EGG-MS-10247
August 1992

**Idaho
National
Engineering
Laboratory**

*Managed
by the U.S.
Department
of Energy*

**METHODOLOGY TO IDENTIFY RISK-SIGNIFICANT
COMPONENTS FOR INSERVICE INSPECTION AND TESTING**

Michael T. Anderson
R. Scott Hartley
James L. Jones, Jr.
Clarke Kido
Jerry H. Phillips

*Work performed under
DOE Contract
No. DE-AC07-76ID01570*

Received by OSTI
AUG 24 1992

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights. References herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

**METHODOLOGY TO IDENTIFY RISK-SIGNIFICANT COMPONENTS
FOR INSERVICE INSPECTION AND TESTING**

Michael T. Anderson
R. Scott Hartley
James L. Jones, Jr.
Clarke Kido
Jerry H. Phillips

Published August 1992

Idaho National Engineering Laboratory
EG&G Idaho, Inc.
Idaho Falls, Idaho 83415

Prepared for the
U.S. Department of Energy
Office of Defense Programs
Under DOE Idaho Field Office
Contract DE-AC07-76ID01570

MASTER

ABSTRACT

Periodic inspection and testing of vital system components should be performed to ensure the safe and reliable operation of Department of Energy (DOE) nuclear processing facilities. Probabilistic techniques may be used to help identify and rank components by their relative risk. A risk-based ranking would allow varied DOE sites to implement inspection and testing programs in an effective and cost-efficient manner. This report describes a methodology that can be used to rank components, while addressing multiple risk issues.

EXECUTIVE SUMMARY

This report describes a methodology for the prioritized classification of standard mechanical components (e.g., pumps, valves, vessels, piping) according to their contributions to overall facility risk. The work was sponsored by the Department of Energy (DOE), Defense Programs Office of Engineering and Operations Support (DP-62), to develop technical guidance for the implementation of inservice inspection (ISI) and testing (IST) programs at DOE nonreactor nuclear processing facilities.

Guidance for ISI/IST programs at commercial nuclear power facilities is found in the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code*, "Rules for Inservice Inspection of Nuclear Power Plant Components." This standard has limited applicability for DOE processing facilities, due to the dissimilarities in system configurations and operating environments. DOE has yet to establish policy and requirements equivalent to the ASME Code for addressing inspection and testing issues at its facilities. Consequently, operating contractors of DOE nonreactor nuclear facilities have no guidance for performing ISI/IST related activities.

The majority of operations at DOE processing facilities most closely resemble those of the petrochemical and manufacturing industries. This report includes the results of a brief study of petrochemical standards to determine if ISI/IST guidance exists for this segment of industry, and to provide additional support for methodology development. The study indicated that although various component manufacturers recommend preservice inspections and tests, no appropriate standards for the periodic inservice inspection and testing of these components exist.

The first step in developing an effective ISI/IST program is to identify components that are crucial to the safe and reliable operation of the targeted process. An effective approach is to use the concept of risk as a basis for this determination. As described in the methodology, proven reliability techniques are used to estimate component failure frequencies and quantify expected consequences of component failure through a structured system of on-site expert analysis. This analysis technique has evolved from the petrochemical industry and is called a Hazard and Operability (HAZOP) study. However, the use of simple fault and event trees was added to the HAZOP process for the purpose of better defining the risk.

Further development of the high and medium risk event sequences is performed and Boolean expressions of these sequences, which include the important components and operator actions, are then written. Computer codes are used to produce a quantified comparison, as described by the Birnbaum importance measure, of individual risk-contributing components. This ranking is then stripped of operator actions and other nonrelevant equipment (for purposes of ISI/IST, only standard mechanical components remain) for a final listing of components to be considered as prime candidates for an inspection and testing program. The entire methodology is called a Process Integrated Risk Correlation (PIRC), as multiple areas of risk are addressed and the resultant list of components represents a hierarchical ranking with respect to component failure.

An integral tool in the ranking process is risk matrices. A separate matrix is developed for each appropriate risk issue, e.g., worker/public safety, environmental, economic loss. The matrices are divided into discrete cells and have two major axes; the vertical axis shows estimated frequencies of subject component failure(s) and the horizontal axis reflects the ultimate consequence(s) of failure. These matrices are initially developed, and ultimately refined, through discussions with expert plant personnel.

This methodology was used at the Idaho Chemical Processing Plant (ICPP), a DOE nuclear fuel reprocessing facility located at the Idaho National Engineering Laboratory (INEL). The PIRC was performed for portions of the First Cycle Extraction process, as detailed in the body of this report. In addition, existing ICPP ISI and IST activities were investigated for comparison with the results of the PIRC. It was found that formal ISI/IST programs did not exist at this facility; however, limited inspection and testing activities are being performed as dictated by operating procedures. Although some inspections/tests are occasionally performed for First Cycle Extraction components, when compared to the results of the PIRC, one concludes that much of the risk-significant equipment is not included in current maintenance and surveillance programs.

This report includes a discussion of further developmental work and refinements needed to enhance the PIRC methodology. Estimations of component failure frequency can be improved through the use of state-of-the-art techniques such as statistical modeling, expert questionnaires, and, most recently, probabilistic fracture mechanics methods. Furthermore, the second portion of the methodology would include determination of applicable inspections and tests, and their implementation rate(s), to fully realize effective ISI/IST programs.

In conclusion, during the course of background studies and literature searches in the development of this methodology, and as reinforced by the results of the PIRC, it is evident that most, if not all, DOE nonreactor nuclear process operating contractors have not adequately addressed the overall risk associated with component failure(s) at their facilities. The PIRC methodology is a viable procedure for identifying component risk, addresses multiple areas of concern, can be used to target analysis needs for high risk components, and, with further development, could be used for a wide variety of DOE processing facilities.

CONTENTS

ABSTRACT	iii
EXECUTIVE SUMMARY	v
INTRODUCTION	1
CODES AND STANDARDS REVIEW	4
RISK METHODOLOGY	7
Process Integrated Risk Correlation	8
Ranking Methodology For Components	14
Alternative Component Ranking Technique	16
Improvements to Component Failure Frequency Estimation	17
MATRICES FOR DETERMINING COMPONENT RISK	20
Plant Loss Matrix	21
Worker/Public Safety Matrix	22
Environmental Risk Matrix	24
Criticality Matrix	24
INITIAL FACILITY PROCESS EVALUATION	27
Results of PIRC at ICPP	38
Criticality Concern Sequences	40
Plant Loss Sequences	42
Birnbaum Ranking	43
ICPP Inservice Inspection and Testing	58
Inservice Inspection	58
Inservice Testing Practices	62
CONCLUSIONS	72
RECOMMENDATIONS	74
REFERENCES	75
APPENDIX A--Tables from the PIRC Study at ICPP	77

Figures

1. PIRC flow diagram.	9
2. Plant loss risk matrix	22
3. Worker/public safety risk matrix	23
4. Environmental risk matrix.	25
5. Criticality risk matrix.	26
6. Graphic representation of Line Segments 100 and 101	29
7. Graphic representation of Line Segment 102	30
8. Graphic representation of Line Segment 103	31
9. Graphic representation of Line Segment 104	32
10. Graphic representation of Line Segment 105	33

11. Graphic representation of Line Segment 106	35
12. Graphic representation of Line Segment 107	36
13. Graphic representation of Line Segment 108	37
14. Contributions of various outcomes to ICPP risk for active components.	39
15. Contributions of various outcomes to ICPP risk for passive components.	39

Tables

1. Comparison of industry codes and standards for the operation and maintenance of petroleum and chemical facilities	6
2. Frequency rating scale	21
3. Facility process evaluation for ICPP - First Cycle Extraction	28
4. Component ranking for risk of plant loss	44
5. Component ranking for risk of criticality	50
6. Component ranking for environmental risk	53
7. Component ranking for risk to worker/public safety	57

METHODOLOGY TO IDENTIFY RISK-SIGNIFICANT COMPONENTS FOR INSERVICE INSPECTION AND TESTING

INTRODUCTION

The nuclear facilities of the Department of Energy (DOE) - Office of Defense Programs (DP) include production reactors and specialized nuclear processing plants having varied components such as vessels, piping, blowers, pumps, and valves whose continued integrity and operability are necessary for safe and reliable operation. For many years DOE facilities have served the public interest by performing activities (producing, storing, separating, enriching, etc. nuclear and other hazardous materials) that are important to national security.

Because of the nature of processes at these facilities, and considering the age of facility components, an inservice inspection (ISI) and inservice testing (IST) program is essential to ensure a reasonable level of safety and reliability. Based on this study, it appears that at many of these facilities little, if any, periodic monitoring of mechanical components is performed to detect degradation that may cause failure during normal or unanticipated process events. The overall condition (structural integrity and operability) of important process components, if left unassessed, could lead or contribute to significant environmental, safety and health (ES&H) consequences.

In the commercial nuclear reactor industry, formal ISI and IST programs are used to detect and monitor component degradation that may prevent systems from performing their safety functions. The term "inservice evaluation" (ISE) represents the combination of testing (IST) of active mechanical components (pumps, valves, blowers, etc.) and inspection/examination (ISI) of passive barriers (tanks, pressure vessels, pipes, etc.). ISE principles are applicable to both reactor and nonreactor nuclear processes.

Given the need for ISI/IST programs, cognizant personnel must decide the appropriate level of implementation for their particular facility. Guidance for ISI/IST implementation at commercial nuclear facilities is found in the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel*

Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components." This standard is not directly applicable to most DOE nuclear processing facilities, whose systems are more easily compared to those of petrochemical or manufacturing plants than to commercial power reactors. The dissimilarities between DOE nonreactor nuclear processing facilities and commercial power reactors effectively eliminate many requirements listed in the ASME standard as useful guidance for developing DOE ISI/IST programs. However, in accordance with the Department's nuclear safety policy, DOE facilities must adhere to appropriate and accepted standards for their design, construction, operation, and decommissioning.

Currently there exists no equivalent to ASME Section XI within DOE to provide guidance to nuclear facilities for addressing ISE issues. Although the configurations and operating characteristics of these facilities are varied, the value of developing a strategy to address facility or process risk has been recognized by DOE.¹

Recent studies of DOE Category A test and research reactors^{2,3} have revealed numerous discrepancies in ISE practices. In addition, safety or risk analyses performed to date at DOE facilities have been restricted in their scope, i.e., the total integrated risk, with respect to significant ES&H issues, has not been fully addressed. The process studied during this project is a good example of this problem. Analytical data associated with criticality events can be found for nearly all processes at ICPP, although these processes are generally contained in shielded cells designed to accommodate criticality with minimal personnel exposure or environmental release. However, data pertaining to other ES&H concerns is scarcely available for use in developing an ISI/IST program, while some very hazardous chemicals are routinely used in various ICPP processes. This situation is believed to exist throughout the DOE community and, in the absence of uniform guidance, it would not be prudent to develop an ISI/IST program based solely on the findings of these limited historical analyses.

The DP Office of Engineering and Operations Support (DP-62) funded this project, *Nuclear Processes Inservice Evaluation Program Development*, to assess the current ISI/IST practices at selected DOE-DP non-reactor nuclear

processing facilities, identify components that should be included in ISE programs, and specify appropriate tests/inspections for these components to enhance reliability. It was determined that the most effective approach might be to use the concept of risk as a basis for ISE program implementation. Reliability techniques can be refined to select and prioritize ISE activities. The goal of this project was to provide technical guidance for ISI/IST program development and implementation that could be used for a wide spectrum of DOE processing facilities. Based on the integrated risk, the methodology presented in this report could enable personnel to properly define the scope of ISI/IST at their facility by producing an ordered list of process components. This philosophy of ranking components parallels the ASME Code safety classification system with the exception that risk is used as a basis rather than design function. Once the components were ranked, DOE facility personnel would then be able to prioritize inspections and tests so that even with a minimum of resources, process safety could be adequately addressed. This approach would provide an ISI/IST program that focuses on significant safety components while substantially saving costs.

Due to a reprioritization of programmatic needs within DP-62, FY-92 funding to continue the project has been eliminated. The purpose of this report is to document the progress to date. It describes a methodology that has been developed for prioritizing risk-significant process components through the conduct of on-site hazards and risk evaluations. The structured methodology includes proven reliability techniques, e.g., Preliminary Hazards Analysis (PHA), Hazards and Operability Study (HAZOP), and Fault and Event Tree Analyses (FTA and ETA), to provide a foundation for ISE activities. A discussion of the results of an on-site hazards and risk evaluation is included to exhibit how this methodology may be applied.

The report includes the findings of a cursory investigation into petrochemical standards, performed to determine whether guidance for ISE activities might exist for that portion of industry and provide support for ISE program development. In addition, future methodology developments and improvements needed for ISE program implementation are discussed.

CODES AND STANDARDS REVIEW

Inservice tests and inspections are currently specified for commercial nuclear power plants in accordance with provisions set forth in the *Code of Federal Regulations*, 10 CFR 50.55a, "Inservice Inspection Requirements". These requirements reference Section XI of the ASME *Boiler and Pressure Vessel Code*, which provides guidance for the ISI and IST of nuclear systems and components. The Nuclear Regulatory Commission (NRC) monitors the licensees that operate commercial nuclear power plants for their compliance with these ISI/IST requirements.

However, it was not clear what types of inspection programs exist (if any) for plants that are not covered by these ASME Code requirements. Thus codes, standards, and other industrial practices that provide direction in the development and implementation of an inservice inspection and test program were surveyed. The survey was restricted to the chemical/petroleum industries. The purpose of the survey was to quickly determine if current industry practices were distinctly different from the guidelines for commercial nuclear power plants. The literature search included technical journals, professional society publications, and established industry standards related to nuclear fuel reprocessing and hazardous material handling.

The initial investigation methodology involved discussions with personnel knowledgeable of Idaho Chemical Processing Plant (ICPP) operations to obtain a list of likely sources. This information was evaluated to refine the technical basis for assessing the ISE programs at the subject DOE facilities. Attention was devoted to the less familiar data sources to determine if any significantly new or different inspection practices existed in industry. Consequently, the ASME, American Society of Testing and Materials (ASTM), and American National Standards Institute (ANSI) codes and standards were not examined in detail at this time.

A cursory review of domestic technical journals and standards identified the American Institute of Chemical Engineers (AIChE), the American Petroleum Institute (API), and Underwriters Laboratories (UL) standards as likely

sources for the information desired. The contents of various references that were evaluated during the literature search are summarized in Table 1, i.e., the types of equipment covered by the standard, tests and inspections, frequency of activity performed (if specified), other comments relating to continued operation of the equipment, systems and plants, and remarks. Whenever the information can be compared to existing ASME/ASTM standards, this is noted in the remarks. Any recommended follow-up actions are noted, such as directly contacting equipment vendors or technical societies.

The literature search revealed an historical tie between the ASME and API Codes. A joint committee comprised of ASME and API personnel developed the API/ASME Code for Unfired Pressure Vessels. Portions of this Code were incorporated into the early 1950s versions of the ASME Code, preceding development of recommended inservice tests and inspections for commercial nuclear plants. In 1956 the API/ASME draft Code was replaced by API Standard 510 for general application in the petroleum and chemical industries. The historical ties between the ASME and API Codes underscore a common philosophy in ensuring component reliability.

In summary, there are numerous standards available for the performance of preoperational equipment tests and inspections, as suggested by the manufacturer following initial installation. Generally, the standards do not address testing and inspection of components after they are placed in service. The recommendations for routine checks are not well defined, and inspection methods usually entail a visual assessment for cracks, vibration, and leaks. The frequencies of the inspections are less well defined, and usually left to the discretion of the plant owner/operator.

TABLE 1. Comparison of industry codes and standards for the operation and maintenance of petroleum and chemical facilities.

Document	Equipment Type	Test / Inspection	Notes
API 510 - 1989 Maintenance, inspection, rating, repair, and alteration	Pressure vessels, safety relief devices	Corrosion inspection every 10 years	Historical link between API and ASME codes for uniform practices
API 574 - 1990 Inspection of piping, tubing, valves, and fittings	Piping, tubing, valves, fittings at petroleum refineries	Wall thickness inspection location for trending leak, corrosion, joints, welds, flanges, UT, RAD, LP tests. Valves: disassemble, inspect internals, check movement, hydro test after reassembly. ASME B31.3 and B16.34 data for wall thickness	Information is consistent with ASME codes for NDT tests - wall thickness, corrosion, remaining material life
API 598 - 1990 Valve inspection and testing	Gate, globe, plug, ball, check, and butterfly valves	Compliance with spec of work order. Mag particle, Rad, LP, and UT exam of steel castings	No retest unless specified in the work order. No guidelines for IST program
MSS SP - 92 Valve user guide	Valves	Backseats can mask stem packing condition. Control position indication via limit switches. Pressure surges can impact piping integrity esp. check valves; recommend periodic stroking for valves that remain in one position. Inspect externals	Presents some awareness of periodic inspections. No frequency indicated, nor methods of inspection. Contact MSS group for further information.
UI 429 Standard for electrically operated valves	Valves rated over 600 V. Service with air, refrigerants, steam, water, and other such fluids	General guidelines for construction and performance. Power loading, temperature, pressure, seat leaks, endurance, vibration, hydrostatic, spray test, 100,000 operating cycles	General guidelines for construction. Little information for IST program

RISK METHODOLOGY

A risk-based ISI/IST program provides a foundation for inspection and testing activities that will minimize the probability of unanticipated failure of critical components. Developing such a program hinges upon the ability of the analysts to identify and rank those components that are important to safety. Because the components that are potentially important are not always obvious, safety-related components are identified by relating the failure of a component to the resulting risk to the facility. The risk must then be quantified both in terms of likelihood and severity of the consequences and a method of ranking the components selected.

One of the most complete methods for ascertaining the risk is a probabilistic risk assessment (PRA), developed under the auspices of the NRC for commercial nuclear plants.^{4,5} However, PRAs take from many months to several years to complete, they can cost hundreds of thousands to millions of dollars, and they address only one outcome (e.g., for reactors this outcome is core damage). Thus PRAs are not suitable for facility process risk assessments, where multiple hazards may be present.

The chemical and oil industries use a qualitative process termed a hazards and operability (HAZOP) study. This technique relies on facility experts using a structured process to identify hazards and operability problems that could compromise the facility. The HAZOP process naturally covers a broad range of outcomes, which are normally ranked by some means such as a dollar value. The process is relatively low cost (tens of thousands to hundreds of thousands of dollars depending on process complexity) and can be accomplished in a time period of from several weeks to several months. One disadvantage of the HAZOP process is that it is mainly qualitative. A method of quantifying the risks identified during the HAZOP process has been developed by the authors. The different outcomes of the HAZOP analysis are separated into risk matrices so that for each HAZOP step the outcomes can be considered and ranked individually.

This method of quantifying risks, named "Process Integrated Risk Correlation" (PIRC), includes the best aspects of the HAZOP technique while

numerically quantifying the risk. The PIRC is a systematic method for identifying all of the ways process equipment can malfunction or be operated improperly and encoding the information quantitatively on a matrix (frequency versus consequence). As with the HAZOP technique, the PIRC is a general, structured, systematic, traceable, timely, group, and cost-effective process. The elements and progression of the PIRC are detailed in Figure 1. A brief description of the process follows.

Process Integrated Risk Correlation

The first step in a PIRC is to collect data from the facility detailing the processes and past and present facility operations. These data are used to plan a preliminary hazards analysis.⁶ This analysis is used to characterize the safety culture of the facility and its operations and identify the most risky portions of the processes. From the initial data and the preliminary hazards analysis, a process is targeted for analysis.

Exhaustive data are then collected on the target process and selection of the facility experts who will be PIRC team members begins. Team members may include the plant superintendent, a process supervisor, a maintenance engineer, an instrument engineer, or a technical engineer. Experts in other facility disciplines can be secured if the analysis requires them. Facility experts bring knowledge of plant design, experience in system and equipment operations, experience in equipment testing and maintenance, knowledge of process chemistry, and knowledge of safety objectives and procedures to the PIRC.

While the facility experts are being selected, the other PIRC team members are developing preliminary risk matrices, a set of process parameters to be examined, and a set of guide words to apply to the process parameters. They also review the piping and instrumentation diagrams (P&IDs) and select process line segments for analysis. A facilitator and two scribes are appointed from among the PIRC team members. The primary scribe serves the same function as the scribe in a standard HAZOP study and uses HAZOP data recording software or HAZOP data recording forms. The sequence scribe takes

Figure 1. PIRC flow diagram.

Figure 1. Continued.

Figure 1. Continued.

TASK 6

Figure 1. Continued.

detailed information on the progression of events that leads to a process upset and to the consequences specified for the matrices.

After the PIRC team members review the risk matrices, the process parameters, the parameter guide words, and the process line segments, the first process line segment is selected and the PIRC gets underway. The general purpose of the process line segment is explained by the facility experts. Further explanations are supplied for all connections to the process line segment. These explanations include the influence of any support systems or utilities connected to or used by this process line segment.

A process parameter (such as flow, temperature, pressure, level, etc.) is selected and the first process guide word (such as no, low, high, as well as, part of, reverse, other than, etc.) is applied to the process parameter (e.g., applying the guide word "no" to the process parameter "flow" yields "no flow"). The PIRC facility experts determine the different causes that will result in the deviation from normal operation described by the guide word applied to the process parameter.

To estimate the frequency of occurrence of this event, the team determines if such a condition has occurred within the lifetime of the facility. If the event has never occurred, the causal frequency (initiator frequency) is estimated by determining the component and human action failures required to make this condition occur. A Boolean combination (such as fault trees, event trees, and/or Boolean equation) of the highest component and human failure probabilities is used to determine the event frequency. [Data on component failure can come from the facility component database (if it exists) or more general sources such as reactor⁷ or chemical industry databases.⁸] The event frequency determines the location of this deviation from normal operating conditions on the frequency scale of the risk matrix.

Once the causes of deviation have been discussed and documented, the facilitator elicits the worst case consequences of the deviation from the facility experts. The magnitude (high, medium, low) of the consequences determines the location of this deviation on the consequence scale of the risk matrix.

Having determined both frequency and consequence, the risk for this deviation can be assigned to the risk matrices developed for the facility (development of these matrices is discussed in the next section). Note that the deviation risk for one matrix outcome may not be the same as risk for another outcome.

The PIRC team then discusses ways to prevent the causes of the deviation and mitigate its consequences. Suggestions are made by the team concerning possible actions that may reduce the potential for occurrence of the deviation.

When all of the guide words have been exhausted for this process line segment and process parameter, the PIRC process is repeated with the next process parameter until analysis of the process line segment is complete. The team then moves to the next process line segment. (Note: line segments are arbitrarily selected based upon the segment complexity and the number of diversions from the segment being selected.) Once all the process line segments have been analyzed, and the results reviewed by the facility experts, the risk-assessment phase of the PIRC is complete.

Finally, the process line segment deviations are converted into Boolean combinations of plant components and human actions to produce an ordered list of active and passive components to be considered for the ISE program. The procedure for this effort is presented in the following section, further details are given in the appendix.

Ranking Methodology For Components

Component ranking, the second part of the PIRC, is detailed in Figure 1. This methodology involves:

- (1) Converting process line segments into Boolean expressions containing failure events for component and human failures,
- (2) Associating each line segment with the matrix or matrices to which they belong,

- (3) Determining the relationship between consequence categories for a given matrix and multiplying the appropriate consequence category by the appropriate process line segment expression to produce process line segment risk expressions,
- (4) Forming a Boolean sum of all the process line segment risk expressions for each matrix to produce matrix risk expressions,
- (5) Reducing the matrix risk expressions to an expression containing only minimal cut-sets (just the minimum number and kind of component and/or human failures needed to produce a given deviation),
- (6) Loading the matrix risk expressions with the failure data for the components and human actions into a PRA Work Station such as the Integrated Reliability and Analysis System (IRRAS)⁹ PRA work station or the Computer Aided Fault Tree Analysis (CAFTA)¹⁰ PRA work station,
- (7) Extracting from the PRA workstation a Birnbaum ranking (the amount of risk a component contributes to the process) for each risk matrix,
- (8) Eliminating electrical components and human actions from the Birnbaum ranking (to keep only components concerned with IST or ISI),
- (9) Separating the components for each matrix into active components (IST concerns) and passive components (ISI concerns).

The first step in ranking is to express the process line segment deviations that are high and medium risk in terms of a Boolean expression (could be a fault tree, event tree or a Boolean equation). (Low risk process line segment deviations are not analyzed.) The analyst reexamines the applicable PIRC process line segment deviations and describes them in terms of the sequences of events or actions that cause them. This sequence is then expressed as a Boolean combination. For example, to cause the deviation, component A or component B has to fail and human action C failure occurs. The Boolean expression for this description is $C * (A + B)$. These steps are taken for each high or medium risk process line segment.

The Boolean expressions are categorized by risk matrix. For a given risk matrix, the process line segments are further divided into consequence categories. Category "A" always represents the most severe consequence while the last letter used always represents the least severe consequence. Each process line segment Boolean expression, for a selected matrix, is logically multiplied (Boolean "and") by the consequence letter for that line segment deviation. The resulting Boolean expressions for a selected matrix are

logically added (Boolean "or") to obtain a single Boolean expression for the selected matrix. This procedure is repeated for each matrix. Each Boolean matrix expression is reduced to a Boolean equation in terms of minimal cut-sets. (A minimal cut-set is the fewest number of component and/or human failures needed to cause the process line deviation and consequence.) Boolean reduction codes such as the Sets Equation Transformation System (SETS),¹¹ the IRRAS⁹ PRA Work Station, or the CAFTA¹⁰ PRA Work Station can be used to produce minimal cut-sets depending on the form of the risk matrix's Boolean expression.

The failure probabilities for the component and human action events that make up the risk matrix Boolean expression are determined from available sources. Examples of these sources, in order of preference, are plant-specific failure rates and the databases cited earlier.^{7,8} The values to be used for the consequence letters (A, B...) are determined from the relative impact each consequence has on the facility (e.g., $A=1$, $B=.1*A$, $C=.01*A$, and $D=.001*A$). From these component and human failure probabilities, consequence letter values, and the minimal cut-set equations from each risk matrix, a PRA Work Station such as the IRRAS PRA Work Station or the CAFTA PRA Work Station can calculate a Birnbaum ranking. A Birnbaum ranking number is simply a measure of the amount of risk that the component contributes to the process. The ranked list of components can be given to the appropriate plant personnel for ISE program development.

Alternative Component Ranking Technique

The technique described above is a comprehensive integrated evaluation of all the components using detailed risk analyses that can be very time consuming. A simpler technique can be used if less detail is required. One approach is to compile a list of components, classified by their consequence category (e.g., Worker/Public Safety, Environmental) and level (A1, A2, B1, etc.), as determined from the event sequences. For example, all the components, from all sequences, that contribute to an A1 Worker/Public Safety consequence can be listed together without further ranking.

It should be noted that, for this approach, only the overall frequencies for consequence levels (A1, A2, B1, etc.) are used to generate the component lists, and specific component failure frequencies are not used to rank the components within a given consequence category/level. An additional level of detail could be added by performing a relative ranking of the components within each consequence category and level. The frequency of failure of each component can be used in a Boolean logic model to estimate the importance or relative ranking of each component. For this type of evaluation, fault trees, event trees or cut-set equations of each sequence are used to rank the importance of each of the components, as they relate to other components in the same consequence category/level list. Computer codes such as IRRAS⁹ can then be used to evaluate the logic models or the analysis can be done by manual calculations^{12,13} since relatively simple logic models can be used to evaluate most of the sequences.

The component ranking technique to be used depends on the level of detail required. This level should be defined by the facility management. A suggested method is to use the most comprehensive approach for high consequence categories and the simpler approach for lower consequence categories.

Several new techniques that should be investigated for their potential to improve the overall risk ranking method and advance the state-of-the-art are briefly discussed below.

Improvements to Component Failure Frequency Estimation

Estimation of component failure frequencies is an important part of the risk evaluation since the failure probability determined from this frequency is one of the two parts of the risk equation (the other being the ultimate consequence of failure). During the PIRC, estimates for this frequency were made using generic databases and historical failures observed by ICPP experts. It should be noted that failure rates are needed for both active and passive components. Other techniques may be investigated and employed, depending on the consequences of the component failure; a more extensive analysis is more appropriate for very large consequence components than for low consequence

components. The authors have identified potential techniques that may be used to better estimate the frequency of failure for both active and passive components. These are statistical data evaluation, expert solicitation (too time consuming to be performed during the PIRC session), questionnaires, and, for passive components, simple or detailed probabilistic fracture mechanics (PFM) models.

Methods can be demonstrated that use statistical techniques to evaluate active component plant data to determine when the "wear out" stage has been reached, i.e., the performance of specific components has degraded to unacceptable levels. These techniques should be used in conjunction with data collection schemes to trend the operating characteristics of risk-significant components. For purposes of risk evaluation, these same statistical modeling techniques may be a valuable tool in estimating component failure frequency.

Questionnaires are another tool for estimating active/passive component failure rates. The questionnaires require experts on the plant or process system to determine parameters and record information that may dominate specific component failure frequencies. The questionnaire lists parameters such as the type of material, number and relative magnitude of mechanical and thermal transients, and fluid chemistry.

Simple PFM models, or scoping studies, are the latest and most promising development in determining passive component failure frequencies. These models are developed from larger fracture mechanics models using a first order approximation technique. Much of the input of these personal computer based codes can be refined, so that calculations take only seconds, as opposed to hours for the larger PFM codes. Output can be in graphic form to aid in interpretation of the results during on-site evaluations. Parametric studies can be performed to determine the properties that most affect failure, and varied inspection frequencies/accuracies can be input to determine the most efficient means of controlling failure frequency.

For components that cause large consequences when failure occurs, the cost of a large probabilistic fracture mechanics code may be justified. Large PFM codes are available to calculate the failure of piping systems as a result

of fatigue, intergranular stress corrosion cracking, creep, and other failure mechanisms. Much of the cost of the analysis is a result of the time it takes to become familiar with the code, determinations of initial flaw size statistical distributions, material properties, transient stresses, and so on. The use of a consultant skilled in these computer codes is often a prudent approach, considering the time required to become familiar with the codes, develop the input distributions, and calculate uncertainties. These codes are the most accurate techniques to determine the failure frequency of passive components and, as with the simple PFM models, inspection accuracy and frequency can be input into calculations to determine the most efficient mitigation technique.

MATRICES FOR DETERMINING COMPONENT RISK

Levels of risk are determined by combining the expected frequency of an event with the severity of its consequences. The types of risks associated with facility operations include personnel injury/death, loss of plant equipment, and damage to the environment. The specific risks of operations depend on many factors, such as the types of materials processed, process temperatures, and criticality concerns. A matrix is a good tool for quantifying risk.

Each matrix has two axes. The vertical axis shows estimated frequencies of subject component failures. There are five frequency divisions numbered, on the right side, 1 to 5 as the expected frequency decreases. In the examples shown here the scale on the left side goes from $f \geq 1.0$, which indicates that a failure is likely about once per year, to $f \leq 10^{-3}$, which indicates that the failure rate is expected to be lower than one per thousand years. The horizontal axis reflects the consequence of a failure. It is divided into sections, labelled on the top with letters reflecting decreasing consequence. The bottom axis is labelled with the consequences, e.g., estimated costs.

Under the original scope of work for this project, the Idaho Chemical Processing Plant (ICPP) was the first DOE facility selected for assessment. The matrices described in this section were developed for the ICPP PIRC to determine the levels of risk posed by the failure of various components (e.g., vessels, piping, blowers, pumps, and valves) considered in the study. These matrices specifically address effects and/or costs associated with equipment failures, namely, "Plant Loss," "Worker/Public Safety," "Environmental Risk," and "Criticality." Also developed was a "Frequency Rating Scale" (Table 2) that was used during the PIRC to estimate the likelihood of an occurrence over time.

The economic impact of a loss, whether it be due to injured personnel or environmental damage, depends, at least in part, on the operating budget of the facility. Dollar values were assigned to events considered for the ICPP

Table 2. Frequency rating scale.

Frequency Scale	Description	Estimated Range of Frequency
1	Likely to occur one or more times per year	$f \geq 1.0/\text{yr}$
2	Likely to occur once every ten years	$10^{-1} \leq f < 1.0/\text{yr}$
3	Likely to occur once every 100 years	$10^{-2} \leq f < 10^{-1}/\text{yr}$
4	Likely to occur once every 1000 years	$10^{-3} \leq f < 10^{-2}/\text{yr}$
5	Expected to occur less than once every 1000 years.	$f < 10^{-3}/\text{yr}$

study based on the annual operating budget for the facility. Such dollar values would certainly vary for disparate facilities with different budgets.

Plant Loss Matrix

The first matrix, Figure 2, regards plant loss. Plant loss includes costs associated with repair/replacement of components, decreased production, and "incentive bonus" or "penalty clause" losses due to schedule delays. Plant loss could occur as a result of a valve failure or a spill in an operating corridor that shuts down operations. It could result from failure of an air lift or a hole in a pipe that slows or stops processing.

The vertical axis of the plant loss matrix shows estimated frequencies of subject component failures. The scale goes from $f \leq 10^{-3}$, which indicates that the failure rate is expected to be lower than one per thousand years, to $f \geq 1.0$, which indicates that a failure is likely about once per year. The lower, horizontal axis reflects the dollar value of the consequence of a failure. The lowest consequence level, D, is associated with an event costing <\$10,000. The highest consequence division, A, is failures with estimated costs >\$1,000,000.

The average cost associated with any particular cell of this matrix can be determined by multiplying the average estimated dollar cost of a consequence of failure times the average failure rate associated with the cell. For cell B-2 in Figure 2 this yields \$250,000.

		PLANT LOSS			
		D	C	B	A
F R E Q U E N C Y	$f \geq 1.0$				1
	$10^{-1} \leq f < 1.0$				2
	$10^{-2} \leq f < 10^{-1}$				3
	$10^{-3} \leq f < 10^{-2}$				4
	$f < 10^{-3}$				5
		<\$10K	\$10K to <\$100K	\$100K to <\$1M	≥\$1M
		CONSEQUENCES			

Note: Plant Loss includes costs associated with repair/replacement of components, product losses, and "incentive bonus" losses, or "penalty clause" losses due to schedule delays.

Figure 2. Plant loss risk matrix.

Worker/Public Safety Matrix

Worker/public safety considers injuries or deaths of facility workers and the public. The lower, horizontal axis in Figure 3 reflects specific consequences of failure in terms of personnel safety. The lowest consequence level, D, is associated with a minor injury; the highest consequence division, A, is failure resulting in multiple deaths. Dollar values or other relative measures can be assigned for comparison purposes with other matrices.

WORKER/PUBLIC SAFETY

		D	C	B	A	
$f \geq 1.0$						1
$10^{-1} \leq f < 1.0$						2
$10^{-2} \leq f < 10^{-1}$						3
$10^{-3} \leq f < 10^{-2}$						4
$f < 10^{-3}$						5
		Minor Injury	Major Injury	One Death	Multiple Deaths	
		CONSEQUENCES				

Worker: Personnel who work in the process area.

Public: Any personnel outside of the process area.

Multiple Deaths: Event causes >1 worker/public death.

One Death: Event results in a singular worker/public death.

Major Injury: Event results in >5 worker/public injuries, or any combination of injuries that causes > 2.5 equivalent lost workdays. This category also includes unanticipated personnel radiation exposure greater than administrative limits.

Minor Injury: Event results in ≤ 5 worker/public injuries, or any combination of injuries not exceeding 5 personnel, that causes ≤ 2.5 equivalent lost workdays. This category also includes unanticipated personnel radiation exposure within administrative limits.

Figure 3. Worker/public safety risk matrix.

Environmental Risk Matrix

Environmental risk considers damage to the environment caused by facility operation. The lower, horizontal axis in Figure 4 reflects specific consequences of failure in terms of spills and releases. The lowest consequence level, D, is associated with a minor spill; the highest consequence division, A, is a failure that results in a major release. Again, values might be assigned for comparison with the other matrices.

Criticality Matrix

Though criticality is not in itself a consequence, it has been an important consideration for risk assessments of operations at ICPP. The criticality matrix, Figure 5, considers only whether an event can lead to a criticality. There are only two divisions on the lower, horizontal axis: events that will not result in a criticality and events that may result in a criticality.

ENVIRONMENTAL RISK

		D	C	B	A		
F R E Q U E N C Y	$f \geq 1.0$					1	
	$10^{-1} \leq f < 1.0$					2	
	$10^{-2} \leq f < 10^{-1}$					3	
	$10^{-3} \leq f < 10^{-2}$					4	
	$f < 10^{-3}$					5	
		Minor Spill	Major Spill	Minor Release	Major Release	CONSEQUENCES	

On/Off-site: - On-site refers to areas within the process boundaries; off-site is any area immediately outside process boundaries.

Major Release: An off-site spill or release with long term or prolonged clean up efforts involving significant costs.

Minor Release: An off-site spill or release that requires short term clean up efforts involving moderate costs.

Major Spill: An on-site spill or release that requires a costly clean up and recovery effort that cannot be accomplished through standard operational procedures.

Minor Spill: An on-site spill or release that can be cleaned-up/recovered with standard operational procedures.

Figure 4. Environmental risk matrix.

CRITICALITY

FREQUENCY	CRITICALITY		
	B	A	
$f \geq 1.0$			1
$10^{-1} \leq f < 1.0$			2
$10^{-2} \leq f < 10^{-1}$			3
$10^{-3} \leq f < 10^{-2}$			4
$f < 10^{-3}$			5
Events that will <u>not</u> Result in Criticality		Events that <u>may</u> Result in Criticality	
CONSEQUENCES			

Figure 5. Criticality risk matrix.

INITIAL FACILITY PROCESS EVALUATION

DOE DP-62 selected the Idaho Chemical Processing Plant as the initial facility for evaluation because ICPP appears to be representative of DOE-DP nonreactor nuclear processing facilities and because, being at the Idaho National Engineering Laboratory, it is close to the authors. An on-site PIRC was performed on the ICPP First Cycle Extraction process during October 14-24, 1991. This process uses tributyl phosphate (TBP) in an organic solution to extract uranium from an aqueous feed. The feed solution is the product of an upstream dissolution process. First Cycle Extraction consists of a series of solvent extraction, wash, and stripping columns, intercycle storage tanks, steam and air driven pumps and lifts, and all associated piping. The extraction equipment is located in separate isolated cells of the building.

The PIRC methodology relied on experienced facility personnel and a facilitator to uncover equipment risk sequences during structured team brainstorming and discussion sessions. In these sessions, both the probability and consequences of events were estimated and documented in a PC computer database for traceability. The areas of expertise of the primary facility participants were process engineering, operations, instrumentation and control, and operational safety. Other facility experts were provided on an "as needed" basis. The PIRC was conducted Monday through Thursday, from 8:00 AM to 12:00 noon for two weeks.

First Cycle Extraction is a complex process that involves numerous systems and components. The evaluation centered on components in primary process flow(s), but important consequence sequences that involved elements of other support components were also considered. Evaluation of the entire process could not be performed in the time period indicated above; however, because the PIRC was performed systematically, and under the direction of a qualified facilitator, the results are valid for the completed portions of First Cycle Extraction. Table 3 lists the line segments for which the PIRC was completed, their descriptions, and corresponding line/equipment numbers. Figures 6 through 13 are graphic representations of these line segments.

TABLE 3. Facility process evaluation for ICPP - First Cycle Extraction.

Line Segment Designation	Description	Line/Equipment Considered
100	Aqueous inlet feed from FDP to vessels G-105, G-155, and G-108	Inlet lines 1.5" FP-AF-5957; 1" 125957; 0.5" DCAF105755
101	Feed receiving tank G-105	Vessel G-105
102	First cycle aqueous feed line	Transfer line 2" PSA-419; steam line 1.5" HSA-327; Vessel G-106
103	First cycle aqueous feed to surge tank G-165	Lines 1" PSA-303, 406, 549, 110086
104	Inlet lines to extraction column G-111	Vessels G-165, G-164; Lines 1.5" PSA-600, 591, 310; 1" PSA-454, 592, 525, VGA-363
105	Extraction column G-111	Vessel G-111; Lines 4" PSA-356; 2" PSA-554; 1" LAN-357
106	Raffinate line from extraction column	Vessels G-112, G-113, G-157; Lines 0.25" L-12-AM-111308; 0.75" PSA-324; 1" PSA-326, 458, 461, AL-G-550, VGA-362, RCV-G-49, RCV-G-36; 1.5" PSA-463, 2" PSA-325
107	Uranium bearing organic line to pulser connection for the H-100 column	Vessels H-132, H-142, H-555; Lines 0.75" PSA-312, 593, PSAR-604; 1" PSA-595; 2" PSA-312, 594, PSAR-605
108	Inlet/outlet organic lines to vessel H-100 and to air pulse system	Vessels H-100, H-124, H-101, H-102; Lines 0.50" AA-354, AL-H-550; 0.75" PSA-327, 539, 314; 1" PSA-540, 559; 2" PSA-314, 541, 558; 4" PSA-313; 2" & 0.75" PSA-328; RRA-100 (abandoned radiation detector)

LINE SEGMENT 100
IS INCOMING STREAM
FROM FDP TO VES G-105

Figure 6. Graphic representation of Line Segments 100 and 101.

LINE SEGMENT 102 IS FLOW TO AND FROM FIRST CYCLE FEED TANK VES-G-106

Figure 7. Graphic representation of Line Segment 102.

LINE SEGMENT 103 IS FIRST CYCLE FEED TO SURGE TANK VES-G-165

Figure 8. Graphic representation of Line Segment 103.

LINE SEGMENT 104
IS INCOMING STREAM TO
EXTRACTION COLUMN VES-G-111

Figure 3. Graphic representation of Line Segment 104.

LINE SEGMENT 105
IS FLOW TO AND FROM
COLUMN VES-G-111

Figure 10. Graphic representation of Line Segment 105.

LINE SEGMENT 105 CONTINUED

H-CELL MIXER/SETTLERS

Figure 10. Continued.

**LINE SEGMENT 106
IS RAFFINATE STREAM
FROM EXTRACTION
COLUMN VES-G-111**

Figure 11. Graphic representation of Line Segment 106.

LINE SEGMENT 107
IS URANIUM BEARING ORGANIC STREAM
TO SCRUB COLUMN VES-H-100

Figure 12. Graphic representation of Line Segment 107.

LINE SEGMENT 108
IS FLOW TO AND FROM
SCRUB COLUMN VES-H-100

Figure 13. Graphic representation of Line Segment 108.

While the unfinished process evaluation was useful from the standpoint of this project, its completion is recommended prior to developing inspection and testing criteria, implementing operational changes, or designing component modifications. Only by completing the evaluation may the relative risk of all First Cycle Extraction components be determined.

The progressive steps used in the PIRC to rank and quantify the importance of components were formulated as a result of the on-site evaluation effort at ICPP. Much information was learned about the ranking process from this evaluation. The following are offered as examples:

- Selection of facility technical personnel for the PIRC team is a crucial factor in the process.
- Individual components that lead to undesirable consequences are usually contained in sequences of equipment malfunctions that can be analyzed by Boolean logic techniques such as fault trees and event trees.
- A second scribe is needed to record the complex sequences leading to consequences for proper evaluation. In early ICPP HAZOP sessions, the lack of a second scribe resulted in cursory definitions of component success/failure states and process mission times.
- Documentation of these sequences should be completed immediately after the evaluation session.
- The software used for performing the on-site PIRC should be further developed/modified to accommodate multiple areas of risk and to allow integration with other available software tools needed to enhance documentation. Only in this manner may the methodology become more comprehensive and repeatable.

The INEL staff anticipates that future methodology demonstrations will yield even more information and contribute to the overall usefulness of PIRC techniques for significantly reducing risk at DOE facilities.

Results of PIRC at ICPP

Four concerns relative to process component failure(s) were evaluated for the First Cycle Extraction process: worker/public safety, environmental safety, criticality safety, and plant economic loss. Results indicate that, for active component failures, consequences involving criticality are the

greatest contributor to facility risk at >99% (Figure 14), while environmental issues dominate the risk sequences at 64% for passive components (Figure 15). These results were, to some extent, expected since the TBP process was thought to be entirely enclosed in radiologically shielded, discrete cells. Furthermore, although criticality is not a personnel or environmental concern due to the shielded cell, it does pose a severe economic and production loss

Figure 14. Contributions of various outcomes to ICPP risk for active components.

Figure 15. Contributions of various outcomes to ICPP risk for passive components.

for the facility. Opinion at the facility is that if a criticality occurs, the facility could be shutdown indefinitely.

The high and medium risk sequences for process line segments studied are given in Appendix Table A-2 and the definitions of the component and human error failure events used in the expressions are given in Appendix Table A-3. There are six high and 48 medium risk sequences. The high risk sequences are described here as examples of sequence construction. Of the six high risk sequences, four are criticality concerns and two are plant loss concerns. Although these sequences each involve only one concern, it is possible for a sequence to raise multiple concerns.

Criticality Concern Sequences

The first sequence for criticality safety is designated as line/item 102-10-2 (Appendix Table A-1). This sequence was determined by applying the process guide word, "as well as" to the process parameter, "material". "Material as well as" means that there is another material, as well as the normal material, within the process line segment being analyzed. Other material can get into this segment by having high flow in the organic stream of extraction column VES-G-111, scrub column VES-H-100, or stripping column VES-H-103, caused by high air pulser flow, which would push the organic solution into the vent/off-gas system for the aforementioned vessels. From the vent/off-gas system, the solution could be carried back to the rework tank, VES-G-108. The rework tank is not safe from criticality for organics carrying uranium. From the rework tank the organics can be jetted back into first cycle feed tank, VES-G-106. From the first cycle feed tank the solution is transferred back into the aqueous inlet for extraction column VES-G-111 and the process begins over again, only this time the uranium is concentrating in the organic stream. In several hours, the concentration of the organics reaching the rework tank exceeds critical concentration and there is a criticality in rework tank VES-G-108. For criticality to occur, the operator must be unaware that the high flow situation exists. Another way of causing unwanted carryover of the organic stream into the vent/off-gas system is to have inadvertent operation of the steam jets. This would lead to the same scenario as discussed previously. The word discussion is converted to a

Boolean expression (Appendix Table A-2) by substituting component and human failure events that describe the scenario.

The second criticality concern sequence is designated as line/item 105-3-2 (Appendix Table A-1). The deviation for this line segment arises from application of the process guide word "high" to the process parameter "flow". The sequence is initiated by high flow from feed pumps P-PA-240 and P-PA-241 caused by a high setting of the stroke controllers or by undetected leakage through remote control isolation valves RCV-H-7 or RCV-H-119 back to the organic inlet stream of extraction column VES-G-111. The high flow rate through the columns leads to high flow in the mixer settler tank VES-H-115. If a restriction occurs in the mixer settler tank, critical concentration can be reached. In order for this sequence to take place, the operator has to fail to control the additional flow to the first stage extraction column VES-G-111. The aforementioned description has been converted to a Boolean expression (Appendix Table A-2).

The third criticality concern is designated as line/item 105-10-1 (Appendix Table A-1). The deviation for this line segment item is a result of the application of the process guide word "as well as" to the process parameter "material". "Material as well as" means that within the process line segment there is another material as well as the normal material. Unwanted material is introduced as aqueous solution going into the organic stream from the last mixer/settler. Normally the last mixer settler sends the aqueous solution to the process equipment waste (PEW) system; however, if the remote controlled PEW isolation valve RCV-H-6 fails to remain open, the aqueous solution goes to the TBP solvent run tank VES-H-118 and then back to the extraction column VES-G-111 in the organic inlet. Valve RCV-H-6 is normally air-to-close (ATC). If the valve malfunctions, the operator would have to jet the water off the bottom of TBP run tank VES-H-118, or the concentrations would approach the technical specification limits and lead to criticality in either extraction column VES-G-111 or scrub column VES-H-100. The same scenario exists if steam jets H-521 and H-522 were inadvertently operated or if water in cooling jacket VES-H-301 leaked into the process steam. The aforementioned description has been converted to a Boolean expression (Appendix Table A-2).

The fourth high risk criticality sequence is line/item 108-3-2 (Appendix Table A-1). The deviation for this line item segment comes from the application of the process guide word "high" to the process parameter "flow". The "high flow" is the high aqueous flow through the jack leg after scrub column VES-H-100. Due to the high flow, uranium concentration builds up in a stagnant layer in the bottom of scrub column H-100. This build up will require several hours; therefore, operators could respond before criticality occurred. High level alarm DAHL-H-100 and pressure transmitter PT-H-100 will indicate to the operator that a problem exists and needs to be corrected. The aforementioned description has been converted to a Boolean expression (Appendix Table A-2).

Plant Loss Sequences

The first plant loss sequence is line/item 105-2-1 (Appendix Table A-1). The deviation for this line segment item is derived from application of the guide word "low" to the process parameter "flow". The "low flow" is an organic low flow caused by buildup in the plates or blockage of the plates in extraction column VES-G-111. This event will result in a loss of column efficiency and possible process shutdown by causing the column to flood, putting organics into the raffinates. In order for extraction efficiency to decrease, the operator would have to fail to notice that the buildup was occurring. Since there are no access ports for the extraction column plates, clean up of this problem can be extremely expensive. The aforementioned description has been converted to a Boolean expression (Appendix Table A-2).

The final high-risk plant loss sequence follows from line/item 105-12-1 (Appendix Table A-1). The deviation for this line segment item resulted from applying the process guide word "low" to the process parameter "level". The "low level" of concern is in the extraction column VES-G-111. This level is a result of failure of the density interfacing controller or the current to pressure (I to P) converter. Extraction column VES-G-111 would fill within an hour and could result in doubling the volume of solution going to the raffinate tank. The filling of the column is an upset condition causing decreased efficiency in the extraction process. Although the cost (consequence) of the failure is low, it occurs with high frequency. The

aforementioned description has been converted to a Boolean expression (Appendix Table A-1).

Birnbaum Ranking

The high-risk sequences were combined with the medium-risk sequences to generate a risk model. The Boolean equations developed for the sequences for the HAZOP line items (Appendix Table A-2) were evaluated using the Sets Equation Transformation System (SETS) computer code. The minimal cut-sets produced by SETS were then loaded into the IRRAS PRA work station with a database (Appendix Table A-4) for all basic events used. IRRAS produced a Birnbaum importance ranking from the cut-set model and the database (see Risk Methodology section). The Birnbaum ranking process assigns importance to events by measuring the difference in the total model frequency when the event is perfectly failed versus when the event is perfectly successful. Tables 4 through 7 list the Birnbaum-ranked components from the high- and medium-risk sequences for the four risk concerns (plant loss, criticality, environmental, and worker/public safety). Since this project deals with standard passive and active components, the tables have been stripped of the human error failures and the instrumentation and control failures. Because the rankings of these passive and active components can indicate the need for inspection or testing, the lists are separated for future use in planning ISI and IST.

Table 4. Component ranking for risk of plant loss.

Rank	Event name	Probability of failure	Birnbaum importance measure
<u>Passive Components</u>			
1	VES-G-111-BLK	9.978E-002	1.000E-001
2	FCV-G-1A-ELK	9.950E-003	9.873E-002
3	FCV-G-1B-ELK	9.950E-003	9.873E-002
4	PSA-592-LK	5.852E-003	9.869E-002
5	PSA-525-LK	5.852E-003	9.869E-002
6	PSA-591-LK	5.852E-003	9.869E-002
7	PSA-600-LK	5.852E-003	9.869E-002
8	PSA-454-LK	5.852E-003	9.869E-002
9	PSA-303-LK	5.867E-004	9.864E-002
10	PSA-110086-LK	5.867E-004	9.864E-002
11	PSA-549-LK	5.867E-004	9.864E-002
12	PSA-406-LK	5.867E-004	9.864E-002
13	PSA-600-RP	2.347E-004	9.863E-002
14	PSA-591-RP	2.347E-004	9.863E-002
15	PSA-592-RP	2.347E-004	9.863E-002
16	PSA-525-RP	2.347E-004	9.863E-002
17	PSA-454-RP	2.347E-004	9.863E-002
18	FCV-2G-PK-LK	8.760E-005	9.863E-002
19	VES-G-165-LK	8.760E-005	9.863E-002
20	VES-G-105-LKK	8.760E-005	9.863E-002
21	PSA-549-RP	2.348E-005	9.863E-002
22	PSA-110086-RP	2.348E-005	9.863E-002
23	PSA-406-RP	2.348E-005	9.863E-002
24	PSA-303-RP	2.278E-005	9.863E-002
25	VES-G-105-RPP	3.504E-006	9.863E-002

Table 4. (continued).

Rank	Event name	Probability of failure	Birnbaum importance measure
26	VES-G-165-RP	3.504E-006	9.863E-002
27	FCV-2G-PK-RP	3.504E-006	9.863E-002
28	VES-G-359-LK	8.760E-005	1.798E-003
29	VES-G-106-LK	8.760E-005	1.798E-003
30	VES-G-105-LK	8.760E-005	1.798E-003
31	VES-G-359-RP	3.504E-006	1.798E-003
32	VES-G-105-RP	3.504E-006	1.798E-003
33	VES-G-106-RP	3.504E-006	1.798E-003
34	FE-G-111-PG	3.612E-002	1.123E-004
35	FP-AF-5957-BK	2.278E-003	9.863E-005
36	FP-AF-125957-BK	2.278E-003	9.863E-005
37	LAA-362-PG	8.760E-004	9.863E-006
38	PSA-458-PG	8.756E-004	9.863E-006
39	PSA-461-PG	8.756E-004	9.863E-006
40	LAN-353-PG	8.760E-004	9.863E-007
41	LAN-221-PG	8.760E-004	9.863E-007
42	LAN-220-PG	8.760E-004	9.863E-007
43	LAA-205-PG	8.760E-004	9.863E-007
44	PSA-559-PG	8.756E-004	9.863E-008
45	HSN-335-STR-PG	3.612E-002	5.509E-008
46	HSN-327-STR-PG	3.612E-002	5.509E-008
47	HSN-328-STR-PG	3.612E-002	5.509E-008
48	HSN-334-STR-PG	3.612E-002	5.509E-008

Table 4. (continued).

Rank	Event name	Probability of failure	Birnbaum importance measure
<u>Active Components</u>			
1	HSV-PO-G504-2-FO	2.200E-003	4.932E-002
2	RCV-G-36-FTRO	1.823E-002	9.865E-003
3	LAVPOG553-18FTRO	1.051E-003	9.863E-003
4	LAVPOG553-13FTRO	1.051E-003	9.863E-003
5	LAVPOG553-14FTRO	1.051E-003	1.077E-003
6	LAVPOG553-15FTRO	1.051E-003	1.077E-003
7	FCV-G-553-FTRO	1.051E-003	1.077E-003
8	SOVPMG533-1-FTRO	5.416E-003	1.072E-003
9	SOVPMG533-2-FTRO	5.416E-003	1.072E-003
10	RCV-PM-225-2-FC	1.000E-003	9.887E-004
11	RCV-PM-225-1-FO	1.000E-003	9.887E-004
12	RCV-G-66-FTRC	1.823E-002	9.865E-004
13	FCV-2G-FO	1.000E-003	9.865E-004
14	RCV-G-37-LK	1.392E-002	9.863E-004
15	RCV-G-35-LK	1.392E-002	9.863E-004
16	PCV-G-550-FTRG	3.096E-002	6.016E-004
17	L15VPOG66-66FTRO	1.051E-003	5.553E-004
18	RCV-G-66-FTO	1.000E-003	5.553E-004
19	L15VPOG66-1-FTRO	1.051E-003	5.553E-004
20	HS-G-66-FTRO	2.880E-007	5.553E-004
21	LAVPOH555-10FTRC	1.332E-003	4.932E-004
22	HSVPOG537-2-FTRC	1.332E-003	1.313E-004
23	HSVPOG537-1-FTRC	1.332E-003	1.313E-004
24	LAVPMG553-16FTO	5.000E-004	1.297E-004
25	RCV-G-65-FTRO	1.823E-002	1.023E-004

Table 4. (continued).

Rank	Event name	Probability of failure	Birnbaum importance measure
26	L15VPOG65-1-FTRO	1.051E-003	1.023E-004
27	L15VPOG65-2-FTRO	1.051E-003	1.023E-004
28	HS-G-65-FTRO	1.051E-003	1.023E-004
29	FCV-2G-FTRO	1.051E-003	1.023E-004
30	PCVPM-125-0-FTRG	3.096E-002	9.887E-005
31	RCVPM-225-0-FTRO	1.823E-002	9.863E-005
32	RCVPM-224-0-FTRO	1.823E-002	9.863E-005
33	SOV-PM-225-0-FTT	7.200E-004	9.863E-005
34	SOV-PM-224-1-FTT	7.200E-004	9.863E-005
35	SOV-PM-225-1-FTT	7.200E-004	9.863E-005
36	LA2VPM225-02FTRO	1.051E-003	9.863E-005
37	RCV-PM-225-1-FC	1.000E-003	9.863E-005
38	LA2VPM224-03FTRO	1.051E-003	9.863E-005
39	SOV-PM-224-0-FTT	7.200E-004	9.863E-005
40	RCV-PM-224-1-FC	1.000E-003	9.863E-005
41	RCV-PM-224-2-FO	1.000E-003	9.863E-005
42	HAVPM225-02-FTRO	1.051E-003	9.863E-005
43	RCV-PM-225-2-FO	1.000E-003	9.863E-005
44	HAVPM-224-0-FTRO	1.051E-003	9.863E-005
45	RCV-PM-224-1-FO	1.000E-003	9.863E-005
46	RCV-PM-224-2-FC	1.000E-003	9.863E-005
47	RCV-G-15-FTRO	1.823E-002	5.451E-005
48	HS-G-15-TV	2.880E-006	5.446E-005
49	RCV-G-33-FTRO	1.823E-002	5.355E-005
50	HS-G-33-TV	1.051E-003	5.343E-005

Table 4. (continued).

Rank	Event name	Probability of failure	Birnbaum importance measure
51	TWVPOG359-11FTRC	1.331E-003	3.611E-005
52	TWVPO-G359-13-LK	1.331E-003	3.611E-005
53	TWVPO-G359-11-LK	1.331E-003	3.611E-005
54	TWVPOG359-13FTRC	1.331E-003	3.611E-005
55	FTV-G-111-B-LK	3.648E-006	3.563E-005
56	FTV-G-111-B-FTRC	3.648E-006	3.563E-005
57	FCV-G-1B-FTRC	1.331E-003	1.798E-005
58	FCV-G-1A-FTRC	1.331E-003	1.798E-005
59	LAVPOG550-11FTRO	1.051E-003	1.036E-005
60	LAVPOG550-12FTRO	1.051E-003	1.036E-005
61	LAVPOG550-14FTRO	1.051E-003	9.887E-006
62	LAVPOG550-17FTRO	1.051E-003	9.887E-006
63	LAV-PO-H1-FTRO	1.051E-003	9.887E-006
64	LAV-PO-G4-FTRO	1.051E-003	9.887E-006
65	LAV-PO-G1-FTRO	1.051E-003	9.887E-006
66	LAVPOG550-16FTRO	1.051E-003	9.887E-006
67	PCVPM-124-O-FTRG	3.096E-002	9.863E-006
68	LAVPOG550-13FTO	5.000E-004	2.073E-006
69	LI2VPMH100-1FTRO	1.051E-003	1.852E-006
70	LI2VPOH101-2FTRO	1.051E-003	1.852E-006
71	LI2VPOH101-1FTRO	1.051E-003	1.852E-006
72	LI5VPOH100-1FTRO	1.051E-003	1.852E-006
73	RCV-G-15-FTRC	1.823E-002	1.618E-006
74	RCV-G-33-FTRC	1.823E-002	1.443E-006
75	G2-9R-VLV-FTRC	3.648E-006	3.565E-007

Table 4. (continued).

Rank	Event name	Probability of failure	Birnbaum importance measure
76	G2-9R-VLV-LK	3.648E-006	3.565E-007
77	FTV-G-111-A-FTRC	3.648E-006	3.565E-007
78	FTV-G-111-A-LK	3.648E-006	3.565E-007
79	HSVPOG512-1-FTRO	1.051E-003	5.509E-008
80	HSVPOG509-2-FTRO	1.051E-003	5.509E-008
81	HSVPOG512-2-FTRO	1.051E-003	5.509E-008
82	HSVPOG504-1-FTRO	1.051E-003	5.509E-008
83	HSVPOG504-2-FTRO	1.051E-003	5.509E-008
84	HSVPOG505-2-FTRO	1.051E-003	5.509E-008
85	HSVPOG505-1-FTRO	1.051E-003	5.509E-008
86	HSVPOG509-1-FTRO	1.051E-003	5.509E-008

Table 5. Component ranking for risk of criticality.

Rank	Event name	Probability of failure	Birnbaum importance measure
<u>Passive Components</u>			
1	LAA-208-PG	8.760E-004	9.089E-005
2	VES-H-301-LK	8.760E-005	2.392E-005
3	LAN-363-PG	8.760E-004	4.549E-008
4	LAN-240-PG	8.760E-004	4.549E-008
5	LAA-228-PG	8.760E-004	4.549E-008
<u>Active Components</u>			
1	RCV-H-6-FTR0	1.823E-002	9.939E-002
2	RCV-H-4-FTRC	1.823E-002	9.971E-003
3	RCV-G-8-FTRC	1.823E-002	9.971E-003
4	RCV-H-4-LK	1.392E-002	9.970E-003
5	PCVPM-126-0-FTRH	3.096E-002	9.941E-003
6	PCVPM-124-0-FTRH	3.096E-002	9.941E-003
7	PCVPM-125-0-FTRH	3.096E-002	9.941E-003
8	RCV-PM-225-1-FO	1.000E-003	9.938E-003
9	RCV-PM-225-2-FC	1.000E-003	9.938E-003
10	RCV-PM-226-1-FO	1.000E-003	9.938E-003
11	RCV-PM-224-2-FC	1.000E-003	9.938E-003
12	RCV-PM-224-1-FO	1.000E-003	9.938E-003
13	RCV-PM-226-2-FC	1.000E-003	9.938E-003
14	SOV-PM-226-0-FO	7.200E-004	9.938E-003
15	SOV-PM-224-0-FO	7.200E-004	9.938E-003
16	SOV-PM-225-0-FO	7.200E-004	9.938E-003
17	LI2VPOH101-2FTR0	1.051E-003	1.860E-003
18	LI5VPOH100-1FTR0	1.051E-003	1.860E-003
19	LI2VPOH101-1FTR0	1.051E-003	1.860E-003
20	LI2VPMH100-1FTR0	1.051E-003	1.860E-003

Table 5. (continued).

Rank	Event name	Probability of failure	Birnbaum importance measure
21	HSVPOH521-2-FTRC	1.332E-003	1.321E-004
22	HSVPOH522-2-FTRC	1.332E-003	1.321E-004
23	HSVPOH522-1-FTRC	1.332E-003	1.321E-004
24	HSVPOH521-1-FTRC	1.332E-003	1.321E-004
25	LAVPOH550-11FTRO	1.051E-003	9.089E-005
26	LAVPOH550-19FTRO	1.051E-003	9.089E-005
27	HSVPOH501-1-FTRC	1.332E-003	5.593E-005
28	HSVPOH501-2-FTRC	1.332E-003	5.593E-005
29	HSVPOG522-2-FTRC	1.332E-003	3.746E-005
30	HSVPOG522-1-FTRC	1.332E-003	3.746E-005
31	HSVPOH504-1-FTRC	3.648E-006	2.655E-005
32	HSVPOH527-1-FTRC	1.332E-003	1.327E-005
33	HSVPOH527-2-FTRC	1.332E-003	1.327E-005
34	HSVPOH525-2-FTRC	1.332E-003	1.327E-005
35	HSVPOH525-1-FTRC	1.332E-003	1.327E-005
36	RCV-H-119-FTRC	1.823E-002	9.042E-006
37	RCV-H-7-FTRC	1.823E-002	9.042E-006
38	LAVPOH550-15-FTO	5.000E-004	3.005E-006
39	FCV-G-1A-FTRC	1.331E-003	9.885E-007
40	PRVPOH550-13FTRG	3.096E-002	9.544E-007
41	LAVPOH550-16FTRO	1.051E-003	9.544E-007
42	LAVPOH550-17FTRO	1.051E-003	9.544E-007
43	LAVPOH550-14FTRO	1.051E-003	9.544E-007
44	LAVPOH550-12FTRO	1.051E-003	9.544E-007
45	LAVPOH555-11FTRO	1.051E-003	9.098E-007

Table 5. (continued).

Rank	Event name	Probability of failure	Birnbaum importance measure
46	LAVPOH555-9-FTRO	1.051E-003	9.098E-007
47	LAVPOH555-7-FTRO	1.051E-003	9.098E-007
48	LAVPOH555-8-FTRO	1.051E-003	9.098E-007
49	LAVPOH555-12FTRO	1.051E-003	9.098E-007
50	HSV-PO-H501-2-LK	3.648E-006	5.609E-007
51	HSV-PO-H501-1-LK	3.648E-006	5.609E-007
52	LAVPOH550-18-FTO	5.000E-004	1.911E-007
53	TWVPOH301-11FTRC	1.323E-002	1.584E-007
54	TWVPOH301-12FTRC	1.823E-002	1.150E-007
55	HSVPOH504-2-FTRC	1.332E-003	7.273E-008
56	PA-241-FTR	5.979E-001	0.000E+000
57	PA-240-FTR	5.979E-001	0.000E+000
58	RCV-10-FTRO	1.823E-002	0.000E+000
59	RCV-11-FTRO	1.823E-002	0.000E+000

Table 6. Component ranking for environmental risk.

Rank	Event name	Probability of failure	Birnbaum importance measure
<u>Passive Components</u>			
1	PSA-559-LK	5.852E-003	1.098E-002
2	PSA-559-RP	2.347E-004	1.098E-002
3	PSA-510-LK	5.852E-003	9.988E-003
4	PSA-327-LK	5.852E-003	9.988E-003
5	PSA-525-LK	5.852E-003	9.988E-003
6	PSA-454-LK	5.852E-003	9.988E-003
7	PSA-356-LK	5.852E-003	9.988E-003
8	PSA-539-LK	5.852E-003	9.988E-003
9	PSA-329-LK	5.852E-003	9.988E-003
10	PSA-354-LK	5.852E-003	9.988E-003
11	PSA-554-CFL-LK	5.852E-003	9.988E-003
12	PSA-592-LK	5.852E-003	9.988E-003
13	PSA-591-LK	5.852E-003	9.988E-003
14	PSA-600-LK	5.852E-003	9.988E-003
15	PSA-554-WFL-LK	5.852E-003	9.988E-003
16	PSA-554-SP-LK	5.852E-003	9.988E-003
17	PSA-314-LK	5.852E-003	9.988E-003
18	PSA-554-LK	5.852E-003	9.988E-003
19	PSA-540-LK	5.852E-003	9.988E-003
20	PSA-509-LK	5.852E-003	9.988E-003
21	PSA-313-LK	5.852E-003	9.988E-003
22	PSA-539-RP	2.347E-004	9.987E-003
23	PSA-313-RP	2.347E-004	9.987E-003
24	PSA-525-RP	2.347E-004	9.987E-003
25	PSA-509-RP	2.347E-004	9.987E-003

Table 6. (continued).

Rank	Event name	Probability of failure	Birnbaum importance measure
26	PSA-454-RP	2.347E-004	9.987E-003
27	PSA-554-CFL-RP	2.347E-004	9.987E-003
28	PSA-510-RP	2.347E-004	9.987E-003
29	PSA-554-RP	2.347E-004	9.987E-003
30	PSA-592-RP	2.347E-004	9.987E-003
31	PSA-600-RP	2.347E-004	9.987E-003
32	PSA-591-RP	2.347E-004	9.987E-003
33	PSA-554-WFL-RP	2.347E-004	9.987E-003
34	PSA-356-RP	2.347E-004	9.987E-003
35	PSA-554-SP-RP	2.347E-004	9.987E-003
36	PSA-540-RP	2.347E-004	9.987E-003
37	PSA-354-RP	2.347E-004	9.987E-003
38	PSA-329-RP	2.347E-004	9.987E-003
39	PSA-314-RP	2.347E-004	9.987E-003
40	PSA-327-RP	2.347E-004	9.987E-003
41	VES-H-100-LK	8.760E-005	9.987E-003
42	FCV-2G-PK-LK	8.760E-005	9.987E-003
43	VES-G-165-LK	8.760E-005	9.987E-003
44	VES-G-165-RP	3.504E-006	9.987E-003
45	VES-H-100-RP	3.504E-006	9.987E-003
46	FCV-2G-PK-RP	3.504E-006	9.987E-003
47	PSA-463-LK	5.852E-003	9.987E-004
48	PSA-458-LK	5.852E-003	9.987E-004
49	PSA-558-LK	5.852E-003	9.987E-004
50	PSA-326-LK	5.852E-003	9.987E-004

Table 6. (continued).

Rank	Event name	Probability of failure	Birnbaum importance measure
51	PSA-325-LK	5.852E-003	9.987E-004
52	PSA-579-CFL-LK	5.852E-003	9.987E-004
53	PSA-579-WFL-LK	5.852E-003	9.987E-004
54	PSA-519-LK	5.852E-003	9.987E-004
55	PSA-324-LK	5.852E-003	9.987E-004
56	PSA-362-LK	5.852E-003	9.987E-004
57	PSA-325-RP	2.347E-004	9.987E-004
58	PSA-326-RP	2.347E-004	9.987E-004
59	PSA-362-RP	2.347E-004	9.987E-004
60	PSA-579-CFL-RP	2.347E-004	9.987E-004
61	PSA-579-WFL-RP	2.347E-004	9.987E-004
62	PSA-324-RP	2.347E-004	9.987E-004
63	PSA-558-RP	2.347E-004	9.987E-004
64	PSA-463-RP	2.347E-004	9.987E-004
65	PSA-519-RP	2.347E-004	9.987E-004
66	PSA-458-RP	2.347E-004	9.987E-004
67	VES-G-113-LK	8.760E-005	9.987E-004
68	VES-G-112-LK	8.786E-005	9.987E-004
69	VES-G-157-LK	8.760E-005	9.987E-004
70	VES-G-113-RP	3.504E-006	9.987E-004
71	VES-G-112-RP	3.504E-006	9.987E-004
72	VES-G-157-RP	3.504E-006	9.987E-004
73	FE-G-111-PG	3.612E-002	1.009E-004
74	FCV-G-1A-ELK	9.950E-003	9.987E-005
75	FCV-G-1B-ELK	9.950E-003	9.987E-005

Table 6. (continued).

Rank	Event name	Probability of failure	Birnbaum importance measure
76	PSA-406-LK	5.867E-004	9.987E-005
77	PSA-110086-LK	5.867E-004	9.987E-005
78	PSA-303-LK	5.867E-004	9.987E-005
79	PSA-549-LK	5.867E-004	9.987E-005
80	PSA-110086-RP	2.348E-005	9.987E-005
81	PSA-549-RP	2.348E-005	9.987E-005
82	VES-G-111-RP	3.504E-006	9.987E-005
83	VES-G-111-LK	8.760E-005	9.987E-005
84	PSA-406-RP	2.348E-005	9.987E-005
85	VES-G-105-RPP	3.504E-006	9.987E-005
86	VES-G-105-LKK	8.760E-005	9.987E-005
87	PSA-303-RP	2.278E-005	9.987E-005
Active Components			
1	FTV-G-111-B-FTRC	3.648E-006	3.608E-004
2	FTV-G-111-B-LK	3.648E-006	3.608E-004
3	FTV-G-111-A-FTRC	3.648E-006	3.610E-006
4	FTV-G-111-A-LK	3.648E-006	3.610E-006
5	G2-9R-VLV-LK	3.648E-006	3.610E-006
6	G2-9R-VLV-FTRC	3.648E-006	3.610E-006

Table 7. Component ranking for risk to worker/public safety.

Rank	Event name	Probability of failure	Birnbaum importance measure
<u>Passive Components</u>			
1	PSA-554-SP-LK	5.852E-003	1.000E-003
2	PSA-554-WFL-LK	5.852E-003	1.000E-003
3	PSA-554-LK	5.852E-003	1.000E-003
4	PSA-356-LK	5.852E-003	1.000E-003
5	PSA-554-CFL-LK	5.852E-003	1.000E-003
6	PSA-554-WFL-RP	2.347E-004	1.000E-003
7	PSA-554-SP-RP	2.347E-004	1.000E-003
8	PSA-356-RP	2.347E-004	1.000E-003
9	PSA-554-CFL-RP	2.347E-004	1.000E-003
10	PSA-554-RP	2.347E-004	1.000E-003

ICPP Inservice Inspection and Testing

Inservice Inspection

Information regarding existing inspection practices for the First Cycle Extraction process components was obtained by interviewing facility personnel and gathering data recorded through interdepartmental plant correspondence. It was evident that no integrated program for the periodic monitoring of First Cycle Extraction components presently exists.

INEL investigations found correspondence dating back to 1978¹⁴ that gave a tentative list of components that were to be included, at that time, in a very informal program for the inspection of ICPP process equipment, including several First Cycle Extraction components. It appears that while many plant systems on this list were eventually incorporated into the "ICPP Materials Monitoring and Corrosion Surveillance Program",¹⁵ First Cycle Extraction components were specifically excluded. As excerpted from the Corrosion Program:

"Corrosion in the first, second, and third cycle extraction process systems has never been a problem. No routine corrosion inspections are scheduled for these extraction systems."

However, some First Cycle Extraction examinations have infrequently occurred, mainly to detect the presence of corrosion in specific vessels and tanks. A recent plant review of past corrosion inspections¹⁶ indicated that many F-, G- and H-cell components had not been examined for corrosion or other degradation in nearly a decade. (Equipment in F-, G-, and H-cells is the majority of First Cycle Extraction process components). A few previously scheduled corrosion inspections were canceled due to area high radiation levels. Furthermore, no record of inspections could be found for several other components.

As a result of these findings, the plant materials engineering group produced an extensive list of First Cycle Extraction components to be scheduled for immediate inspection. Facility personnel then decided to

prioritize the component list and examine a smaller sampling of equipment believed to be indicative of the material condition for the entire First Cycle Extraction system. The components chosen were:

- VES-G-106, Aqueous Feed Tank
- VES-G-115, Waste Run Tank
- VES-G-116, Waste Run Tank
- VES-H-130, Product Evaporator
- VES-F-101, Centrifuge Manifold Tank

Additional component inspections were to then be scheduled based on the results of these examinations. As of the date of this report, no information pertaining to the outcome of these examinations has been submitted by the facility operating contractor.

To summarize, no integrated program for monitoring material degradation presently exists for components of the First Cycle Extraction system. Facility personnel have recently selected several components for near-term corrosion examinations, based on equipment accessibility and schedule. It is suggested that a formal, structured plan for the periodic surveillance of equipment be developed to ensure the safe and reliable operation of important process systems. In addition, the plan should address all anticipated degradation mechanisms (corrosion, fatigue, intergranular attack, etc.), based on the best judgement of materials and design experts, to enable adequate examination development.

Evaluation of PIRC Findings. As indicated by the PIRC, many passive components contribute to the First Cycle Extraction process facility risk, as evidenced by the narrow range of Birnbaum importance rankings shown for a relatively large subset of the passive components (see Tables 4-7). The risks for these components are associated with environmental concern and plant loss; for the process segments studied, no credible passive component failures resulted in a consequence that would directly affect worker/public safety or initiate a criticality event. During the PIRC, passive component failures were defined as losses in pressure boundary integrity, ranging from benign leakage to catastrophic rupture of process equipment.

Examples of risk-significant passive components and their related events are described below to provide a foundation for discussions relative to ISI development and implementation.

Environmental. The most highly-ranked passive component/event for environmental concerns involves a leak or rupture of line number PSA-559, a portion of the air pulse system used to move product-laden organic solution through the scrubbing column (VES-H-100). This 1-in. diameter line consists of stainless steel piping originating at the scrubbing column organic inlet line (PSA-313), located in H-Cell, extending through the Service Corridor, and converting to line PSA-579 in the Plant Make-up Area. The worst case event would be a rupture of line(s) PSA-559 in the Service Corridor or PSA-579 in the Plant Make-up Area. It is anticipated that this loss of pressure boundary integrity would lead to a reverse flow of process organic solution in the line(s). As opposed to the self-contained and shielded cells, a significant amount of solution, containing highly-radioactive fission products, could be released into an operating area not designed to easily accommodate this type of problem. (The radiation levels of fission products in the organic solution at this stage of the process are on the order of thousands of Roentgens at contact.) The consequences of this event could involve an elaborate and costly clean-up operation, as these plant locations are normally maintained at a minor contamination level so that personnel may routinely work in these areas. It should be noted that high radiation alarms are present in these areas, which decreases the probability of accidental radiation exposure or significant contamination to personnel in the event described above.

Plant Loss. Failure of the primary extraction column (VES-G-111) caused by flow blockage ranked highest for passive components in the plant loss risk category. Although the occurrence frequency of this event is estimated to be relatively low ($< 10E-2$), the resulting costs would be significant. VES-G-111 consists of a stainless steel shell that houses a series of perforated disks, or sieve plates, through which the aqueous feed and organic solutions are counterflowed, allowing extraction to occur. It has been postulated that the sieve plates could become plugged, either due to corrosion product buildup or unanticipated solid precipitate from the aqueous feed solution.

The probability of a corrosion problem in VES-G-111 is believed to be higher than those of other extraction process vessels because it is possible for uncomplexed, residual acids from the fuel dissolution process to exist in aqueous feed solutions. In addition, if feed solution chemistry and temperature are not properly controlled, a solid precipitate is very likely to be formed and carried-over to the extraction column. The worst-case event would involve sieve plate blockage that could not be corrected except by extensive repair or replacement. This would result in a prolonged and expensive outage, from which a facility of the vintage of First Cycle Extraction might not recover. It should be noted, however, that even a minor amount of flow blockage would lead to decreased extraction efficiency and diversion of product to waste streams, ultimately producing a cumulative plant economic loss.

Finally, corrosion in VES-G-111 is not limited to the sieve plates. The shell and disengaging heads are also susceptible to this form of degradation, which could result in an equivalent scenario to the worst case event described above.

Conclusions. Many passive components, and their associated failures, contribute to the overall risk of the First Cycle Extraction process. Because the entire First Cycle Extraction was not analyzed, the events discussed above represent only a small segment of the potential consequences of passive component failures. The probabilities of various events, as determined by the PIRC, are simple conservative estimates, and should only be viewed as such. However, passive component failure probabilities grow with elapsed time, and, as with any aging facility, reliability and safety become increasingly dependent upon assessing the general condition of process components.

Currently, no formal program exists for periodic monitoring of First Cycle Extraction passive components. It is, therefore, conceivable that degradation may be present, to some extent, in most risk significant process components. ICPP personnel have identified a few components as a sample to examine for overall corrosion effects; however, the PIRC top-ranked equipment are not among these.

The difficulties associated with performing component examinations for First Cycle Extraction are well recognized, i.e., normally high radiation levels in the equipment cells and the extended length of process campaigns. However, with the proper planning, and associated decontamination operations, the accessibility of most components is equivalent to that of components in the commercial nuclear industry. The PIRC results indicate which First Cycle Extraction components are risk significant, and form a basis for implementing ISI activities. It is suggested that consideration be given to augmenting the planned corrosion examination sample with an acceptable percentage of high ranking components from Tables 4 through 7.

Inservice Testing Practices

The maintenance and testing practices at ICPP were briefly assessed and compared to IST practices for safety-related pumps and valves at commercial nuclear power plants. The results of that assessment, as presented here, are based upon discussions with plant personnel and the review of various ICPP Technical Specification (TS) surveillance requirements,^{17,18,19,20} Standard Operating Procedures,^{21,22} and the preventive maintenance (PM) program. The testing of components is driven primarily by the Technical Specifications and PM program requirements. The ICPP does not have a formal IST program similar to those found at commercial nuclear power plants for periodically testing pumps and valves to assess their operational readiness. Furthermore, there is little, if any, dependence on the guidance of industry codes and standards, such as Section XI of the ASME Boiler and Pressure Vessel Code, for determining test methods and practices.

Commercial nuclear power plants are required by Title 10 of the Code of Federal Regulations (CFR), Part 50, to test certain safety-related pumps and valves. The regulations specify many test plan attributes, including baseline test requirements, inservice test methods and frequencies, acceptance criteria, corrective actions, records requirements, etc. The testing is intended to assess the operational readiness of the components covered. The CFR also allows the regulatory authority, the Nuclear Regulatory Commission, to grant relief from the requirements. There are no such requirements for testing components at DOE non-reactor nuclear facilities.

Much of the component testing done at ICPP is associated with the PM program. That program, developed primarily to address DOE requirements for equipment operation and maintenance, does deal with some of the issues addressed by IST programs at commercial nuclear power plants. The ICPP PM program is described by several procedures^{23,24,25} and a DOE Order.²⁶ The procedures identify interdepartmental functions and activities for developing PM procedures, issuing PM work orders, and upgrading PM procedures. There are also administrative controls for developing PM procedures, processing PM procedures via the work control system, and evaluating post-PM actions. Generally, the post-maintenance tests are developed by the cognizant system engineer. In some cases, additional guidance is obtained from equipment vendors (such as suppliers of ASME "N" stamp vessels) and industry codes that were in place at the time of original construction (1950s vintage ASME Boiler and Pressure Vessel Code²⁷ and various ANSI piping codes²⁸).

The selection of ICPP equipment to receive PMs and tests is usually based on the judgment of the equipment custodian (often the project manager), operating experience, and equipment history. The list of equipment identified for PM is transmitted to plant engineering, plant services, and engineering programs for action. A centralized equipment database, Maintenance Inventory Procurement System (MIPS), is used to track PM activities at ICPP.

The ICPP plant TS also stipulates tests intended to ensure operability of safety-related equipment. Equipment is prioritized in the TS as vital (failure could shut down the plant), critical (failure could shut down a process), or standard (failure would have minimal impact). The ICPP TS also categorizes certain valves; the Category 1 designation includes the most important valves and identifies valves that directly affect criticality.

Equipment categorized as vital must always be kept operating or in a state of readiness to assure continued safe plant operation. Such equipment provides essential plant services, including emergency electrical power, compressed air, ventilation, and fire protection. Tests and inspections for vital equipment are controlled by both administrative procedures and TS. The vital equipment is tested regularly, usually monthly or quarterly. The schedule is similar to that found at commercial nuclear power plants.

However, the test methods are much less rigorous than those done on similar components at commercial nuclear power plants. (Some types of equipment classified as vital by ICPP, such as compressors and blowers, are not addressed by IST programs at commercial nuclear power plants.)

The ICPP has a procedure, "System Operability (SO) and Integrated Testing,"²⁹ that establishes personnel responsibilities and requirements for test preparation, review and approval, execution, changes, and documentation. The SO and integrated tests are intended to help ensure that facility systems function as designed. Prerequisites to testing usually include checks for proper calibration of instruments and equipment, training as required to perform the task, and documentation of equipment condition and test results. The SO also specifies post-maintenance test requirements that are intended to check for operation and the capability to perform functions that may have been affected by the maintenance activity, and to ensure that the original problem was corrected and new ones were not created. The test results receive an administrative review by the facility Test Results Review Team.

Several types of tests are done on components at ICPP, usually after or as part of a maintenance activity or prior to startup for processing. During preoperational startup testing, the Category 1 valve positions are checked by visual inspection of valve stem positions and testing for leakage past the valve seat. A synthetic solution is used to simulate the process fluid and to verify proper system operation via instrument readings (flow, pressure, temperature, fluid level, density, and presence or absence of radioactivity). This may be considered a qualitative test of some of the system components. Once processing begins, valve position indications are checked intermittently, but the valves themselves are not usually exercised or tested to assess their condition. Malfunction of some valves may be detected indirectly, by column upsets and local alarms, during process operation. One operating period can last over a year and include 100 individual batches. During the extraction process, high radiation and contamination levels may preclude access to components for certain tests or repairs. Few of the tests identified in the review were considered to be very effective for quantitatively assessing equipment degradation.

To summarize, the component testing practices at ICPP are driven in a large part by the plant TS and PM program. The plant TS identifies safety-related equipment and categorizes valves based on their importance. It also specifies tests for many of these components. Much of the testing is done in association with the PM program, particularly post-maintenance testing. The specific tests are considered to be very limited in their ability to assess component condition. There is no formal program for IST, such as found at commercial nuclear power plants. Many of the attributes usually associated with formal IST programs were not evident at the ICPP.

Evaluation of IST Practices. The ICPP program meets the general intent of DOE Order 4330.4A²⁶ for maintenance management. The specific test procedures were determined by collective input from the participating technical staff and management. The basic elements for equipment operability assurance are contained in the maintenance program, the departmental responsibilities, and review by technical staff and management. The ICPP IST activities do not follow the regimented format of commercial nuclear power plant IST programs; rather, the test requirements and procedures are tailored to the unique operating conditions at ICPP. Additionally, the ICPP staff has extensive operating experience and knowledge of the plant equipment and systems. That knowledge and experience provided guidance in areas of facility operations not usually addressed by industry codes and standards. They also have significant experience with a variety of component types, such as pneumatically-operated diaphragm pumps, airlifts, and steam jets, that are not included in commercial nuclear power plant IST programs. The ICPP documentation, such as piping and instrumentation drawings (P&IDs), and operating procedures, generally appear to be current and complete.

ICPP management is apparently increasing the attention devoted to equipment and system operability. For instance, prior to the upcoming startup of the First Cycle Extraction process, the ICPP management committed to test the Category 1 valves for leaks. The methods for leak detection include visual observation, system flow measurements using simulated process fluid, and control panel readings. The ICPP documentation is undergoing review and revision to correct errors, clarify instructions, and add details needed to enhance these tests. P&IDs are also being updated. Senior technical staff

are committed to reviewing and approving these changes prior to implementation.

One area of concern is that test intervals are not prescribed. Broad application of formal codes and standards that specify tests and frequencies is not apparent. The test intervals are assigned at the discretion of the cognizant engineer. Routine maintenance actions, such as lubrication, leak detection, verification of valve position, and measurement of vibration, are performed on some equipment independent of the operating status of the system. However, even when a system is temporarily out of service between batches, the verification of equipment operability prior to startup can involve as little as position indication and external leak detection. It is recommended that testing be considered for appropriate valves between batches to help ensure their continued operability.

Another concern is that the types of tests performed may not be adequate to detect degradation of the components. The large number of interconnections between vessels indicates a need for reverse flow leak tests of important remote control isolation valves and check valves to prevent inadvertent transfers. The corrosive environment of the system indicates a need for stroke tests, selective inspection, detection of blockages, and periodic repair and replacement. The extensive use of steam jets and airlifts via manual supply valves establishes the need for proper labeling, position indication, and reasonable access to the valve controller.

It is also of concern that only a few of the operating parameters are monitored or measured during the verification tests. The equipment operating characteristics are verified to some degree at the time of initial installation (baseline), but may not be checked on a regular basis thereafter. Little or no trending analysis is performed on the equipment test data. However, some analysis is performed for rotating equipment, such as oil analysis, bearing temperature check, and vibration analysis. The operability tests for other components are performed, if needed, only to meet the requirements of the responsible department. A thorough assessment of the specific tests and maintenance done on a particular valve at ICPP may require

consultations with several different departments and a careful review of a variety of unrelated startup and maintenance procedures.

Another consideration is that valves are assigned a Category 1 status only if they are important in the prevention of a criticality. Other risks (plant loss, environment, and worker safety) play an important role in the continued safe operation of the plant.

Evaluation of PIRC Findings. The IST-related component contributions to risk are most evident in the criticality and plant loss risk matrices. No IST events were listed for the worker/public safety matrix. Although the environmental effects matrix listed six components, they all had very low importance. Neither of these matrices were considered in the IST evaluation.

Criticality-Related Events. The criticality-related events for IST components are presented in Table 5, which lists 59 active components including 14 Category 1 valves. Since the Category 1 designation is based on criticality, it was expected that the PIRC criticality table would have a large percentage of components identified as Category 1. However, the highest ranking event involves failure of a component, valve RCV-H-6, that is not included in the Category 1 equipment list; this valve has an importance value ($10E-2$) that is an order of magnitude greater than that of the highest ranked Category 1 valve. Valve RCV-H-6 directs aqueous solution from mixer-settler tank H-117 to the plant equipment waste system. Failure of the valve to remain open would introduce unwanted aqueous solution into the organic stream entering the last mixer-settler tank and lead to a possible criticality in either extraction column G-111 or scrub column H-100. It is recommended that this valve be included on the Category 1 list as a minimum precaution against criticality. Periodic tests should also be conducted to adequately assess the valve's capability to perform its function.

The next three events involve Category 1 valves (RCV-G-8 once and RCV-H-4 twice). These valves are located on the return lines leaving columns G-111 and H-100 by which solution can be directed back to vessel G-106. Failure of the valves to remain closed, coupled with the inadvertent operation of the column transfer jets, could lead to a possible criticality in vessels G-106 or

G-108. Due to the high importance ranking of these components and their probability of failure, it is recommended that these valves be tested and inspected more frequently than required by Category 1 guidelines. The feasibility of additional periodic stroke or leak tests between batch operations should be considered.

The next group of events involves valves that control the air supply and operation of the air pulsers (PM-124/125/126 and PM-224/225/226). Taken together, these valves have the same probability of failure and the same importance ranking. They are not identified as Category 1 components. It is recommended that the entire air pulser unit, including poppit valves, associated pressure control valves, and isolation valves, be tested and serviced as a functional assembly. If degradation of any individual air pulser valve is detected, such that repair or replacement is necessary, then repair or replacement of the other valves should also be considered.

Another group of components in the criticality table is the manual steam valves used to operate steam jets G-522, H-521, H-522, and H-501. It is noted that jets G-522 and H-501 are Category 1 components, but jets H-521 and H-522 are not. The PIRC results indicate that the manual valves to all four jets have the same probability of failure and importance ranking. Therefore, it is recommended that jets H-521 and H-522 be included on the Category 1 equipment list and receive testing as a precaution against criticality.

Three highly-ranked events with Category 1 valves were discussed above; the 11 remaining Category 1 valves on the PIRC table are ranked relatively low in importance. This indicates an inconsistency in the way the Category 1 designation is applied. Reevaluation of the Category 1 valve list is recommended.

The remaining PIRC events were not evaluated because the importance ranking and contribution to criticality risk was very low (less than $10E-4$).

Plant Loss Events. The plant loss events for active components are presented in Table 4, which lists 86 components including three Category 1 valves. The small percentage of Category 1 valves was expected because the

ICPP technical staff indicated that plant loss due to process inefficiency, spills, blockages, and reduced process flows was considered to be secondary to the prevention of a criticality.

The most highly-ranked event in this risk category was failure of the blowdown compressors, which are used to clear the lines. Testing of compressors is outside the scope of a typical pump and valve IST program. However, based on their importance to production, it is recommended that the ICPP staff evaluate the adequacy of the present test plan for the compressors and augment that plan if necessary.

The second event was failure of manually-operated steam valve HSV-PO-G504-2 in the open position, causing a process upset due to unwanted operation of jet G-504. The importance ranking is two orders of magnitude greater than that of other manual steam valves. It is recommended that this valve be exercised and leak tested prior to startup and between batch operations. In addition, the valve position (open or closed) should be positively indicated and controlled. Similar treatment for the other manual steam and air supply valves should be considered. Also, many other manually-operated valves were found with poor or no positive position indication.

The third event is failure of isolation valve RCV-G-36, such that the raffinate stream to vessel G-115 is blocked. The importance value for this valve is one order of magnitude greater than those for isolation valves G-35 and G-37, which also isolate flow to G-115. It is recommended that all three valves be tested as appropriate prior to startup and between batch operations.

The other highly-ranked events, control of the air supply, air pulsers and airlifts, steam supply and jet operation, parallel those discussed under risk of criticality and the same recommendations for testing apply here.

As shown in the rankings, several valves are involved with controlling the proper feed rate into extraction column G-111. The ICPP staff has already acknowledged these problems and accepted the consequences of totally shutting the process down, if necessary, to maintain control. There is a 1% probability that the valves will fail during operation. Therefore, it is

recommended that the process feed valves (FCV-2G and RCV-G-66) be appropriately tested prior to startup and between batch operations.

The remaining PIRC events were not evaluated because their importance ranking and contribution to plant loss risk was very low (less than $10E-4$).

The PIRC analysis (accident sequence 105-13-2) also identified the need to install a new isolation valve in line 0.5-PSA-330 between column G-111 and interface jet G-523.

Conclusions. The PIRC results and evaluation of testing and maintenance activities at ICPP identified some areas of concern and some positive attributes, both in general and in comparison to commercial nuclear power plant IST practices. As a result of the study, the staff at ICPP gained a general understanding of the PIRC methodology and currently has the resources needed to complete the PIRC for the First Cycle Extraction process.

One area of concern is that the Category 1 designation for valves is based only on importance in the prevention of a criticality. Of the valves identified in the PIRC that were ranked highly for their contribution to risk in the tables for plant loss, environmental effects, and worker/public safety, very few were identified as Category 1. Also, a large number of the Category 1 designated valves appeared in the criticality table, but their distribution was sporadic instead of being clustered near the top. These findings indicate that the basis for the Category 1 status should be reconsidered and possibly broadened to address the other important concerns, such as environmental and worker safety, in addition to criticality.

Another area of concern is the ability of much of the testing to assess component condition. Periodic testing is a vital ingredient for helping to ensure the continued safe operation of commercial nuclear power plants. Though no codes or standards have been developed specifically for the types of components and operations seen at DOE non-reactor facilities, the reviewers believe that efforts should be made to thoroughly assess the goals of testing and maintenance activities at ICPP to see if they are appropriate and are being met. Existing codes and standards, such as the ASME Code, Section XI,

which is used for component testing at commercial nuclear power plants, should also be considered.

On the positive side, the staff at ICPP is extremely knowledgeable about plant operations and the specific systems and components included in this study. The plant documentation was quite good. The plant drawings were current and sufficiently detailed, and very good controls were in place for plant practices and procedures.

CONCLUSIONS

The value of developing a strategy to address facility or process risk has been recognized by DOE, as well as commercial industry. Environmental, safety, and health requirements have become increasingly more challenging and, with limited availability of resources, areas of significant need should be identified and appropriate measures applied to reduce risks. This study showed the practices for inspection and testing of high-risk components at ICPP to generally be rudimentary and inconsistent. In the absence of an ISE policy, this is suspected to be the case for most DOE nonreactor nuclear facilities.

Facility risk evaluation involves a series of ranking levels. A PHA can be used to prioritize the processes or sections of processes that should be evaluated. Selection or screening criteria can be quickly developed to address all the parameters affecting the risk categories that could be found at a particular facility. The modified HAZOP methodology is then used to identify the risk-significant components within these processes, and finally, Boolean techniques are used to rank components within the risk categories.

This project has developed techniques that will identify and prioritize risk-significant components. Risks to worker/public safety and the environment, programmatic (economic) loss, and other concerns can be appropriately evaluated. The techniques developed are of use to all facilities whether or not a PRA has been developed. Furthermore, PRAs are normally developed based on only one consequence, such as criticality or core damage, and other consequences must be assessed to produce a comprehensive evaluation of facility risk. The authors are unaware of a PRA that addresses multiple risks. The INEL PIRC methodology may be more appropriate for DOE facilities as it is less expensive and time consuming than a PRA, and addresses multiple areas of risk. The techniques involved are fairly standard, use the tools originally developed for PRAs, and can identify further analysis needs for high-risk components.

Based on the findings of this study, it is clear that additional work is needed to refine the component ranking methodology and develop methods for

inspection and testing to reduce the risk of operations at DOE nonreactor nuclear facilities.

Refinement of the Process Integrated Risk Correlation method is necessary before it is ready to be used to evaluate risk and rank components for prioritized testing and inspection at all types of DOE facilities. The INEL risk ranking methodology was only partially demonstrated for one specific process at a nuclear fuel reprocessing facility. The original concept for ISE development had two parts: 1) instituting a structured system for identifying and ranking risk-significant components, and 2) establishing the "tools" necessary for implementing ISE, e.g., selection of applicable inspection or test techniques and frequencies. The component ranking effort was halted prior to its full development and demonstration. Further demonstration of the ranking process at other types of facilities is necessary to make the technique more global, repeatable, and comprehensive.

RECOMMENDATIONS

It is proposed that the PIRC methodology be further developed on a minimum of two additional DOE nonreactor nuclear processes, each varied in configuration and function from one another and the initial demonstration process, so that a broader sampling of the DOE complex facilities is represented. It is further suggested that, for the near-term, on-site investigations be used to highlight risk-significant process components, and detailed evaluations of these components be conducted to determine if appropriate tests/inspections are currently being performed. Prior to the on-site evaluations, existing HAZOP software will be modified to accept multiple risk outcomes and more detailed event sequence documentation, and integrated with other fault/event tree-generating software to fully document PIRC results.

A long-term goal should be the implementation of a standardized policy for ISE activities at all DOE facilities. One successful method for achieving this goal is being used by the commercial nuclear industry. It involves working committees made up of ASME, NRC, and industry representatives, that are assigned Code development tasks for establishing ISI, IST, and other pertinent rules concerning the operation of nuclear power plants. In a similar manner, input from varied DOE participants should be compiled to determine the best approach for development of ISE. It is recommended that an ad hoc committee be formed to represent DP facilities in establishing standard component testing and inspection techniques/frequencies and in developing future rules for ISI/IST activities at all DP facilities. Investigations of other industries should continue to identify inspection and testing techniques that may be applicable for DOE nonreactor nuclear processing facilities.

The results from the efforts described above should be the basis for a DP technical guidance document commensurate with the Regulatory Guides published by the NRC for commercial reactors. This guide would support and provide direction for ISI/IST program development. Future rules relative to ISI/IST implementation are required, if DOE nonreactor nuclear facilities are to continue safe operation.

REFERENCES

1. Advisory Committee on Nuclear Facility Safety to the Secretary of Energy, *Final Report on DOE Nuclear Facilities*, November 1991.
2. M. T. Anderson and D. A. Aldrich, *Review of Inservice Inspection and Nondestructive Examination Practices at DOE Category A Test and Research Reactors*, Report No. EGG-MS-9254, September 1990.
3. R. S. Hartley, M. R. Holbrook, and C. B. Ransom, *Inservice Testing of Pumps and Valves at DOE Category-A Reactors*, Report No. EGG-NTA-9270, October 1990.
4. U.S. Nuclear Regulatory Commission, *Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Plants*, WASH 1400 (NUREG 75/014), October 1975.
5. U. S. Nuclear Regulatory Commission, *Severe Accident Risk: An Assessment of Five U.S. Nuclear Power Plants*, NUREG 1150, June 1989.
6. S. B. Gibson, "The Design of New Chemical Plants Using Hazard Analysis", *Process Industry Hazards*, 1976.
7. S. A. Eide, S. V. Chmielewski, and T. D. Swantz, *Generic Component Failure Data Base for Light Water and Liquid Sodium Reactor PRAs*, EG&G Report EGG-SSRE-8875, February 1990.
8. AIChE, *Guidelines for Process Equipment Reliability*, New York: Center for Chemical Process Safety of the American Institute of Chemical Engineers, 1989.
9. K. D. Russell, M. B. Sattison and D. M. Rasmuson, *Integrated Reliability and Risk Analysis System (IRRAS) Version 2.0 User's Guide*, NUREG/CR-5111, EGG-2535, June 1990.
10. *CAFTA User's Manual*, version 2.1, Science Applications International Corporation, 1990.
11. W. B. Worrell, *SETS Reference Manual*, NUREG/CR-4213, May 1985.
12. J. B. Fussell, "How to Hand-Calculate System Reliability and Safety Characteristics," *IEEE Transactions on Reliability*, Vol. R-24, No. 3, August 1975.
13. N. J. McCormick, *Reliability and Risk Analysis Methods and Nuclear Power Applications*, Academic Press, 1981.
14. Correspondence, G. F. Offutt to E. Enwall, Off-94-78, "In Service Inspection List," October 13, 1978.
15. *ICPP Materials Monitoring and Corrosion Surveillance Program*, Westinghouse Idaho Nuclear Company Report No. WIN-224, April 1987.

16. Correspondence, W. J. Dirk to D. L. Olsen, Dirk-17-91, "Corrosion Inspection of F, G, and H Cell," April 18, 1991.
17. WINCO Technical Specification (TS) 4.1B1, "Vital Equipment Operability," March 6, 1988.
18. WINCO TS 4.1C1, "Testing of Vital Utilities," March 16, 1988.
19. WINCO TS 6.3B2, "Tributyl Phosphate (TBP) Extraction Process Jets and Valves Control Requirements," May 19, 1988.
20. WINCO TS 15C1, "Category 1 Valves and Jets," February 8, 1991.
21. WINCO SOP PO-44, "Vital Equipment Operability," December 12, 1989.
22. Westinghouse Idaho Nuclear Company (WINCO), Inc. Standard Operating Procedure (SOP) 3.8.2, "First Cycle Extraction System - Preparation for Startup," October 26, 1990.
23. Westinghouse Idaho Nuclear Company (WINCO), Inc. Standard Operating Procedure (SOP) WP-5, "Real Property Maintenance Management," March 27, 1989.
24. Westinghouse Idaho Nuclear Company (WINCO), Inc. Standard Operating Procedure (SOP) WE-20, "Preventive Maintenance Activities," November 21, 1990.
25. Westinghouse Idaho Nuclear Company (WINCO), Inc. Standard Operating Procedure (SOP) PO-60, "Preventive Maintenance Administration," July 12, 1991.
26. DOE-ID Order 4330.4A, "Maintenance Management Program," January 9, 1987.
27. American Society of Mechanical Engineers (ASME), *Boiler and Pressure Vessel Code*, published since 1950.
28. American National Standards Institute (ANSI), various piping codes published since 1950.
29. Westinghouse Idaho Nuclear Company (WINCO), Inc. Standard Operating Procedure (SOP) WE-19, "System Operability and Integrated Testing," August 4, 1989.

APPENDIX A

TABLES FROM THE PIRC STUDY AT ICPP

APPENDIX A

TABLES FROM THE PIRC STUDY AT ICPP

The tables in this appendix give details obtained during the PIRC at ICPP. The hazards identified reflect the main concerns for this type of facility, i.e., worker/public safety, environmental safety, criticality, and plant equipment loss. Examples of hazards evaluated are

- criticality events,
- releases of radioactivity,
- excessive (beyond an area designation) radiation fields,
- releases of substances harmful to the environment,
- releases of combustible substances,
- fires in the operating areas,
- fires in the process areas, and
- releases of toxic substances.

The hazards identified using the HAZOP technique are documented in Table A-1, Process Segment Line Items from PIRC Study at ICPP. This table is a listing of the segment line items and observations by the PIRC team as the items were analyzed during the PIRC, October 14 - 28, 1991. Each line item can contain up to four hazards (one for each of the facility concerns). In practice, the average number of hazards documented in each line item was slightly greater than one.

After the hazards identification was completed, the accident sequences were developed. An accident sequence is a series of events, starting with an initiator, that leads to an undesired consequence. The sequences were developed as Boolean expressions without the use of event trees. These Boolean expressions were reduced to cutsets using the SETS computer code. The cutsets from the SETS analysis were loaded into the IRRAS PRA workstation. Using the Birnbaum function of IRRAS, rankings for the various concerns were generated. Common cause failures were not modeled due to the simplicity of most of the systems. The contribution to risk from systems that do have redundant components, as determined by the risk matrices, is low.

The probabilities of events in the cutsets were quantified from five primary sources, plant specific data (i.e., ICPP failure data), *Generic Component Failure Data Base for Light Water and Liquid Sodium Reactor PRAs*,¹ *Component External Leakage and Rupture Frequency Estimates*,² *Guidelines for Process Equipment*,³ and *Advanced Test Reactor Probabilistic Risk Assessment*,⁴ and from the judgement of the HAZOP facilitator, based on experience from past studies, of human reliability.^a The likelihood or frequency of each scenario was estimated by determining initiation frequencies and basic event probabilities from the rates in the above sources. Each cutset in a scenario has an initiator and may include one or more basic events. Based on the likelihood or frequency and consequences, the events were assigned high, medium, or low risk. The high and medium risk line items and their failure event sequences are given in Table A-2; the event definitions are given in Table A-3. The initiators of the failure, derived from the "Possible Causes" section of Table A-1, are underlined in the event sequences of Table A-2.

There is one initiator for each cutset once the Boolean expression is expanded. The unit of frequency for the initiators is years. Where necessary, frequencies were converted to years. For example:

Pipe break - convert "per foot per hour" value from source³ to per year by multiplying by 8760 h/yr and 500 ft. (Pipe break frequencies are from Reference 3 and the assumed pipe length is 500 ft.)

Mechanical and Electrical Components - convert the failure rate in failures per hour to yearly frequencies by multiplying by 8760 h/yr.

Human error - the number of times per year that the error can be made times the human error probability. Note: The human error probabilities

a. Quantification of the human error probabilities was done "on the fly" during the HAZOP process. No attempt was made to refine these values since the real focus of this analysis is active and passive components. Although the rankings are influenced by the human error values, the absolute ranking of the components is not critical to the establishment of the IST/ISI program so the screening values for the human error probabilities are adequate.

used in this analysis were simple estimates made during the HAZOP process by the HAZOP facilitator, based on previous experience.

The basic event estimates are given in Table A-4, as are frequency per year values. Basic failure events were quantified in various ways because of their differing types. Some basic events have failure rates (from data sources listed above) and were quantified over mission times determined in the HAZOP process, while other basic events are demand probabilities. Mission time is the time needed for the initiated sequence to reach a stable condition. Mission time was often estimated to be 24 hours (Table A-1).

An illustration of the process for quantifying basic events is given below. DT-H-118-FAILS represents the failure of density transmitter DT-H-118 to indicate density changes in the process fluids. HSV-PO-H501-1-LK denotes the failure of steam valve HSV-PO-H501-1 by a steam leak past the valve seat. PRVPOH550-13FTRG is the failure of pressure regulating valve PRV-PO-H550-13 to provide air to air lift pump AL-H-550. And LAVPMG553-16FTO is the failure of flow bypass valve LAV-PM-G553-16 to open on demand.

Basic Event	Failure Rate (per hour)	Demand Probability	Mission Time (Hr)	Event Probability
DT-H-118-FAILS	3.00E-6	N/A	24	7.2E-5
HSV-PO-H501-1-LK	1.52E-7	N/A	24	3.6E-6
PRVPOH550-13FTRG	3.59E-6	N/A	8760	3.1E-2
LAVPMG553-16FTO	N/A	5.00E-4	N/A	5.0E-4

The sequence frequency is the initiator frequency times the probabilities of additional events (if any). Uncertainty and sensitivity analyses were not performed. Consider, as an example, the sequence of no flow from the fluorine dissolution process to tanks G-105, G-155, and G-108 resulting from crystallization in the line due to bad chemistry or extended loss of power. This is line/item 100-1-3 from Table A-1, and Table A-2 gives its event sequence as: (OPFAILS-FCSEG100 * 1/yr * OP2FLS-FCSEG100) + ACP-LOSS * OPERROR-EMERGPWR. There are two initiators for this sequence, bad chemistry and loss

of power. The bad chemistry occurs if operators connect the decontamination drop hoses to the wrong place and decontamination chemicals are inserted into the improper location. OPFAILS-FCSEG100 represents the human error probability that the operator attaches the hose to the wrong connection and fails to verify the connection. OP2FLS-FCSEG100 represents the probability that the second independent check also misses the fact that the hoses are connected to the wrong location. This procedure occurs once per year and, when multiplied by the human failure probability, the yearly frequency for this occurrence results. The loss of power initiator, ACP-LOSS, causes the flow to stop. If loss of power is long enough, crystallization will occur as the stagnant fluid cools. The "long enough" factor is caused by OPERROR-EMERGPWR, which is the probability that operators will not align the emergency power source to the process equipment. Quantification proceeds as follows:

	Point Estimate	Source
OPFAILS-FCSEG100	0.001	ICPP ^a
OP2FLS-FCSEG100	0.1	ICPP
ACP-LOSS	0.85/yr	ICPP
<u>OPERROR-EMERGPWR</u>	0.001	ICPP

a. ICPP failure data

The value of sequence 100-1-3 is

$$(.001 * 1/\text{yr} * .1) + (0.85/\text{yr} * .001) = 9.5\text{E-}4/\text{yr}.$$

References

1. S. A. Eide, S. V. Chmielewski, and T. D. Swantz, *Generic Component Failure Data Base for Light Water and Liquid Sodium Reactor PRAs*, EG&G Report EGG-SSRE-8875, February 1990.
2. S. A. Eide et al., *Component External Leakage and Rupture Frequency Estimates*, EG&G Report EGG-SSRE-9639, November 1991.
3. AIChE, *Guidelines for Process Equipment Reliability*, New York: Center for Chemical Process Safety of the American Institute of Chemical Engineers, 1989.
4. S. A. Eide, et al., *Advanced Test Reactor Probabilistic Risk Assessment*, EG&G Report EGG-PRP-8823, Revision 1, September 1991.

Table A-1. Process Segment Line Items from the PIRC Study at ICPP.

HAZOP STUDY IDENTIFIER : TBP Extraction
 LINE OR EQUIPMENT DESIGNATION : 100
 LINE DESCRIPTION : Inlet from FDP to G-105, G-155 and G-108
 LINE/EQUIPMENT CONSIDERED : INLET 1.5" FP-AF-5957,1" 125957, .5" DCAF105755
 DRAWING DESIGNATION(S) : 092239 REV 3

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-1-1	Flow-No	No flow from FDP.	None significant.	D1

COMMENTS: Consequence PL matrix.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-1-2	Flow-No	RCV-G-40/41 Fails close.	No significant impact, but possibly could fail pump in FDP.	C5

COMMENTS: Could be 40 psi of pressure against valves that would not normally see it. Could fail pump with 1E-4. PL Matrix.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-1-3	Flow-No	Flow blockage. Crystallization due to bad chemistry, low temperature or extended loss of power.	Potential shutdown of the line for several months.	B3

COMMENTS: Have been able to clear the blockage in a matter of hours. Has happened twice to date. PL Matrix. Estimate that .05 of the blockages will be full blockages. Prevention of this event is done by procedures.

ACTION: A- Verify FDP and TBP procedure adequately address extended loss of power.

AUDIT NOTES: It takes about an hour or more from loss of all power before there is any trouble that could happen. Don't know what is done for an extended loss of power.

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-1-4	Flow-No	Flow blockage due to foreign objects. Purge dams have caused blockages.	See item 1-3 above.	B3
COMMENTS: PL matrix. Have had valve damage due to foreign objects other than purge dams. Flushing is the first method tried to clear the blockage.		ACTION:		
AUDIT NOTES:		Question as to worker safety for this type of blockage. Interpretation is that there is just an increase in dose to the personnel due to the extra work. Maintenance caused by this blockage would be difficult.		
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-2-1	Flow-Low	Line 5957 leak or rupture.	Release of uranium solution and dissolver product.	B4
COMMENTS: PL Matrix. Environmental Risk Matrix C-4.		ACTION:		
AUDIT NOTES:		The area of the leak is enclosed with HVAC. There are radiation alarms but they will not respond to a process leak. The sump level alarms that will respond to the leak. These detectors are calibrated. A slow leak may crystalize on the floor before reaching the sump. Even after routine decon hot spots will be found. Ventilation is normally operating and it is not going to matter when there is a pipe break. If the leak is in the buried part of the trench, it is very expensive to dig up the pipe and clear the blockage. There are between 800' and 1000' of piping.		
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-2-2	Flow-Low	Diversion through flush line 5755. Over pressure in 5957 and flush valves left open.	Have excessive personnel exposure due to release of uranium solution/dissolver product to PM area.	C4
COMMENTS: Environmental Matrix. Worker/Public Safety D-4.		ACTION: A-1. Maximum radiation levels from releases. Biggest problem would be an aerosol release.		
AUDIT NOTES:		Number of batches per year is 120 with a 3E-3 failure rate for the air-operated valve fails closed. You could expect some kind of valve failure 1 or 2 times a year. Flushing is done once or twice per year. When a similar event happened, the consequences to personnel were not extremely severe. The airborne hazard is less severe (nitric acid) because the Hydrogen Fluoride is complexed. Contamination due to the DECON drops are somewhat of a problem. Toxicity is less of a concern than radiation and acid effects.		
Clearing Action Items				
10/16/91, Received copy procedure 3.7.1. Feed preparation receives dissolver product solution from CPP-666 FDP.				
Presently no analysis for release in the PM area. Still checking on dose calculations.				

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

Clearing Action Items

1. Are there analysis for release of solution into the PM area? No.
2. Procedures for transfer of solution and blocked line? Received procedures 10/21/91.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-3-1	Flow-High	None Identified.		

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-4-1	Flow-Reverse	Back flushing on purpose or accidentally. (45 and 42 valves).	None identified.	

COMMENTS: Back flushing is part of the line clearing procedure.

ACTION:

AUDIT NOTES: Criticality analysis for 45 and 42 valves being looked at by DOE.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-5-1	Pressure-Low	Break (see item 2-1 above), pump problem or low pressure feed from FDP.	Low or no feed availability. Potential Process upset.	D4

COMMENTS: PL Matrix.

ACTION:

AUDIT NOTES: 10/28/91 Added the words "Potential process upset" to the "CAUSES" section and made the classification of "D-4" for this sequence based on item 100-2-1. By James L. Jones, Jr.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-6-1	Pressure-High	See items 1-2, 1-3 and 1-4.		

COMMENTS:

ACTION:

AUDIT NOTES: Question as to the nitrogen pressure that could over pressure the pipe following process fluid transfer. We discussed that the pipe can handle several thousand pounds of pressure and in the past 1500 psi pressure from mini-pumps has been used to depressurize the lines. There is a procedure to unblock the line. A closed valve could give you a higher than normal pressure. The AOVs will stand so much pressure and will then lift off the seat and relieve the pressure to the tank.

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-6-2	Pressure-High	Intentional pressurization of the line using a hydrostatic pump.	Possible valve bellows damage which could result in a leak to the operating area through the air actuator. Worker safety concern.	D3

COMMENTS: Worker public safety matrix.

ACTION:

AUDIT NOTES: 10/16/91, Received procedures 4.1.8 and 3.7-ACP.b1 for plugged lines.

Clearing Action Items

1. Please provide procedure for clearing blocked line. Received procedure 10/21/91.

2. Need Likelihood calculation. -- Assume that a plug occurs once per year. Assume one out of ten of the plugs are not clearable. Out of the plugs that are cleared, assume one out of ten of these are cleared incorrectly. From this reasoning we set a likelihood of 3.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-7-1	Temperature-Low	Low temperature from FDP or low flow resulting a solution cooling.	Crystallization and possible line blockage.	B4

COMMENTS: PL Matrix. Previous 1E-1 or 1E-2 due to loss of off site power or due to compressors for blowing down the lines. But a very low flow is necessary to keep the line warm. Process lines are not heat traced.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-8-1	Temperature-High	High temp from FDP. Above 40 degrees C is a concern.	Increased corrosion rates. This is a chronic problem which could result in a leak if temp remained high long enough.	D4

COMMENTS: Less than 1E-2. PL matrix. Likelihood is 4 for extended high temperature events.

ACTION:

AUDIT NOTES: 11/05/91
Added to the comments "less than 4 for extended high temperature events" from comments of Dennis Henneke.
--- James L. Jones, Jr.

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-9-1	Material-Other than	Decon in line from flush connection from the PM area.	Could be a caustic solution and cause Uranium to precipitate out during the processing of the solutions.	A5

COMMENTS: Criticality risk matrix.

ACTION:

AUDIT NOTES: Fluid other than the normal process fluid. Could get decon solution. Double verification required for hook up and solution verification as to correct chemistry of the decon solution. First operator error is 10-3, second operator verification is 10-1 resolutions in a 10-4. Assume 1 hookup per year. 05-05-92 By James L. Jones, Jr.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-10-1	Material-As well as	Too much Flush water added to line.	Extraction efficiency deterioration, Uranium in raffinate tanks and would have to recycle the batch. Consequence would be minimal since normally wait on FDP.	D4

COMMENTS: PL Matrix. Would take 500 liters to cause a problem. 2 flushes per year times 1E-3 error rate.

ACTION:

AUDIT NOTES: Could cause efficiency effect such as loss of a shift but the extraction process is faster than fdp and much time is spent waiting on FDP so the loss is minimal.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-10-2	Material-As well as	Heel out solution, Uranium bearing residuals from tanks.	Increased wear and tear on the system, occurs for uranium inventory concerns but not every batch.	D1

COMMENTS: PL matrix. Occurs about every 10th batch which occurs approximately monthly.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
100-11-1	Material-Part of	FDP failed to complex the fluorides leading to high corrosion rates. Problem would be in FDP.	Increased acute corrosion rate would be seen in less than a day effects.	C5

COMMENTS: PL matrix. Solution with "part of" missing

ACTION:

AUDIT NOTES:

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

HAZOP STUDY IDENTIFIER : TBP Extraction
 LINE OR EQUIPMENT DESIGNATION : 101
 LINE DESCRIPTION : Feed receiving tank
 LINE/EQUIPMENT CONSIDERED : Vessel G-105
 DRAWING DESIGNATION(S) : 92239 Rev 3

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-1-1	Flow-No	None identified.		

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-2-1	Flow-Low	None Identified.		

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-3-1	Flow-High	None Identified.		

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-4-1	Flow-Reverse	None Identified.		

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-5-1	Pressure-Low	External vessel leak or rupture.	Spill of uranium solution in the G-cell.	B4

COMMENTS: PL Matrix. Environmental Risk Matrix C-4. Vessel has no pressure.

ACTION:

AUDIT NOTES: G-cell volume is 800-900 gallons. Liquid could spill out the door into the

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

access corridor. The operator would notice a dropping tank level and a rise in the sump level. With these indications, the operator should transfer the contents to the other vessel away from the sump.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-5-2	Pressure-Low	Leak into the heating jacket around vessel G-105.	Inflow of water into G-105 and possible radioactivity into the service waste stream.	B4

COMMENTS: PL Matrix.

ACTION:

AUDIT NOTES: Cooling or heating jacket water goes out to the percolation pond. Cooling water is available at 90psi. There is a dual radioactive emissions detector. Upon detection the flow is automatically diverted. Replacement of the tank (which is corroded) costs greater than \$100,000.00. Frequency Class 4 (greater than 1E-3 and less than 1E-2) because there are ten vessels that have been in service for thirty years without a failure.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-6-1	Pressure-High	Failure of vent off gas system.	Can lead to the pressurization of the vessels and possible transfer of solution to undesired locations (ex. sample cubicle)	D3

COMMENTS: PL Matrix. This causes a process upset.

ACTION:

AUDIT NOTES: Frothing and solidification of the froth can cause a plugging of the vessel off gas line and pressurize the G-105 tank. As a result, it is possible that the tank contents can be transferred to some other tank. One location would be into the sample cubicle where the sample valve is normally open. Pressurization could occur as a result of the spargers.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-7-1	Temperature-Low	Failure of the heating jacket water system.	Results in transfer to another vessel. Worst case with no operator action you may get precipitation of zirconium.	C4

COMMENTS: PL Matrix. Time to react in terms of hours.

ACTION: A- Review or look at effect of fail to open of steam valve for jacket heating.

AUDIT NOTES: The heating jacket system has an automatic controller. The temperature switch TSL (temperature [solid state] switch low and is a thermocouple) G-105 is not alarmed it just turns the system on or off. Failure of the switch is approximately 3E-3/yr. and happens about 200 times per year so failure would be .6/yr. valve fail to open. The operator failed to read indicator at 2hr. interval is 1E-2. Combined failure is 6E-3.

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-8-1	Temperature-High	High flow or high temperature from the heating jacket. Steam supply valve fails open.	Accelerated corrosion of G-105.	D4
COMMENTS: PL matrix. Chronic failure due to corrosion.			ACTION:	
AUDIT NOTES:				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-8-2	Temperature-High	Excessive steam sparge, jet blockage or operation of recycle jet.	Excessive corrosion due to heat up of the solution.	D3
COMMENTS: PL matrix. Excess of steam sparge (condensate) dilutes the concentration. Recycle jet and steam sparging normally operated only during decontamination of the cell.			ACTION:	
AUDIT NOTES:				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-9-1	Material-Other than	See item 100-9-1.		
COMMENTS:			ACTION:	
AUDIT NOTES:				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-10-1	Material-As well as	Additional water from blocked steam jets, excessive sparging, jacket cooling leak and same as 100-10-1.	Same as 100-10-1.	D3
COMMENTS: PL Matrix.			ACTION:	
AUDIT NOTES:				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-11-1	Material-Part of	Improper nitrate concentration in recycle solution.	May have to recycle the raffinate or do a chemical adjustment.	D2

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

COMMENTS: PL matrix. Most common chemical adjustment is to add aluminum nitrate. This incident has happened in the past for recycle activities.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-12-1	Level-Low	See item 101 5-1.		B4

COMMENTS: PL Matrix. Environmental Matrix C-4.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
101-13-1	Level-High	Too much solution, transferred from other tank, addition of flush water recycled steam, jacket leak.	Overfill into other tanks.	D4

COMMENTS: LSH G-105 alarmed at 82%.

ACTION:

AUDIT NOTES: 10/28/91 Added consequence D and frequency 4 to this record.

HAZOP STUDY IDENTIFIER : TBP Extraction
 LINE OR EQUIPMENT DESIGNATION : 102
 LINE DESCRIPTION : First Cycle Feed Tank
 LINE/EQUIPMENT CONSIDERED : Transfer line, 2 '' PSA-419 steam line 1.5"
 HSA-327, Ves-G-106
 DRAWING DESIGNATION(S) : 92239 rev3, 92240 rev3.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-1-1	Flow-No	Blocked steam jet G-504.	No transfer, use alternate route, (20 min. transfer to another tank).	D3

COMMENTS: PL Matrix, Recognized by level not going down in the tank, steam strainers have clogged but can be cleaned outside the cell. Estimated to occur once per 30 years.

ACTION:

AUDIT NOTES:

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-1-2	Flow-No	No steam from high pressure steam header, possible strainer line outside the cell]. block.	See item 1-1 could unblock the	D2
COMMENTS: PL Matrix.		ACTION:		
AUDIT NOTES: 10/28/91				
Two manual block valves (manual operation to open). Steam control are outside the cell and if blockage occurs it is likely that the repair will be made the same shift that blockage happens . The estimate of failure is 8 to 10 years, which results in a plugged strainer with a frequency of 1E-1/yr. Plugged valves are also considered. --- James L. Jones, Jr.				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-2-1	Flow-low	Leak or rupture of a line, 2" PSA-419.	Uranium solution leaks to the cell floor, can be jettied to recycle cell and back to feed tanks.	B4
COMMENTS: PL Matrix. Environmental Risk Matrix C-4, Line drains after transfer of fluid, line normally does not leak, would have to shut down to look into the loss of the line.		ACTION:		
AUDIT NOTES:				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-3-1	Flow-High	High flow of steam to jet G-504. Jet high flow can occur when regulating valve is wide open.	Boiling of uranium solution and vapor locked jet prior to transfer.	D1
COMMENTS: Operator controls inlet steam pressure to 60 to 80 psi using Gauge G-504 to prevent vapor-locked jet and no flow in the main line. Same result obtained by failure to blow out steam condensate line. PL matrix.		ACTION:		
AUDIT NOTES: 10/28/91				
An estimate of 100 actions per year times the human error factor of 1E-2 leads to a frequency class of "1" (greater than or equal to 1 time per year). --- James L. Jones, Jr.				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-4-1	Flow-Reverse	Failure to vent steam line to transfer jet after use, steam can collapse and fluid can be sucked into the steam line.	Potential contamination of steam line and personnel exposure.	E2
COMMENTS: Worker/Public Safety Risk Matrix.		ACTION:		

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

AUDIT NOTES: Fluid could be sucked into the operating area, but there are area monitors that could indicate the presence of the process fluid in the operating area. Some lines are wrapped with lead if there have been past problems. Weekly contamination measurement we think takes place (an estimate). An estimate of once per 10 years with a human error rate of $1E-2$ leads to a frequency class of "2" (greater than $1E-1$ /yr. but less than 1/yr.).

CLEARING ACTION ITEMS 10/24/91

1. "Reevaluate worker/public safety risk matrix consequences to consider dose rate in the consequences." The HAZOP leaders decided that this was an important step; however, due to the scope of this HAZOP, radiation effects on the matrices would be added to the future HAZOPs. --- James L. Jones, Jr.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-4-2	Flow-Reverse	Overfill of vessel G-106.	Could send flow to VOG, vessels 105, 155, 108, 116 raffinate tank, sample system. More effort to clean up at sample area but less than \$10K.	D2

COMMENTS: PL matrix. Has been done before and process fluid went to many areas, has occurred due to instrument failure and density correction problems with instruments, High level alarm LAH-G-106 single group one instrument. ACTION:

AUDIT NOTES: 10/28/91
The overfill is a nuisance for G-105, G-155, and G-108 but overfill is caused by operator error. The operator has two level instruments and a "group" alarm to monitor. --- James L. Jones, Jr.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-5-1	Pressure-Low	Vessel G-106 leak or rupture.	See item 101-5-1.	C4

COMMENTS: Environmental Risk Matrix. This vessel has a bottom nozzle unlike vessel 105. If the break is at the bottom nozzle you would have a C-5. ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-5-2	Pressure-Low	Leak into heating jacket around vessel G-106.	See item 101-5-2.	B4

COMMENTS: PL Matrix. Leak is more likely to enter service waste due to the relative height of the manifold and the vessel. ACTION:

AUDIT NOTES:

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-6-1	Pressure-High	Failure of vent off gas.	See item 101-6-1.	D3
COMMENTS: PL Matrix		ACTION:		
AUDIT NOTES:				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-7-1	Temperature-Low	Failure of heating jacket water system.	See item 101-7-1.	C4
COMMENTS: PL Matrix		ACTION:		
AUDIT NOTES:				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-8-1	Temperature-High	High flow or high temperature in heating jacket, excessive steam sparge, jet blockage, or operation of the recycle jet.	See item 101-8-1.	D4
COMMENTS: PL matrix.		ACTION:		
AUDIT NOTES:				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-8-2	Temperature-High	Excessive steam sparge, jet blockage or operation of recycle jet.	See item 101-8-2.	D3
COMMENTS: PL matrix.		ACTION:		
AUDIT NOTES:				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-9-1	Material-Other than	Operator inadvertently performs DECON drop into wrong line from PM area.	Mess up chemistry, criticality problem from addition of caustic. See also item 100-9-1.	A5
COMMENTS: Criticality Matrix. PL Matrix C-4.		ACTION:		
AUDIT NOTES: Only different way of changing the contents of this tank is the DECON drop. DECON drop should not be used during normal operation (would require an operator error on the valve lineup which has a double verification). Caustics that could be added are NaOH, NH4OH which could possibly lead to criticality.				
=====				

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-10-1	Material-As well as	Additional water from blocked steam jets, excessive sparging, jacket cooling leaks, etc.	See item 100-10-1.	D3

COMMENTS: PL Matrix

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-10-2	Material-As well as	Column H-100, H103, or G-111 upset resulting in organics coming in through the vent off gas.	Potential criticality in G-108.	A4

COMMENTS: Criticality Matrix

ACTION:

AUDIT NOTES: Clearing action items

1. Evaluate the likelihood after assessing one of the above columns. Per discussion on item 105-13-2, the likelihood is evaluated as 1/yr. * 1E-2 * 0.1 = 1E-3 which is category 4.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-10-3	Material-As well as	Jetting columns G-111, H-100, or H-103 to G-108 then feeding into G-106.	Potential criticality problem in G-106 or G-108.	A5

COMMENTS: Criticality Matrix.

ACTION:

AUDIT NOTES: Testing on the jetting valves is very little. A small leak through RCV-G-8, in cell process valve, could overheat the jet. Common mechanical failure to lead to this event at a failure 4E-5 per year. Double operator failure of 1E-4.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
102-11-1	Material-Part of	See item 101-11-1.		

COMMENTS:

ACTION:

AUDIT NOTES:

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

HAZOP STUDY IDENTIFIER : TBP Extraction
 LINE OR EQUIPMENT DESIGNATION : 103
 LINE DESCRIPTION : First cycle feed to Surge tank, G-165
 LINE/EQUIPMENT CONSIDERED : 1" PSA-303, 406, 549, 110086
 DRAWING DESIGNATION(S) : 92240 Rev3, 92241 Rev5

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
103-1-1	Flow-No	RCV-G-15 fails closed due to loss of air, control failure, or inadvertent PPS.	Uranium Process shutdown. Alternate feed line may be available.	D2

COMMENTS: PL Matrix

ACTION:

AUDIT NOTES: Made an assumption that we are running in the high flow mode through FCV-1GA. The low flow mode is 300 liters per hour max. The high flow mode is 500 or less liters per hour. If the flow control valve went full open you can get up to 1000 liters per hour. The fail position of FCV-1A and FCV-1B are fail open while RCV-33 and RCV-15 are fail close valves. Failure rate for the valve and controller estimated at 1E-4/hr. based on "PROCEDURES EQUIPMENT RELIABILITY DATA", Center for Chemical Process Safety.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
103-1-2	Flow-No	FCV-1GA fails closed due to valve closure, instrument/control failure of LRCA-G-165 loop.	Same as 1-1. Possible loss of both main and bypass feed.	D2

COMMENTS: PL matrix.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
103-2-1	Flow-Low	Controller is controlling low or the wrong line through G1B is being used.	Slow the processing and a lower control level in G-165.	D1

COMMENTS: PL matrix. A mechanical connection is used to change out valves and do repairs. Leakage is most probable through the mechanical connections.

ACTION:

AUDIT NOTES:

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
103-2-2	Flow-Low	Line leak or rupture.	See item 101-5-1.	B3

COMMENTS: PL Matrix. Environmental risk matrix C-3. Lines such as 1" PSA-549 are involved. ACTION:

AUDIT NOTES: Once every ten years a valve leaks as estimated by plant data. There are three valves of this type which equates to 30 years operation. Valve G-2 has leaked through its bellows. The frequency class is estimated to be class "3" (greater than 1E-2/yr. and less than 1E-1/yr.)

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
103-3-1	Flow-High	FCV-1GA fails open due to AOV fails open, loss of the control air or positioner air, instrument control malfunction.	Criticality concern in vessels G-111, H-100, Mixer settlers H-115 and/or H-116, if the high flow continues for hours.	A5

COMMENTS: Criticality matrix. ACTION:

AUDIT NOTES: G-165 has a high level alarm, and two level indicators. There is also a flow alarm FY-G106, which is off the level indication. FRA-G106 is a group 1 instrument and is calibrated every 12 months. There are three level detectors where one is an input to the computer. There is a two out of three logic for the operator to confirm the level. A probe line contains two separate differential transmitters and there is another probe for this line. Flow instruments are calibrated more frequently than level instruments. Failure of the instrument which controls the valve, then the operator has to make a decision as to which reading is correct. Transmitter failure rate is 1E-4/hr. (0.8/yr.). for the first level instrument failing high, alarm failure of .01, and operator failure of .1.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
103-3-2	Flow-High	Leakage through valves 1GB and 33G (bypass line) or the valves fail open.	Overfill 165 that could possibly go into the vent off gas system and could see drainage into the 108 vessel, repair of valves.	C2

COMMENTS: PL Matrix. Actually seen leakage due to sludge problems other than FDP solution. ACTION:

AUDIT NOTES: 10/28/91
The operator sees high level on G-165 and tries to close valves. Usually there is a common mode failure for both valves (Use DECON connection to flush, trying to reseal, but still have flow to G165). --- James L. Jones, Jr.

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
103-4-1	Flow-Reverse	A column upset causes entrained organic to get into G-106 back through the column through G-165.	See item 102-10-2.	A5

COMMENTS: Criticality Matrix

ACTION:

AUDIT NOTES: Have a massive column upset in H-100 which allows organic to come back through the 1BR stream into G-165. During fluctuations in level of G-165 some of the solution can move back through the normal outflow line from G-106. You know you had an upset in H-100. Not unusual occurrence for G-165 to equilibrate G-106.

Raffinate tanks are drained weekly to avoid organic layer on the top.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
103-5-1	Pressure-Low	See item 2-2 above.		

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
103-6-1	Pressure-High	See item 102-6-1.		

COMMENTS: High pressure in the vent off gas system.

ACTION:

AUDIT NOTES: 10/28/91
Added the comment "High pressure in the vent off gas system" to the comments section. --- James L. Jones, Jr.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
103-7-1	Temperature-Low	Low temperature due to extended low flow.	Solidification of solution precipitate in the line causing line blockage.	C2

COMMENTS: PL Matrix. Cell is not as warm as it needs to be in order to keep the solution temperature within its normal range

ACTION: A- Evaluate possibility of blockage of line due to crystallization from lack of flow after batch. May want procedure change to flush after batch.

AUDIT NOTES:

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
103-8-1	Temperature-High	See item 102 8-1 and 8-2.		
COMMENTS:		ACTION:		
AUDIT NOTES:				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
103-9-1	Material-Other than	See item 102-9-1.		
COMMENTS:		ACTION:		
AUDIT NOTES:				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
103-10-1	Material-As well as	See item 102-10-1.		
COMMENTS:		ACTION:		
AUDIT NOTES:				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
103-11-1	Material-Part of	See item 102-11-1.		
COMMENTS:		ACTION:		
AUDIT NOTES:				
=====				
HAZOP STUDY IDENTIFIER : TBP Extraction				
LINE OR EQUIPMENT DESIGNATION : 104				
LINE DESCRIPTION : Extraction column G-111 inlet				
LINE/EQUIPMENT CONSIDERED : Vessel G-165, Vessel G-164, 1.5" PSA-600, PSA-591, 1" PSA-454, 1" PSA-592, 1" VGA-363, 1.5" PSA-310, 1" PSA-525				
DRAWING DESIGNATION(S) : 092241 Rev5, 092240 Rev3				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-1-1	Flow-No	Loss of air to air lift AL-G-553, plugging, air valve failures, or PPS inadvertent actuation.	Shutdown the process.	C2

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

COMMENTS: PL Matrix. Worst case would be to cut out plug and replace line.

ACTION:

AUDIT NOTES: Feed rate through the extraction column is 500-600 liters per hour. The operator looks at FE-G-111 or you can bypass the flow detector and go off the level of 106.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-1-2	Flow-No	G-65 fails closed, FCV-2G fails closed, valve failure, instrumentation failure/control failure (FRC-G-111), air failure.	Manual control using bypass and air lift pump. Potential technical specification violation. Potential overflow of G-164 into vent off gas system.	02

COMMENTS: PL Matrix.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-1-3	Flow-No	Plugging the (FE-G-111) vendor.	Contamination of the area (can happen when unplugging).	C3

COMMENTS: Environmental Matrix. PL Matrix D-1.

ACTION:

AUDIT NOTES: Attempts to blow out the plugged vendor has in the past lead to PM area contamination. Failure to properly isolate valves can cause contamination to be released due to the rupture of the flow instrument bellows.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-1-4	Flow-No	Failure of steam jet G-537 or failure of valve RCV-G-165 during clean out operations following campaign.	Failure to clean out vessel G-165 and outlet piping from G-165.	D3

COMMENTS: PL Matrix.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-2-1	Flow-Low	Inadvertent operation of jet, G-537, or tank G-165 is over filled and the valve RCV-G-165 is open or leaks by.	Transfer to G-108.	D3

COMMENTS: PL Matrix.

ACTION:

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

AUDIT NOTES: 10/28/91
Estimated frequency category for this event is "3" (greater than 1E-2 and less than 1E-1). Jet operation occurs several times per shift, and there is double verification for transfers. It is estimated that there are 1000 verifications per year plus an equal number of second verifications.
--- James L. Jones, Jr.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-2-2	Flow-Low	Leakage or rupture of the vessel G-165 or the lines.	Release of uranium solution and dissolver product into G-Cell.	B3

COMMENTS: PL Matrix. Environmental Matrix C-3. FCV-2G has leaked before (the valve has mechanical connections). ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-2-3	Flow-Low	Leak of the heater jacket (G-359).	Potential contamination of the service waste header.	B4

COMMENTS: PL matrix. Heater is not normally in use. There is a potential inflow to the service waste header. Have to shutdown to fix. Do not know of inflow unless the system is turned on for flow. ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-3-1	Flow-High	Valve FCV-2G fails open, bypass RCV-G-66 fails open, or manual control set high.	Possible technical specification violation and you are going to get a high flow alarm from vessel G-106.	C2

COMMENTS: PL matrix. Most you can put through the column is 900-1100 liters per hour. ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-4-1	Flow-Reverse	Failure to vent steam line to transfer jets, or air lift supply line following plugging.	See item 102-4-1.	E3

COMMENTS: Worker/Public Safety. Height of the vessels is designed to make reverse flow improbable for line PSA-600. ACTION:

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

AUDIT NOTES: 10/28/91
Steam is usually used to clear the plugged jet. If unsuccessful, then the vent line cannot be used because steam has condensed in the blocked line. ---
James L. Jones, Jr.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-5-1	Pressure-Low	See item 2-2 above.		

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-6-1	Pressure-High	See item 102-6-1.		

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-7-1	Temperature-Low	Inadvertent operation of the cooling jacket G-359 on line PSA-600.	Possible crystallization and plugging of the line in low flow conditions which could lead to plugging and operational upset.	C2

COMMENTS: PL Matrix. Flushing capabilities to fix the problem with the steam jet and the air lift line.

ACTION: A- Verify that valves TWV-PO-G359-11/13 are on the preoperational check list or equivalent.

AUDIT NOTES: You know you don't have water running through the pipe by physically touching the pipe. There is no temperature reading on the line. There is no lock out or tag out on the valve.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-8-1	Temperature-High	Operation of the steam jet with RCV-G-165 closed.	Accelerated corrosion problems in vessel G-165 and down stream.	B4

COMMENTS: PL Matrix.

ACTION:

AUDIT NOTES: If the valve RCV-G-165 were closed and the steam jet continued, there would be agitation in vessel G-165 and heating of the solution. There have been some fairly serious leaks in the cell where operation has continued. Due to environmental concerns, situations like this are not being tolerated today. The steam jet is only used once per year to clean out the lines. Operator would have to fail to vent the steam header after use. There are two operators that would have to fail

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

because of independent check. Primary check is 10-2 independent check is 10-1. Manual valve fail to close is 5×10^{-4} so operator action dominates the calculation. The estimated time for decontamination of the cell, repair of equipment, and probably look at other equipment for similar corrosion effects is 3 months.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-9-1	Material-Other than	Operator inadvertently performs DECON drop.	See 102-9-1.	A5

COMMENTS: Criticality matrix. PL matrix C-4.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-10-1	Material-As well as	See items 102-10-1, 102-10-2 and 104-2-3 (Leak in the cooling jacket).		

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
104-11-1	Material-Part of	See item 1-1 above.		

COMMENTS:

ACTION:

AUDIT NOTES: 10/28/91
Problems with the nitrate solution would be detected by earlier vessel checks
and alarms. Level control is in equilibrium with other vessels. --- James L. Jones, Jr.

HAZOP STUDY IDENTIFIER : TBP Extraction
 LINE OR EQUIPMENT DESIGNATION : 105
 LINE DESCRIPTION : Extraction Column
 LINE/EQUIPMENT CONSIDERED : Vessel G-111, 4" line PSA-356, 2" PSA-554,
 1" LAN-357
 DRAWING DESIGNATION(S) : 92241 rev 5, 92244 rev 3

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-1-2	Flow-No	Failure of the air pulse system, RCV-PM-224-0 or 224-1 fail closed, 224-2 fails open, or failure of the frequency controller that operates the 4-way solenoid.	High uranium in the raffinate, efficiency problem.	D1
COMMENTS: PL Matrix.		ACTION:		
AUDIT NOTES:		11/01/91 -- Added another possible cause which was failure of the frequency controller that operates the four-way solenoid valve. --- James L. Jones, Jr.		
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-1-1	Flow-No	No flow of organic from vessel H-118 (valve fails closed) and no PPS alarm.	Criticality in column G-111.	A5
COMMENTS: Criticality Matrix.		ACTION:		
AUDIT NOTES:		10/28/91 The column will saturate to capacity and the uranium goes to the raffinate stream. Pump output (if organic is not flowing) could be detected by the PPS and depletion of the H-118 volume. G-111 is not geometrically safe. Organic is a combination of TBP and kerosene (8-10% TBP concentration acceptable). Above 12% TBP concentration is a concern for criticality. TBP breaks down radiolytically and needs to be freshened periodically. Makeup is checked before it is added to the column. --- James L. Jones, Jr.		
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-2-1	Flow-Low	Blockage or buildup in the plates of the column G-111.	Extraction efficiency goes down, the column tries to flood, and puts organics into the raffinate (shows up first in vessels G-115 and G-116).	A3
COMMENTS: PL Matrix.		ACTION:		
AUDIT NOTES:		Assessment of frequency- Nothing in the foreseeable future about running ROVER type fuel again. No access ports to the plates in the column. There are plates at every 3" spacing which makes approximately about a hundred plates (the plates have .25" holes). If the plate blockage or build up happened with the worst type fluid and it happened once and now you have a fluid an order of magnitude better then the frequency should be an order of magnitude lower at greater than 1E-2. CLEARING HAZOP ACTION ITEMS 10/24/91 1. "Cover high organics to vessels G-115 and G-116 when they occur." High organics to vessels G-115 and G-116 was covered by HAZOP line items 106-1-3, 106-1-4, and 106-2-3. --- James L. Jones, Jr.		
=====				

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-2-2	Flow-Low	Vessel G-111 leaks or ruptures.	Dumping the contents of the vessel to the G-Cell.	C3

COMMENTS: Environmental risk matrix.

ACTION:

AUDIT NOTES: Bottom nozzles have leaked at the thermal well which has since been plugged. A bottom nozzle leak can drain the whole vessel. Volume, 500 liters, would be retained in the cell. Do have a CO2 fire suppression system that covers G & H cells. System has a possibility for extinguishing an operator (Worker/Public safety). Very little electrical equipment except lighting (explosion proof) and thermocouples. Has a flash point at 145 degrees F. TBP has a flash point that is worse. During a major hexone leak, the amount through the off gas system was not within the upper and lower flammability limits. Expect the concentrations with the TBP and Kerosene to be much lower. People can be in the vent tunnel during a campaign. HEPA filters for the HVAC system can handle particulates but not smoke (clogs the filters). Cannot identify ignition sources and there is a recent increased plant awareness for housekeeping.

Clearing Action Items

1. Reevaluate previous environmental risks due to matrix changes.--- Changed all previous environmental risk matrix consequences to "C" that were previously labelled "D"

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-2-3	Flow-Low	Air pulse line, water/air flush line, sono probe line, or capped flush lines (2) leak or rupture.	Organic kerosene mixture released to PM area.	C2

COMMENTS: Environmental Risk Matrix. Worker/Public Safety Matrix D-2. ACTION:

AUDIT NOTES: 11/05/91
Changed the consequences from a "C4" for the Environmental Risk Matrix and a "D4" for the PL Matrix to a "C2" and "D2" respectively. This change was made based upon the results from item 108-4-1. Based on comment from Dennis Henneke.
--- James L. Jones, Jr.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-3-1	Flow-High	High flow from the air pulse system. SC-G-111 fails high or set incorrectly, or valve 224-1 fails open or 224-2 failing closed. Vessel PM-124-0 Pressure High.	Vessel high level carryover (possibly lift the contents of the column) back to vessel G-108 or forward to H-100, resulting in plant shutdown.	C2

COMMENTS: PL Matrix. Could move column material to the vent off gas system. back to vessel G-108 or forward (downstream) to H-100. There is a weekly requirement to empty vessel G-108. ACTION:

AUDIT NOTES: For a small upset, the contents mostly go to H-100 and presents an operability problem. For G-108, organics get into the vessel. Failure points for the vessel is 12 g/l. The starting

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

point from vessel G-111 is 7 g/l. An operator failure would be needed along with a major column upset for criticality in G-108. Operator action is estimated to be 1E-2 per setting of SC-G-111.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-3-2	Flow-High	Operator sets the stroke controllers ZIC-PA-240/241 for the organic solution high, undetected flow from H-118 (leaking through RCV-H-7 or RCV-H-119).	Challenging the criticality safety of H-103, H-115 and H-116 (mixer/settler tanks).	A4

COMMENTS: Criticality Matrix.

ACTION: A- Track this item when mixer/settler tanks H-103 and H-115 are studied

AUDIT NOTES: 10/28/91
Undetected flow from H-118 due to leaking valve RCV-H-7 or from RCV-H-119. No high level indication in mixer H-115. It may take 20 hours of process upset to get a criticality problem. The operator checks the valve hourly. Spurious failure of the valve is 3E-3. --- James L. Jones, Jr.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-4-1	Flow-Reverse	See items 2-1 (plate failure) and 2-3 (reverse flow to air pulse line) above.		

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-5-1	Pressure-Low	Low air pressure from the air pulse system.	See item 1-2 above.	D2

COMMENTS: PL matrix.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-6-1	Pressure-High	High pressure in the vent off gas system.	Off normal system operation.	D4

COMMENTS: PL Matrix.

ACTION:

AUDIT NOTES: Level instrument may change by approximately .5" due to column vacuum, get a air bubble in the organic output line. Purge air at 0.1 cuft/hr.

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-7-1	Temperature-Low	Low temperature of the organic. None identified.		
COMMENTS:		ACTION:		
AUDIT NOTES:		<p>10/28/91 Low temperature of the organic (300 l/hr.), feed solution (500 l/hr.), scrub solution (75 l/hr.). Existing cooling jackets not used. Temperature readings taken from G-106 (aqueous feed), and H-118 (organic feed). --- James L. Jones, Jr.</p>		
105-8-1	Temperature-High	See item 104-8-1.		
COMMENTS:		ACTION:		
AUDIT NOTES:				
105-9-1	Material-Other than	Operator inadvertently performs DECON Drop.	See item 102-9-1. (Can precipitate out uranium)	A5
COMMENTS: Criticality Matrix.		ACTION:		
AUDIT NOTES:				
105-10-1	Material-As well as	Aqueous solution from the solvent run tank, from valve RCV-H6 failure in the PEW line, from the steam jets H-521/22, and from cooling jacket H-301 leak.	Criticality problem in the upper head of G-111.	A3
COMMENTS: Criticality Matrix		ACTION: A- Check on the timing of the criticality event.		
AUDIT NOTES:		<p>Unwanted aqueous solution goes into the organic stream. Normally the last mixer settler is dropping off to PEW. If the valve in the line would fail it would carry aqueous over into the solvent run tank H-118 and then would be pumped back to G-111. If so, then there is a need to jet off the water from the bottom of H-118, otherwise, the concentrations will approach the technical specification limit. It would take several hours before you would get criticality. Sample run tank three times a week. Frequency calculation =basis- getting the aqueous solution into the organic with frequency of 1.0/yr. and a failure of the density strip chart recorder or the operator failing to read and respond to the strip chart information (relates to operator training) is approximately 1E-2 to 1E-3 per demand. Aqueous in the organic is a concern for the action item resulting in decreased</p>		

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

solvent flow rate and increased uranium extraction rate that results in buildup of uranium in the top of G-111 which is a criticality concern. Normal mixer rate (30 to 40 l/hr.) could be adjusted to compensate for the organic flow need. Radiolytic degradation of TBP (from 8% to 6% in two weeks), three samples taken per week.

HAZOP DECISION: Ventilation system to be reviewed later.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-10-2	Material-As well as	Inadvertent jet G-523 operation to tank H-115 and jet G-522 to G-108.	Jet G-523 steam line disconnected so no operation, no consequences expected. G-522 results in uranium and organics reaching a large diameter tank, Criticality.	A5

COMMENTS: Evaluated this item under 102-10-3. Criticality Matrix. Group 1 administrative controls (double verification) in place for jet and valve operation.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-11-1	Material-Part of	Low TBP concentration in the incoming organic stream to G-111 caused by radiolytic disintegration or operator error in makeup.	Could have criticality in G-111 or H-100.	A5

COMMENTS: Criticality Matrix.

ACTION: A- Verify the procedure used by the Laboratory technicians to measure the TBP concentration.

AUDIT NOTES: Solution is generally 90% kerosene and 10% TBP. Low TBP concentration could lead to potential criticality in G-111 or H-100. Solution is sampled three times a week and it takes approximately two weeks for criticality to occur. Make up is performed approximately once a month (approximately 20 liters). You have twelve samples during this period.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-12-1	Level-Low	Density interfacing controller fails, Transmitter fails, I to P converter fails, ratio relay fails, or air system fails.	Column upset causing decreased efficiency of uranium extraction.	D2

COMMENTS: PL Matrix.

ACTION:

AUDIT NOTES: Interface controller could be causing a problem. The controlling range for this controller is 8" of column. Worst case is if the interface is just below the upper set point.

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

At 300 l/hr. It would take an hour to fill the column. After an hour or so you would have double the solution dumping into the raffinate tank.

LR- would change.

If the transmitter fails, the alarm may not function.

11/15/91

During the presentation on November 14, 1991 results to the CPP personnel of the HAZOP results, ED Wagner said the new information about this sequence saying the proposed static head of organics in G-111 that would lead to criticality will not occur because due to system design this situation is physically impossible. Therefore, the only concern of this sequence is from a plant loss standpoint.

--- James L. Jones, Jr.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-13-1	Level-High	High level failure of components listed in 12-1.	Initially an overflow of aqueous into the organic getting high levels of radioactivity down stream.	D3

COMMENTS: Environmental Matrix. PL Matrix D-2.

ACTION:

AUDIT NOTES: There is an additional high level alarm LAH-G-111 and a high density alarm DAHL-G-111. On control pot G-112 there is an orifice on bleed off line .25" DCA-106496 that is subject to plugging that gives high level. Attempts to clear G-112 may not be able to get it vented and will pull stuff back up. Blockage happens more frequently than the controller failures. System design has been changed, an air vent system hard piped into it, to make contamination less likely. There has been a previous contamination. Estimated frequency is category "2" [event has already happened] (less than 1/yr. but greater than .1/yr.) that is reduced to category "3" (less than .1/yr. but greater than 0.01/yr.) because of system design improvement.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
105-13-2	Level-High	Air lift AL-H-555 plugging or possibly being left off, air lift goes to H-100.	Criticality in mixer settler tank H-116. If H-115 is doing its job you will not see a problem in H-116.	A4

COMMENTS: Criticality Matrix

ACTION: Recommendation: Put a valve in the interface jet line .5" PSA-330.

AUDIT NOTES: LTH-G-111 (LI-A) level comes up high, column of organic layer builds up into the head. May go over to the 523 Jet and drop off into the mixer settlers H-115. Goes into the off gas to vessel H-100 (this is the safe path). To fix you use the steaming or mini-pumping air lift. Controls for pumping are located in the operating corridor. Timing on criticality in H-116 is approximately 20 hours. A new alarm (FAL-H-155 or FSL-H-555) to indicate that airlift failed is going to be installed. There is no valve in the interface jet line for isolation. If you shutdown the plant for criticality then the overall cost would be approximately \$100,000,000. Frequency is about 1E-4. The risk per year is 10,000. There is a benefit for putting a valve in the interface jet line. The intentional use of the interface jet could change the same problem. If the airlift or jet is plugged, then use the mini-pump or steam to clear the line.

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

NOTE: Organic lines do not plug as frequently as the aqueous lines.
RECOMMENDATION: Put a valve in the interface jet line .5" PSA-330.

HAZOP STUDY IDENTIFIER : TBP Extraction
LINE OR EQUIPMENT DESIGNATION : 106
LINE DESCRIPTION : Raffinate Line from Extraction Column
LINE/EQUIPMENT CONSIDERED : Ves-G-112, VES-G-113, VES-G-157, 3/4"-PSA-324,
2"-PSA-325, .25" 111308, 1" PSA-326, AL-G-550,
1.5" PSA-463, 1" PSA-458, 1" VGA-362, RCV-G-49,
1" PSA-461, RCV-G-36
DRAWING DESIGNATION(S) : 092241 rev 5, 092242 rev 3

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-1-1	Flow-No	DIC-G-111 and associated control failures resulting in high pressure to vessel G-112.	See Item 105-13-1.	

COMMENTS:

ACTION:

AUDIT NOTES: Assumed lineup for this process through G-157 to G-115. Alternate paths could
use G-158 and G-116.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-1-2	Flow-No	Airlift failure G-550.	High Level in G-111 and potential alignment of airlift G-551.	D2

COMMENTS: PL Matrix

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-1-3	Flow-No	RCV-G-36 fails to remain open or plugged.	Operational upset.	C4

COMMENTS: PL Matrix. RCV-G-36 is a Fail close valve

ACTION:

AUDIT NOTES: Could use the level increase in G-115 as an indicator. You will only know
that your flow has stopped. Most likely scenario would be to go to the
alternate airlift. Last thing is to shut down and try to figure it out.

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-1-4	Flow-No	Vent off gas valve RCV-G-49 fails to remain open or valve blockage.	Air from airlift would carry over to vessel G-115.	D3

COMMENTS: PL Matrix

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-2-1	Flow-Low	DIC-G-111 and associated controls drifts high resulting in low flow from G-112.	See Item 105-11-1.	

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-2-2	Flow-Low	Reduced flow from airlift G-550 due to operator error or blockage or low air pressure.	High interface level in G-111 requiring use of second airlift.	D2

COMMENTS: PL Matrix

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-2-3	Flow-Low	Diversion of flow through RCV-G-37 due to valve leakage.	Flow to G-116 (potential transfer out of unsampled materials).	D2

COMMENTS: PL Matrix

ACTION:

AUDIT NOTES: Try to go to the other airlift system which has separate isolation valves. Cannot operate with only one raffinate tank. Temporary uranium control problem unless leakage has started into the tank that is currently being transferred. Valves are opened about 300 times per year. Valve leak through is about 1E-4. Therefore frequency is between .1 and 1 per year. Valve fail to close is about 1E-3.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-2-4	Flow-Low	Valve DCV-PM-G-157-1 fails to remain closed or inadvertently left open.	Potential contamination into the PM area.	D5

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

COMMENTS: Environmental Risk Matrix

ACTION:

AUDIT NOTES: Valve is infrequently used. Contamination into the PM area.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-2-5	Flow-Low	Line or vessel (G-112,G-113, or G-157) leak or rupture.	Release of raffinate into G-Cell.	D2

COMMENTS: Environmental Risk Matrix.

ACTION:

AUDIT NOTES: Raffinate has same corrosion potential as feed solution. There has been

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-3-1	Flow-High	DIC-G-111 and associated control failures low output.	See item 105-12-1.	

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-3-2	Flow-High	Airlift G-550 high output.	Vapor carryover into VOG, potential contamination of VOG.	D2

COMMENTS: PL Matrix. Cannot not easily clean out the contamination

ACTION:

AUDIT NOTES: Normally run the airlift pumps near the high.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-4-1	Flow-Reverse	None identified.		

COMMENTS:

ACTION:

AUDIT NOTES: Filling the raffinate tanks will have flow going toward the waste tanks.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-5-1	Pressure-Low	See item 3-1 above.		

COMMENTS:

ACTION:

AUDIT NOTES:

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-6-1	Pressure-High	See items 1-1 and 1-4 above.		
COMMENTS:		ACTION:		
AUDIT NOTES:				

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-7-1	Temperature-Low	See item 104-7-1.		
COMMENTS:		ACTION:		
AUDIT NOTES:				

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-8-1	Temperature-High	Inadvertent operation of the steam line to the airlift supply.	Potential long term corrosion problem	D4
COMMENTS: PL Matrix		ACTION:		
AUDIT NOTES: Steam condensation in the rotometer is a nuisance rather than a problem.				

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-9-1	Material-Other than	Inadvertent operation of DECON drop.	No significant consequences	
COMMENTS:		ACTION:		
AUDIT NOTES:				

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-10-1	Material-As well as	See items 105-2-1 and 105-12-1.		
COMMENTS: Caused by organic in the raffinate, such as plate blockage.			ACTION:	
AUDIT NOTES:				

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
106-11-1	Material-Part of	None identified.		

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

COMMENTS: ACTION:

AUDIT NOTES:

HAZOP STUDY IDENTIFIER : TBP Extraction
 LINE OR EQUIPMENT DESIGNATION : 107
 LINE DESCRIPTION : Uranium bearing organic line to pulser connection
 for the H-100 column
 LINE/EQUIPMENT CONSIDERED : 2" PSA-312, .75" PSA-312, VES-H-142, H-555,
 .75" PSA-593, .75" PSAR-604, VES-H-132,
 2" PSAR-605, PSA-594, 1" PSA-595
 DRAWING DESIGNATION(S) : 092380 rev 2, 057986 rev 2, 092241 rev 5

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
107-1-1	Flow-No	See item 105-13-2.		

COMMENTS: Air lift G-555 plugs and backs up organic into column
 G-111. Organic can also bypass through the vent off
 gas system to the H-100 column. ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
107-2-1	Flow-Low	Flow diversion caused by plug down stream of airlift H-555.	Loss of extraction efficiency and possibly fouling the evaporator (if aluminum, material can plate out).	B4

COMMENTS: PL Matrix. Potentially carrying chemicals (aqueous)
 which could affect the evaporator. Flow diversion
 causes air flow back through the line to the top of
 H-100 above the interface level. ACTION:

AUDIT NOTES: Solution through VOG at vessel H-142, enters H-100 above interface. Fouling
 of the evaporator is a nuisance to clean up. A bigger problem is carryover
 plus caustic wash from H-100 scrub solution. It is estimated to take
 \$100,000.00, once per fifty years.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
107-2-2	Flow-Low	Pipe leak or rupture or PM sump plugs up.	Potential criticality concern due to leaks into the PM area, and fire potential	A5

COMMENTS: Criticality Matrix, Pl Matrix C-5, Worker/Safety C-5. ACTION:

AUDIT NOTES: Have leak detection, capacitance probe, in the PM area sump to the H-Cell sump.
 You have to have the line leak and the sumps plug.

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

There is no automatic fire suppression system in the PM area, have to use manual suppression.
Not continually under a vacuum from the VOG. Two indications, radiation alarms, CAM-PM-001, and
a level alarm LAH-PM-H-132, 132-1 (H-Cell sump probes).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
107-3-1	Flow-High	High flow through airlift H-555 caused by high air pressure, or operator error.	No significant problems	

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
107-4-1	Flow-Reverse	See Item 2-1 above.		

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
107-5-1	Pressure-Low	See item 105-5-1.		

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
107-6-1	Pressure-High	See item 105-6-1.		

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
107-7-1	Temperature-Low	See item 104-7-1.		

COMMENTS:

ACTION:

AUDIT NOTES:

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
107-8-1	Temperature-High	See item 104-8-1.		
COMMENTS:		ACTION:		
AUDIT NOTES:				

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
107-9-1	Material-Other than	None identified.		
COMMENTS:		ACTION:		
AUDIT NOTES:				

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
107-10-1	Material-As well as	None identified.		
COMMENTS:		ACTION:		
AUDIT NOTES:				

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
107-11-1	Material-Part of	None identified.		
COMMENTS:		ACTION:		
AUDIT NOTES:				

HAZOP STUDY IDENTIFIER : TBP Extraction
 LINE OR EQUIPMENT DESIGNATION : 108
 LINE DESCRIPTION : Inlet and outlet organic piping to VES-H-100 scrub
 and to air pulse system
 LINE/EQUIPMENT CONSIDERED : 4" PSA-313, VES-H-100, 2" PSA-314, .75" PSA-539,
 .5" AA-354, AL-H-550, 1" PSA-540, VES-H-124,
 2" PSA-541, RRA100 (abandoned radiation detector),
 .75" PSA-314, 2" PSA-558, 1" PSA-559,
 .75" PSA-327, VES-H-101, 2" & .75" PSA-328,
 VES-H-102
 DRAWING DESIGNATION(S) : 092380 rev 2, 092381 rev 2

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-1-1	Flow-No	Air pulse Malfunction: valve RCV-PM-225-0 fails closed, RCV-PM-225-1 fails closed, RCV-225-2 fails open, SOV-225-0 and SOV-225-1 fail, or LEH-100 signal failure	Column efficiency problems and possible down stream fouling of the evaporators H-130.	D2

COMMENTS: PL Matrix. You get 1 or 2 valve failures a year out of 4. The sono probe is LEH-100 and the air pulser poppet valves are SOV-225-0 and SOV-225-1. ACTION:

AUDIT NOTES: Loss of efficiency in the column H-100, failure to adequately mix the aqueous and organic in the column, possible carryover of aluminum down stream of the column, fouling of the down stream evaporator (takes on the order of days and should be found before it happens). Indication is a blinking light on the control panel for the pulsers in the operating corridor. The makeup in the PM area, scrub, is aluminum nitrate plus ammonium hydroxide. Aluminum nitrate maintains a high salting strength.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-1-2	Flow-No	H-100 density control system fails causing a high air pressure in the jack leg, I to P converters fail.	Process upset causing possible shutdown, possible evaporator fouling, or if continues you can send uranium to the mixer settlers possible criticality.	A5

COMMENTS: Criticality Matrix. PL Matrix B-4. ACTION:

AUDIT NOTES: No flow of aqueous solution out of the column caused by binding of the column by the jack leg system. This situation would occur very rapidly because of the 3" organic level above the aqueous solution. This results in flow of the aqueous with the organic out of the column causing rapid (order of an hour of this kind of over flow) evaporator fouling. When the density alarm alarms the operator will try to bring the interface down. When you get aluminum in the evaporator the boiling point goes up. Don't think the PPS would respond to this upset. Criticality would most likely be in H-116.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-1-3	Flow-No	RCV-1BS-1 or RCV-1BS-2 fail closed, manual valves fail to remain open, P-PM-206-0 fail or running out of scrub solution.	Efficiency problem.	D3

COMMENTS: PL Matrix. Scrub flow from the PM area. Except for running out of solution it has never happened. ACTION:

AUDIT NOTES: No scrub flow from the PM area. There is a PPS signal DRA-PM-107-0-1,2, or 3 (2 out of 3 logic) for density of the scrub flow. If the PPS detects the wrong density it shuts it off. If there is a PPS trip it is a very big deal. PPS failure is not an immediate process but is on a timer.

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-1-4	Flow-No	Failure of airlift H-550, or line plugging or operator error.	Column high level going VOG draining into the mixer settlers causing a potential criticality problem.	A4

COMMENTS: Criticality matrix. No flow in the organic line.

ACTION:

AUDIT NOTES: No flow in the organic line. There is a high level alarm on the column LAH-H-100. A new airlift H-550 low flow alarm FAL-H-550 will be installed before the next operational campaign. It doesn't say that the airlift is working but that air is getting to it.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-2-1	Flow-Low	Partial column plate blockage due to solid buildup.	Aqueous in the organic line. See 1-2 above. Getting organic into vessel H-165. See also 103-5-1.	A4

COMMENTS: Criticality matrix. PL Matrix A-4.

ACTION:

AUDIT NOTES: Low flow in the column. Less likely to block than the G-111 column. The PL matrix is based on column H-100 replacement. The column costs \$48,000 and estimates of \$3,000,000 to put a new one in.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-2-2	Flow-Low	General leaks and ruptures. Most probable line is the .5" PSA-510 line.	Leak into the service corridor or the H-Cell (worst case).	C3

COMMENTS: Environmental risk matrix. The lines PSA-509/510 is a stagnant line and has been out of service for 20 years and condition of the pipe is questionable.

ACTION: A- Recommendation: Evaluate removal of line .5" PSA-510, PSA-509, and .5" CA-633.

AUDIT NOTES: The final cap on the unused potential diversion line .5" PSA-510 is out in the service corridor. This line is capped and welded. Ancestry is dubious for this line. The sump that is closest to this line has a group 1 instrument to monitor it. This line has the potential to drain half of the column. If the line fails in the cell the waste will go through the recycle jet. Eventual destination of the solution will be L-Cell. If the leak is in the service corridor, it would go to the recycle cell.

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-3-1	Flow-High	High flow of the pulser, RCV-225-1 locks open, high pressure in tank, operator error trying to pulse too fast or RCV-225-2 fail closed.	Carry over into G-108, into the VOG, into the mixer settler tanks and also an evaporator problem.	B3

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

COMMENTS: PL Matrix. There is a high level alarm LAH-H-100. The estimated cost to cleanup is \$100,000.00 using caustic. There is no auto shutdown, the plant relies on the operator's response to alarms. ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-3-2	Flow-High	High aqueous flow through the jack leg caused by loss of air to the jack leg, failure of the density indicating controller.	Build up of uranium concentration in a stagnant layer in the bottom of column H-100 requiring several hours. Potential criticality concern in G-111 and H-100.	A4

COMMENTS: Criticality matrix. PL Matrix D-4. High flow through the aqueous (jack legs). Have many indications, as low density alarm, solvent inventory going down in the H-118 vessel, low pressure indication off of control pot and G-106 feed stop. ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-3-3	Flow-High	High makeup caused by the bypass of the rotometer being left open or the rotometer fails high.	No significant consequences (only run out of scrub solution earlier than usual)	

COMMENTS: High flow in the PM makeup line, low level alarm on the 107 vessel at 22" ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-3-4	Flow-High	High Organic : High air pressure to airlift H-555 or operator error. Bypass around the rotometer, pressure regulator malfunction.	Excess air to the vent off gas system can cause carry over solution into the VOG as a mist	D2

COMMENTS: PL matrix. Regulator malfunction also means that the reducing valve gives higher than expected pressure. ACTION:

AUDIT NOTES: 11/01/91
Changed air lift "H-550" to "H-555" - Typographical error.
--- James L. Jones, Jr.

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-3-5	Flow-High	Inadvertent operation of jet H-501 and opening of RCV-H-4. Dominated by operator action.	Potential criticality in G-108	A5

COMMENTS: Criticality matrix. Slow developing criticality
(>20hr.). Valves have category 1 controls. See also
102-10-3.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-3-6	Flow-High	Inadvertent operation of jet H-502	Not possible due to jet steam line not connected.	

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-4-1	Flow-Reverse	Air pulse line, water air flush line, sono probe line, or capped flush lines leak or rupture.	See item 105-2-3.	D2

COMMENTS: Environmental Matrix.

ACTION:

AUDIT NOTES: 11/05/91 Clearing of Action Items

1. Reevaluate item 105-2-3 frequency. -- Frequency reevaluated on 11/05/91
based on comments from Dennis Henneke. New frequency is "2".

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-5-1	Pressure-Low	None identified.		

COMMENTS: Already considered under low flow.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-6-1	Pressure-High	High pressure in VOG.	See item 105-6-1.	D4

COMMENTS: PL Matrix.

ACTION:

AUDIT NOTES:

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
-----------	----------------------------------	-----------------	----------------------	------------------------

108-7-1	Temperature-Low	See item 105-7-1.		
---------	-----------------	-------------------	--	--

COMMENTS: Usually no problem keeping aqueous above freezing. At this point in the process, we have gotten rid of the raffinates and reduced the corrosion potential.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
-----------	----------------------------------	-----------------	----------------------	------------------------

108-8-1	Temperature-High	None identified.		
---------	------------------	------------------	--	--

COMMENTS:

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
-----------	----------------------------------	-----------------	----------------------	------------------------

108-9-1	Material-Other than	Inadvertent water or caustic addition through DECON drop.	Potential criticality (multiple hour)	A5
---------	---------------------	---	---------------------------------------	----

COMMENTS: Criticality Matrix. When you dilute the scrub solution it turns into a strip solution and stripped uranium goes back into aqueous and back to G-111 then to H-100 again. This event has happened in 1978.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
-----------	----------------------------------	-----------------	----------------------	------------------------

108-10-1	Material-As well as	See item 9-1 above.		
----------	---------------------	---------------------	--	--

COMMENTS: Worst case scenario is dilution of the scrub solution.

ACTION:

AUDIT NOTES:

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
-----------	----------------------------------	-----------------	----------------------	------------------------

108-11-1	Material-Part of	Sending insufficient salt solution from tank PM-107-0 in the PM area.	Same as 9-1 above. Also potential PPS shutdown on density.	A5
----------	------------------	---	--	----

COMMENTS: Criticality matrix. PL matrix C-5. Low density scrub solution is alarmed and would actuate the PPS.

ACTION:

AUDIT NOTES: 10/28/91-
Changed the consequence on the PL matrix from C-3 to C-5 because the low density scrub solution is alarmed and would actuate the PPS. --- James L. Jones, Jr.

Table A-1. Process Segment Line Items from the PIRC Study at ICPP (continued).

LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-12-1	Level-Low	See item 3-2 above.		
COMMENTS:		ACTION:		
AUDIT NOTES:				
=====				
LINE/ITEM	PROCESS PARAMETER/ GUIDE WORD	POSSIBLE CAUSES	POSSIBLE CONSEQUENCE	CONSEQ./ LIKELIHOOD
108-13-1	Level-High	See item 1-4 above.		
COMMENTS: Jack leg fails closed.		ACTION:		
AUDIT NOTES:				

Table A-2. High and medium risk line items and their event sequences.

LINE IDENTIFICATION	RANK	PARAMETER DESIGNATION	SEQUENCE
100-1-3	M	NO FLOW	(OPFAILS-FCSEG100 * 1/yr * OP2FLS-FCSEG100) + ACP-LOSS * OPEROR-EMERGPR
100-1-4	M	NO FLOW	(FP-AF-5957-BK + FP-AF-125957-BK) * FBLK-FULL * FBLK-NOCLEAR
100-7-1	M	LOW TEMPERATURE	(ACP-LOSS + EARTHQUAKE + HIGHWINDS) * (OPEROR-EMERGPR + BDCOMPRESRS-FAIL)
100-9-1	M	MATERIAL OTHER THAN	OPFAILS-FCSEG100 * 1/yr * OP2FLS-FCSEG100
101-5-2	M	LOW PRESSURE	VES-G-105-LKK + VES-G-105-RPP
101-5-2	M	LOW PRESSURE	(VES-G-105-LK + VES-G-105-RP) * RAD-ALRM-SW-FLS
102-1-2	M	NO FLOW	(HSVPOG504-1-FTRO + HSVPOG504-2-FTRO + HSN-327-SIR-PG) * (HSVPOG505-1-FTRO + HSVPOG505-2-FTRO + HSN-328-STR-PG) * (HSVPOG509-1-FTRO + HSVPOG509-2-FTRO + HSN-335-STR-PG) * (HSVPOG512-1-FTRO + HSVPOG512-2-FTRO + HSN-334-STR-PG)
102-3-1	M	HIGH FLOW	(PI-G-504-FAIL + OPEROR-6504 + HSV-PO-6504-2-F0) * NTG504 * (FS-G-105-FAIL + OPEROR-G105)
102-4-2	M	REVERSE FLOW	NTG106 * ((LSH-G-106-FAIL + OPEROR-G106) * (LT-G-106-FAIL + OPEROR-G106) + (DT-G-106-FAIL + OPEROR-G106))
102-5-2	M	LOW PRESSURE	(VES-G-106-LK + VES-G-106-RP) * RAD-ALRM-SW-FLS
102-9-1	M	MATERIAL OTHER THAN	(OPFAILS-FCSEG102 * 1/yr * OP2FLS-FCSEG102)
102-10-3	M	MATERIAL AS WELL AS	((RCV-G-8-FTRC + OPFAILS-RCV68 * 1/yr) * (HSVPOG522-1-FTRC * HSVPOG522-2-FTRC + OPEROR-J522) + (RCV-H-4-FTRC + OPFAILS-RCVH4 * 1/yr) * (HSVPOH501-1-FTRC * HSVPOH501-2-FTRC + OPEROR-J501) + (HSVPOH504-1-FTRC * HSVPOH504-2-FTRC + OPEROR-J504 * 1/yr) * (HSVPOH527-1-FTRC * HSVPOH527-2-FTRC + HSVPOH525-1-FTRC * HSVPOH525-2-FTRC + OPEROR-J525 + OPEROR-J527))
103-1-1	M	NO FLOW	(SOV-PO-633-PPS + HS-G-33-TV + OPEROR-RCV633 * 1/yr + LRCA-G-165-FAILS + RCV-G-33-FTRO) * (SOV-PO-G-15-PPS + HS-G-15-TV + LRCA-G-165-FAILS + OPEROR-RCV615 + RCV-G-15-FTRO) + LOSS-AIR
103-2-1	M	LOW FLOW	(LRCA-G-165-FL + (RCV-G-15-FTRO + LOSS-AIR-RCV615 + SOV-PO-G-15-PPS) * (RCV-G-33-FTRC) * FLIU-PSA549 + (RCV-G-33-FTRO + LOSS-AIR-RCV633 + SOV-PO-G33-PPS) * (RCV-G-15-FTRC) * FLIU-PSA110086) * OP-ACT-LRCAG165
103-2-2	M	LOW FLOW	(FCV-G-1A-ELK + FCV-G-1B-ELK + PSA-549-LK + PSA-549-RP + PSA-110086-LK + PSA-110086-RP + PSA-303-LK + PSA-303-RP + PSA-406-LK + PSA-406-RP)
103-3-1	M	HIGH FLOW	(FCV-G-1A-FTRC * (FSH-G-106-FAILS + OPFAILS-FSHG106) * (LSH-G-165-FAILS + OPFAILS-LSHG165)) * VES-H-116-RESTR

Table A-2. High and medium risk line items and their event sequences (continued).

LINE IDENTIFICATION	RANK	PARAMETER DESIGNATION	SEQUENCE
103-3-2	M	HIGH FLOW	((FCV-G-1B-FTRC * RCV-G-33-FTRC) + (FCV-G-1A-FTRC * RCV-G-15-FTRC)) * (OPERROR-G165 + LRCAH-G-165-FL + FRA-G-106-FL)
104-1-1	M	NO FLOW	(SOVPMG533-1-FTRO + SOVPMG533-2-FTRO + SOVPMG-533-1-PPS + SOVPMG-533-2-PPS) * (FI-G-553-FAILS + OPERROR-FIG553) + (LAVPG553-13FTRO + LAVPG553-18FTRO) + (FCV-G-553-FTRO + OPERROR-FCVG553 * 1/YR + LAVPG553-15FTRO + LAVPG553-14FTRO) * (OPERROR-FIG553 + FI-G-553-FAILS + LAVPMG553-16FTO) + LOSS-AIR + LA-362-PG * FBLK-FULL * FBLK-NUCLEAR
104-1-2	M	NO FLOW	((RCV-G-65-FTRO + FCV-2G-FTRO + FE-G-111-PG + L15VPOG65-1-FTRO + HS-G-65-FTRO + L15VPOG65-2-FTRO + FIC-G-111-FAILS + FY-G-111-1-FAILS + FY-G-111-2-FAILS)) * (RCV-G-66-FTO + FR-G-111-FAILS + OPERROR-FG111 + L15VPOG66-1-FTRO + HS-G-66-FTRO + L15VPOG66-66FTRO) + LOSS-AIR
104-1-3	M	NO FLOW	FE-G-111-PG * ((FTV-G-111-A-FTRC + FTV-G-111-A-LK + OPERROR-FTVA) * (G2-9R-VLV-FTRC + G2-9R-VLV-LK + OPERROR-G29R) + (FTV-G-111-B-FTRC + FTV-G-111-B-LK + OPERROR-FTVB))
104-2-2	M	LOW FLOW	(VES-G-165-RP + VES-G-165-LK + FCV-2G-PK-LK + PSA-600-LK + PSA-454-LK + PSA-591-LK + PSA-525-LK + PSA-592-LK + PSA-600-LK + FCV-2G-PK-RP + PSA-600-RP + PSA-454-RP + PSA-591-RP + PSA-525-RP + PSA-592-RP)
104-2-3	M	LOW FLOW	(VES-G-359-LK + VES-G-359-RP) * RAD-ALRM-SV-FLS
104-3-1	M	HIGH FLOW	(FCV-2G-FO * 1/YR + FIC-G-111-FAILH + RCV-G-66-FTRC) * (LSH-G-111-FAILS + OPERROR-HFG111) + (OPERROR-RCVG66 + OPERROR-FCV2G) * 1/YR
104-7-1	M	LOW TEMPERATURE	(TWVPOG359-11FTRC + TWVPO-6359-11-LK + OPERRORTWG35911 * 1/YR) * (TWVPOG359-13FTRC + TWVPO-6359-13-LK + OPERRORTWG35913)
104-8-1	M	HIGH TEMPERATURE	(OPERROR-G537 * 1/YR + HSVPOG537-1-FTRC * HSVPOG537-2-FTRC)
104-9-1	M	MATERIAL OTHER THAN	(OPFAILS-FCSEG104 * 1/YR * OP2FLS-FCSEG104)
105-1-1	M	NO FLOW	((PA-240-FTR * PA-241-FTR) + (RCV-10-FTRO * RCV-11-FTRO)) * (LSH-H-118-FAILS) * (LT-H-119-1-LAF * LT-H-119-2-LAF * LT-H-119-3-LAF)
105-1-2	M	NO FLOW	(LOSS-AIR + (SC-G-111-FAILS + LA2VPM224-03FTRO + RCVPM-224-0-FTRO + HAVPM-224-0-FTRO + (RCV-PM-224-1-FC + SOV-PM-224-0-FIT + SOV-PM-224-1-FIT + RCV-PM-224-2-FO) * 1/YR) * OPERROR-FG111
105-2-2	M	LOW FLOW	(VES-G-111-LK + VES-G-111-RP)
105-2-3	M	LOW FLOW	(PSA-554-LK + PSA-554-RP + PSA-356-LK + PSA-356-RP + PSA-554-SP-LK + PSA-554-SP-RP + PSA-554-WFL-LK + PSA-554-WFL-RP + PSA-554-CFL-LK + PSA-554-CFL-RP)
105-3-1	M	HIGH FLOW	(SC-G-111-FH + (RCV-PM-224-1-FO + RCV-PM-224-2-FC) * 1/YR + PCVPM-124-0-FTRG * (PIPM-124-0-FAILS + OPERROR-PIPM124) * (PIPM124-02-FAILS + OPERROR-PIPM124)) * OP-ACTION-G111

Table A-2. High and medium risk line items and their event sequences (continued).

LINE IDENTIFICATION	RANK	PARAMETER DESIGNATION	SEQUENCE
105-9-1	M	MATERIAL OTHER THAN	(OPFAILS-FCSEGI05 * 1/yr * OP2FLS-FCSEGI05)
105-11-1	M	MATERIAL PART OF	(OPFAILS-FCSEGI05 * 1/yr * OP2FLS-FCSEGI05)
105-13-2	M	HIGH LEVEL	(LAVPOH555-12FTRO + LAVPOH555-11FTRO + LAVPOH555-9-FTRO + LAVPOH555-7-FTRO + LAVPOH555-8-FTRO + (LAA-228-PG + LAN-363-PG + LAN-240-PG) * FBK-FULL) * (LTH-G-111-FAILS + OPERORR-LG111) * (FAL-H-100-FAILS + OPERORR-FH100) * VES-H-116-RESTR
106-1-2	M	NO FLOW	LOSS-AIR + (PCV-G-550-FTRG + OPERORR-PCV550C * 1/yr + LAVPOG550-17FTRO + LAVPOG550-16FTRO + LAVPOG550-14FTRO + LAV-PO-H1-FTRO + LAV-PO-G1-FTRO + LAV-PO-G4-FTRO) * (FI-G550-FAILS + OPERORR-FIG550) + (LAVPOG550-12FTRO + LAVPOH550-11FTRO) * (LAVPOG550-13FTO + OPERORR-G55013) + (LAN-220-PG + LAN-353-PG + LAN-221-PG + LAA-205-PG) * FBK-FULL * FBK-NOCLEAR
106-1-3	M	NO FLOW	RCV-G-36-FTRO + (PSA-458-PG + PSA-461-PG) * FBK-FULL * FBK-NOCLEAR
106-2-3	M	LOW FLOW	(NTYG115 * RCV-G-37-LK + NTYG116 * RCV-G-35-LK) * OPERORR-6115116
106-2-5	M	LOW FLOW	(VES-G-112-LK + VES-G-112-RP + VES-G-113-LK + VES-G-113-RP + VES-G-157-LK + VES-G-157-RP + PSA-324-LK + PSA-324-RP + PSA-325-LK + PSA-325-RP + PSA-326-LK + PSA-326-RP + PSA-463-LK + PSA-463-RP + PSA-458-LK + PSA-458-RP + PSA-519-LK + PSA-519-RP + PSA-362-LK + PSA-362-RP)
106-3-2	M	HIGH FLOW	PCV-G-550-FTRG * (PI-6-550-FAILS + OPERORR-PIG550)
108-1-1	M	NO FLOW	(LOSS-AIR + (SC-H-100-FAILS + LA2VPM225-02FTRO + RCVPM-225-0-FTRO + HAVPM225-02-FTRO + (RCV-PM-225-1-FC + SOV-PM-225-0-FTT + SOV-PM-225-1-FTT + RCV-PM-225-2-FO) * 1/yr + LEH-100-FAILS + PSA-559-PG * FBK-FULL + FBK-NOCLEAR)) * OPERORR-FLH100
108-1-2	M	NO FLOW	(DIC-H-100-FAILS + DY-H-100-1-FAILS + DY-H-100-2-FAILS) * (DAHL-H-100-FAILS + OPERORR-DAHL100) * VES-H-116-RESTR
108-1-4	M	NO FLOW	((LAA-208-PG + LAVPOH550-19FTRO + (LAVPOH550-16FTRO + LAVPOH550-17FTRO) * (LAVPOH550-18-FTO + OPERORR-H55016) + (PRVPOH550-13FTRG + LAVPOH550-14FTRO + LAVPOH550-12FTRO) * (LAVPOH550-15-FTO + OPERORR-H55015) + LAVPOH550-11FTRO) + LOSS-AIR) * VES-H-116-RESTR
108-2-2	M	LOW FLOW	(PSA-509-LK + PSA-509-RP + PSA-510-LK + PSA-510-RP + PSA-314-LK + PSA-314-RP + PSA-354-LK + PSA-354-RP + PSA-327-LK + PSA-327-RP + PSA-329-LK + PSA-329-RP + PSA-313-LK + PSA-313-RP + VES-H-100-LK + VES-H-100-RP + PSA-559-LK + PSA-559-RP + PSA-354-LK + PSA-354-RP + PSA-539-LK + PSA-539-RP + PSA-540-LK + PSA-540-RP)
108-3-1	M	HIGH FLOW	((RCV-PM-225-1-FO + RCV-PM-225-2-FC + OPERORR-PLSRH1) * 1/yr + SC-H-100-FH + PCVPM-125-0-FTRG * (PTPM-125-0-FAILS + OPERORR-PTPM125) * (PI-H-100-FAILS + OPERORR-PTPM125)) * (LAH-100-FAILS + OPERORR-LAH100))

Table A-2. High and medium risk line items and their event sequences (continued).

LINE IDENTIFICATION	RANK	PARAMETER DESIGNATION	SEQUENCE
108-3-2	H	HIGH FLOW	(DIC-H-100-FH + DY-H-100-2-FAILS + DY-H-100-1-FAILS + LI5VPOH100-1FTRO + LI2VPMH100-1FTRO + LI2VPOH101-2FTRO + LI2VPOH101-1FTRO) * (DAHL-H-100-FAILS + OPERORR-DAHL100) * (PT-H-100-FAILS + OPERORR-PTH100)
108-3-4	M	HIGH FLOW	(PCV-G-550-FTRG + OPERORR-PCVG550 * 1/yr) * (FI-H-555-FAILS + OPERORR-H555) * (PI-G-550-FAILS + OPERORR-H555) + (LAVPOH555-10FTRC + OPERORRLAVH55510 * 1/yr) * (PI-G-550-FAILS + OPERORR-H555)
108-3-5	M	HIGH FLOW	OPCNCTJ501 * 1/yr * (HSVPOH501-2-FTRC + HSV-PO-H501-2-LK) * (HSVPOH501-1-FTRC + HSV-PO-H501-1-LK) * (RCV-H-4-FTRC + RCV-H-4-LK + OPFAILS-RCVH4)
108-4-1	M	REVERSE FLOW	(PSA-558-LK + PSA-558-RP + PSA-559-LK + PSA-559-RP + PSA-579-WFL-LK + PSA-579-WFL-RP + PSA-579-CFL-LK + PSA-579-CFL-RP)
108-9-1	M	MATERIAL OTHER THAN	NTDD-H115-H116 * OP-DCV-PM-H100-1 * OP2DCV-PM-H100-1
102-10-2	H	MATERIAL AS WELL AS	(SC-G-111-FH + (OP-ERROR-G111 + RCV-PM-224-1-FO + RCV-PM-224-2-FC + SOV-PM-224-0-FO) * 1/yr + PCVPM-124-0-FTRH) * (OP-ACTION-G111 + LSH-G-111-FAILS) + (SC-H-100-FH + (OP-ERROR-H100 + RCV-PM-225-1-FO + RCV-PM-225-2-FC + SOV-PM-225-0-FO) * 1/yr + PCVPM-125-0-FTRH) * (OP-ACTION-H100 + LSH-H-100-FAILS) + (SC-H-103-FH + (OP-ERROR-H103 + RCV-PM-226-1-FO + RCV-PM-226-2-FC + SOV-PM-226-0-FO) * 1/yr + PCVPM-126-0-FTRH) * (OP-ACTION-H103 + LSH-H-103-FAILS)
105-2-1	H	LOW-FLOW	(VES-G-111-BLK * OP-FAIL-G111)
105-3-2	H	HIGH-FLOW	((ZIC-PA-240-FH + ZIC-PA-241-FH) * (FIT-119-1-FAILS * FIT-119-2-FAILS * FIT-119-3-FAILS + OPERORR-SC-G111) + (RCV-H-7-FTRC + RCV-H-119-FTRC)) * OPERORR-HF-G111 * VES-H-116-RESTR
105-10-1	H	MATERIAL AS WELL AS	(RCV-H-6-FTRC + OPERORR-H6 + (HSVPOH521-1-FTRC * HSVPOH521-2-FTRC) + (HSVPOH522-1-FTRC * HSVPOH522-2-FTRC) + (TWVPOH301-12FTRC * TWVPOH301-11FTRC * VES-H-301-LK)) * 1/yr * (DT-H-118-FAILS + OPERORR-DTH118)
105-12-1	H	LOW LEVEL	(DIC-G-111-FAILS + DY-G-111-1-FAILS + DY-G-111-2-FAILS) * 1/yr * (DAHL-G-111-FAILS + OPERORR-DAHLG111)

Table A-3. Basic failure event definitions.

Event	Definition
ACP-LOSS -	Loss of power to the process.
BDCOMPRESRS-FAIL -	Blowdown compressors for the lines in line segment 100 fail.
DAHL-G-111-FAILS -	High density alarm DAHL-G-111 fails. The high density alarm is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
DAHL-H-100-FAILS -	High density alarm DAHL-H-100 fails. The high density alarm is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
DIC-G-111-FAILS -	Density indicating controller DIC-G-111 fails. Controller is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
DIC-H-100-FAILS -	Density indicating controller DIC-H-100 fails. Controller is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
DIC-H-100-FH -	Density indicating controller DIC-H-100 controls such that it causes high aqueous flow. Indicator is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
DT-G-106-FAIL -	Density transmitter DT-G-106 fails. This transmitter is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239 Rev 3.
DY-G-111-1-FAILS -	Instrument DY-G-111-1 fails high. Instrument DY-G-111-1 is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
DY-G-111-2-FAILS -	Instrument DY-G-111-2 fails high. Instrument DY-G-111-2 is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
DT-H-118-FAILS -	Density transmitter DT-H-118 fails to indicate density changes. Density transmitter is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
DY-H-100-1-FAILS -	Instrument DY-H-100-1 fails high. Instrument DY-H-100-1 is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
DY-H-100-2-FAILS -	Instrument DY-H-100-2 fails high. Instrument DY-H-100-2 is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
EARTHQUAKE -	Earthquake (external event) causes loss of off site power.
FAL-H-100-FAILS -	Proposed flow high alarm for vessel VES-H-100 fails. Flow alarm probably will be on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 3.
FBLK-FULL -	Blockage is a full blockage. Estimated that .05 of blockages are full blockages.
FBLK-NOCLEAR -	Cannot clear the blockage. Estimated that one out of 50 blockages are unclearable.
FCV-2G-F0 -	Flow control valve FCV-2G fails wide open. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FCV-2G-FTR0 -	Flow control valve for the aqueous stream to G-111 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.

Table A-3. Basic failure event definitions (continued).

Event	Definition
FCV-26-PK-LK -	Flow control valve FCV-26 has a packing or valve body leak. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FCV-26-PK-RP -	Flow control valve FCV-26 has a packing or valve body rupture. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FCV-G-1A-FTRC -	Flow control valve FCV-G-1A from VES-G-106 fails to remain closed. Failure includes air supply and controls. This valve is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
FCV-G-1A-ELK -	Flow control valve FCV-G-1A from VES-G-106 leaks externally. Failure includes air supply and controls. This valve is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
FCV-G-1B-FTRC -	Flow control valve FCV-G-1B from VES-G-106 fails to remain closed. Failure includes air supply and controls. This valve is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
FCV-G-1B-ELK -	Flow control valve FCV-G-1B from VES-G-106 leaks externally. Failure includes air supply and controls. This valve is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
FCV-G-553-FTRC -	Flow control valve FCV-G-553 to air lift AL-G-553 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FE-G-111-PG -	Flow element FE-G-111 plugs. This flow element is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FI-G-553-FAILS -	Flow Indicator FI-G-553 fails to indicate flow. This Indicator is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FI-G550-FAILS -	Flow indicator FI-G550 fails to indicate flow. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FI-H-555-FAILS -	Flow indicator FI-H-555 fails to provide indication. Indicator is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
FIC-G-111-FAILH -	Flow indicating controller fail giving a high flow signal. Flow indicating controller is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FIC-G-111-FAILS -	Flow indicating controller for flow control valve FCV-26 fails. This flow indicating controller is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FIT-119-1-FAILS -	Flow indicating transmitter fails. This transmitter is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
FIT-119-2-FAILS -	Flow indicating transmitter fails. This transmitter is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
FIT-119-3-FAILS -	Flow indicating transmitter fails. This transmitter is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.

Table A-3. Basic failure event definitions (continued).

Event	Definition
FLIU-PSA110086 -	Fraction of the time the flow goes through line PSA-110086. Estimated to be 0.7.
FLIU-PSA549 -	Fraction of the time the flow goes through line PSA-549. Estimated to be 0.3.
FOT-OUT-DOOR -	Fraction of the time that vessel VES-G-105 spills and the contents get out the door of G-Cell into the access corridor. Estimated to be of out of a hundred spills.
FP-AF-125957-BK -	Flow blockage in Line segment 100 line FP-AF-125957. Line is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239 Rev 3.
FP-AF-5957-BK -	Flow blockage in Line segment 100 line FP-AF-5957. Line is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239 Rev 3.
FR-G-111-FAILS -	Flow recorder FR-G-111 fails to provide indication of flow. This flow recorder is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FRA-G-106-FL -	Flow recorder alarm for VES-G-106 fails. This recorder alarm is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
FS-G-105-FAIL -	Flow sensor fails to indicate high flow. Sensor is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239 Rev 3.
FSH-G-106-FAILS -	Flow switch for VES-G-106 fails. This switch is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
FTV-G-111-A-FTRC -	Isolation manual valve closest to flow transmitter FT-G-111 and nearest the top of the page fails to remain closed during an unplugging operation for flow element FE-G-111. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FTV-G-111-A-LK -	Isolation valve closest to flow transmitter FT-G-111 and nearest the top of the page leaks during an unplugging operation for flow element FE-G-111. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FTV-G-111-B-FTRC -	Isolation valve closest to flow transmitter FT-G-111 and below valve FTV-G-111-A fails to remain closed during an unplugging operation for flow element FE-G-111. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FTV-G-111-B-LK -	Isolation valve closest to flow transmitter FT-G-111 and nearest the top of the page leaks during an unplugging operation for flow element FE-G-111. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FY-G-111-1-FP%LS -	Part 1 of the I/P converter FY-G-111-1 to the flow indicating controller FIC-G-111 fails. FY-G-111-1 is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
FY-G-111-2-FAILS -	Part 2 of the I/P converter FY-G-111-2 from the flow indicating controller FIC-G-111 to flow control valve FCV-26 fails. FY-G-111-1 is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
G2-9R-VLV-FTRC -	Isolation valve to flow element FE-G-111 that is in the PM area and closest to penetration G2-9R fails to remain closed during attempt to clear flow blockage in flow element FE-G-111. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.

Table A-3. Basic failure event definitions (continued).

Event	Definition
G2-9R-VLV-LK -	Isolation valve to flow element FE-G-111 that is in the PH area and closest to penetration G2-9R leaks during an attempt to clear flow blockage in flow element FE-G-111. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
HAVPM-224-0-FTRO -	Valve operating air supply valve HAV-PM-224-0 to isolation valve RCV-PM-224-0 fails to remain open. Valve is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
HAVPM225-02-FTRO -	Valve operating air supply valve HAV-PM-225-0-2 to isolation valve RCV-PM-225-0 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
HIGHWINDS -	High winds (external event) cause loss of off site power.
HS-G-15-TV -	Valve HS-G-15 fails by transferring position. This Valve is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
HS-G-33-TV -	Valve HS-G-33 fails by transferring position. This Valve is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
HS-G-65-FTRO -	Valve HS-G-65 which vents air to remote control valve RCV-G-65 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
HS-G-66-FTRO -	Valve HS-G-66 which vents air to remote control valve RCV-G-66 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
HSN-327-STR-PG -	Blockage of strainer in steam line HSN-327. Line is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239
HSN-328-STR-PG -	Blockage of strainer in steam line HSN-328. Line is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239
HSN-334-STR-PG -	Blockage of strainer in steam line HSN-334. Line is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239
HSN-335-STR-PG -	Blockage of strainer in steam line HSN-335. Line is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239
HSVPG504-1-FTRO -	Steam manual valve HSV-P0-G504-1 to steam Jet-G-504 fails to remain open. Valve is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239 Rev 3.
HSV-P0-G504-2-F0 -	Steam manual valve HSV-P0-G504-2 to steam Jet-G-504 fails wide open. Valve is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239
HSVPG504-2-FTRO -	Steam manual valve to HSV-P0-G504-2 steam Jet-G-504 fails to remain open. Valve is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239 Rev 3.
HSVPG505-1-FTRO -	Steam manual valve HSV-P0-G505-1 to steam Jet-G-505 fails to remain open. Valve is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239 Rev 3.

Table A-3. Basic failure event definitions (continued).

Event	Definition
HSVPOG505-2-FTR0 -	Steam manual valve HSV-PO-G505-2 to steam Jet-6-505 fails to remain open. Valve is on drawing CPP-601, 6-CELL, FlowSheet 3 of 8, 092239 Rev 3.
HSVPOG509-1-FTR0 -	Steam manual valve HSV-PO-G509-1 to steam Jet-6-509 fails to remain open. Valve is on drawing CPP-601, 6-CELL, FlowSheet 3 of 8, 092239 Rev 3.
HSVPOG509-2-FTR0 -	Steam manual valve HSV-PO-G509-2 to steam Jet-6-509 fails to remain open. Valve is on drawing CPP-601, 6-CELL, FlowSheet 3 of 8, 092239 Rev 3.
HSVPOG512-1-FTR0 -	Steam manual valve HSV-PO-G512-1 to steam Jet-6-512 fails to remain open. Valve is on drawing CPP-601, 6-CELL, FlowSheet 3 of 8, 092239 Rev 3.
HSVPOG512-2-FTR0 -	Steam manual valve HSV-PO-G512-2 to steam Jet-6-512 fails to remain open. Valve is on drawing CPP-601, 6-CELL, FlowSheet 3 of 8, 092239 Rev 3.
HSVPOG522-1-FTRC -	Steam isolation manual valve HSV-PO-G522-1 to Jet-6-522 fails to remain closed. This valve is on drawing CPP-601, 6-CELL, FlowSheet 5 of 8, 092241 Rev 5.
HSVPOG522-2-FTRC -	Steam isolation manual valve HSV-PO-G522-2 to Jet-6-522 fails to remain closed. This valve is on drawing CPP-601, 6-CELL, FlowSheet 5 of 8, 092241 Rev 5.
HSVPOG537-1-FTRC -	Steam isolation manual valve HSV-PO-G537-1 to Jet-6-537 from VES-G-165 to VES-G-108 fails to remain closed. This valve is on drawing CPP-601, 6-CELL, FlowSheet 5 of 8, 092241 Rev 5.
HSVPOG537-2-FTRC -	Steam isolation manual valve HSV-PO-G537-1 to Jet-6-537 from VES-G-165 to VES-G-108 fails to remain closed. This valve is on drawing CPP-601, 6-CELL, FlowSheet 5 of 8, 092241 Rev 5.
HSVPOH501-1-FTRC -	Steam isolation manual valve HSV-PO-H501-1 to Jet-H-501 fails to remain closed. This valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
HSV-PO-H501-1-LK -	Manual steam valve HSV-PO-H501-1 leaks by. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
HSVPOH501-2-FTRC -	Manual steam isolation valve HSV-PO-H501-2 to JET-H-501 fails to remain closed. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
HSV-PO-H501-2-LK -	Manual steam valve HSV-PO-H501-2 leaks by. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
HSVPOH504-1-FTRC -	Steam isolation manual valve HSV-PO-H504-1 to Jet-H-504 from H-103 to VES-H-115 fails to remain closed. This valve is on drawing CPP-601, H-CELL, FlowSheet 2 of 9, 092381 Rev 2.

Table A-3. Basic failure event definitions (continued).

Event	Definition
HSVPOH504-2-FTRC -	Steam isolation manual valve HSV-PO-H504-2 to Jet-H-504 from H-103 to VES-H-115 fails to remain closed. This valve is on drawing CPP-601, H-CELL, FlowSheet 2 of 9, 092381 Rev 2.
HSVPOH521-1-FTRC -	Steam manual valve HSV-PO-H521-1 to steam Jet-H-521 fails to remain closed. Valve is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
HSVPOH521-2-FTRC -	Steam manual valve HSV-PO-H521-2 to steam Jet-H-521 fails to remain closed. Valve is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
HSVPOH522-1-FTRC -	Steam manual valve HSV-PO-H522-1 to steam Jet-H-522 fails to remain closed. Valve is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
HSVPOH522-2-FTRC -	Steam manual valve HSV-PO-H522-2 to steam Jet-H-522 fails to remain closed. Valve is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
HSVPOH525-1-FTRC -	Steam isolation manual valve HSV-PO-H525-1 to Jet-H-525 from VES-H-115 to VES-G-108 fails to remain closed. This valve is on drawing CPP-601, H-CELL, FlowSheet 3 of 9, 092382 Rev 4.
HSVPOH525-2-FTRC -	Steam isolation manual valve HSV-PO-H525-2 to Jet-H-525 from VES-H-115 to VES-G-108 fails to remain closed. This valve is on drawing CPP-601, H-CELL, FlowSheet 3 of 9, 092382 Rev 4.
HSVPOH527-1-FTRC -	Steam isolation manual valve HSV-PO-H527-1 to Jet-H-527 from VES-H-115 to VES-G-108 fails to remain closed. This valve is on drawing CPP-601, H-CELL, FlowSheet 3 of 9, 092382 Rev 4.
HSVPOH527-2-FTRC -	Steam isolation manual valve HSV-PO-H527-2 to Jet-H-527 from VES-H-115 to VES-G-108 fails to remain closed. This valve is on drawing CPP-601, H-CELL, FlowSheet 3 of 9, 092382 Rev 4.
L15VPO665-1-FTRO -	Isolation valve L15V-PO-665-1 to remote control valve RCV-G-65 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
L15VPO665-2-FTRO -	Isolation valve L15V-PO-665-2 to remote control valve RCV-G-65 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
L15VPO666-1-FTRO -	Isolation valve L15V-PO-666-1 to remote control valve RCV-G-66 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
L15VPO666-66FTRO -	Isolation valve L15V-PO-666-66 to remote control valve RCV-G-66 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LA2VPM224-03FTRO -	Isolation valve LA2V-PM-224-0-3 to air pulser for VES-G-111 fails to remain open. Valve is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.

Table A-3. Basic failure event definitions (continued).

Event	Definition
LA2VPM225-02FTRO -	Isolation valve LA2V-PH-225-0-2 to air pulser for VES-H-100 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAA-205-PG -	Air line LAA-205 plugs. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAA-208-PG -	Air line LAA-208 is plugged. The air line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAA-228-PG -	Line LAA-228 is plugged. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAA-362-PG -	Line LAA-362 to the air lift AL-553 plugs. This line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAN-220-PG -	Air line LAN-220 plugs. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAN-100-FAILS	Alarm LAN-100 to column VES-H-100 fails. The alarm is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAN-221-PG -	Air line LAN-221 plugs. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAN-240-PG -	Line LAN-240 is plugged. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAN-353-PG -	Air line LAN-353 plugs. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAN-363-PG -	Line LAN-363 is plugged. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAVPM6553-16FTO	Flow bypass valve LAV-PH-6553-16 fails to open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAV-P0-61-FTRO -	Plant air line LAN-329 manual isolation valve LAV-P0-61 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAV-P0-64-FTRO -	Plant air line LAN-328 manual isolation valve LAV-P0-64 fails to remain open. Valve is on drawing CPP-601, G-CELL, FlowSheet 7 of 8, 092243 Rev 6.
LAVP06550-12FTRO -	Air isolation manual valve LAV-P0-G550-12 to flow indicator FI-G-550 fails to remain open. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAVP06550-13FTO -	Air manual bypass valve LAV-P0-G550-13 for flow indicator FI-G-550 fails to open. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAVP06550-14FTRO -	Air isolation manual valve LAV-P0-G550-17 to air supply through flow indicator FI-G-550 fails to remain open. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.

Table A-3. Basic failure event definitions (continued).

Event	Definition
LAVP06550-16FTRO -	Air isolation manual valve LAV-P0-G550-16 to air lift AL-G-550 fails to remain open. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAVP06550-17FTRO -	Air isolation check valve LAV-P0-G550-17 to air lift AL-G-550 fails to remain open. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAVP06553-13FTRO -	Air isolation manual valve LAV-P0-G553-13 to air lift AL-G-553 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAVP06553-14FTRO -	Air isolation manual valve LAV-P0-G553-14 to flow control valve FCV-G-553 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAVP06553-15FTRO -	Air isolation manual valve LAV-P0-G553-15 to flow control valve FCV-G-553 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAVP06553-18FTRO -	Air isolation manual valve LAV-P0-G553-18 to air lift AL-G-553 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAV-P0-H1-FTRO -	Plant air line LAM-329 manual isolation valve LAV-P0-H1 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAVP06550-11FTRO -	Air isolation manual valve LAV-P0-G550-11 to flow indicator FI-G-550 fails to remain open. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LAVP0H550-11FTRO -	Air isolation manual valve to air lift AL-H-550 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAVP0H550-12FTRO -	Air isolation manual valve LAV-P0-H550-12 to pressure control valve PRV-P0-H550-13 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAVP0H550-14FTRO -	Air isolation manual valve LAV-P0-H550-14 to pressure control valve PRV-P0-H550-13 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAVP0H550-15-FTO -	Air bypass manual valve to pressure control valve PRV-P0-H550-13 fails to open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAVP0H550-16FTRO -	Air isolation manual valve LAV-P0-H550-16 to flow indicator FI-H-100 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAVP0H550-17FTRO -	Air isolation manual valve LAV-P0-H550-17 to flow indicator FI-H-100 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.

Table A-3. Basic failure event definitions (continued).

Event	Definition
LAVPOH550-18-FTO -	Air bypass manual valve LAV-PO-H550-18 for flow instrument FI-H-550 fails to open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAVPOH550-19FTRO -	Air isolation manual valve to air lift AL-H-550 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAVPOH555-10FTRO -	Manual bypass valve LAV-PO-H555-10 for flow indicator FI-H-555 fails to remain closed.
LAVPOH555-11FTRO -	Air isolation check valve to air lift AL-H-555 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAVPOH555-12FTRO -	Air isolation manual valve to air lift AL-H-555 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAVPOH555-7-FTRO -	Air isolation manual valve to flow indicator FI-H-155 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAVPOH555-8-FTRO -	Air isolation manual valve to flow indicator FI-H-155 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LAVPOH555-9-FTRO -	Air isolation manual valve to air lift AL-H-555 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LEH-100-FAILS -	Sonoprobe detector LEH-100 for air pulser line H-100 inadvertently closes valve RCV-PM-225-0. Detector is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LI2VPMH100-1FTRO -	Manual valve LI2V-PM-H100-1 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LI2VPOH101-1FTRO -	Check valve LI2V-PO-H100-1 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LI2VPOH101-2FTRO -	Manual valve LI2V-PO-H101-2 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LI5VPOH100-1FTRO -	Manual valve LI5V-PO-H100-1 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LOSS-AIR -	Loss of air from the plant air system.
LOSS-AIR-RCVG15 -	Loss of plant air to Valve RCV-G-15.
LOSS-AIR-RCVG33 -	Loss of plant air to Valve RCV-G-33.

Table A-3. Basic failure event definitions (continued).

Event	Definition
LRA-G-165-FAILS -	Level device for vessel VES-G-165 inadvertently closes RCV-G-33/RCV-G-15. This device is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 3.
LRA-G-165-FL -	Level device for vessel VES-G-165 inadvertently controls level low through RCV-G-33/RCV-G-15. This device is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 3.
LRAH-G-165-FL -	High level alarm for VES-G-165 fails. This alarm device is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 3.
LSH-G-106-FAIL -	Level switch for VES-G-106 fails. This switch is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239 Rev 3.
LSH-G-111-FAILS -	Level switch to the high level alarm on G-111 fails high. Level switch is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LSH-G-165-FAILS -	Level switch for VES-G-165 fails. This switch is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
LSH-H-100-FAILS -	Level switch to the high level alarm on H-100 fails high. Level switch is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
LSH-H-103-FAILS -	Level switch to the high level alarm on H-103 fails high. Level switch is on drawing CPP-601, H-CELL, FlowSheet 2 of 9, 092381 Rev 2.
LSH-H-118-FAILS -	Level switch LSH-H-118 fails. Switch is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
LT-G-106A-FAIL -	Level transmitter LT-G-106A fails. This transmitter is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239 Rev 3.
LT-H-119-1-LAF -	Low level alarm on LT-H-119-1 for vessel VES-H-119 fails. Level is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
LT-H-119-2-LAF -	Low level alarm on LT-H-119-2 for vessel VES-H-119 fails. Level is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
LT-H-119-3-LAF -	Low level alarm on LT-H-119-3 for vessel VES-H-119 fails. Level is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
LIH-G-111-FAILS -	Level transmitter LIH-G-111 fails. Transmitter is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
NTDD-H115-H116 -	Number of times per year a decon drop is made into VES-H-115 or VES-H-116.
NTFG106 -	The average number of time per year that a transfer is made to G-106. Estimated at approximately 100.
NTG504 -	Estimated number of actions per year for the operator controlling inlet steam pressure using gauge G-504. Estimated to be 100 times per year.
NTVG115 -	Estimated number of transfers from VES-G-115 per year. Estimated at 150 from the HAZOP.

Table A-3. Basic failure event definitions (continued).

Event	Definition
NTYG116 -	Estimated number of transfers from VES-G-116 per year. Estimated at 150 from the HAZOP.
OP-ACT-LRCAG165 -	Operator fails to respond to low flow through controller LRCA-G-165.
OP-ACTION-G111 -	Operator fails to control the air pulser in its normal range when there is high flow.
OP-ACTION-H100 -	Operator fails to control the air pulser in its normal range when there is high flow.
OP-ACTION-H103 -	Operator fails to control the air pulser in its normal range when there is high flow.
OP-DCV-PM-H100-1 -	Operator inadvertently hook up to VES-H-100 decon line.
OP2DCV-PM-H100-1 -	Second operator fails to notice that the first operator inadvertently hooked up to VES-H-100 decon line.
OP-ERROR-G111 -	Operator controls the air pulser high.
OP-ERROR-H100 -	Operator controls the air pulser high.
OP-ERROR-H103 -	Operator controls the air pulser high.
OP-FAIL-G111 -	The operator fails to notice blockage in vessel 6-111.
OP2FLS-FCSEG100 -	The second operator fails to verify that the decon connection is hooked to the flush connection in the PM area for line segment 100.
OP2FLS-FCSEG102 -	The second operator fails to verify that the decon connection is hooked to the flush connection in the PM area for line segment 102.
OP2FLS-FCSEG104 -	The second operator fails to verify that the decon connection is hooked to the flush connection in the PM area for line segment 104.
OP2FLS-FCSEG105 -	The second operator fails to verify that the decon connection is hooked to the flush connection in the PM area for line segment 105.
OPCNCTJ501 -	Operator inadvertently connects the steam line to JET-H501.
OPERROR-G106 -	Operator fails to notice other indications of high level.
OPERROR-DAHL100 -	Operator fails to notice the change in density of the process streams.
OPERROR-DAHLG111 -	Operator fails to heed the density alarm from 6-111.

Table A-3. Basic failure event definitions (continued).

Event	Definition
OPERROR-DTH118 -	Operator fails to notice the change in density of the process streams from density transmitter DT-H-118.
OPERROR-EMERGPWR -	Operator fails to align emergency power to vital equipment.
OPERROR-FCV26 -	Operator inadvertently opens fully FCV-26.
OPERROR-FCV553 -	Operator accidentally flow control valve closes valve FCV-G-553.
OPERROR-FG111 -	Operator fails notice that flow has stopped through G-111.
OPERROR-FH100 -	Operator fail to notice alarm from FAL-H-100.
OPERROR-FI6550 -	Operator fails to notice the flow.
OPERROR-FI6553 -	Operator fails to notice flow on flow indicator.
OPERROR-FLH100 -	Operator fails to flow stopped through column VES-H-100.
OPERROR-FTVA -	Operator fails to close valve FTV-G-111-A during valve lineup.
OPERROR-FTVB -	Operator fails to close valve FTV-G-111-B during valve lineup.
OPERROR-G105 -	Operator fails to notice high flow in vessel VES-G-105.
OPERROR-G115116 -	Operator fails to notice leakage by valve RCV-G-37 when moving solution into VES-G-115 and leakage by valve RCV-G-35 when moving solution into VES-G-116.
OPERROR-G165 -	Operator fails to notice high level in VES-G-165 and lets the vessel overflow.
OPERROR-G29R -	Operator fails to close valve 62-9R-VLV during valve lineup.
OPERROR-G504 -	Operator opens steam Jet-G-504 control valve HSV-PO-6504-2 too wide.
OPERROR-G537 -	Operator fails to secure the steam jet for JET-G-537.
OPERROR-G55013 -	Operator fails to open bypass valve when needed.
OPERROR-H55015 -	Operator fails to open bypass valve LAV-PO-H550-15 when needed.
OPERROR-H55018 -	Operator fails to open bypass valve LAV-PO-H550-18 when needed.

Table A-3. Basic failure event definitions (continued).

Event	Definition
OPERROR-H555 -	Operator fails to notice that the pressure is high organic flow in H-100. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
OPERROR-H6 -	Operator fails to notice that RCV-H-6 is closed and doesn't jet the water off the bottom of TBP run tank VES-H-118, that the steam jet isolation valves are open or that there is a leak from cooling jacket 301 into the system.
OPERROR-HF-G111 -	Operator fails to control flow back to G-111.
OPERROR-HF-G111 -	Operator inadvertently controls flow high.
OPERROR-J522 -	Operator inadvertently operates JET-G-522.
OPERROR-J501 -	Operator inadvertently operates JET-H-501.
OPERROR-J504 -	Operator inadvertently operates JET-H-504.
OPERROR-J527 -	Operator inadvertently operates JET-H-525.
OPERROR-J525 -	Operator inadvertently operates JET-H-527.
OPERROR-LAH100 -	Operator fails to notice the high level alarm LAH-100.
OPERRORLAVH55510 -	Operator inadvertently opens the bypass valve LAV-P0-H555-10 around flow indicator FI-H-555.
OPERROR-LG111 -	Operator fails to notice high level in G-111.
OPERROR-PCV550C -	Operator inadvertently closes pressure control valve PCV-G-550.
OPERROR-PCVG550 -	Operator inadvertently opens PCV-G-550.
OPERROR-PIG550 -	Operator fails to notice that the pressure is high.
OPERROR-PIPM124 -	Operator fails to notice the high pressure.
OPERROR-PIPM125 -	Operator fails to notice the high pressure from the instrumentation.
OPERROR-PLSRHI -	Operator controls the pulser too high.
OPERROR-PTH100 -	Operator fails to notice the low pressure.
OPERROR-RCVG15 -	Operator accidentally vents RCV-G-15.

Table A-3. Basic failure event definitions (continued).

Event	Definition
OPEROR-RCVG33 -	Operator accidentally vents RCV-G-33.
OPEROR-RCVG66 -	Operator inadvertently opens RCV-G-66.
OPEROR-SC-6111 -	Operator fails to control flow in the normal range.
OPERORTWVG35911 -	Operator inadvertently opens isolation valve TWV-PO-6359-11.
OPERORTWVG35913 -	Operator inadvertently opens isolation valve TWV-PO-6359-13.
OPFAILS-FCSEG100 -	The first operator fails to verify that the decon connection is hooked to the flush connection in the PM area for line segment 100.
OPFAILS-FCSEG102 -	The first operator fails to verify that the decon connection is hooked to the flush connection in the PM area for line segment 102.
OPFAILS-FCSEG104 -	The first operator fails to verify that the decon connection is hooked to the flush connection in the PM area for line segment 104.
OPFAILS-FCSEG105 -	The first operator fails to verify that the decon connection is hooked to the flush connection in the PM area for line segment 105.
OPFAILS-FSHG106 -	Operator fails to notice that the flow is high for VES-G-106.
OPFAILS-LSHG165 -	Operator fails to notice that the flow is high for VES-G-165.
OPFAILS-RCVG8 -	Operator accidentally opens valve RCV-G-8.
OPFAILS-RCVH4 -	Operator accidentally opens valve RCV-H-4.
PA-240-FTR -	Pump PA-240 fails to run. Pump is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
PA-241-FTR -	Pump PA-241 fails to run. Pump is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
PCV-G-550-FTRG -	Pressure control valve PCV-G-550 fails to regulate and pressure goes high. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PCVPM-124-0-FTRG -	Pulsar control valve PCV-PM-124-0 regulates the pressure high. Valve is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.

Table A-3. Basic failure event definitions (continued).

Event	Definition
PCVPM-124-0-FTRH -	The pressure regulator to the air pulser to G-111 fails such that the pressure is unregulated high. Valve is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
PCVPM-125-0-FTRG -	Pressure control regulator valve PCV-PM-125-0 does not regulate and the pressure is high. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PCVPM-125-0-FTRH -	The pressure regulator to the air pulser to H-100 fails such that the pressure is unregulated high. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PCVPM-126-0-FTRH -	The pressure regulator to the air pulser to H-103 fails such that the pressure is unregulated high. Valve is on drawing CPP-601, H-CELL, FlowSheet 2 of 9, 092381 Rev 2.
PI-G-504-FAIL -	Pressure indicator PI-G-504 fails in a mode that indicates low pressure. Indicator is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239
PI-G-550-FAILS -	Pressure indicator PI-G-550 fails to indicate correct pressure. Indicator is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PI-H-100-FAILS -	Pressure indicator PI-H-100 fails to indicate correct pressure. Indicator is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PIPM-124-0-FAILS -	Pressure indicator PI-PM-124-0 fails to indicate the correct pressure. Indicator is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
PIPM124-02-FAILS -	Pressure indicator PI-PM-124-0-2 fails to indicate the correct pressure. Indicator is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
PIPM-125-0-FAILS -	Pressure indicator PI-PM-125-0 fails to indicate pressure. Indicator is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PRVPH550-13FTRG -	Pressure regulating valve PRV-P0-H550-13 to air lift AL-H-550 fails to provide air. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-110086-LK -	Line PSA-110086 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
PSA-110086-RP -	Line PSA-110086 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
PSA-303-LK -	Line PSA-303 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
PSA-303-RP -	Line PSA-303 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.

Table A-3. Basic failure event definitions (continued).

Event	Definition
PSA-313-LK -	Line PSA-313 leaks. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-313-RP -	Line PSA-313 ruptures. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-314-LK -	Line PSA-314 leaks. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-314-RP -	Line PSA-314 ruptures. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-324-LK -	Line PSA-324 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-324-RP -	Line PSA-324 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-325-LK -	Line PSA-325 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-325-RP -	Line PSA-325 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-326-LK -	Line PSA-326 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-326-RP -	Line PSA-326 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-327-LK -	Line PSA-327 leaks. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-327-RP -	Line PSA-327 ruptures. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-329-LK -	Line PSA-329 leaks. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-329-RP -	Line PSA-329 ruptures. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-354-LK -	Line PSA-354 leaks. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-354-RP -	Line PSA-354 ruptures. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-356-LK -	Air pulse line PSA-356 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-356-RP -	Air pulse line PSA-356 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-362-LK -	Line PSA-362 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-362-RP -	Line PSA-362 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-406-LK -	Line PSA-406 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.

Table A-3. Basic failure event definitions (continued).

Event	Definition
PSA-406-RP -	Line PSA-406 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
PSA-454-LK -	Line PSA-454 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-454-RP -	Line PSA-454 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-458-LK -	Line PSA-458 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-458-PG -	Line PSA-458 is plugged. Valve is on drawing CPP-601, G-CELL, FlowSheet 6 of 8, 092242 Rev 3.
PSA-458-RP -	Line PSA-458 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-461-PG -	Line PSA-461 is plugged. Valve is on drawing CPP-601, G-CELL, FlowSheet 6 of 8, 092242 Rev 3.
PSA-463-LK -	Line PSA-463 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-463-RP -	Line PSA-463 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-509-LK -	Line PSA-509 leaks. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-509-RP -	Line PSA-509 ruptures. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-510-LK -	Line PSA-510 leaks. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-510-RP -	Line PSA-510 ruptures. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-519-LK -	Line PSA-519 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-519-RP -	Line PSA-519 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-525-LK -	Line PSA-525 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-525-RP -	Line PSA-525 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-539-LK -	Line PSA-539 leaks. Line is on drawing CPP-601, H-CELL, FlowSheet 2 of 9, 092381 Rev 2.
PSA-539-RP -	Line PSA-539 ruptures. Line is on drawing CPP-601, H-CELL, FlowSheet 2 of 9, 092381 Rev 2.
PSA-540-LK -	Line PSA-540 leaks. Line is on drawing CPP-601, H-CELL, FlowSheet 2 of 9, 092381 Rev 2.
PSA-540-RP -	Line PSA-540 ruptures. Line is on drawing CPP-601, H-CELL, FlowSheet 2 of 9, 092381 Rev 2.

Table A-3. Basic failure event definitions (continued).

Event	Definition
PSA-549-LK -	Line PSA-549 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
PSA-549-RP -	Line PSA-549 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
PSA-554-CFL-LK -	Capped flush lines on PSA-554 leak. Lines are on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
PSA-554-CFL-RP -	Capped flush lines on PSA-554 rupture. Lines are on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
PSA-554-LK -	Air pulse line PSA-554 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
PSA-554-RP -	Air pulse line PSA-554 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
PSA-554-SP-LK -	Sonoprobe line on PSA-554 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
PSA-554-SP-RP -	Sonoprobe line on PSA-554 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
PSA-554-WFL-LK -	Water flush line on PSA-554 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
PSA-554-WFL-RP -	Water flush line on PSA-554 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
PSA-558-LK -	Line PSA-558 leaks. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-558-RP -	Line PSA-558 ruptures. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-559-LK -	Line PSA-559 leaks. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-559-PG -	Line PSA-559 plugs. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-559-RP -	Line PSA-559 ruptures. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-579-CFL-LK -	Capped fill lines on PSA-579 leaks. Lines are on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-579-CFL-RP -	Capped fill lines on PSA-579 ruptures. Lines are on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-579-WFL-LK -	Water fill line on PSA-579 leaks. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-579-WFL-RP -	Water fill line on PSA-579 ruptures. Line is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
PSA-591-LK -	Line PSA-591 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5. Rev 5.
PSA-591-RP -	Line PSA-591 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.

Table A-3. Basic failure event definitions (continued).

Event	Definition
PSA-592-LK -	Line PSA-592 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-592-RP -	Line PSA-592 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-600-LK -	Line PSA-600 leaks. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PSA-600-RP -	Line PSA-600 ruptures. Line is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
PT-H-100-FAILS -	Pressure transmitter PT-H-100 fails to transmit pressure. Transmitter is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
RAD-ALRM-SW-FLS -	Radiation alarm on the service waste system fails.
RCV-10-FTR0 -	Flow control valve for pump PA-240 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
RCV-11-FTR0 -	Flow control valve for pump PA-241 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
RCV-G-15-FTRC -	Flow isolation valve RCV-G-15 in line with FCV-G-1A fails to remain closed. Failure includes air supply and controls. This valve is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
RCV-G-15-FTRC -	Valve RCV-G-15 fails to remain closed. This Valve is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
RCV-G-15-FTR0 -	Valve RCV-G-15 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
RCV-G-33-FTRC -	Flow isolation valve RCV-G-33 in line with FCV-G-1B fails to remain closed. Failure includes air supply and controls. This valve is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
RCV-G-33-FTR0 -	Valve RCV-G-33 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
RCV-G-35-LK -	Remote control isolation valve RCV-G-35 from VES-G-116 when transferring to VES-G-116. Valve is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
RCV-G-36-FTR0 -	Remote control valve RCV-G-36-FTR0 to vessel VES-G-115. Valve is on drawing CPP-601, G-CELL, FlowSheet 6 of 8, 092242 Rev 3.
RCV-G-37-LK -	Remote control isolation valve RCV-G-37 from VES-G-115 when transferring to VES-G-116. Valve is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
RCV-G-65-FTR0 -	Remote control isolation valve to flow control valve FCV-26 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.

Table A-3. Basic failure event definitions (continued).

Event	Definition
RCV-G-66-FIO -	Flow bypass valve for flow control valve FCV-2G fails to open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
RCV-G-66-FTRC -	Remote control valve RCV-G-66 fails to remain closed. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
RCV-G-8-FTRC -	Isolation valve for the return of solution from G-111 to G-106 through Jet-G-522 and vessel VES-G-168 fails to remain closed. This valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
RCV-H-119-FTRC -	Return valve to G-111 fails to remain closed. This valve is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
RCV-H-4-FTRC -	Isolation valve for the return of solution from H-100 to G-106 through Jet-G-522 and vessel VES-G-168 fails to remain closed. This valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
RCV-H-4-LK -	Remote control valve RCV-H-4 leaks by. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
RCV-H-6-FIRO -	Valve to service waste system fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
RCV-H-6-FTRC -	Valve to service waste system fails to remain closed. Valve is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
RCV-H-7-FTRC -	Return valve to G-111 fails to remain closed. This valve is on drawing CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3.
RCVPM-224-0-FTRO -	Remote control valve RCV-PM-224-0 to air pulser for VES-G-111 fails to remain open. Valve is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
RCV-PM-224-1-FC -	Air poppit valve RCV-PM-224-1 for air pulser to G-111 fails closed. Valve is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
RCV-PM-224-1-FO -	Air poppit valve RCV-PM-224-1 for air pulser to G-111 fails open. Valve is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
RCV-PM-224-2-FC -	Air poppit valve RCV-PM-224-2 for air pulser to G-111 fails closed. Valve is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
RCV-PM-224-2-FO -	Air poppit valve RCV-PM-224-2 for air pulser to G-111 fails open. Valve is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
RCVPM-225-0-FTRO -	Remote control valve RCV-PM-225-0 to air pulser for VES-H-100 fails to remain open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
RCV-PM-225-1-FC -	Air poppit valve RCV-PM-225-1 for air pulser to H-100 fails closed. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.

Table A-3. Basic failure event definitions (continued).

Event	Definition
RCV-PM-225-1-F0 -	Air poppit valve RCV-PM-225-1 for air pulser to H-100 fails open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
RCV-PM-225-2-FC -	Air poppit valve RCV-PM-225-2 for air pulser to H-100 fails closed. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
RCV-PM-225-2-F0 -	Air poppit valve RCV-PM-225-2 for air pulser to H-100 fails open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
RCV-PM-226-1-F0 -	One of the two poppit valves for the Air pulser to H-103 fails open. Valve is on drawing CPP-601, H-CELL, FlowSheet 2 of 9, 092381 Rev 2.
RCV-PM-226-2-FC -	One of the two poppit valves for the Air pulser to H-103 fails closed. Valve is on drawing CPP-601, H-CELL, FlowSheet 2 of 9, 092381 Rev 2.
SC-G-111-FAILS -	Air pulse controller to G-111 on Drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3 fails to allow flow.
SC-G-111-FH -	Air pulse controller to G-111 on Drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3 fails high.
SC-H-100-FAILS -	Air pulse controller to H-100 on Drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2 fails, gives no flow.
SC-H-100-FH -	Air pulse controller to H-100 on Drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2 fails high.
SC-H-103-FH -	Air pulse controller to H-103 on Drawing CPP-601, H-CELL, FlowSheet 2 of 9, 092381 Rev 2 fails high.
SOV-PM-224-0-F0 -	Solenoid operated valve that opens air pulser poppit valve RCV-PM-224-1 fails open. Valve is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
SOV-PM-224-0-FTT -	Solenoid control valve SOV-PM-224-0 to air poppit valve RCV-PM-224-1 fails to transfer. Valve is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
SOV-PM-224-1-FTT -	Solenoid control valve SOV-PM-224-1 to air poppit valve RCV-PM-224-2 fails to transfer. Valve is on drawing CPP-601, G-CELL, FlowSheet 8 of 8, 092244 Rev 3.
SOV-PM-225-0-F0 -	Solenoid operated valve that opens air pulser poppit valve RCV-PM-225-1 fails open. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
SOV-PM-225-0-FTT -	Solenoid control valve SOV-PM-225-0 to air poppit valve RCV-PM-225-1 fails to transfer. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.

Table A-3. Basic failure event definitions (continued).

Event	Definition
SOV-PM-225-1-FTT -	Solenoid control valve SOV-PM-225-1 to air poppet valve RCV-PM-225-2 fails to transfer. Valve is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
SOV-PM-226-0-F0 -	Solenoid operated valve that opens air pulser poppet valve RCV-PM-226-1 fails open. Valve is on drawing CPP-601, H-CELL, FlowSheet 2 of 9, 092381 Rev 2.
SOVPMG533-1-FTRO -	Solenoid valve SOV-PM-6-553-1 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
SOVPMG-533-1-PPS -	PPS failure to Solenoid valve SOV-PM-6-553-1 causes the valve to close. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
SOVPMG533-2-FTRO -	Solenoid valve SOV-PM-6-553-2 fails to remain open. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
SOVPMG-533-2-PPS -	PPS failure to Solenoid valve SOV-PM-6-553-2 causes the valve to close. This Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
SOV-PO-G-15-PPS -	Solenoid Valve SOV-PO-G15 vents air off of and closes RCV-G-15 due to a PPS malfunction. This Valve is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
SOV-PO-G-33-PPS -	Solenoid Valve SOV-PO-G33 vents air off of and closes RCV-G-33 due to a PPS malfunction. This Valve is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
TWVPOG359-11FTRC -	Isolation valve TWV-PO-G359-11 for cooling jacket G-359 fails to remain closed. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
TWVPO-G359-11-LK -	Isolation valve TWV-PO-G359-11 for cooling jacket G-359 leaks. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
TWVPOG359-13FTRC -	Isolation valve TWV-PO-G359-13 for cooling jacket G-359 fails to remain closed. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
TWVPO-G359-13-LK -	Isolation valve TWV-PO-G359-13 for cooling jacket G-359 leaks. Valve is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
TWVPOH301-11FTRC -	Isolation manual valve TWV-PO-H301-11 to VES-H-301 fails to remain closed. Density transmitter is on drawing CPP-601, H-CELL, FlowSheet 7 of 9, 092386 Rev 3.
TWVPOH301-12FTRC -	Isolation manual valve TWV-PO-H301-12 to VES-H-301 fails to remain closed. Density transmitter is on drawing CPP-601, H-CELL, FlowSheet 7 of 9, 092386 Rev 3.
VES-G-105-LK -	Vessel VES-G-105 leaks into cooling jacket. VES-G-105 is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239 Rev 3.

Table A-3. Basic failure event definitions (continued).

Event	Definition
VES-G-105-LKK -	Vessel VES-G-105 leaks into G-Cell. VES-G-105 is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239 Rev 3.
VES-G-105-RP -	Vessel VES-G-105 ruptures into cooling jacket. VES-G-105 is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239 Rev 3.
VES-G-105-RPP -	Vessel VES-G-105 ruptures into G-Cell. VES-G-105 is on drawing CPP-601, G-CELL, FlowSheet 3 of 8, 092239 Rev 3.
VES-G-106-LK -	Vessel VES-G-106 leaks. VES-G-106 is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
VES-G-106-RP -	Vessel VES-G-106 ruptures. VES-G-106 is on drawing CPP-601, G-CELL, FlowSheet 4 of 8, 092240 Rev 3.
VES-G-111-BLK -	Vessel G-111 build up and/or blockage on the plates in vessel G-111.
VES-G-111-LK -	Vessel VES-G-111 leaks. Vessel VES-G-111 is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
VES-G-111-RP -	Vessel VES-G-111 ruptures. Vessel VES-G-111 is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
VES-G-112-LK -	Vessel VES-G-112 leaks. Vessel VES-G-112 is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
VES-G-112-RP -	Vessel VES-G-112 ruptures. Vessel VES-G-112 is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
VES-G-113-LK -	Vessel VES-G-113 leaks. Vessel VES-G-113 is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
VES-G-113-RP -	Vessel VES-G-113 ruptures. Vessel VES-G-113 is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
VES-G-157-LK -	Vessel VES-G-157 leaks. Vessel VES-G-157 is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
VES-G-157-RP -	Vessel VES-G-157 ruptures. Vessel VES-G-157 is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
VES-G-165-LK -	Vessel VES-G-165 leaks. Vessel is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
VES-G-165-RP -	Vessel VES-G-165 ruptures. Vessel is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
VES-G-359-LK -	Vessel VES-G-359, cooling and heating jacket, leaks. VES-G-359 is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
VES-G-359-RP -	Vessel VES-G-359, cooling and heating jacket, ruptures. VES-G-359 is on drawing CPP-601, G-CELL, FlowSheet 5 of 8, 092241 Rev 5.
VES-H-100-LK -	Vessel VES-H-100 leaks. Vessel is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.
VES-H-100-RP -	Vessel VES-H-100 ruptures. Vessel is on drawing CPP-601, H-CELL, FlowSheet 1 of 9, 092380 Rev 2.

Table A-3. Basic failure event definitions (continued).

Event	Definition
VES-H-116-RESTR -	Restriction in vessel H-116 causes accumulation of uranium.
VES-H-301-LK -	Leak in cooling jacket H-301 into line PSA-347. Cooling jacket is on drawing CPP-601, H-CELL, FlowSheet 7 of 9, 092386 Rev 3.
ZIC-PA-240-FH -	Stroke controller for the organic solution fails high. This controller is on drawings CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3 and CPP-601, Access Corridor North End, FlowSheet, 057004 Rev 33.
ZIC-PA-241-FH -	Stroke controller for the organic solution fails high. This controller is on drawings CPP-601, H-CELL, FlowSheet 8 of 9, 092387 Rev 3 and CPP-601, Access Corridor North End, FlowSheet, 057004 Rev 33.

Table A-4. ICPP events for quantification.^a

Event Name	Point Estimate	Mission/Operating Time (hr.)	Source
ACP-LOSS	8.500E-001/yr		ATR
BDCOMPRESRS-FAIL	2.500E-003	24	Reactors
DAHL-G-111-FAILS	8.800E-003	8760	Equipment
DAHL-H-100-FAILS	8.800E-003	8760	Equipment
DIC-G-111-FAILS	4.500E-001	8760	Equipment
*DIC-H-100-FAILS	4.500E-001/yr		Equipment
*DIC-H-100-FH	4.500E-001/yr		Equipment
DT-G-106-FAIL	2.600E-004	8760	Reactors
DT-H-118-FAILS	7.200E-005	24	Reactors
DY-G-111-1-FAILS	2.600E-002	8760	Reactors
DY-G-111-2-FAILS	2.600E-002	8760	Reactors
*DY-H-100-1-FAILS	2.600E-002/yr		Reactors
*DY-H-100-2-FAILS	2.600E-002/yr		Reactors
EARTHQUAKE	1.000E-002/yr		ATR
FAL-H-100-FAILS	2.400E-005	24	Reactors
FBLK-FULL	5.000E-002		ICPP
FBLK-NOCLEAR	2.000E-002		ICPP
FCV-2G-FO	1.000E-003/dem		Reactors
*FCV-2G-FTRO	1.000E-003/yr		Equipment
*FCV-2G-PK-LK	8.800E-005/yr		Equipment
			Component
*FCV-2G-PK-RP	3.500E-006/yr		Equipment
*FCV-G-1A-ELK	9.950E-003/yr		ICPP
*FCV-G-1A-FTRC	1.300E-003/yr		Equipment
*FCV-G-1B-ELK	9.950E-003/yr		ICPP
*FCV-G-1B-FTRC	1.300E-003/yr		Equipment

a. Mantissa of point estimate is rounded to the nearest tenth. Failure probabilities come from the following sources: ICPP-ICPP failure data, *Reactor-Generic Component Failure Data Base for Light Water and Liquid Sodium Reactor PRAs*,¹ *Component-Component External Leakage and Rupture Frequency Estimates*,² *Equipment-Guidelines for Process Equipment Reliability Data*,³ *ATR-Advanced Test Reactor Probabilistic Risk Assessment*,⁴ and *Judgement-HAZOP* facilitator. Stars (*) denote initiating events, double stars (**) pipe events that are initiating events, /dem per demand, AP human error action probability, 1C human error 1st check probability, 2C human error 2nd check probability, RP human error reading probability, CCP human error component check probability, and CP human error commission probability.

Mission/operating time given if applicable.

Table A-4. ICPP events for quantification (continued).

Event Name	Point Estimate	Mission/Operating Time (hr.)	Source
*FCV-G-553-FTRO	1.000E-003/yr		Equipment
*FE-G-111-PG	3.600E-002/yr		Reactors
FI-G-553-FAILS	8.700E-003	24	Reactors
FI-G550-FAILS	2.400E-005	24	Reactors
FI-H-555-FAILS	2.400E-005	24	Reactors
*FIC-G-111-FAILH	4.500E-001/yr		Equipment
*FIC-G-111-FAILS	4.500E-001/yr		Equipment
FIT-119-1-FAILS	3.400E-003	24	Equipment
FIT-119-2-FAILS	3.400E-003	24	Equipment
FIT-119-3-FAILS	3.400E-003	24	Equipment
FLIU-PSA110086	7.000E-001		ICPP
FLIU-PSA549	3.000E-001		ICPP
FOT-OUT-DOOR	1.000E-002		ICPP
*FP-AF-125957-BK	2.300E-003/yr		Reactors
*FP-AF-5957-BK	2.300E-003/yr		Reactors
FR-G-111-FAILS	6.000E-004	24	Reactors
FRA-G-106-FL	6.000E-004	24	Reactors
FS-G-105-FAIL	2.400E-005	24	Reactors
FSH-G-106-FAILS	8.000E-003	8760	Reactors
FTV-G-111-A-FTRC	3.600E-006	24	Equipment
FTV-G-111-A-LK	3.600E-006	24	Equipment
FTV-G-111-B-FTRC	3.600E-006	24	Equipment
FTV-G-111-B-LK	3.600E-006	24	Equipment
*FY-G-111-1-FAILS	2.600E-002/yr		Reactors
*FY-G-111-2-FAILS	2.600E-002/yr		Reactors
G2-9R-VLV-FTRC	3.600E-006	24	Equipment
G2-9R-VLV-LK	3.600E-006	24	Equipment
HAVPM-224-0-FTRO	1.100E-003	8760	Equipment
*HAVPM225-02-FTRO	1.100E-003/yr		Equipment
HIGHWINDS	1.000E-006/yr		ATR
HS-G-15-TV	2.900E-006	24	Equipment
*HS-G-33-TV	1.100E-003/yr		Equipment
*HS-G-65-FTRO	1.100E-003/yr		Equipment
HS-G-66-FTRO	2.900E-006	24	Equipment
*HSN-327-STR-PG	3.600E-002/yr		Reactors
HSN-328-STR-PG	3.600E-002	8760	Reactors
HSN-334-STR-PG	3.600E-002	8760	Reactors
HSN-335-STR-PG	3.600E-002	8760	Reactors
HSV-PO-G504-2-FO	2.200E-003/dem		Equipment
HSV-PO-H501-1-LK	3.600E-006	24	Equipment

Table A-4. ICPP events for quantification (continued).

Event Name	Point Estimate	Mission/Operating Time (hr.)	Source
HSV-PO-H501-2-LK	3.600E-006	24	Equipment
*HSVPOG504-1-FTRO	1.100E-003/yr		Equipment
*HSVPOG504-2-FTRO	1.100E-003/yr		Equipment
HSVPOG505-1-FTRO	1.100E-003	8760	Equipment
HSVPOG505-2-FTRO	1.100E-003	8760	Equipment
HSVPOG509-1-FTRO	1.100E-003	8760	Equipment
HSVPOG509-2-FTRO	1.100E-003	8760	Equipment
HSVPOG512-1-FTRO	1.100E-003	8760	Equipment
HSVPOG512-2-FTRO	1.100E-003	8760	Equipment
HSVPOG522-1-FTRC	1.300E-003	8760	Equipment
HSVPOG522-2-FTRC	1.300E-003	8760	Equipment
*HSVPOG537-1-FTRC	1.300E-003/yr		Equipment
HSVPOG537-2-FTRC	1.300E-003	8760	Equipment
HSVPOH501-1-FTRC	1.300E-003	8760	Equipment
HSVPOH501-2-FTRC	1.300E-003	8760	Equipment
*HSVPOH504-1-FTRC	3.600E-006/yr		Equipment
*HSVPOH504-2-FTRC	1.300E-003	8760 hr./yr	Equipment
HSVPOH521-1-FTRC	1.300E-003	8760	Equipment
HSVPOH521-2-FTRC	1.300E-003	8760	Equipment
HSVPOH522-1-FTRC	1.300E-003	8760	Equipment
HSVPOH522-2-FTRC	1.300E-003	8760	Equipment
HSVPOH525-1-FTRC	1.300E-003	8760	Equipment
HSVPOH525-2-FTRC	1.300E-003	8760	Equipment
HSVPOH527-1-FTRC	1.300E-003	8760	Equipment
HSVPOH527-2-FTRC	1.300E-003	8760	Equipment
L15VPOG65-1-FTRO	1.100E-003	8760	Equipment
*L15VPOG65-2-FTRO	1.100E-003/yr		Equipment
L15VPOG66-1-FTRO	1.100E-003	8760	Equipment
L15VPOG66-66FTRO	1.100E-003	8760	Equipment
LA2VPM224-03FTRO	1.100E-003	8760	Equipment
*LA2VPM225-02FTRO	1.100E-003/yr		Equipment
*LAA-205-PG	8.800E-004/yr		Equipment
LAA-208-PG	8.800E-004	8760	Equipment
*LAA-228-PG	8.800E-004/yr		Equipment
*LAA-362-PG	8.800E-004/yr		Equipment

Table A-4. ICPP events for quantification (continued).

Event Name	Point Estimate	Mission/Operating Time (hr.)	Source
LAH-100-FAILS	2.400E-005	24	Reactors
*LAN-220-PG	8.800E-004/yr		Equipment
*LAN-221-PG	8.800E-004/yr		Equipment
*LAN-240-PG	8.800E-004/yr		Equipment
*LAN-353-PG	8.800E-004/yr		Equipment
*LAN-363-PG	8.800E-004/yr		Equipment
LAV-PO-G1-FTRO	1.100E-003	8760	Equipment
LAV-PO-G4-FTRO	1.100E-003	8760	Equipment
LAV-PO-H1-FTRO	1.100E-003	8760	Equipment
LAVPMG553-16FTO	5.000E-004/dem		Reactors
*LAVPOG550-12FTRO	1.100E-003/yr		Equipment
LAVPOG550-13FTO	5.000E-004/dem		Reactors
*LAVPOG550-14FTRO	1.100E-003/yr		Equipment
*LAVPOG550-16FTRO	1.100E-003/yr		Equipment
*LAVPOG550-17FTRO	1.100E-003/yr		Equipment
*LAVPOG553-13FTRO	1.100E-003/yr		Equipment
*LAVPOG553-14FTRO	1.100E-003/yr		Equipment
*LAVPOG553-15FTRO	1.100E-003/yr		Equipment
*LAVPOG553-18FTRO	1.100E-003/yr		Equipment
*LAVPOH550-11FTRO	1.100E-003/yr		Equipment
LAVPOH550-12FTRO	1.100E-003	8760	Equipment
*LAVPOH550-14FTRO	1.100E-003/yr		Equipment
LAVPOH550-15-FTO	5.000E-004/dem		Reactors
*LAVPOH550-16FTRO	1.100E-003/yr		Equipment
*LAVPOH550-17FTRO	1.100E-003/yr		Equipment
LAVPOH550-18-FTO	5.000E-004/dem		Reactors
*LAVPOH550-19FTRO	1.100E-003/yr		Equipment
*LAVPOH555-10FTRC	1.300E-003/yr		Equipment
LAVPOH555-11FTRC	1.300E-003	8760	Equipment
*LAVPOH555-11FTRO	1.100E-003/yr		Equipment
*LAVPOH555-12FTRO	1.100E-003/yr		Equipment
*LAVPOH555-7-FTRO	1.100E-003/yr		Equipment
*LAVPOH555-8-FTRO	1.100E-003/yr		Equipment
*LAVPOH555-9-FTRO	1.100E-003/yr		Equipment
*LEH-100-FAILS	5.500E-001/yr		Equipment
*LI2VPMH100-1FTRO	1.100E-003/yr		Equipment
*LI2VPOH100-1FTRO	1.100E-003/yr		Equipment
*LI2VPOH101-1FTRO	1.100E-003/yr		Equipment
*LI2VPOH101-2FTRO	1.100E-003/yr		Equipment
*LI5VPOH100-1FTRO	1.100E-003/yr		Equipment

Table A-4. ICPP events for quantification (continued).

Event Name	Point Estimate	Mission/Operating Time (hr.)	Source
LOSS-AIR	5.000E-004/yr		ATR
*LOSS-AIR-RCVG15	1.000E-004/yr		ATR
*LOSS-AIR-RCVG33	1.000E-004/yr		ATR
*LRCA-G-165-FAILS	2.000E-001/yr		Reactors
*LRCA-G-165-FL	2.000E-001/yr		Reactors
LRCAH-G-165-FL	6.000E-004/yr	24	Reactors
LSH-G-106-FAIL	2.400E-005	8760	Reactors
LSH-G-111-FAILS	2.400E-005	24	Reactors
LSH-G-165-FAILS	2.400E-005	24	Reactors
LSH-H-100-FAILS	2.400E-005	24	Reactors
LSH-H-103-FAILS	2.400E-005	24	Reactors
LSH-H-118-FAILS	2.400E-005	24	Reactors
LT-G-106A-FAIL	7.200E-005	24	Reactors
LT-H-119-1-LAF	7.200E-005	24	Reactors
LT-H-119-2-LAF	7.200E-005	24	Reactors
LT-H-119-3-LAF	7.200E-005	24	Reactors
LTH-G-111-FAILS	7.200E-005	24	Reactors
NTDD-H115-H116	2.000E+001/yr		ICPP
NTFG106	1.000E+002/yr		ICPP
NTFG115	1.500E+002/yr		ICPP
NTG504	1.000E+002/yr		ICPP
NTYG115	1.000E+001		ICPP
NTYG116	1.000E+001		ICPP
OP-ACT-LRCAG165	1.000E-002		Judgement AP
OP-ACTION-G111	1.000E-002		Judgement AP
OP-ACTION-H100	1.000E-002		Judgement AP
OP-ACTION-H103	1.000E-002		Judgement AP
OP-DCV-PM-H100-1	1.000E-003		Judgement CCP
OP-ERROR-G111	1.000E-001		Judgement RP
OP-ERROR-H100	1.000E-001		Judgement RP
OP-ERROR-H103	1.000E-001		Judgement RP
OP-FAIL-G111	1.000E-001		Judgement RP
OP2DCV-PM-H100-1	1.000E-001		Judgement RP
OP2FLS-FCSEG100	1.000E-001		Judgement 2C
OP2FLS-FCSEG102	1.000E-001		Judgement 2C
OP2FLS-FCSEG104	1.000E-001		Judgement 2C
OP2FLS-FCSEG105	1.000E-001		Judgement 2C
OPCNCTJ501	1.000E-002		Judgement CP
OPERROR-DAHL100	1.000E-002		Judgement AP
OPERROR-DAHLG111	1.000E-002		Judgement AP