide some confidence regarding changes in facility configuration.

- Under certain circumstances PUREX may be able to meet with IAEA timeliness goal (detection of diversion of 1 SQ in 30 days). However, it could not meet the goal of detecting a 1 SQ diversion over a year.

- While this exercise centered on PUREX, most of the conclusions would apply at Savannah River Site facilities and other old, large scale reprocessing plants in weapons states. It must be recognized that PUREX will not be an operational plant in the future. The identified facility impacts do not directly apply to the actual PUREX Plant (except those related to monitoring a shutdown facility or one in a transition mode) but, rather, may apply to "PUREX-like" facilities elsewhere.

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1.0 Overview of PUREX Exercise

1.1 Introduction

In a September 1993 address to the United Nations General Assembly, President Clinton announced a new nonproliferation and export control policy. The new policy established a framework for U.S. efforts to prevent the proliferation of weapons of mass destruction and proposed that the United States undertake a comprehensive approach to the growing accumulation of fissile material. One of the key elements was for the United States to support a special nuclear materials (SNM) multilateral convention prohibiting the production of highly enriched uranium (HEU) or plutonium for nuclear explosives purposes or outside of international safeguards. This convention is often referred to as the President's Cutoff Initiative or the Fissile Material Cutoff Treaty (FMCT).

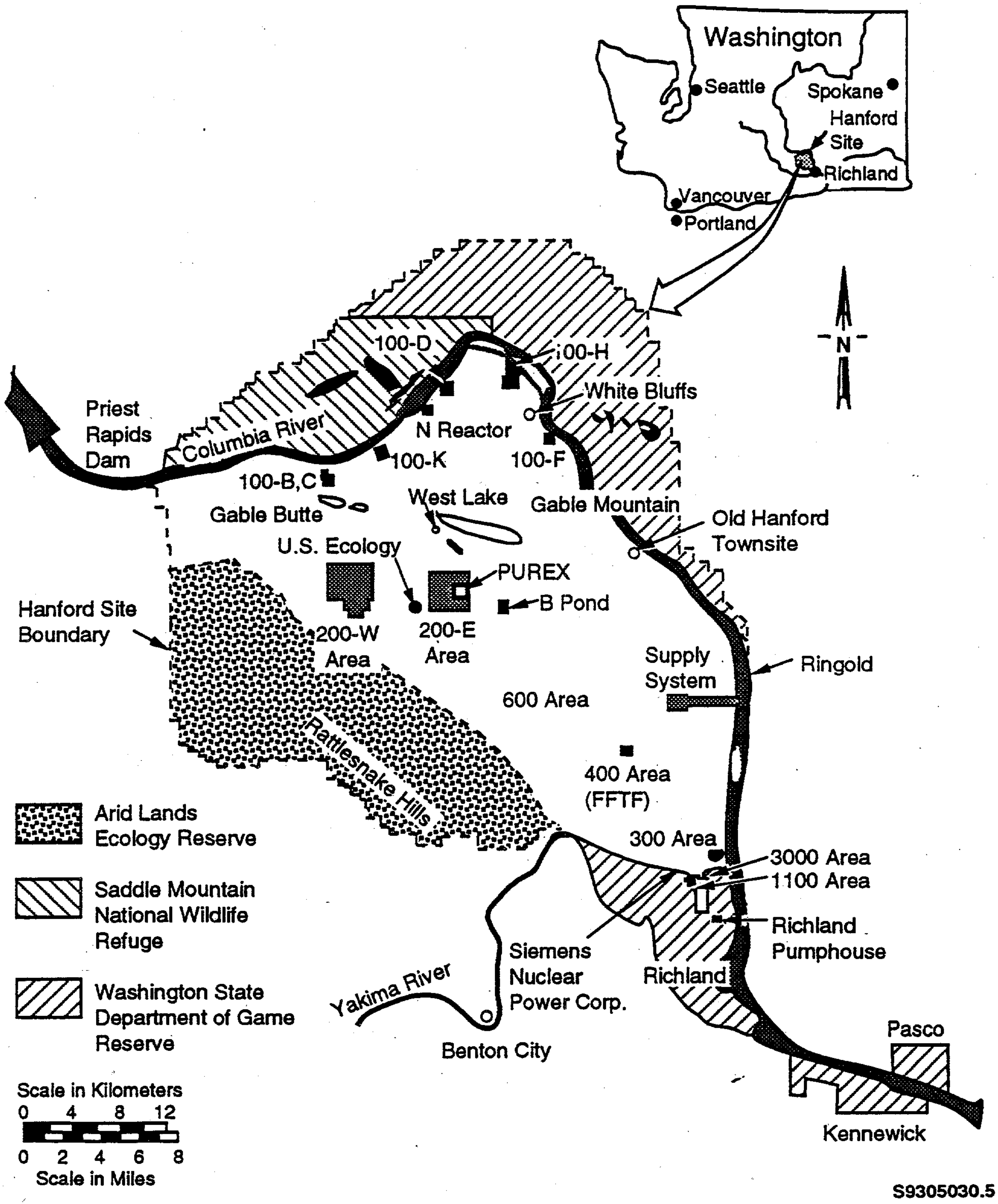
Under the President's Initiative for an FMCT, all states would agree to stop further production of SNM (HEU and plutonium) for weapons purposes. Several states, both major weapons states and emerging weapons states, have nuclear fuel reprocessing facilities that are capable of separating plutonium from irradiated fuel. In some cases, such as in the United States, these facilities have been shut down--with the exception of some plants that are continuing to work off backlogs or to cleanup inventories prior to decommissioning. In other cases, such as in Russia, these facilities may be used for the reprocessing of civilian fuel. These plants were built many years ago without design features which would allow the imposition of modern material accountancy methods.

1.2 Background

The Plutonium-Uranium Extraction (PUREX) Plant located on the Hanford Site in Washington State is a former production reactor fuel reprocessing plant currently undergoing a transition to a "decontamination and decommissioning (D&D) ready" mode (see map, Figure 1.1). Because both the U.S. Department of Energy (DOE) and foreign reprocessing facilities similar to PUREX will likely to be inspected under a production cutoff treaty, the DOE Office of Arms Control and Nonproliferation, Negotiations and Analysis Division (DOE/NN-41) tasked the Pacific Northwest Laboratory (PNL) to perform an information gathering exercise using PUREX. The PUREX Exercise was conducted March 29-30, 1994, to 1) examine aspects of imposing several possible cutoff regimes and 2) study how to verify that SNM is not being produced for nuclear weapons purposes or outside of safeguards. A follow-up activity to further examine other verification regimes was held at Los Alamos National Laboratory (LANL) on May 10, 1994. The impacts resulting from the implementation of safeguards at PUREX have been identified. It must be recognized, however, that since PUREX will not be operational in the future, almost all of these are not real impacts to PUREX but, rather, represent the impacts to a PUREX-like facility operating in some other country.

This report provides an analysis and a technical evaluation of the issues and impacts resulting from implementing a production cutoff initiative at PUREX. Input was provided by representatives

Figure 1.1. Hanford Site



from DOE Headquarters, DOE Richland Operation Office (RL), the DOE national laboratories, and Westinghouse Hanford Company (WHC) staff. This report also provides an evaluation of the application of traditional safeguards, alternative measures, and a combination of alternative safeguards measures to PUREX and similar facilities.

There is no precedent for applying "IAEA-type" safeguards to these facilities. IAEA methods under INFCIRC/153 are designed to monitor material ("for the exclusive purpose of verifying that such material is not diverted to nuclear weapons or other nuclear explosive devices") rather than monitoring the facilities themselves. Applying methods designed for safeguarding operating facilities will be difficult and costly in dollars, intrusiveness, and inspectorate manpower. It is likely the development of alternative safeguards measures and associated procedures will be required to provide confidence at an acceptable cost that new production is not occurring.

1.3 Objectives of Study

The overall objective of the PUREX Exercise was to help the U.S. government, DOE, and other agencies understand problems and issues associated with applying international safeguards to U.S. and foreign reprocessing facilities that are/were used to separate SNM for weapons purposes.

All the U.S. plutonium separations facilities are old plants built in the 1950's with subsequent upgrades in safety systems and process instrumentation. They were designed to then-current standards; they were not designed to meet the type of independent material accountancy requirements currently placed on such facilities by international safeguards. During the PUREX Exercise, a variety of safeguards options potentially applicable to old reprocessing plants were examined; significant time was also spent on the application of traditional IAEA INFCIRC/153 measures required for new facilities currently being placed under IAEA safeguards. A variety of alternative measures were also evaluated because of known problems associated with applying safeguards measures to old facilities; for example, in verifying the facility design.

The specific objectives of the PUREX Exercise were to accomplish the following:

- Develop a number of **alternative safeguards approaches** for safeguarding existing reprocessing plants.

- Assist the U.S. government in **understanding the problems and issues** that might be involved in allowing international inspections of existing reprocessing plants.

- Understand and **document the effects of plant operating status on inspection problems** for each of the following:

  - -- an operating reprocessing plant; i.e., a facility separating direct use material from fission products (spent fuel and targets)

-- a shutdown facility which is not currently separating direct use material but which is processing or stabilizing materials (without dissolution); e.g., a facility processing nuclear material for waste stabilization, plutonium cleanup, etc.

-- a shutdown plant that is still capable of operating, but which is not currently operating.

Technical objectives established for the exercise were to define issues associated with the following:

- the ability to perform a design verification including facility piping, piping reconfiguration, and vessel calibrations;
- the ability to perform initial and periodic material inventories including verification of tank sampling and volume measurements, solid holdup, liquid holdup, product holdup, and on-site spent fuel;
- the ability to meet timeliness goals; e.g., inventory takings;
- the ability to meet significant quantity goals; i.e., an estimate of the expected errors in the material unaccounted for (MUF) statistic;
- the cost of performing safeguards based on specific criteria; i.e., IAEA 1991-1995 Criteria, new facility (THORP) requirements, and alternative measures;
- the inspector-day-equivalent requirements;
- appropriate technical fixes for verification problems and estimate associated costs; and
- constraints imposed by environment, health and safety (ES&H), or other requirements.

1.4 Methodology

To address these objectives, the PUREX Exercise was organized in a modified form of a seminar war game or table top/roundtable discussion. The participants were divided into three teams: a Facility Team, an Inspector Team, and a Control Team. Table 1.1 lists the participants. The Facility Team was generally responsible for understanding the workings of PUREX under various operating conditions and for discussing the effects of various inspection strategies on facility operations. The Inspector Team was responsible for developing a series of alternative inspection strategies that could be applied at PUREX. The Control Team was charged with facilitating the course of the exercise and capturing the results.

The Facility Team prepared a Design Information Questionnaire (DIQ) before the exercise. The DIQ and a presentation entitled "PUREX Inspection Exercise, DIQ Preparation" can be found in the

Table 1.1. Purex Exercise Participants

Name	ORG.	Telephone	Fax Number
Facility Team:			
Mike Ehinger	ORNL	615-574-7132	615-574-4624
Alan Bieber	BNL	516-282-2928	516-282-7533
Paul Ethington	WHC	509-373-2110	509-373-4901
Ken Plummer	ORNL	615-574-7069	615-574-4643
R. W. ("Bill") Bailey	WHC	509-373-4494	509-373-4901
Inspection Team:			
Larry McRae	WHC	509-376-8100	509-376-0150
Cal Delegard	WHC	509-373-4658	509-373-2843
Ken Apt	LANL	505-667-5796	505-665-0492
Arnold Hakkila	LANL	505-667-2170	505-667-7626
Jack Hartwell	INEL	208-526-9366	208-526-9267
Cindy Heinberg	DOE (SAIC)	301-903-8418	301-903-8704
Control Team:			
Josh Segal	DOE/NN-41	202-586-2104	202-586-2104
Michael Whitaker	DOE/NN-44	202-586-0725	202-586-6789
John Brown	PNL	509-372-1955	509-372-2373
Dick Libby	PNL	509-372-4160	509-372-4412
Rodney Wilson	SNL	505-844-5269	505-844-8814
John M. Puckett	LANL	505-667-6394	505-665-0492
Bill Stanbro	LANL	505-667-6779	505-667-7626
Chuck Goergen	WSRC/DP-22	301-903-2753	301-903-5821
Sharon M. Deland	SNL	505-844-8740	505-844-8814
OBSERVER:			
W. Connie Johnson	DOE-RL	509-376-6953	509-376-4485

Volume 2, Appendices A and B, of this report. The DIQ, which is required by the International Atomic Energy Agency (IAEA) for each facility, provides the information necessary for the IAEA to design an Inspection Plan for a facility (see Volume 2, Appendix C). The DIQ provides a vehicle for a Facility Team to use to explain the facility to the participants. An early version of the DIQ was provided to the Inspector Team to help it develop the Inspection Plan for the PUREX Exercise. The Facility Team then responded to the Inspection Plan once it was presented by the Inspection Team.

The initial Inspection plan was based on "Safeguards Criteria, 1991-1995: Section 7, Reprocessing Plants," which covers inspections under INFCIRC/66 and INFCIRC/153. During the exercise, design verification, initial inventory, and the routine inspection plans were presented by the Inspection Team using both traditional IAEA safeguards measures and alternative safeguards measures. The Inspection Plan was presented to the exercise participants for comment on its feasibility and impact.

The Control Team provided coordination, facilitated discussions, and recorded exercise results. The Control Team was also responsible for providing the logistic support of the exercise, developing questions to stimulate discussion, and preparing this final report.

One of the objectives of the PUREX Exercise was to expand the range of possible inspections options or alternatives. During the Hanford phase, the pros and cons (see Volume 3, Appendix J) of each measure were assessed; during the LANL phase, individual and combined alternatives were assessed with the goal of developing more effective verification schemes. All the single and combined schemes were rated as to their effectiveness, intrusiveness, and cost (see Chapter 3.0).

The PUREX Plant, although shut down, is still active in the sense that there are many ongoing activities and a large number of critical milestones facing staff at the facility. To minimize interference with these milestones, one goal of the exercise was to achieve the exercise objectives with a minimal use of Westinghouse Hanford Company (WHC) plant staff. All work was performed to ensure non-interference with Tri-Party Agreement (DOE/Environmental Protection Agency/State of Washington) milestones. Although key WHC staff were involved with the preparation of the DIQ and in the exercise itself, the majority of the exercise team members were from the DOE national laboratories. Most team members had prior inspection experience either as actual inspectors, as developers of instrumentation or inspection procedures, or as facility representatives.

Two of the three days devoted to the PUREX Exercise were spent at the PUREX Plant (see Agenda, Table 1.2), which allowed use of the video tapes, photographs and graphics, and models located in the facility. Also, experienced plant personnel were readily available for consultation. On the last day, the PUREX Exercise was conducted in a PNL conference room to accommodate potential classified discussions.

The final agenda item, during the Hanford phase of the exercise, was a comparison of lessons learned at the PUREX Plant with possible application to other reprocessing plants. In particular, comparisons with the F and H canyons at the Savannah River Site (SRS), the Idaho Chemical

Table 1.2. Agenda for PUREX Exercise

March 29, 1994
<u>ROB Lobby</u>

8:00 a.m.	Badging - All offsite visitors need to obtain a dosimeter at ROB	
8:30 a.m.	Leave for PUREX from ROB Building - Car pools to be arranged	

PUREX Building Conference Room

9:15 a.m.	Welcome	Richard A. Libby/John B. Brown, Jr./ Joshua E. Segal
9:30 a.m.	Presentation of PUREX DIQ	Facility Team
12:00 p.m.	Lunch	
1:00 p.m.	Presentation of Inspection Plan -Facility Team Comments	Inspection Team
3:30 p.m.	Adjournment	

March 30, 1994
PUREX Building Conference Room

TBD	Continued Inspection Plan Presentation -Facility Team Comments	Inspector Team
12:00 p.m.	Lunch	
1:00 p.m.	Continued Inspection Plan Presentation -Facility Team Comments	Inspector Team
3:30 p.m.	Adjournment	

Table 1.2. Agenda for PUREX Exercise (contd)

March 31, 1994
Sigma 3, Sky Room

8:30 a.m.	Complete Inspection Plan Presentation -Facility Team Comments	Inspector Team
12:00 p.m.	Lunch	
1:00 p.m.	Wrap-up Lessons Learned; Application to Other Facilities	Inspector Team
5:00 p.m.	Wrap Up	Richard A. Libby/John B. Brown, Jr.

Processing Plant at the Idaho National Engineering Laboratory (INEL), and the Tarapur Reprocessing Plant in India were discussed. Since these facilities, as well as similar ones in other weapons states, have never been under continuous international inspection, it is important to understand any issues involved in the implementation of international inspections at these older, existing facilities. In addition, application to foreign facilities is important since bilateral agreements may start before a full international agreement is reached.

1.5 Reporting Outline

This report consist of three volumes. Volume 1 is summary of the PUREX Exercise. Chapter 2.0 contains the Design Information Questionnaire (Appendix A), a presentation on the significant DIQ questions (Appendix B), and the Inspection Plan (Appendices C). Volume 3 contains handouts, presentations, published literature, the applicable DOE Order and other pertinent background and reference material pertinent to safeguarding reprocessing facilities (Appendices D-J).

Unresolved issues and lessons-learned are documented in Chapter 4.0 for application to future exercises, either at Hanford or other DOE sites. Chapter 4.0 also documents issues related to personnel interactions, cost considerations, length of future exercises, and inspector experience. Future exercises will likely include other facility types, broader U.S. participation at a similar facility, or international participation at a U.S. or foreign facility.

2.0 PUREX Plant Description

This chapter provides descriptive information on the PUREX Plant including its design, construction, operation, structural components, and processing system. For additional information, reference the DIQ found in Volume 2, Appendix A, where elaborate figures are available on the design and function of the various structural components and processes found at PUREX. This chapter also contains a detailed description of the PUREX site, buildings, canyon, galleries, product removal room, and specialized cells; most of this information was obtained from the PUREX Technical Manual, Chemical Processing (WHC-SP-0479) and the PUREX Operations Training Manual (RHO-MA-228). In addition, a brief overview is provided of the PUREX process including feed preparation, solvent extraction, solvent treatment, acid recovery, and waste handling steps.

2.1 Overall Description

The PUREX Plant, located in the 200-East Area of the Hanford Site, is currently operated by WHC under the direction of DOE. An overhead photograph of the PUREX Plant is provided in Figure 2.1. PUREX was designed and constructed to provide supplemental fuel reprocessing capability to separate plutonium and uranium products from irradiated fuel. The PUREX Plant was the last, and by far the largest, of the five reprocessing plants built at Hanford during the 1940s and 1950s. Although it was not the first to use the "PUREX" process (Savannah River facilities were the first large-scale PUREX process facilities), the PUREX Plant was the first to use pulse columns in the chemical separations area. PUREX is a good example of a large, flexible chemical reprocessing plant with high capacity and which operated reliably for several decades. The present status of PUREX as well as its extensive history makes it an ideal laboratory to investigate the implementation of international inspections.

The PUREX process was developed at Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee, and was an improvement over reduction oxidation (REDOX) an earlier process used previously at Hanford. PUREX used a recoverable salting agent resulting in substantial reductions in unit costs and waste volumes. The PUREX Plant and process were designed to reprocess aluminum-clad uranium metal fuel to recover weapons-grade plutonium and depleted uranium, but was modified to reprocess zirconium alloy (zircaloy) clad fuel from N Reactor to recover fuels-grade plutonium, slightly enriched uranium, and neptunium.

The original plans for the plant were developed during the Korean War when plutonium production requirements were in excess of current capacity. Planning criteria determined that a new reprocessing plant with an initial capacity of 200 metric tons (MT) of fuel per month (about 2000 MT/year allowing for shutdown) was necessary to meet military plutonium requirements and to handle the output of the last two large single-pass production reactors (KE and KW). In addition, the plant would be designed to have capacity expandable up to 400 MT/month with process and/or equipment changes.

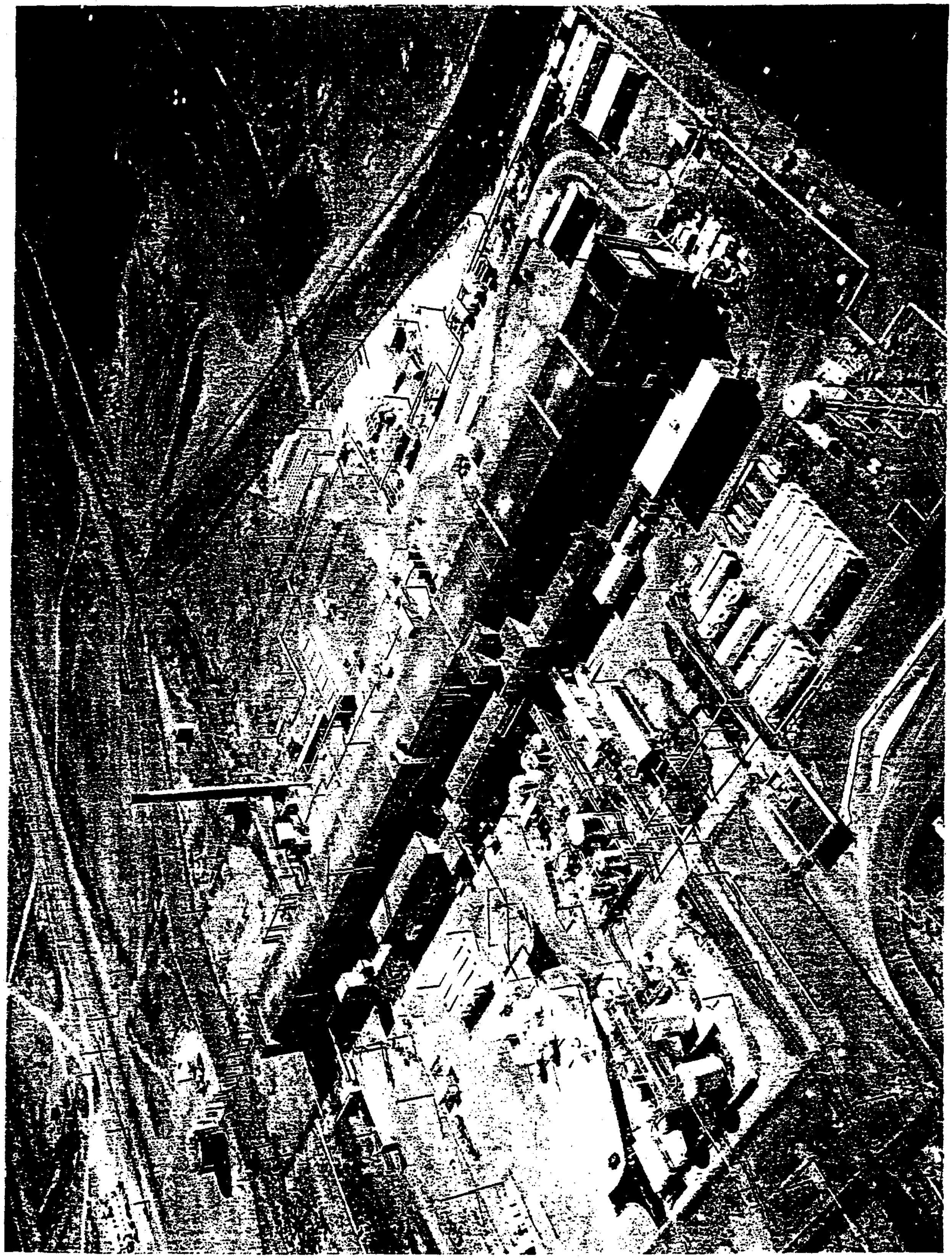


Figure 2.1. Overhead View of the PUREX Plant

Design engineering began in July 1952, construction began in April 1953, and the plant was essentially complete by April 1955. Cold runs (with unirradiated fuel) began later that year and hot processing (radioactive fuel) began in January 1956. The first year of PUREX operations demonstrated a capacity well in excess of design requirements. During 1956 actual production was over 2500 MT which increased to nearly 4400 MT in 1957. During the next several years, capacity continued to increase, with actual throughput over 6200 MT in 1960. Due to the large capacity and economic operation, plans to renovate B-Plant and T-Plant (the first two reprocessing plants dating from the Manhattan Project) were abandoned. Nearly all of the Hanford-generated irradiated fuel (aluminum-clad uranium metal) was subsequently sent through PUREX (REDOX plant continued to process the slightly enriched uranium through 1966).

Since the PUREX Plant began operations, PUREX has reprocessed a variety of fuels. The fuel enrichments have varied from 0.72% to 2.1% ^{235}U; fuel exposures have varied from 300 to ~3000 MWd/t U (megawatt days per ton of uranium); and cooling times have varied from 120 days to 7 years. Both aluminum-clad and zirconium-clad fuels have been processed at PUREX. The types of fuels processed include uranium metal, uranium and plutonium oxides, and thoria targets. Operations improvements were made to increase production rates, provide a diverse capability to handle various fuel types, provide higher quality products, decrease environmental releases, and improve the safety of the operation.

As the single-pass reactors were shut down in the late 1960s and early 1970s, plant modifications were made that would allow processing of the zirconium-clad N Reactor fuel and other fuel types. Improvements were made while the plant was on standby from September 1972 to October 1983. The plant was again placed on standby in October 1990, and a final closure order was issued in December 1992. The plant is currently in a transition phase to a "decontamination and decommissioning (D&D) ready" state, at which time it will be periodically evaluated to determine when final D&D will begin. During this transition, chemicals and most radioactive materials are being removed. Major pieces of equipment are not being removed; however, some equipment is being disconnected.

The PUREX Plant is a complex of several buildings and support facilities. This chapter presents a general description of the major features of the structural components constituting the PUREX Plant with an emphasis on those related to international safeguards issues. A cross section of the PUREX Plant is provided in Figure 2.2; this can be compared to the PUREX Area Plot Plan, Figure 2.3. Additional information on PUREX support structures is available in the Design Information Questionnaire found in Volume 2, Appendix A, Question 13.

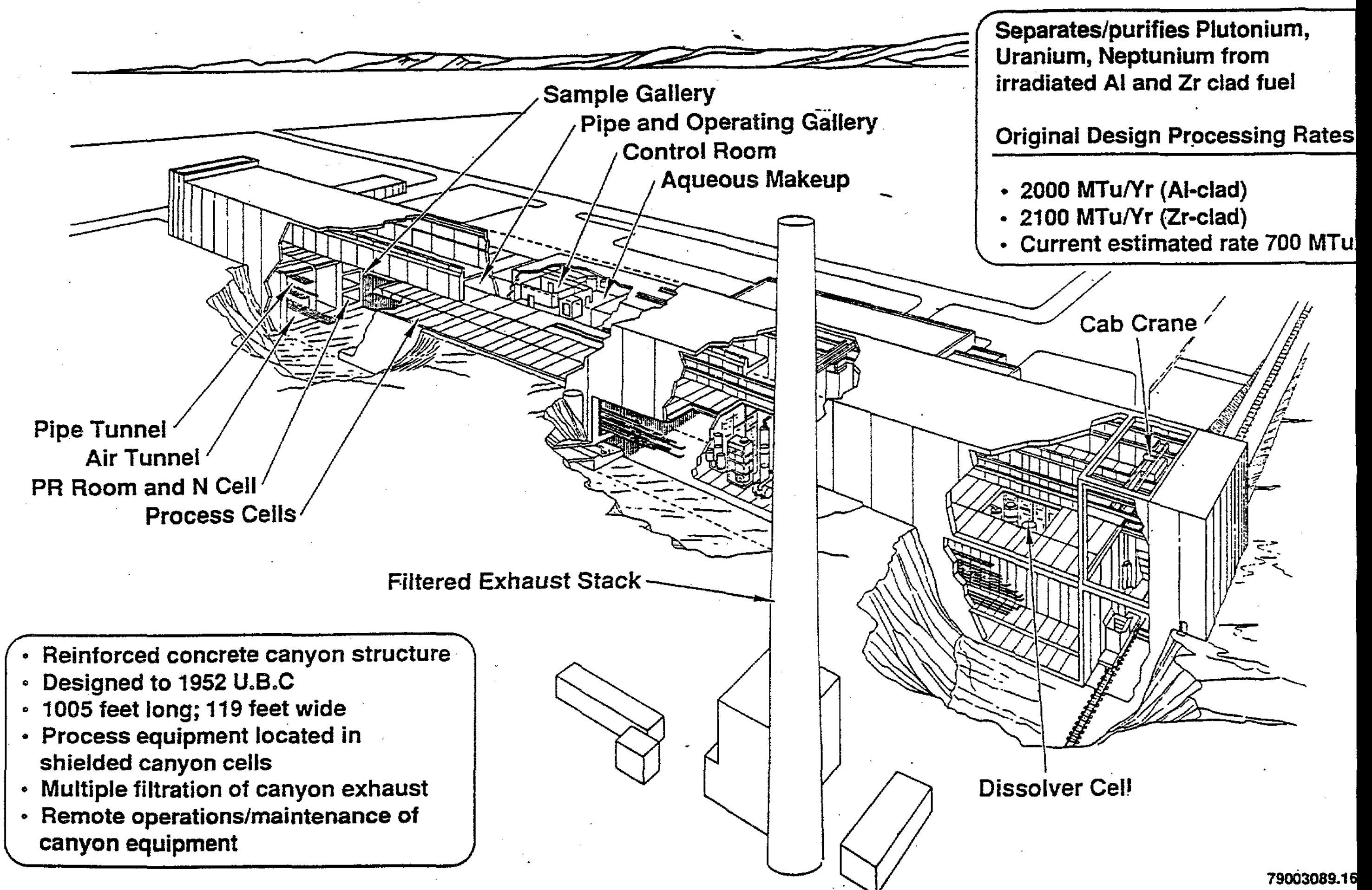


Figure 2.2. Purex Plant Cross Section

1. 275-EA Warehouse
2. CSL PIT
3. 295-AC CSL (Chem. Sewer Line)
4. 206-A Fractionator
5. Laboratory Sample Receiving Dock
6. 203-A UNH Pump House/Control Room
7. PR-Dock
8. 295-AB PDD (Process Distillate Discharge)
9. A-4 PIT/PDD PIT
10. 213-A Reg Maint. Workshop
11. 291-AB Sample Shack
12. Shielded Valve PIT
13. 291-AC Instr. Shack
14. 291-AG Instr. Shack
15. 291-AJ Instr. Shack
16. 291-AE #4 Filter Bldg.
17. 295-AA SCD (Steam Condensate Discharge)
18. 291-AD Ammonia Offgas Filter Bldg.
19. 291-AH Ammonia Offgas Sampler Bldg.
20. 212-A Load Out
21. 294-A Instr. Shack
22. 293-A Dissolver Offgas Bldg.
23. 292-AB Main Stack Bldg.
24. 295-A ASD (Ammonia Scrubber Discharge)
25. 201-A Pump PIT
26. 295-AD CWL (Cooling Water Line)
27. BT2 Exhauster Area

K = Kaiser Related Facilities

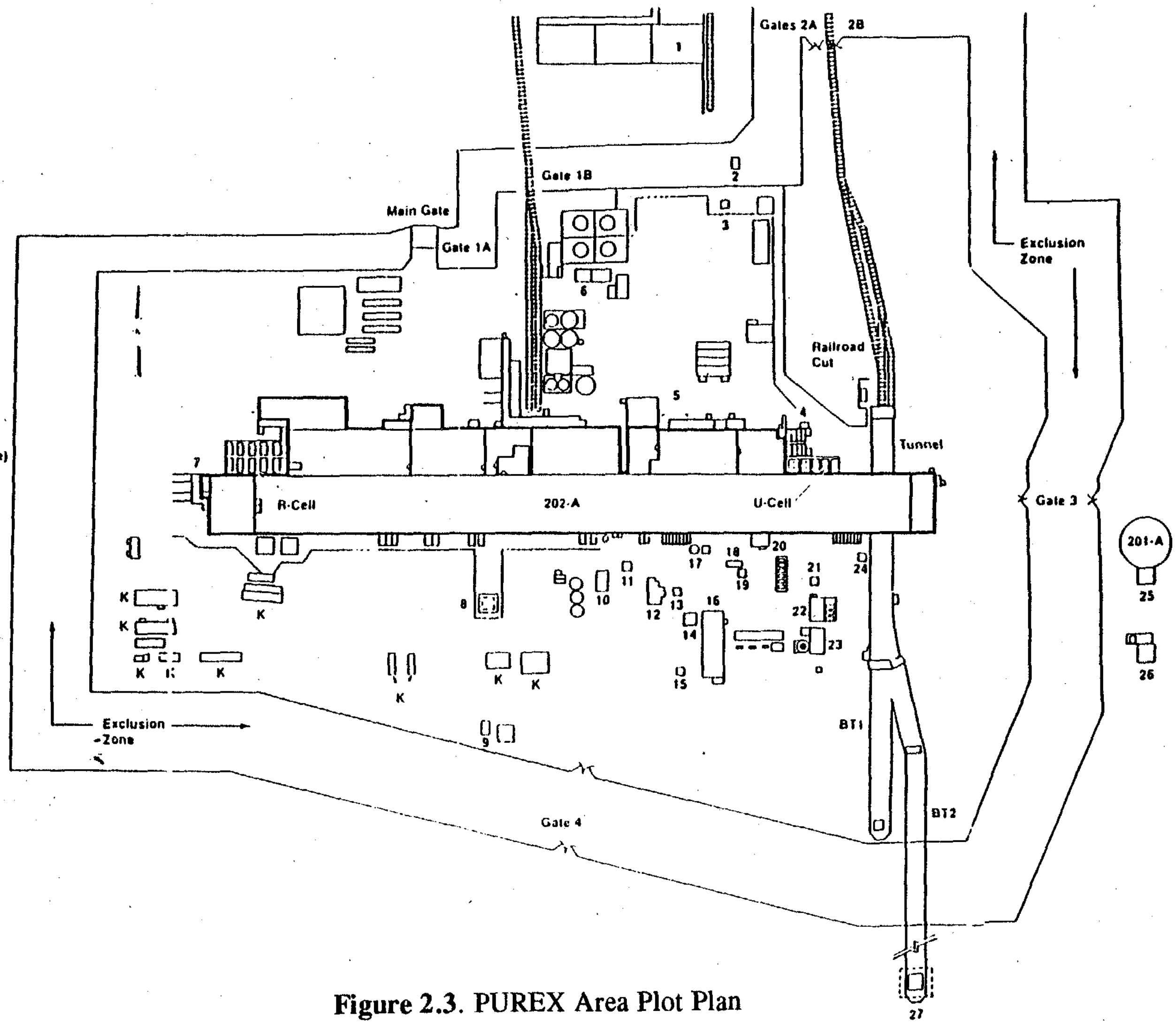


Figure 2.3. PUREX Area Plot Plan

2.2 PUREX Processing Building (202-A)

The 202-A Building, in which the fuels are reprocessed, is a reinforced concrete structure 1005 feet (ft) long, 119 ft wide at its maximum, and 100 ft high, with about 40 ft of this height below grade. The building consists of three main structural components:

1. Canyon--a concrete canyon in which the equipment for radioactive processing is contained in cells below grade

2. Galleries--pipe and operating (P&O), sample, and storage galleries

3. Annex--houses offices, process control rooms, laboratories, and the building services.

The portion of the canyon below grade is subdivided into a row of process equipment cells paralleled by a ventilation air tunnel and pipe tunnel through which intercell solution transfers are made. The air tunnel exhausts the ventilation air from the cells to the main ventilation filters and stack.

Running nearly the full length of the canyon building, above the cells and pipe trench, is a crane-way for three gantry-type maintenance cranes that are used to handle cell cover blocks, remotely remove and replace process cell equipment, and charge irradiated fuel into the dissolvers. The galleries contain service piping to the cells, samplers for obtaining process samples, and electrical switchgear. The service section next to the galleries consists of two separate annexes. The larger annex contains the maintenance shops, offices, lunchroom, locker room, radiation zone entry lobby (SWP lobby), blower room, switchgear room, compressor room, central control room, and the aqueous makeup (AMU) area. The smaller annex contains the Analytical Laboratory, the Headend Control Room, and a switchgear room. These general features are illustrated in Figure 2.4.

2.2.1 Canyon

The canyon contains a single row of 12 process cells, with an overall length of 813 ft. The cells run east and west and each cell is 14 ft wide and 39.5 ft deep; lengths of the cells vary depending on function. In Cells A, B, and C (the first three cells from east to west) fuels are chemically declad and dissolved. These cells are essentially identical in function and equipment content. In addition to a dissolver, each cell contains dissolver off-gas (DOG) treatment equipment, including a downdraft condenser, ammonia scrubber and absorber, steam and electric heaters, silver reactor, and filter.

Cells D and E are used for preparation of the metal solution feed for the solvent extraction columns. Also, in E cell, the coating waste is centrifuged and reacted with caustic prior to transfer to underground storage (UGS). The centrifuge cake is processed and dissolved to recover uranium and plutonium, and the off-gas from the caustic reaction is water scrubbed to remove ammonia.

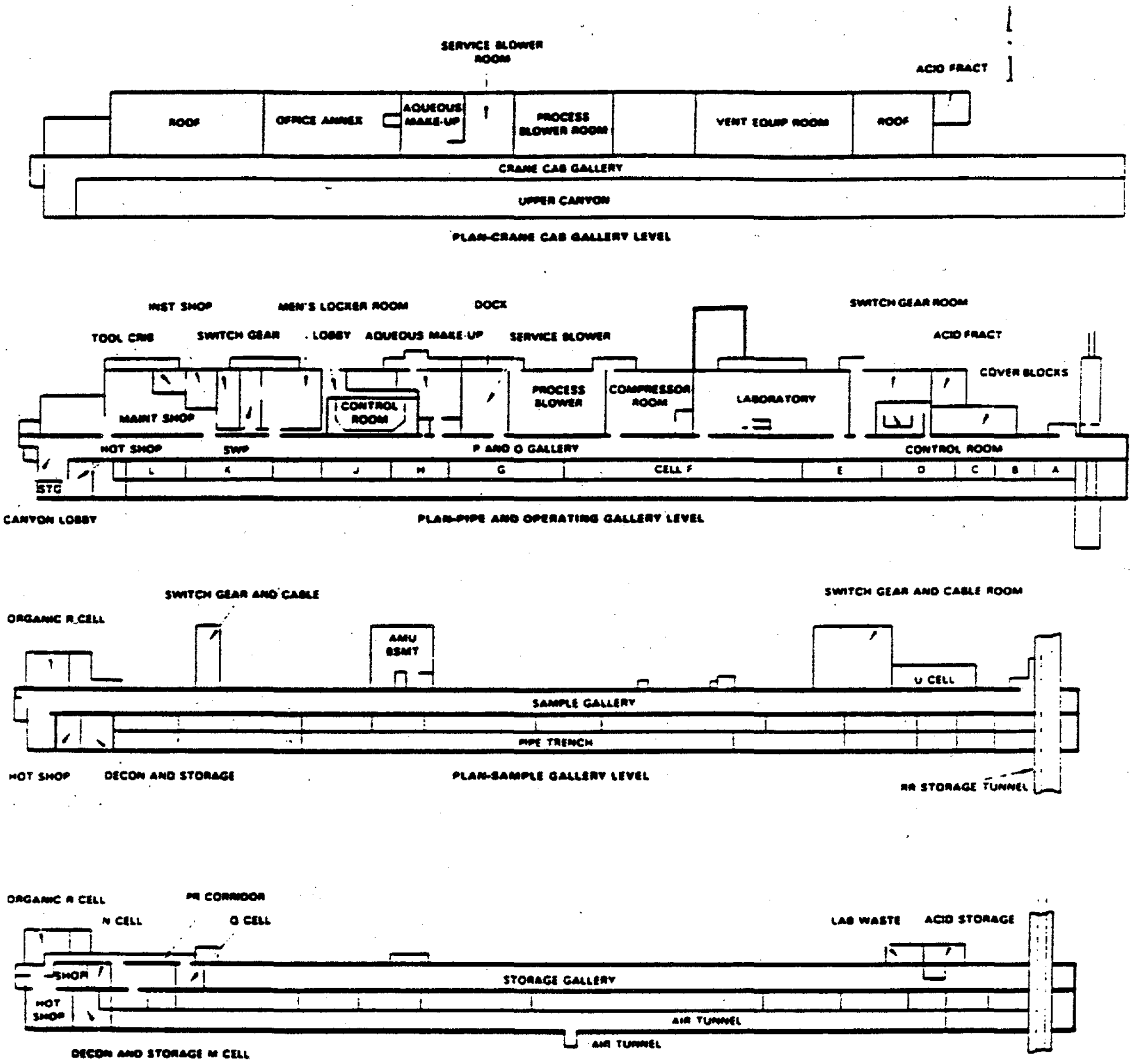


Figure 2.4. Plan Views of the 202-A Building

F Cell is used for the recovery of nitric acid used in the process, for treatment of the aqueous high-level waste from the fuel processing steps, and for concentrating ammonia scrubber wastes from the dissolver and E Cell.

In G Cell, all the spent process organic solvent, except that from the Final Uranium Cycle, is washed and prepared for reuse.The solvent extraction processing steps are carried out in H, J, K, and L Cells, which contain the tanks, pulsed extraction columns, concentrators, and auxiliaries needed in the continuous countercurrent aqueous-organic stream flow operations.

The pool cell (for storing contaminated equipment), M Cell (for equipment decontamination and plutonium nitrate storage), and the "hot" maintenance shop are located on the west end of the cell row at cell floor level. M Cell is separated from the hot shop by a 3-ft-thick concrete wall.

A 6-ft-thick concrete wall separates the cells from the galleries. The wall above the cells is 4 ft thick, and the extension of this wall upward forms a shielded cabway (Crane Cab Gallery) for two gantry-type, 40-ton capacity cranes. A master 40-ton capacity crane that may be operated either directly or remotely is located on rails above the cranes. Crane maintenance platforms are located at the crane cab level on both east and west ends of the craneway.

At the east end of the canyon is the basin where irradiated fuel may be stored either dry or under water. Casks containing fuel are brought into the canyon through a railroad tunnel running north and south on the west side of the storage basin. The tunnel, which is also the route for removing and delivering process equipment, connects to a railroad spur outside the 202-A Building.

The pipe tunnel, or "hot" pipe trench, contains an array of pipe headers connecting the cells permitting intercell solution transfers. The hot pipe trench also contains piping for transfers to and from cells to facilities external to PUREX. The pipe trench, which parallels the cells, is 30 ft deep and 12 ft wide at the top. It narrows to 11 ft as the wall between the cells and pipe trench widens from 1.5 ft to 2.5 ft. The wall between the cells and trench supports one edge of the 3-ft-thick concrete blocks covering the cells and the 2.5-ft-thick blocks covering the trench.

The air tunnel directly under the pipe trench is 11 ft wide and 7.5 ft high. Through this tunnel, air from the cells is drawn to the ventilation exhaust filters and the outside stack. The south wall of the canyon at the air tunnel and pipe trench levels is 5.5 ft thick. From the canyon deck level to the master crane level, the south wall is 4 ft thick and narrows to 2.5 ft from the crane level to the roof. The roof is formed as a concrete beam 2.5 ft thick at the edges and 1 ft thick in the center. No internal trusses support the canyon roof.

Short intracell transfers between adjacent pieces of equipment are made by direct jumper piping connections within the cell; longer transfers require jumpers to the pipe trench wall. The connections are made via the trench piping, which terminates on the trench wall opposite the equipment piece being connected. The pipe trench contains three spare piping systems in addition to the spare process line intended for occasional use. These spare systems are known as General Spare Systems 1, 2, and 3.

System 1 consists of a series of lines bent in semiloops in the pipe trench. The ends of each semiloop penetrate the trench wall and terminate with male connectors inside the cells. Adjacent lines can be connected with short "hairpin" jumpers to accommodate most jet or pump transfers. With System 2, connectors exist on both pipe trench and cell sides of the line penetrations. By installing hairpin jumpers in the trench and cells, liquid transfers can be made as with System 1. System 3 consists of pipe stubs spaced at 40-ft horizontal intervals in the pipe trench. These stubs originate as vertical connectors in the pipe trench and terminate with blanked ends outside the south shield wall of the building. By connecting Systems 2 and 3, it is possible to join canyon vessels to outside facilities.

Washdown nozzles for decontamination are located in the cell walls 5 ft above the cell floors. Specially located nozzles are installed at different levels to aim at equipment with relatively high potentials for contamination. Flows from these special nozzles are controlled individually with controls separate from those of the main washdown nozzles.

Canyon vessels not used for boiling or denitration are vented to the vessel vent header running the length of the pipe trench. Vacuum on this header is maintained by a jet in F Cell. Boilup and denitration tanks for acid recovery and waste treatment in F Cell are exhausted through a condenser to the Process Vent System. All other tanks used for boiling solutions in the canyon are vented through condensers to the condenser vent header in the pipe trench. Vacuum on both boilup vent systems is maintained by separate jets located in F Cell. The jets on all three vent systems discharge to a condenser in F Cell where condensate is removed from the vent stream. Noncondensables are routed from the condenser through a heater, a silver reactor, and a filter, all in F Cell before being discharged to the air tunnel. Vacuum on all of the vent systems is regulated by air bleed.

2.2.2 Galleries

The storage, sample, pipe and operating (P&O), and crane cab galleries parallel the north wall of the canyon and are located at different levels, one above the other. The Storage Gallery is 19.5 ft wide and has a floor area of 15,900 ft^2, while the P&O, crane cab, and the sample galleries are 20 ft wide and have floor areas of about 19,000 ft^2 each. The gallery locations with respect to the rest of the 202-A Building are shown in Figure 2.4.

The storage gallery is used primarily for storage of dry chemicals and spare equipment. A 5-ton capacity elevator serves the Storage and P&O Galleries, as well as the four floors of the AMU area.

The sample gallery contains remote equipment for taking process solution samples from the cell equipment. Samples are sent on a dumbwaiter to the sample receiving room in the Analytical Laboratory. A shielded pipe chase behind the remote sampler boxes contains headers for recovered nitric acid, organic solvent, sampler drains, and sampler lines to and from cell equipment. Spares for the acid and solvent headers are also installed in the pipe chase. Unshielded lines bearing recovered solvent and process condensate are located on the wall above the pipe chase.

The pipe and operating (P&O) gallery (see Figure 2.5) provides space for the electrical switchgear, instrument racks, nonradioactive piping, and associated gang valves that serve the in-cell equipment. Since most of the valves are controlled from the control panels, only a few operations are required in the gallery. A few batch chemical addition tanks are located in this gallery.

Shortly after initial plant startup, a wall about 9 ft high was installed across the gallery opposite the middle of K Cell after the gallery west of the wall location had become contaminated. After cleanup, the wall was put in to serve as a ventilation barrier in case this area became contaminated in the future. Protective special work permit (SWP) clothing is required to be worn for entry to the area west of the wall, now known as the White Room.

The crane cab gallery is located above the P&O Gallery, and is the corridor of travel for the two master crane cabs. The south wall of the gallery shields the cabs and crane operators from canyon radiation. Crane maintenance platforms are located at both ends of the gallery.

2.2.3 Product Removal Room

The Product Removal Room (PR Room), which is used for filling shipping containers and for sampling plutonium nitrate prior to transfer to the Plutonium Oxide Production Facility, is located at the west end of the Storage Gallery adjacent to L Cell. The PR Room is 41 ft long and 19.5 ft wide and contains a plutonium nitrate sampler tank (TK-L9) and a receiver tank (TK-L11) used to collect various plutonium solutions for rework. The tanks are shielded from the working area by concrete walls.

The loadout head tank (TK-L14) and associated equipment are located inside the L-14 Glovebox. The glovebox is constructed of stainless steel with laminated safety glass windows. The loadout glovebox provides the capability to transfer plutonium nitrate to and from PR cans and FL-10-1 containers.

A doorway from the PR Room provides access to L Cell for contact maintenance of the Third Plutonium Cycle equipment. The room layout is shown in Volume 2, Appendix A, page A.14.

2.2.4 Q Cell

The Neptunium Purification Facility, known as Q Cell, is located in the west end of the Storage Gallery adjacent to the east wall of the PR Room. Q Cell includes a control room, a shielded hot cell, a maintenance room with shielded access gloveboxes, a product loadout room, and an AMU area. The AMU area is on a separate floor above the control room. Entry to Q Cell is from the radiation zone entry lobby.

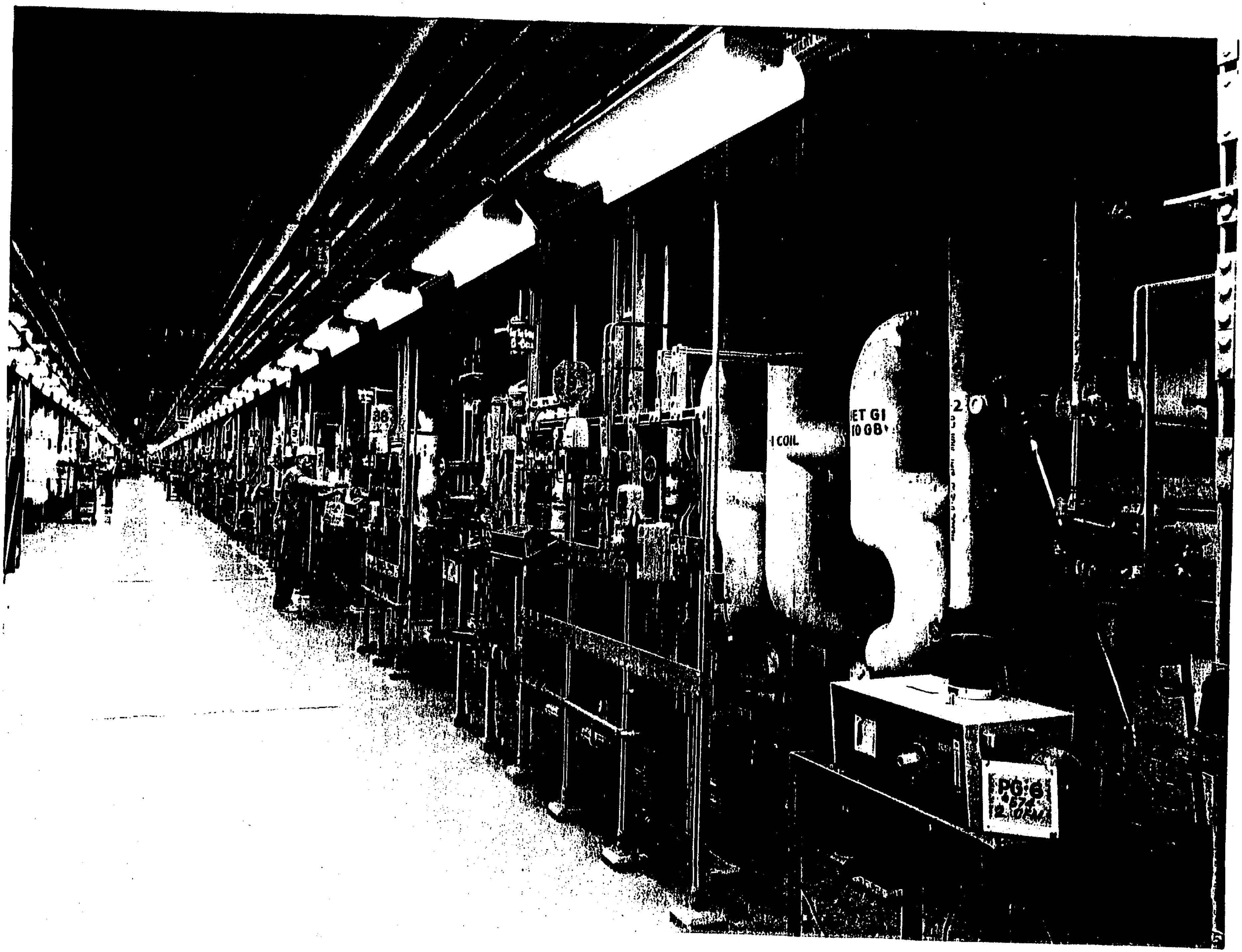


Figure 2.5. PUREX Pipe and Operating (P&O) Gallery

2.2.5 N Cell

N Cell is located in the Storage Gallery west of the PR Room. This cell was formerly used for plutonium product purification by ion exchange. The ion exchange unit was replaced by the L Cell Third Plutonium Cycle. N Cell has been modified for use as a facility for the preparation of plutonium oxide powder.

2.2.6 R Cell

The equipment in R Cell is used to wash the organic waste stream from the Final Uranium Cycle and prepare it for reuse. R Cell, also designated as the "cold" solvent building (276-A), is located at the northwest corner of the 202-A Building.

2.2.7 U Cell

U Cell, the acid storage vault, is located along the north wall of the 202-A Building, just east of the Headend Control Room. It is constructed below grade with removable concrete blocks 1 ft above grade forming the roof. The cell has reinforced concrete walls 1.5 ft thick, 76 ft long, 20 ft wide, and 35 ft deep. It contains four large tanks; two for collecting and sampling low-activity laboratory waste, and two for storage of recovered nitric acid that is returned to the process through a header in the Sample Gallery. Entry to the cell is from the Sample Gallery through an electrically operated door and air lock or through a hatchway at cover block level.

2.3 PUREX Plant Function

As discussed in Section 2.1, the PUREX Plant and process were designed to reprocess aluminum-clad uranium metal fuel to recover weapons-grade plutonium and depleted uranium, but was modified to reprocess zirconium alloy (zircaloy) clad fuel from N Reactor to recover fuels-grade plutonium, slightly enriched uranium, and neptunium.

2.3.1 Feed Material

For the purpose of this exercise, the feed material was assumed to be N Reactor fuel elements made of uranium metal with zircaloy cladding. The fuel elements, of a tube-in-tube design, are of two enrichments: 1) both inner and outer tubes 0.947% ^{235}U (Mark IV), and 2) the inner tube 0.947% ^{235}U and the outer tube 1.25% ^{235}U (Mark IA or "spike fuel"). The outer element is 2.4 inches in diameter and from approximately 15 to 26 inches in length (most being approximately 26 inches). The fuel elements are black due to the formation of zirconium oxide on the surface during fabrication and irradiation in the reactor. After exposure of ~1000 to 3000 MWd/t the fuel is discharged from N Reactor; stored in the N Reactor, K-East, or K-West Basins; cooled 180 days or longer; and shipped in cask cars to PUREX for processing.

2.3.2 Products

The plutonium product of the PUREX Plant can be a nitrate solution containing approximately 350 g Pu/L and approximately 7$\underline{M}$ HNO_3. The uranium content is <2000 parts per million parts (ppmp) plutonium. It can also be PuO_2.

The uranium product of the PUREX Plant is a concentrated uranyl nitrate solution containing approximately 4.2 lb U/gal and <0.1 lb HNO_3/gal. The plutonium content is <10 parts per billion parts (ppbp) uranium. The maximum allowable fission product concentrations are as follows:

^{95}Zr-Nb	10 μCi/lb U
^{103}Ru and ^{106}Ru-Rh	20 μCi/lb U
All others, excluding ^{99}Tc	20 μCi/lb U

The maximum allowable concentrations of other impurities are:

iron	40 ppmp U
chromium	16 ppmp U
nickel	12 ppmp U
sodium	20 ppmp U
organic	Nondetectable

The uranium product solution is shipped to the 244-U Building in the 200 West Area for calcination to uranium trioxide. The product is then shipped offsite for enrichment with ^{235}U and reuse as nuclear fuel.

The PUREX Plant neptunium product is a nitrate solution containing approximately 40 g Np/L, and >0.3$\underline{M}$ HNO_3. At these conditions, the neptunium valence is stabilized at the +5 state. Maximum allowable actinide concentrations are:

plutonium	1.0 wt% Np
uranium	1.0 wt% Np
thorium	3.0 wt% Np
^{234}Th	25 μCi/g Np

Allowable ^{95}Zr-Nb and ruthenium total concentration is 25 μCi/g neptunium. While awaiting shipment, the neptunium solution is stored in canyon vessel TK-J2. This tank holds ~1,200 gal, which is equivalent to the total volume of neptunium produced during many years of PUREX operation. The neptunium solution formerly in storage has recently been disposed of as waste to UGS.

2.3.3 Plant Processing Rate

The PUREX Plant processes N Reactor fuel at a nominal rate of 10 tons of uranium per day through the solvent extraction system on a campaign basis. The limiting parts of the process are the coating removal and coating waste treatment steps in the headend. During a campaign, the batch-operated head-end is started to build up a feed inventory of ~35 tons of uranium as UNH solution in the solvent extraction feed tanks. The solvent extraction system is then started while the headend is operated to provide a continuous feed supply. The solvent extraction system, consisting of 14 pulse columns, various feed tanks, pumps, concentrators, and associated equipment, operates as a continuous process. The plutonium and neptunium processing rates are dependent on the uranium processing rate and on the plutonium and neptunium concentrations in irradiated fuel elements, which depend on the irradiation history of the fuel elements. The neptunium content in the fuel is also dependent on the ^{236}U content of the uranium used in making the fuel elements. Approximate plutonium and neptunium processing rates at various irradiation levels (MWd/t) of N Reactor fuel, corresponding to a uranium processing rate of 10 tons per day, are tabulated in Table 2.1 for 0.947% and 1.15% ^{235}U enriched fuel.

Table 2.1. Approximate Plutonium and Neptunium Processing Rates

N Reactor Irradiation Level (MWd/t)	^{240}Pu (%)[a]	Neptunium (g)[b]	Plutonium (kg)[b]
0.947% ^{235}U enriched 2,435	12	~300	18.3
1,670	9	~220	13.5
1,030	6	~140	9.0
1.15% ^{235}U enriched 2,950[c]	12	~280	16.0
2,030	9	~240	14.4
1,280	6	~150	9.8

(a) In total plutonium
(b) Processed per day at 10 tons of uranium per day
(c) Decontaminated uranium solution is blended with this fuel to meet criticality specifications for solvent extraction processing.

2.4 PUREX Process Description

Figure 2.6 is a process flow diagram of the PUREX Process, including feed preparation, solvent extraction, solvent treatment, acid recovery, and waste handling steps. Individual parts of the process are discussed in the following subsections.

This flow diagram shows the code letters usually used to identify the main process streams in the PUREX Process. For example, the HAF stream is the uranium-plutonium feed stream to the HA Column, the first solvent extraction column in the process. The first two letters (or numeral plus one or two letters) in this code identify the equipment piece or cycle (the HA Column in the preceding example). The last letter (or two-letter group) identifies the stream. Influent stream abbreviations end in F, X, R, S, or IS, which stand for feed (uranium, plutonium, or neptunium), extractant, recycle, scrub, and intermediate scrub, respectively. Effluent stream abbreviations end in P, U, N, W, D, A, or C, which stand for plutonium (or product), uranium, neptunium, waste, distillate, acid, and concentrate, respectively. Effluent streams containing uranium, plutonium, and neptunium end only in P. Thus, the HAP is the effluent stream from the HA Column containing uranium, plutonium, and neptunium.

2.4.1 Feed Preparation

The purpose of the feed preparation process is to prepare a solution from the irradiated fuel elements that is suitable as a feed to the solvent extraction battery. The feed preparation process includes the following steps.

- The Zircaloy jackets are removed by dissolution in a boiling solution of 5.5$\underline{M}$ NH_4F and 0.5$\underline{M}$ NH_4NO_3. The resulting jacket removal waste is processed through a centrifuge to recover small amounts of uranium and plutonium that react with the fluoride during jacket removal. The waste is then treated with caustic to remove ammonia and sent to the 242-A Evaporator for concentration to a slurry acceptable for storage in underground double-shell tanks.

- The slurried centrifuge cake and the declad fuel elements are contacted with potassium hydroxide to convert the fluoride compounds to oxide compounds (metathesis). Most of the fluoride is transferred in the waste from this operation as soluble potassium fluoride, thus minimizing the corrosion rate during cake or uranium metal dissolution and subsequent processing operations.

- The remaining uranium metal and the centrifuge cake containing plutonium, neptunium, and fission products are dissolved in 10.4$\underline{M}$ and 12.2$\underline{M}$ HNO_3, respectively, with sufficient aluminum nitrate to complex any residual fluoride remaining from the metathesis step.

- The dissolver solution is moved to feed tanks where it is sampled for product accountability. High exposure spike fuel is blended with decontaminated uranium solution to meet criticality specifications for processing in the solvent extraction system.

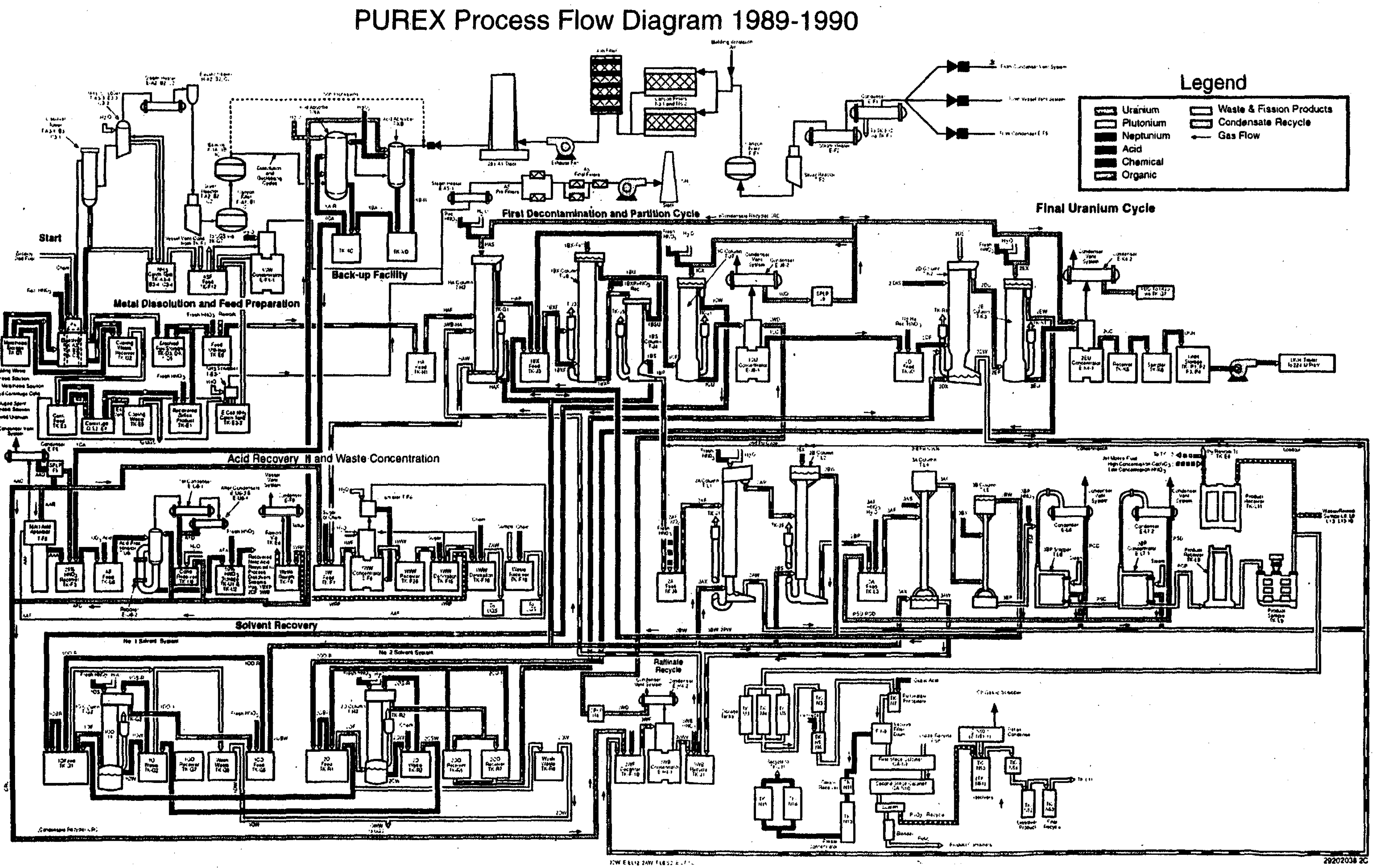


Figure 2.6. Process Flow Diagram of the PUREX Process

2.4.2 Solvent Extraction

Pulsed solvent extraction columns are employed in the PUREX process to effect the decontamination necessary to produce acceptable products. A number of cycles make up the total solvent extraction process as described below.

Codecontamination and Partition Cycle. The Codecontamination and Partition Cycle separates the feed into a fission product-containing aqueous stream (HAW), a uranium and neptunium aqueous stream (ICU), and a plutonium aqueous stream (1BP).

The feed solution (HAF) from the feed preparation section is continuously fed to the intermediate feed point of the HA Column. This feed contains uranium, plutonium, neptunium, fission products, and nitric acid as a salting agent. A countercurrent flow of TBP in a hydrocarbon diluent (HAX) rises through the aqueous phase in the column, and extracts the uranium, plutonium, and neptunium into the solvent phase, but leaves the majority of the radioactive fission products in the aqueous phase. A back-cycle waste stream (3WB), containing some product from other column waste streams and nitric acid, is added to the HA Column just below the feed point to provide most of the salting strength in the column. An aqueous scrub stream (HAS), introduced at the top of the column, further decontaminates the uranium, plutonium, and neptunium by washing fission products back from the solvent phase to the aqueous phase. Uranium is in the +6 valence state, and plutonium is chiefly in the +4 valence state in the HA Column. A small stream of sodium nitrite is added near the bottom of the column to oxidize neptunium to the +6 valence state to effect a more complete extraction into the organic. The organic stream (HAP) containing the uranium, plutonium, and neptunium overflows to the feed tank of the Partition Cycle.

The organic stream is mixed with four organic recycle streams (1BSU, 2BW, 3BW, 2PW) to form the 1BXF feed stream, which is pumped to the bottom of the partitioning column (1BX). An aqueous stream, containing ferrous sulfamate reductant added to the top of the 1BX Column to reduce plutonium to the inextractable +3 valence state, descends through the column and carries the plutonium from the bottom of the 1BX Column to the top of the 1BS Column in the 1BXP stream. The small amount of uranium in this stream is scrubbed out by contacting with organic flowing up through the 1BS Column. The aqueous plutonium stream (1BP) leaves the bottom of the column, then goes to the Second Plutonium Cycle. The organic stream (1BSU) leaving the 1BS Column goes back to the 1BS Column feed tank.

The uranium and neptunium leave the top of the 1BS Column in the organic stream, and go to the bottom of the 1C Column where they are countercurrently stripped into a dilute acid scrub stream (1CX), which is then fed to the 1CU Concentrator where it is concentrated as feed (1UC) for the Final Uranium Cycle.

Final Uranium Cycle. The Final Uranium Cycle completes the decontamination of uranium from neptunium, residual traces of radioactive fission products, and plutonium with uranium from the partition cycle.

Nitric acid and hydrazine are added to the 1UC stream to increase the salting strength and provide a holding reductant (to react with nitrous acid) in the feed (2DF) to the 2D Column. Organic, added to the bottom of the column, extracts uranium from the feed as the organic moves up through the 2D Column, and overflows (2DU) to the 2E Column. A scrub stream (2DIS) containing hydroxylamine nitrate as a reductant, is added to the top of the 2D Column to reduce any plutonium to the inextractable +3 valence state. The column is operated at a high aqueous-to-organic ratio (A/O) to keep the organic saturated with uranium, thus forcing fission products, neptunium, and plutonium to leave in the aqueous 2DW stream enroute to the Backcycle Waste System.

The uranium in the 2DU stream is stripped by a dilute acid aqueous scrub stream (2EX) in the 2E Column, and is then concentrated to the 2EU Concentrator to form the UNH product that is stored in the 203A Tanks prior to shipment to 224-UA Building (UO_3 Plant) for calcination.

Final Plutonium Cycles. Final Plutonium Cycles which are composed of the second and third cycles, complete the decontamination of the plutonium. The aqueous product stream from the 1B Scrub Column (1BP) contains plutonium in the +3 valence state. This plutonium is oxidized to the +4 valence state in TK-J5 (2AF) by the addition of sodium nitrite and sometimes, nitric acid. The oxidized solution (2AF) is fed to the center feed point of the 2A Column. In the bottom section of the column, the plutonium is extracted into a TBP-NPH solution (2AX). In the upper portion of the column, the organic stream is contacted with nitric acid solution (2AS), which is fed to the top of the column to scrub fission products from the plutonium. The organic solution cascades to the bottom of the 2B Column where the plutonium is transferred back into the aqueous phase by countercurrent extraction with an aqueous strip solution (2BX) containing hydroxylamine nitrate and hydrazine as a reductant and holding reductant, respectively. A second organic stream (2BS) is added near the bottom of the column to provide additional uranium decontamination.

The aqueous plutonium product from the 2B Column (2BP) flows to the 3A Column feed tank (TK-L3) where additional nitric acid is added to form the (3AF) feed stream, which is introduced to the midpoint of the 3A Column. Organic is added to the bottom, and extracts plutonium from the feed as it moves up through the 3A Column to form the product stream (3AP). A scrub stream (3AS) is added to the top of the column to scrub fission products from the organic, and flows countercurrently to form the 3AW stream.

The 3AP stream containing the plutonium goes to the bottom of the 3B Column, where it is stripped back into an aqueous dilute nitric scrub stream (3BX). The plutonium nitrate leaves the bottom of the 3B Column as the 3BP stream. Organic wastes from the Final Plutonium Cycles (2BW, 3BW) are recycled to the 1BX feed tank.

The 3BP stream is butted with nitric acid to prevent plutonium polymerization during subsequent process steps. The plutonium nitrate is then stripped of organic in the 3BP Stripper and concentrated to its PUREX product form in the 3BP Concentrator. Process condensates from the 3BP Stripper-Concentrator are routed to the Third Plutonium Cycle Feed tank for rework.

Final Neptunium Cycle. Neptunium is collected from the Backcycle Waste System on a batch basis and decontaminated in two solvent extraction columns and an ion exchange column. Collection of neptunium (operating Phase I) is started by diverting part of the backcycle waste concentrate (3WB) to the midpoint of the 2N Column. A scrub stream (2NS) containing ferrous sulfamate reductant is then introduced at the top of the column and an organic stream (2NX) is introduced at the bottom. These streams flow countercurrently through the column while the neptunium is reduced to the extractable +4 valence state and the plutonium is reduced to the inextractable +3 valence state.

The neptunium leaves the top of the 2N Column in the organic 2NP stream, enters the 2P Column where it is stripped back into dilute nitric acid and returned as 2PN-R to the 2N Column feed tank. The major portion of the plutonium and fission products exit the 2N Column in 2NW, which is routed to the Backcycle Waste System.

When a batch of neptunium (2,000 g) is collected, the feed from the backcycle waste to the 2PN feed tank is replaced with nitric acid and the two columns are operated as Phase II for neptunium decontamination. The 2NS and 2PX scrub stream flow rates are increased minimally, and the columns are operated until the fission product and plutonium content of the 2PN-R is reduced to an acceptable intermediate level. Most of the uranium exits the system in the organic stream leaving the 2P Column (2PW) to the 1BX feed tank during Phases I and II.

When the collected neptunium is sufficiently decontaminated, Phase III is started to remove neptunium. During Phase III, the scrub stream flow rates are reduced to a minimum, nitric acid is used as feed to the 2N Column, and the 2PN-R is routed either to TK-J2 or to Q Cell as 2PN. In TK-J2, the 2PN neptunium solution can be concentrated and stored awaiting final disposition. In Q Cell, the 2PN is concentrated and loaded onto an ion exchange column that contains Amberlite IRA-99 ion exchange resin. The column is scrubbed with several streams to attain final fission product and plutonium decontamination and is eluted with dilute nitric acid giving a product solution containing 40 g Np/L. Loading and scrub waste streams are collected, sampled, and routed to the Backcycle Waste System or to underground storage, depending on product content. The forecut and aftercut from the elution step are recycled to the 2PN Stripper-Concentrator.

2.4.3 Solvent Treatment

The solvent treatment section of the plant reclaims the combined TBP and NPH for recycle to the process. Two solvent treatment systems are employed. Solvent Treatment System No. 1 (Solvent System 1) processes the solvent from all of the solvent extraction cycles, except for the Final Uranium Cycle, which is processed by Solvent Treatment System No. 2 (Solvent System 2).

Solvent System 1 receives organic (1CW) from the 1C Column. The organic is contacted by passing through packing in TK-G1 concurrent with a solution of sodium carbonate and potassium permanganate to remove fission products and degraded organic. The organic is then scrubbed with dilute nitric acid in the 10 Column and returned to the process as HAX, 1BS, 2AX, 2BS, 3AX, and 2NX. The spent carbonate-permanganate solution is sent to UGS.

Solvent System 2 receives organic (2EW) from the 2E Column. This liquid is treated similarly as in Solvent System 1 and returned to the process as DX. Since there are fewer fission products and degradation products associated with this solvent, the spent aqueous wash solutions from this system are usually transferred to Solvent System 1 for reuse.

2.4.4 Backcycle Waste System

Aqueous waste streams containing nitric acid, uranium, plutonium, neptunium, fission products from various columns in the plant, and condensates from some plant condensers, are collected and concentrated in the Backcycle Waste System. Streams entering the Backcycle Waste System include: 2DW, 2AW, 3AW, and 2NW; T-L6 and E-L7-1 tube bundle stream condensates; and condensates from Condensers E-F5, E-U6, E-L12, and E-Q9. The 3AW stream is fed to the backcycle waste concentrator receiver tank, while all other streams are fed to the concentrator feed tank. Most of the concentrated waste (3WB) containing high acid concentration is fed to the HA Column to provide salting strength and for product recovery. The remaining 3WB is fed to the Final Neptunium Cycle for collection of neptunium.

2.4.5 Acid Recovery and Waste Treatment

The principal aqueous process wastes from the PUREX Plant receive the following treatment:

- Highly radioactive waste (HAW) containing nitric acid is concentrated, with simultaneous recovery of the acid. The concentrate is denitrated with sugar with partial recovery of the NO_x gases produced. The denitrated solution is treated with caustic and sodium nitrite and sent to UGS.

- Spent organic wash solution and sump wastes are made alkaline and transferred to UGS.

- Ammonia scrubber waste collected during coating dissolution and coating waste treatment is transferred to UGS.

- Process condensates from high-level waste concentration, backcycle waste concentration, acid fractionation, and partition cycle concentration are recycled as scrub streams to various columns instead of being discharged to cribs (covered, rock-filled trenches). Condensate from the Final Uranium Cycle is sent to UGS.

- Recovery of nitric acid from dissolver off-gas NO_x is accomplished by two acid absorbers (T-XA and T-XB). This dilute nitric stream is routed to the vacuum fractionator (T-U6) with the dilute acid recovered from the high-level radioactive waste. These streams plus nitric acid recovered at the UO_3 Plant are processed in the vacuum fractionator to produce a 10.4<u>M</u> acid, which is then reused in the plant.

3.0 Results

In support of the U.S. cutoff negotiating strategy and in preparation for U.S. cutoff treaty inspections, DOE has undertaken the use of old DOE SNM production facilities as verification testbeds for assessing issues and concepts. The March 1994 PUREX Exercise was one such exercise for determining the technical challenges and related issues found in monitoring an old fuel reprocessing facility. An assumption was made that the IAEA will likely play an important part in implementing a cutoff treaty and that alternative safeguards measures might be developed and specifically negotiated. During the PUREX Exercise, two safeguards scenarios were tested--one using traditional safeguards and the other using alternative safeguard measures. Alternative safeguards measures were also combined and the schema were evaluated considering implementation effectiveness, intrusiveness, and cost.

Chapter 3.0 of this report provides a discussion of various safeguards measures that could be applied to an old reprocessing plant such as PUREX. In Section 3.1 evaluates the application of traditional IAEA safeguards measures; Section 3.2 discusses the application of alternative safeguards measures, and Section 3.3 reviews the application of combinations of alternative measures. Finally, Section 3.4 assesses any unresolved issues and problems that still need to be addressed.

3.1 Traditional IAEA Safeguards Measures

The first PUREX Exercise scenario assumed traditional IAEA safeguards measures. According to the May 1984 publication of IAEA Safeguards, Safeguards Techniques and Equipment, traditional IAEA safeguards consist of two complimentary activities: 1) material accountancy and 2) containment and surveillance. Below is the definition in the IAEA publication:

> The basic verification measure used by the IAEA is nuclear material accountancy, with containment and surveillance as important complementary measures. If nuclear material accountancy is to be effective, inspectors have to make independent measurements so as to verify the figures presented in the accounts. These measurements are done either using destructive analysis techniques (chemical measurements) or non-destructive analysis primarily using measurements of gamma and neutron activity.
>
> Containment and surveillance (C/S) techniques are applied to economize on the safeguards inspection effort (e.g., by reducing the frequency of accountancy verification) and also to give assurance that nuclear material follows predetermined routes, that the integrity of its containment remains unimpaired, and that the material is accounted for at the correct measurement points. A variety of techniques are applied, with optical surveillance and sealing measures used most often. These measures serve to back up nuclear materials accountancy by providing the means by which access to nuclear material can be controlled and any undeclared movement of nuclear material detected.

An analysis of traditional IAEA safeguards measures is provided below. Additional information on the application of traditional IAEA safeguards can be found in Volume 3 of this report, Appendices D, E, and F. For the PUREX Exercise, the Inspection Team based the Inspection Plan on INFIRC/153 safeguards, 1991-1995 Criteria.

Design Verification: Very detailed facility design data (especially with respect to measurements) are necessary to plan and evaluate monitoring approaches and effectiveness. The details of plant operation and design are important. From the inspector's standpoint, much needs to be done before the plant is entered for the first time. U.S. weapons-program reprocessing facilities are much larger than facilities with which the IAEA has had experience (although they are comparable in size to THORP in terms of plutonium throughput). Verifying the design of a large, complex, highly radioactive facility such as PUREX is extremely difficult. It was estimated that 10 years were spent verifying the Tokai facility using periodic inspections as the plant construction progressed. Many inspection activities can be performed on a plant under construction to verify design that can not be carried out in an already constructed, contaminated plant. There are few as-built piping drawings that are completely accurate. It is impossible to chase down piping arrangements except by an extensive sampling program. Photographs could be used to verify that no additional changes have been made. However, there are many possible flow routes that are not visible (flows to tanks, cribs, various alternate routes) which could be used in an emergency or to divert.

The ability to easily and rapidly reconfigure PUREX requires additional measures, e.g., video cameras, crane monitors, radiation monitors. C/S measures can provide some confidence regarding changes in the facility configuration. However, many potential problems in evaluation will arise. For example, if a video shows the crane going over to a location in a cell and a jumper being changed, what is the significance of this action? The facility operator would say something broke and needed to be fixed.

PUREX Quantity, Timeliness Goals: Initial rough estimates suggest that under certain conditions (limited throughput, nitrate product only, idealized steady-state operation with no process upsets) PUREX could meet the IAEA timeliness goal of detecting diversion of 1 SQ in a 30-day material balance period. A realistic facility capacity based on past performance (rather than theoretical capacity) was used. Doubling the plant throughput will likely cause the uncertainty in output to exceed the quantity goal. This scenario requires that inspectors maintain some continuity of knowledge of operating conditions before the period of interest. This information is available to the plant operators but is not normally available to inspectors. These estimates were based on the use of an operator-initiated inventory procedure that may permit modifying the existing agency in-process inventory verification process. This procedure would consist of a reported inventory by plant operators followed by verification of calculated inventory in a few selected, randomly chosen locations. In a traditional inventory verification, samples and measurements would be taken (perhaps in all locations). To be successful the operator-initiated inventory procedure requires operator confidence in the declared inventory values and a willingness to be challenged on the inventory values. Materials to be inventoried would be moved to tanks that are capable of being sampled.

The use of these procedures would have to be explicitly reflected in the facility attachment. The procedures are similar to those used in other types of facilities [e.g., mixed oxide fuel (MOX) fuel fabrication plants] in which the safeguarded material is moved to a few easily measured/sampled locations (containers) for inventory. The use of routine process sampling and process data recording (together with minor additions in the areas of data collection and evaluation) in the operator-initiated inventory procedure might be achieved without significantly increasing facility and inspector costs. It is, however, questionable whether the goal of detecting a diversion of 1 SQ over a 1-year material balance period can be met with existing PUREX systems.

Input Inventory: It is difficult to determine the plutonium content of irradiated fuel input at PUREX since individual fuel assemblies are not identified. (At facilities reprocessing commercial fuel, visual identification of assembly serial numbers and reactor calculations associated with the specific assembly are used to estimate plutonium content.) This situation affects diversion detection sensitivity, especially in the head-end material balance area (MBA). It probably also applies to other weapon states. For example, CANDU reactor fuel is not identified by serial number.

Rework and Recycle of Nonsafeguarded Material: This scenario assumes the metal (fuel) dissolution head end is shut down. The feed to the plant is unirradiated nitrate solution, oxide powder, or metal. The feed is prepared in new small-quantity (10kg/day) dissolvers in N cell; high U feed goes to E6 tank, other feeds to L3 tank. A typical campaign consists of 100 kg of plutonium accumulated over 10 days and processed over a 2-day period. C/S measures are used to monitor head end shutdown status and the railroad tunnel. Radiation monitoring in N cell is used to verify that no irradiated material is introduced as feed. Seals are placed on valves used for chemical additions to the dissolver. Gaseous effluent is monitored. The dissolver could be used for non-irradiated material by prior arrangement (no unannounced use of the dissolver). This situation would require additional measures to verify that no "new" material is being processed. It is important to be very careful to monitor what is placed in the dissolvers. Stack monitoring would be a big help in detecting fission products from "new" material production. Gross gamma detection (e.g., NaI detector) at the dissolver is possible. HAW would be monitored to ensure absence of fission products.

Shut Down But Operable, Plant with no Safeguarded Inventory: This scenario assumes the plant has been cleaned out (i.e., <0.3 SQ inventory). The facility would not be safeguarded under 153 safeguards (safeguards would be terminated). The facility would be periodically inspected to verify the shutdown status under agreements similar to INFCIRC/66. Environmental monitoring/remote sensing could be used to verify that PUREX remained shut down (but this might not be adequate at other facilities). However, low-rate processing at PUREX might not be detectable by remote monitoring. Low-rate processing would imply a backing-off in acid temperatures in the dissolver so as not to cause boiling. This would slowly leach the metal and together with clean-up of the NO_x effluent would substantially reduce easily observable production indicators. Power (and steam) usage would not necessarily increase above the "noise" of normal activities. Most steam consumption is used to concentrate waste streams so increased volumes of waste would require disposal if steam usage is limited. Periodic site visits would be necessary to provide high confidence in continued shutdown status. C/S measures would also be required.

Technical Modifications: The following is a list of the technical modifications and fixes that might assist in implementing safeguards at PUREX:

- tracer studies for volume verification; fuel assembly monitor;
- video cameras on cranes to monitor dissolver charges (radiation hardened lens and container for camera);
- secure dissolver Kr-85 off-gas monitor;
- on-site mass spectrometer, K-edge densitometer, hybrid K-edge densitometer, high-level neutron coincidence counter (HLNCC), high-resolution gamma spectrometer system;
- seals on valves, etc.;
- camera on railcar unloading area;
- camera on product loadout areas;
- process monitoring;
- inspector standards (weights, sources, etc.); and
- an inspector electromanometer system.

3.2 Alternative Safeguards Measures

The second PUREX Exercise scenario applied alternative safeguards measures for verification of SNM production cutoff at a reprocessing facility. Alternative safeguards measures were evaluated for effectiveness in obtaining confidence that nuclear material has not been diverted for weapons purposes. Prior to treaty negotiations, it is imperative the safeguards and verification measures under consideration be evaluated for effectiveness (degree of confidence), intrusiveness (loss of information, disruption of facility operations), and costs (real dollars spent). The Inspection Team attempted to derive safeguards measures that would maximize operational impact while minimizing intrusiveness and costs to both the facility and the inspectorate.

Below is a list of the nine safeguards alternatives developed during the PUREX Exercise with their definition and an evaluation of the effectiveness, intrusiveness and cost (summarized in Table 3.1). Detailed "Pros and Cons" of alternative safeguards measures are listed in Volume 3, Appendix I, of this report.

Table 3.1. Evaluation of Safeguards Alternatives

Safeguards Alternatives	Effectiveness	Intrusiveness	Cost
Materials Balance Accounting with Interim Inspections	High	High	High
Randomized Inspections to Determine Material Balance	Moderate	Moderate to High	Moderate to High
Randomized Inspections to Look for a "Smoking Gun"	Moderate	Low to Moderate	Low
Randomized Inspections using Only Visual Observations	Low	Low	Low
Portal/Perimeter Monitoring around the Entire Facility	Moderate	Low	High
Portal/Perimeter Monitoring around the Key Points	Low	Moderate	Low to Moderate
Running Book Inventory	Moderate	Moderate	Moderate
Process Monitoring with On-Site Readout	High	High	High
Process Monitoring with Off-Site Readout	High	High	High
Zone Approach	High	High	High
Environmental Monitoring Inside of Facility	Moderate	Low to Moderate	Low
Environmental Monitoring Outside of Facility	Low	Low	Low
Enhanced Information Management	Low	Low	Low to Moderate
Enhanced Containment/Surveillance	Moderate	Moderate	Moderate to High

3.2.1 Alternative Safeguards Measures Evaluations

1. Materials Balance Accounting with Interim Inspections of In-Process Inventories

Definition: Full material balance (MB) safeguards supplemented with C/S (cameras and seals)

Effectiveness: Most effective means of detecting abrupt or trickle diversion of material. However, difficult to meet timeliness and quantity goals in plants with large throughput.

Intrusiveness: Highly intrusive, requires extensive access to material and records.

Cost: Extremely costly. Requires significant personnel commitments.

2a. Randomized Inspections to Obtain a Materials Balance

Definition: Full material balance safeguards except that there is a less than 100% probability that any specific verification activity will be carried out. This would be a regime similar to that described in "Safeguards Criteria, 1991-1995" produced by the IAEA Department of Safeguards. These criteria cover inspections under both INFCIRC/66 and INFCIRC/153. Verification scheduling could also be randomized.

Effectiveness: Allows verification of material balance with confidence dependent upon the number of verification activities actually carried out (e.g., C/S review, seal verification, NDA measurements, records review). Confidence can be evaluated using material unaccounted for (MUF-D) method. (MUF-D is a statistic calculated by the IAEA to allow the comparison of an operators declared MUF with the estimates made by the Agency inspectors on the basis of their sampling and analysis). Note that to be effective, the verification strategy must be designed to include all strata. Deterrent value is not highly dependent on verification strategy.

Intrusiveness: Varies depending upon which verification activities are carried out and how often. Always somewhat intrusive because access to materials and records are required. Anomaly resolution may be highly intrusive because of an increased probability of false alarms.

Cost: Personnel-intensive due to necessity for preparation of Design Information Questionnaire, Facility Attachment, routine records and reports, and inspection activities including anomaly resolution. Dollar costs depend upon the degree of disruption of facility activities and required modifications to existing facility procedures.

2b. Randomized Inspections to Look for a "Smoking Gun"

Definition: Detailed forward declarations of facility operations combined with short or no-notice inspections aimed at detection of undeclared activities.

Effectiveness: Does not provide material balance information. Detection capability depends strongly upon which inspection activities are permitted and upon the knowledge and expertise of inspectors.

Intrusiveness: Low to Moderate. Inspection activities would be designed to avoid unnecessary interference with declared facility operations.

Cost: Low.

2c. Randomized Inspections with Only Visual Inspection Walkthroughs

Definition: Unlimited short or no-notice inspection with visual access only.

Effectiveness: High for shutdown facilities, but negligible for operating facilities.

Intrusiveness: Generally low.

Cost: Low.

3a. Portal/Perimeter Monitoring with the Perimeter Enclosing the Entire Facility

Definition: Perimeter encloses the entire facility and has defined portals for all movement of material in or out. Provisions are made to ensure that all movements are through the defined portals. (In practice, some access would be required inside facility.) Portals have instrumentation capable of detecting SNM. Declared product may be verified.

Effectiveness: Depends upon detection sensitivity of portal instrumentation and on the ability to maintain surveillance of the perimeter. Perimeter may have to be very large. Does not allow detection of on-site stockpiling. (Very effective for a completely shut down and cleaned out facility.)

Intrusiveness: Low if only external monitoring of vehicles is required. High, if inspection/search is required.

Cost: Very high (especially for inspectorate).

3b. Portal/Perimeter Monitoring with the Perimeter Enclosing Only Key Points

Definition: Perimeters established around key process areas such as head end and product loadout. Portals are instrumented to detect all movements of SNM in and out.

Effectiveness: High for shutdown facilities. Low for operating facilities due to numerous possibilities for by-passing perimeters.

Intrusiveness: Moderate.

Cost: Low to moderate.

4. Running Book Inventory/Adjusted Running Book Inventory

Definition: Verification (by surveillance and sampling) of input accountability tank values and balancing of input values against product values (subject to verification).

Effectiveness: Can provide good material balance data. Can meet diversion quantity goals, but not diversion timeliness goals. Does not provide verified inventory data.

Intrusiveness: Moderate - Requires inspector sampling of feed and product.

Cost: Moderate to high.

5a. Process Monitoring with On-Site Data Read-out and Storage

Definition: Use of standard current state-of-the-art process instrumentation (e.g., electromanometers, conductivity monitoring, etc.) plus valve position monitors, etc. Data storage on strip chart records or electronic media. If existing facility equipment is inadequate, new instrumentation would be backfitted. Process data would be supplemented by sampling and analysis as necessary to compute quantities.

Effectiveness: Dependent upon the ability to authenticate data, and ability to reduce and evaluate data. Can provide timely inventory and material balance data.

Intrusiveness: High, but data are potentially useful for operator.

Cost: Very high initial cost, moderate to high continuing costs

5b. Process Monitoring with Off-Site Data Read-out and Storage

Definition: Use of current state-of-the-art process instrumentation plus any necessary data authentication procedures to transmit real-time process parameter data, including all data needed to compute SNM quantities, to a remote site.

Effectiveness: Same as on-site process monitoring, but subject to spoofing if not supplemented by sampling and analysis.

Intrusiveness: Same as on-site process monitoring; some countries may object to off-site data transmission.

Cost: Higher than on-site process monitoring initially, but less on-site presence required. Data evaluation may be easier to automate.

6. Zone Approach - Zone Could Be PUREX/Plutonium Finishing Plant or Entire Hanford Site

Definition: Complete verified material balance accounting at all facilities within the zone, with simultaneous verified physical inventories at all facilities.

Effectiveness: Provides complete verified material balance data. Prevents concealment of diversion by substitution of material. Effectiveness increases as the size of the zone is increased. Limited utility for small zones.

Intrusiveness: Requires the simultaneous shutdown of all facilities in zone for physical inventory.

Cost: High. Large numbers of inspectors required for physical inventory verification.

7a. Environmental Monitoring Inside of Facility

Definition: Use of swipe samples, air monitors, stack monitors, waste stream monitors, etc. to detect new dissolution of irradiated material.

Effectiveness: Good to excellent for shutdown facilities. Does not provide material balance or diversion information. Can provide rough throughput data if facility design can be verified/reverified.

Intrusiveness: Low to moderate.

Cost: Low

7b. Environmental Monitoring Outside of Facility

Definition: Collection and analysis of air, water, soil, biota and utility use from the immediate vicinity of a facility, including visual observation.

Effectiveness: High for shutdown reprocessing facilities. Provides confidence of status of operating facilities.

Intrusiveness: Low or negligible.

Cost: Low.

8. **Enhanced Information Management**

Definition: Collection, collation and analysis of as much open-source and declared data as available.

Effectiveness: May provide information on national intent and aid in focussing other efforts.

Intrusiveness: None

Cost: Low to moderate.

9. **Enhanced Use of Containment/Surveillance**

Definition: Use of devices such as visual surveillance systems (cameras), tamper indicating devices (TIDs), crane motion monitors, etc. to provide continuity of knowledge.

Effectiveness: Does not provide material balance information, very effective for static situations or shutdown facilities.

Intrusiveness: Moderate

Cost: Moderate to high.

3.2.2 Types of Data Provided by Alternative Safeguards Measures

Table 3.2 reflects several types of information that could conceivable be provided by each alternative safeguards measure developed during the PUREX Exercise. Below is a brief description of the types of data provided by the verification measure and its significance when applied to a reprocessing facility in an SNM production cutoff regime. The extent and effectiveness with which the alternative provides this information is dependent on the details of implementation.

Abrupt Diversion (Detection): Abrupt diversion is the removal of significant amounts of nuclear material from its proper location in a relatively short period of time. Verification options seeking to detect this activity must respond quickly, but would usually be dealing with a relatively large amount of material (kilograms).

Trickle Diversion (Detection): Trickle diversion is the removal of material from its proper location in small amounts over a long period of time. Detection of trickle diversion is difficult because it requires the ability to detect small losses against the background of large flows of material.

"Smoking Gun" (Detect Prohibited Activity): If obviously prohibited activity can be defined for a facility, the detection of this activity provides *prima facia* evidence of an attempt to circumvent an agreement. Defining such obvious activities is somewhat difficult, but possibilities include stockpiling

Table 3.2. Potential Data Provided by Each Safeguards Alternative

Safeguards Alternatives	Type of Data: Abrupt Diversion	Trickle Diversion	"Smoking Gun"	Quantity	Rework	Operating	National Intent
Material Balance Accounting with Interim Inspections	X	X	X	X	X	X	
Randomized Inspections to Determine Material Balance	X	X	X		X	X	
Randomized Inspections to Look for a "Smoking Gun"			X		X	X	
Randomized Inspections using only Visual Observation			X			X	
Portal Perimeter Monitoring around the Entire Facility				X		X	
Portal Perimeter Monitoring around the Key Points				X		X	
Running Book Inventory		X		X	X	X	
Process Monitoring with On-Site Readout	X	X	X	X	X	X	
Process Monitoring with Off-Site Readout	X	X	X	X	X	X	
Zone Approach	X	X	X	X	X	X	
Environmental Monitoring Inside of Facility			X	X	X	X	
Environmental Monitoring Outside of Facility			X		X	X	
Enhanced Information Management							X
Enhanced Containment/Surveillance			X		X	X	

of product for a breakout and use of dissolvers under circumstances that do not agree with previous declarations.

Quantity (Determine Total Quantity of Material Produced): In contrast to the diversion scenarios which look for loss of safeguarded material, it is also possible that a state would introduce extra spent fuel into a reprocessing plant that would then be used to produce extra material that would be kept out of safeguards. Therefore, there is a need to determine the total amount of material that a facility is processing and producing.

Rework (Differentiate from Reprocessing): A reprocessing plant can be used to rework (remove ^{241}Am) in already produced plutonium as well as separate new plutonium from spent fuel. The actual chemical processes involved are similar except that it would usually be unnecessary to use the dissolver at the head end. It is important to be able to differentiate these processes so that clandestine reprocessing would be discovered.

Operating (Differentiate from Not Operating): While a relatively easy task, it is extremely important to determine if a facility is operating or not. Inexpensive options that will differentiate the two states are very desirable.

National Intent (Determine): Indicators of a national intent to violate an international agreement are of possible interest as a means of directing inspection effort and of identifying suspicious facilities. Properly done, these measures can be quite cost effective.

3.3 Combinations of Alternative Safeguards Measures

Seven combinations of alternative safeguards measures were developed and evaluated during the PUREX Exercise (see Table 3.3). The evaluation of these combinations assumes the facility is operating, a state System of Accounting for and Control of Nuclear Material (SSAC) is functioning, and inventory and flow have been declared. Alternative safeguards combinations were not explicitly considered for a shutdown plant because a number of the individual alternatives would provide adequate coverage. Possible types of declarations include the following:

- design information (such as an IAEA DIQ)
- inventories (all physical inventories)
- flow (all inventory changes)
- operations (present and future in detail)

Table 3.3. Evaluation of Combinations of Safeguards Alternatives

Combination of Safeguards Alternatives	Effectiveness	Intrusiveness	Cost
Visual Only Random Inspections plus Inside Facility Environmental Monitoring	Moderate	Low to Moderate	Low
"Smoking Gun" Random Inspections plus Portal/Perimeter Monitoring around Entire Site	High	Moderate to High	High
"Smoking Gun" Random Inspections plus Running Book Inventory	High	High	Moderate to High
"Smoking Gun" Random Inspections plus Process Monitoring with On-Site or Off-Site Readout	High	High	High
"Smoking Gun" Random Inspections plus Outside Environmental Monitoring	Moderate	Low to Moderate	Low
Visual Only Random Inspections plus Running Book Inventory	Moderate	Moderate	Moderate
Portal/Perimeter Monitoring around the Entire Facility plus Outside Environmental Monitoring	Moderate	Low to Moderate	High

- design or process changes
- accounting system changes
- measurement system changes
- material balances (at each physical inventory).

All seven combinations are improved to some extent with the addition of environmental monitoring outside the facility (7b) and enhanced information monitoring (8). These would not add appreciably to intrusiveness or cost. Therefore, they are not explicitly considered except for combinations 5 and 6. Zone approaches were not thought to add anything to any combination, so they were not considered further.

The effectiveness of any of the combinations could also be increased with the enhanced use of containment and surveillance. In these cases, intrusiveness would be raised to at least the moderate level as would the cost. Depending on the type of equipment used and its placement, intrusiveness and cost could become high.

3.3.1 Seven Combinations of Safeguards Alternatives

Below is a list of seven combined safeguards alternatives with an evaluation of the effectiveness, intrusiveness and cost (also summarized in Table 3.3).

1. Visual Only Random Inspections (2c) plus On-Site Environmental Monitoring (7a)

   Effectiveness: Provides evidence of facility operation for new Pu separation and order-of-magnitude estimate of throughput.

   Intrusiveness: Low

   Cost: Low

2. **"Smoking Gun" Random Inspections (2b) plus Portal Perimeter Monitoring of the Entire Facility (3a)**

   Effectiveness: Provides the ability to detect shipment of undeclared product and accumulation of inventory within facility.

   Intrusiveness: Moderate to high.

   Cost: High

3. **"Smoking Gun" Random Inspections (2b) plus Running Book Inventory (4)**

   Effectiveness: Enhances Running Book Inventory by improving timeliness and providing capability to detect accumulated inventory.

   Intrusiveness: Moderate

   Cost: Moderate to High

4. **"Smoking Gun" Random Inspections (2b) plus Process Monitoring with Either On-Site or Off-Site Data Readout (5a or 5b)**

   Effectiveness: Enhances effectiveness of process monitoring by providing independent verification and reduces spoofing vulnerability.

Intrusiveness: High

Cost: High

5. **"Smoking Gun" Random Inspections (2b) plus Outside Environmental Monitoring (7b)**

   Effectiveness: Provides enhanced ability to detect undeclared operation. Does not provide material balance or diversion detection information.

   Intrusiveness: Moderate to low.

   Cost: Low

6. **Visual Only Random Inspections (2c) plus Running Book Inventory (4)**

   Effectiveness: Provides limited throughput information plus very limited ability to detect stockpiled inventory.

   Intrusiveness: Moderate

   Cost: Moderate

7. **Portal/Perimeter Monitoring Around the Entire Facility (2c) plus Outside Environmental Monitoring (7b)**

   Effectiveness: Provides limited throughput information plus ability to detect new separation of irradiated material.

   Intrusiveness: Same as Portal/Perimeter Monitoring Around the Entire Facility (1c).

   Cost: High to very high

3.4 Unresolved Issues

One of the goals of the PUREX Exercise was to assist the U.S. government in understanding the problems and issues involved in allowing international inspections of operating, existing reprocessing plants. The unresolved issues submitted by participants are grouped below under the broad headings of effectiveness, intrusiveness, and cost. Detailed comments on specific issues submitted by PUREX Exercise participants are detailed in Volume 3, Appendix H.

3.4.1 Unresolved Issues Related to Effectiveness

National Intent: The effectiveness of monitoring activities is highly dependent upon the cooperation and openness of the facility (i.e., the national intent). If the facility (state) is not cooperative and open, monitoring will be less effective. With respect to unallowed activities, the operator has the upper hand (especially for the old, flexible facilities like PUREX) because of the many different operational scenarios which may be undertaken to evade monitoring activities.

Verification Goals: An evaluation of specific verification alternatives requires detailed definitions of specific verification goals (you need to know what you're trying to accomplish before you can accomplish it).

Facility Attachments: The effectiveness of monitoring activities depends upon the outcome of negotiations regarding implementation. Negotiations typically become adversarial. This is true even when both sides may have the best of intentions. Misunderstandings are likely. Inspectors may ask seemingly irrelevant questions of the facility operators which may frustrate the "let's get the job done in a quick, efficient manner" attitude of the operators. Thus, a positive attitude on the part of the operators may be seen as a possible evasion by the inspectors who do not want to feel they are being led to a specific outcome. The monitoring agency and the facility have different agendas and objectives. This exercise did not attempt to negotiate a facility agreement, so the difficulties of this can not be assessed.

Data Authentication: To achieve diversion and timeliness goals equivalent to those currently used by the IAEA, the monitoring agency must be able to independently verify and authenticate data. This requires the facility to supply data that can be verified/authenticated. Timeliness of the data will be important.

Verification Requirements: Changes in Facility Procedures: The implementation of international safeguards under a cutoff convention will almost certainly require changes in facility procedures to verify flows and inventories. It may also require the installation of additional equipment such as surveillance cameras. Such changes will require the facility to perform safety analyses and, possibly, criticality and/or personnel radiation dose analyses. The performance of required safety, criticality, or personnel radiation dose evaluations is costly and time-consuming. The costs and time required for these activities must be considered in evaluating the various proposed options for implementing international safeguards under a cutoff convention. An analysis of possible conflicts with DOE, Occupational Safety and Health Act or Environmental Protection Agency requirements should also be done when evaluating various safeguards options.

Verification Requirements: Changes in Accounting System: INFCIRC/153 safeguards require facilities to submit extensive and detailed nuclear materials accounting reports to the IAEA. Safeguards activities also typically involve examining facility accounting records in detail and comparing records with reports by IAEA inspectors. Experience with implementing IAEA safeguards at U.S. facilities has shown that some changes are usually necessary to make facility accounting systems comply with IAEA records-keeping and reporting requirements. Changes to facility nuclear materials accounting systems typically require modifications to existing computer software. Planning, testing, and implementing these changes (and training personnel to use the new system correctly and accurately) is costly and time-consuming. Any analysis of possible safeguards options for a cut-off treaty must include an analysis of potential costs due to new reporting and records-keeping requirements imposed on facilities. [Changes in Nuclear Materials Management and Safeguards System (NMMSS) and DOE orders must also be considered.]

Defining MBA and C/S: A diversion scenario assessment similar to what the Agency uses would be required. One can estimate costs for the pieces of a C/S inspection regime, but the estimate for a system depends on diversion scenarios being covered. Given the nature and current definition of the MBAs at PUREX, it may be difficult to detect a diversion [e.g., it might be possible to pipe around the key measurement points (KMPs)]. Two approaches might solve this problem. The first would be to redefine the MBAs, but this action would not eliminate the ID and would significantly increase the cost (e.g., number of samples, number of inspectors, other efforts). Another approach would be to expand the containment/surveillance activities beyond their current scope (which could be ineffective for PUREX diversions) to include other activities (e.g., detectors and cameras at many locations or remote monitoring) to identify inconsistencies. This approach would be expensive and be a non-trivial effort to monitor and review.

Item Counting before Charge to Dissolver: Regarding the loss of item pieces before charge to dissolver: How are these accounted for? Are they written off as reactor calculation errors? What happens to undissolved fines? Where do they come out?

Issues/Concerns Related to Design Information Questionnaire (DIQ):

- What type of change control must be used for any information that is discussed in the DIQ?

- Three specific questions on DIQ:
  1. #33 on physical inventory: when the process is being emptied for a physical inventory, is it possible to predict through models how much uranium-plutonium is left in the process? It is possible that computer codes, such as FACSIM, could be tested against actual PUREX activities. The code would follow the buildup of plutonium in a PUREX process on startup and should work equally well going from normal feed to acid feed.

  2. #25 How well do we have to dynamically measure/know inventory of the solvent extraction contactors? The MUF has three components: throughput, measurable inventory, unmeasured (estimated) inventory. The contractor inventory and, therefore, contribution to MUF is small relative to throughput and measurable inventory, and estimates to within $\pm$ 10% to 20% are probably acceptable. This needs to be evaluated on a case by case basis for each facility.

  3. #35 vii: Check analytical method and error for nitrate to loadout (M tank or L9 tank)

#35 viii: Check sampling error for D5 input accountability tank--0.05% seems low when tanks that are easier to sample are 0.1%. These values are used in error propagation and could significantly affect the detection limits.

Preparation of Samples for Offsite: In preparation to send IAEA samples off-site, the following knowledge is necessary:

- requirements for moving materials off-site
- requirements (e.g., certified containers and packers)
- paperwork and signature requirements for NMMSS
- necessary approvals
- referee sample requirements (in case of discrepancies).

IAEA Space Requirements: Need to summarize IAEA total space requirements for the following:

- locked/sealed area for spike vials
- locked/sealed area for calibration weights
- lab area for sample preparation
- area for HLNCC/Ge
- supply room for liquid nitrogen
- storage area for calibrating NDA equipment and for working with the standards (HP knowledge of location & content)
- place to review tapes.
- place for maintaining/repairing equipment
- office area for paperwork.

Bypass of D-5 Input Accountability Tank: How easy is it to bypass the D-5 input accountability tank? Any possible means of bypassing the input or output accountability tank must be declared in the DIQ; the facility attachment must include advising the IAEA of any piping changes prior to making the changes.

Detector at Railroad Car: A green fuel monitor (gamma) is present as fuel elements are pulled from the railroad cars to the dissolver. How sensitive is the detector? Is the limit on detecting fuel tied to the sensitivity of the detector or to the normal background? Perhaps redesigning or relocating the detector could permit it to be used to count fuel cans transferred to the dissolver.

3.4.2 Unresolved Issues Related to Intrusiveness

Process Monitoring: Process monitoring can be very effective and the equipment is available, but the equipment is costly. Data evaluation is critical to effective monitoring and can be as costly as data collection. The technical ability to perform the analysis is not trivial and expertise is limited. It requires an ability to interpret what is going on in the plant and a desire on the part of inspectors to seek out and resolve anomalies. Twenty million to $30 million (1987 dollars) would be required for process monitoring equipment installation at PUREX. The future of a facility must be factored into the decision to add required equipment.

Plant operators may be reluctant to give out process information if the inspectorate is insufficiently skilled to analyze the data properly. The facility may be falsely accused of diversion during periods of upset conditions if inspectors cannot recognize what is actually occurring. Since THORP will be the first attempt at a facility giving out detailed process information, lessons will be learned from the THORP experience. Having a full-time inspector presence on-site would be an alternative to a process monitoring system.

Inspectors may require access to complete data, not just data from specific KMPs (e.g., if the accountability tank was one KMP, records of levels in tanks adjacent to accountability tanks would be important). A potential diversion scenario was proposed in which a tank was valved out and material diverted. If inspectors have access to all information, loss of material would be apparent in the readings at other tanks nearby (either in a reduced material volume or material where there should not be material). While additional technical measures could be undertaken to further mask behavior at surrounding tanks, additional measures mean a more complicated diversion scenario with added risk to both operations and detection. Complete information access drives prohibited material production from declared facilities to undeclared facilities.

The effectiveness of process monitoring is an unresolved issue because facility operators may not be willing to allow inspectors to verify/authenticate data not collected at agreed-upon points. In addition, the number of individuals with the knowledge and operational experience required to know how and when to collect and evaluate these data are limited and may not be readily available (and are becoming less available). The inspectorate will likely have a few very experienced individuals. Most will have strong educational backgrounds but will not have any actual operational experience. This drives the need for computerized data collection and analysis (the example was given of data collected at Tokai which can not be used in a meaningful way). Inspectors have a lot to do in a short time. Equipment may not work properly and there is not the luxury of looking at a second strip chart when trouble is occurring with the first chart.

Facility attachments must be very carefully negotiated in order to assure that all necessary data can be collected and verified/authenticated by inspectors. A poorly negotiated facility attachment is likely to be very frustrating for the inspectors. The analogy with inadequate plant procedures was made: if something is not documented, then it does not exist; if something is not in a procedure, then it can not happen. An unresolved issue is that it is not clear how the knowledge required to negotiate a meaningful facility attachment would be imparted to negotiators, who may or may not request assistance. There are many possible players in this: Department of State, Arms Control Disarmament Agency, Nuclear Regulatory Commission, Department of Energy, etc.

3.4.3 Unresolved Issues Related to Costs

IAEA Laboratory Capability: At several points, independent IAEA lab capability was discussed:

- will an additional IAEA lab analysis be required to perform tests
- need assurance that equipment and procedures meet U.S. regulatory agencies' requirements.

Verification Costs: Verification costs are dependent on the verification goals (confidence costs). A balance between treaty acceptability and comfort that the treaty goals are being met must be obtained. If traditional IAEA INFCIRC/153 safeguards are applied, then the agency is in a box with respect to requiring a goal of independent authentication that one SQ of material during a timeliness period has not been diverted from safeguards. The timeliness goal implies an elaborate and expensive monitoring system. With respect to the cutoff treaty the definition of "effective" may require different verification requirements. The real value (cost effectiveness) in requiring authentication of process sensor data must be evaluated. INFCIRC/153 goals on old plants may not make sense.

Costs and impacts of implementation fall into three broad categories: implementation, continuing operation, and maintenance. Specific costs and impacts include: escorts for inspectors; revisions to records and reports systems (e.g., the information management software for IAEA reporting); extra sampling activities; safety, criticality, and personnel dose analyses for new procedures and equipment; instrumentation upgrades (e.g., process monitoring, NDA/analytical instrumentation); allocation of space for: the storage of inspectors' equipment, laboratory work, new process monitoring equipment, inspector offices, hot cell activities; sample preparation, packaging, and transportation activities; additional inspection and facility personnel; increased calibration and instrument maintenance (and calibration standards); interruption of facility processing schedules; procedure development and personnel training; C/S system installation and maintenance (including environmental, safety, and health requirements for new equipment); inspector training (including radiation worker, criticality safety, and other safety training); State Department and Defense Nuclear Facility Safety Board (DNFSB) involvement in facility review (and inspectorate interactions with these agencies); and Tri-Party Agreement impact (and the large number of stakeholders involved).

U.S. Versus Foreign Facilities: Most U.S. facilities have limited missions, whereas foreign facilities may continue reprocessing into the indefinite future. Within the United States, the safeguards burden on plants not being operated to separate plutonium from fission products (only limited material stabilization or cleanout campaigns) is relatively modest. Foreign countries with older reprocessing plants that continue to operate would have to subscribe to long-term costs.

4.0 Conclusions

The PUREX Exercise identified important issues that need to be evaluated further for effective negotiation and implementation of traditional, alternative, and/or a combination of alternative safeguards inspection measures at reprocessing facilities to verify cutoff of SNM production. In Section 4.1, the alternative safeguards approaches developed during the exercise are applied to other U.S. and foreign facilities. Section 4.2 summarizes the lessons learned from the PUREX Exercise, which should help the U.S. government understand some of the problems and issues associated with applying international safeguards to U.S. and foreign reprocessing facilities used to separate SNM for weapons purposes.

4.1 Applicability to Other Facilities

The PUREX Exercise team included members from the SRS and Idaho National Engineering Laboratory, as well as individuals with inspection experience in foreign facilities. Sections 4.2.1 and 4.2.2 provide comparisons of the PUREX Plant with the separations facilities at SRS and the Idaho Chemical Processing Plant (ICCP), respectively. Section 4.2.3 summarizes the applicability of PUREX Plant information to foreign reprocessing facilities.

4.1.1 Savannah River Site

There are several differences between the separations facilities at SRS and those at PUREX. At Hanford there is a considerable distance between PUREX and the UO_3 plant, so the uranium conversion activities are divorced from the plutonium operations. At SRS, however, reprocessing plant facilities include the B-line, which is the plutonium conversion process, and the A-line, which is the uranium conversion process, either in the same or an adjacent building. In addition, SRS has both the F-area, which reprocesses the uranium targets and separates plutonium, and the H-area, which reprocesses the highly enriched uranium fuel assemblies. In H-area the reactor fuel-grade plutonium in the assemblies is not separated but remains with the fission product waste, however, the neptunium is recovered.

There is no item accountability for the F-area slugs. They are brought from the reactors in buckets (similar to the canisters used at PUREX) and are dumped into a chute leading to the dissolver. They can be heard in the chute, but that is about as much validation as is done. The irradiated fuel in H-area is in the form of fuel bundles. These can be tracked back to the reactors where they were packaged. It is possible to identify exactly where in the core lattice they were irradiated, so there is complete traceability.

It would be possible to accommodate monitoring of the hot canyon tunnel entrance and the warm canyon truck well. A seal could be placed on the door. However, waste removals could mask the monitoring of subject material removal. For example, at PUREX a piece of failed equipment is put into a railroad car, and the car is pushed into a storage tunnel. At SRS, failed equipment is taken out in a box, and that box is highly radioactive. Subject material could be placed into such a box, moved out of the plant, and lifted out of the box in a location outside of the inspector's view.

Meeting the timeliness goal for accountability would be difficult. Accounting for one significant quantity level over the entire system is probably not possible. Currently, SRS performs a bimonthly inventory to stagger the inventory takings between F- and H-areas. When both were performed together the laboratory analysts could not finish the accountability for one area before the other area accountability was started. The laboratory resources are typically strained to the limit.

As with PUREX, another major problem is the difficulty in confirming the design information. Site documentation of what is inside the canyon is maintained. SRS uses what is called a scroll to confirm canyon piping arrangements. Annual inspections are also performed to confirm that the jumper set-up on the scroll match the actual canyon configuration. The question will always be, "what does that termination in the canyon connect to on the other side of the wall?" Tracking or tracing the embedded piping is nearly impossible.

Controlling changes (e.g., jumper changes) creates a big operations problem. For example, if a leak occurs in the warm canyon and material flows to the sump, it has to be removed. The only way to do that is to use the crane to set up a flex jumper between the pump-out header and the sump. Two warm canyon sumps cannot be jetted at the same time. Further, the ability to get workers out into a canyon needs to be part of the emergency response capability.

Another major problem arises when a gasket in the cooling water line bursts. In this situation, there would be a lot of water inside the cell unless repairs were undertaken immediately. Problems may also arise when new facilities are added. For example, the old B-line is being torn out. To conserve costs, a glove box was built where the old transfer routes came into the old B-line. Jumpers were put in so that material could be routed to different locations. As a result, the new B-line facility has a material flow routing system that is external to the facility which determines where all flows go for the facility.

There are several potential problems with inter-area sample transport and chain-of-custody. The analytical lab is in the F-area, and H-area samples are transported by truck. In F-canyon, there is no charge/accountability receipt relationship. For example, 15 buckets of slugs may be charged to the dissolver. That slug charge amounts to a certain number of tons of metal and so much plutonium. When the dissolver solution is measured, it comes out of the dissolver in two cuts. If those two cuts were summed, the total will be less than what was charged because of a remaining dissolver heel. The dissolver inventory measurement in H-area is better. The H-area dissolvers are charged and essentially all the material is dissolved. The dissolver is probed to ensure that no undissolved material fragments remain.

In addition, there are several unmeasured losses. Digested resin leaves the facility without analysis, because it is a gelatinous sticky substance. SRS facilities also have a different head-end than PUREX. Silicate material that can cause interfacial crud in the solvent extraction process is removed with a gelatin strike. Undissolved fines in the dissolver solution are removed in the centrifuge, and that slurry is transferred to the waste tanks in a form which cannot be analyzed. Any time material precipitates in the waste tanks, samples cannot be analyzed to adequately to characterize the content. The assumption is that a certain percentage of throughput goes out of the plant as undissolved fines and an inventory number is assigned to that loss.

SRS facilities have multiple cranes: two each on the hot side and the warm side. PUREX has one long canyon; and SRS has two parallel canyons. Maintaining camera transmissions from the cranes will be a challenge. SRS uses a radio frequency (RF) link between the cranes and the control room. An antenna cable runs down the canyon and the crane has another antenna. There are only a couple inches between the two antennas and even with this close spacing RF links are lost. Eight cameras are located on the cranes, and site experience shows that the likelihood of keeping all eight cameras operating is very low. Four operating cameras is typical.

Another problem is in finding space for the inspectors. The sample aisles are very narrow, and it would be very difficult to add-on online samplers. In the analytical lab, there is almost no space. Whenever a facility has expanded or added capabilities, lab operations has said that analytical space must be provided in the new or expanded facility.

Finally, SRS does not use pulse columns; instead mixer/settlers are used to partition the process streams. These have been characterized pretty well, so inventory taking does not present a big problem with these items. The typical inventory is not a total process inventory. When inventories are performed, material is moved to the best tanks to simplify the inventory (usually the tanks with samplers). Not all the tanks have samplers that function, because the equipment has been in service since 1955.

4.1.2 Idaho National Engineering Laboratory

There are some very important differences between PUREX and the facilities at the Idaho Chemical Processing Plant (ICPP). Design capacity at ICPP is about 2 MT/yr, but it is more typical to process 1 MT/yr. That translates into about 1 MT/yr for fissile material output. The plant is a very highly enriched uranium chemical processing plant that, although it primarily processes classified Naval fuels, has also processed all sorts of DOE highly enriched research reactor fuel.

The spent naval cores were reprocessed at ICPP, the uranium was converted to UO_3, transferred to Y-12, and blended with other uranium to form the proper enrichment for the reactor fuel. The uranium was shipped to Savannah River and fuel elements for the production reactors were fabricated out of the material. SRS then internally recycled the uranium from those fuel elements. Once the requirement for production reactor fuel was no longer present, the only reason to run the ICPP was to dispose of naval fuel. The Navy decided that operating the plant was not a cost-effective means for fuel disposal, so further separations are not planned.

Some important aspects of ICPP are 1) the primary dissolver storage area is in a separate building from the separations facility (the facility is called FAST, and has a storage basin and a dissolver cell),

2) the dissolvers are total dissolution dissolvers, and 3) there is an accountability tank at the outlet of the FAST facility and another accountability tank in Building 601, which is in the separation facility. Samples are taken from both of those tanks.

Unlike most fuel storage ponds where an individual can go up to the edge of the storage pool, look over, and see all the fuel in racks, the fuel storage pond at ICPP has locked covers on the fuel elements because they are classified fuel forms. This means that both the fuel elements and even the crane fixtures used to move those fuel elements cannot be seen. Hence, an inspector cannot watch the elements being charged into the dissolver.

The plant has a very good computer system that allows the status, tank variables, flows, pump status, and valve positions to be read for most, but not all of the critical components. The plant generally runs sequentially. The head-end operates for a period of many months dissolving fuel, going through the first cycle, and storing material in new process storage tanks in the separation cycle. It then campaigns the back-end operations in the waste calciner because that process is much more rapid.

The elements are very well characterized. These are cores or core pieces that have already been examined in the expended core facilities (Naval Returns Facility or NRF). Therefore, a lot is known about the burnup of those units. The output of the plant is UO_3, but there is no plutonium cycle. The plutonium goes to the waste with the rest of the fission products. The output product of the ICPP is really "junk" material. It is not material that goes back into naval reactors or is used for the weapons program. It is material that formerly was used as fuel to charge the reactors at Savannah River. Because of the high burnup, it is high in undesirable isotopes like ^{236}U and ^{232}U, which causes a dose-rate problem.

The plant currently has some material in interim storage. Most of the material has been campaigned through the plant. UO_3 is stored in the vault and spent fuel remains in the fuel storage pond.

4.1.3 Foreign Facilities

Limited information is available on the applicability of this study to foreign reprocessing plants. However, it is known that most or all reprocessing plants use the PUREX process, many use the "canyon" type design, and most are old and have the same inaccessibility problems as PUREX. Several of the largest civilian facilities are already under international safeguards (e.g., the Thermal Oxide Reprocessing Plant [THORP] in the U.K. and the new UP-2 and UP-3 facilities in France); other civilian plants (such as Trombay in India) are not under such international safeguards on a routine basis (although there may have been times when international safeguards may have been in force). Other facilities around the world are military facilities (such as those in France, U.K., Russia and China). The use of safeguards in these facilities may run the gamut from essentially no use of material accountancy (using instead containment and physical security) to systems that exceed those employed at PUREX. The throughput of these facilities also span a wide range, as is indicated in Table 4.1.

Table 4.1. Estimated Capacities of Various Reprocessing Plants

Facility	Country	Capacity
PUREX	U.S.	950 T/Y
Savannah River	U.S.	2700 (Two Plants)
UP-2	France	800
UP-3	France	800
Thorp	U.K.	700-1200
Mol	Belgium	100
Wak	Germany	35
Tokai-mura	Japan	210
Rokkasho-mura	Japan	800

During the PUREX Exercise, information was presented on the safeguards at the Indian plant at Trombay. This plant normally processes fuel from the Indian CANDU-type reactors. This fuel did not have unique identification (like typical Hanford slugs). The fuel pins are arranged into a cylindrical bundle. There were typically broken items (parts of a bundle), making item accounting difficult. The fuel was natural uranium with zirconium cladding and a typical burnup of 7000 MWD/MTU. A chop/leach dissolution process was used. In addition to the natural uranium CANDU fuel, the plant could also process low-enriched uranium dioxide fuel from the Tarapur reactor. Many of the issues identified for PUREX are likely relevant to Trombay, since the plant is also old. In addition, since the plant is often operated outside of international safeguards, continuity of knowledge as to the operational state of the plant is not maintained.

For facilities that have primitive or non-existent material accountancy systems, the issues identified for PUREX are even more relevant. For example, if no material accountancy capability exists, it will be impossible to perform monthly inventories without installing both a monitoring system and the capability for sampling at least some tankage. Both the cost and manpower estimates developed for PUREX are likely to understate the inspection resources necessary for this type of facility.

Although the impacts identified in this report are significant (to both the operating country and to the inspectorate), there are a number of factors that serve to ameliorate these impacts. First, the number of PUREX-type facilities throughout the world is rather limited (Table 4.1 indicates about a dozen military/civilian plants not currently under safeguards). Second, many of these plants are old and either have closed or are likely to close in the near future. These closures may result from the fact that additional material is no longer needed or because a military reprocessing plant is not permitted under a cutoff treaty. It is probable that only three to four of these plants have a future civilian mission after implementation of a cutoff treaty. The U.S. facilities are good examples of this. The only remaining mission is stabilization of existing material followed by cleanout and D&D. Impacts and costs under these conditions are relatively low while effectiveness is high, especially for some of the alternative measures.

4.2 Summary of Lessons Learned

A summary of the lessons learned from the PUREX Exercise are listed below.

- A wide range of verification strategies exist that could be applied at PUREX. The effectiveness, intrusiveness, and cost are highly dependent on the goals of the cutoff agreement and the operating status of the facility. It is easy to tell if a facility is not operating; it is harder to tell if an operating facility is violating the agreement.

- If information on materials balance is not required for verification, several attractive verification schemes are available. If information on materials balance to detect diversion is a requirement of the agreement, then no approach is available that improves on classical materials balance accounting with interim inspections of in-process inventories. However, this option can be further improved with the use of adjunctive measures.

- Verification costs are dependent on verification goals ("Confidence Costs!"):

  - In the absence of significant automation, a continuous inspector presence would be required to achieve the highest levels of confidence (~1000 inspector days/yr).

  - Process monitoring can be effective, but is costly to install in a facility such as PUREX ($20-$30 million in 1987 dollars).

- Design verification at a large, complex, highly radioactive facility such as PUREX is <u>extremely</u> difficult. C/S measures can provide some confidence regarding changes in facility configuration.

- Under certain circumstances, PUREX may be able to meet with IAEA timeliness goal (detection of diversion of 1 SQ in 30 days). However, it could not meet the goal of detecting a 1 SQ diversion over a year.

- While this exercise centered on PUREX, most of the conclusions would apply at Savannah River Site facilities and other old, large scale reprocessing plants in weapons states.

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