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Spent Nuclear Fuel Project Design Basis Capacity Study

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Abstract: A parametric study of the Spent Nuclear Fuel Project system capacity is presented. The study was completed using a commercially available software package to develop a summary level model of the major project systems. A base case, reflecting the Fiscal Year 1998 process configuration, is evaluated. Parametric evaluations are also considered, investigating the impact of higher fuel retrieval system productivity and reduced shift operations at the canister storage building on total project duration.

* - COGEMA Engineering Corp.

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Executive Summary

This study of the design basis capacity of process systems was prepared by Fluor Daniel Northwest for the Spent Nuclear Fuel Project. The evaluation uses a summary level model of major process sub-systems to determine the impact of sub-system interactions on the overall time to complete fuel removal operations. The process system model configuration and time cycle estimates developed in the original version of this report were updated to describe modifications that have evolved in the Fiscal Year 1997-1998 time period. The updated configuration (FY 98 Base Case) continues to indicate that fuel removal activities at the basins will be completed in slightly over 2 years.

The results indicate that, within the modeling accuracy, the current design time cycles, operating efficiency, and operating plans described by the FY 98 Base Case satisfy the original project goal of completing operations in 2 years. The best estimate operating time of 2 years demonstrated in this study is considered to be consistent with recent high confidence operating time period estimates of 33 months. The high confidence operating time schedule adds 2 months to the design basis operating time period for transportation delays that may result from bad weather and 7 months to the operating time period to produce a 90% confidence that fuel removal is completed within the high confidence schedule prediction.

Comparison of model predictions using the FY 96 configuration indicate that the cycle time updates did not significantly alter estimates for completing the overall fuel removal activities. Therefore, parametric studies resulting in operating times that differ from past projections are due to changes in the process system configuration or operating assumptions.

The FY 98 Base Case represents the current MCO sealing strategy, where hot conditioning has been eliminated and the CSB provides stations for welding a cover on MCOs after receipt. The CSB also provides a sampling station that supports monitoring of the first 12 MCOs produced from each basin. As in earlier evaluations, the FY 98 Base Case includes a single fuel retrieval, basket queue, and cask loadout system in each basin. Five cask/transport trailers are assumed available to support fuel movements and the CVD Facility is assumed to contain four vacuum drying stations. Depending on weld station availability, fuel received at the CSB can either be staged in a storage tube, or transferred directly to a weld station for final closure. Two weld stations are available to support final closure operations. The first 12 MCOs from each basin are assumed processed according to a monitoring plan where they are sampled after 1 month, 6 months, and 12 months of storage prior to final closure welding.

Each system is operated on a 7 day/week, 24 hr/day, operating schedule. A single transport team is assumed to be available to support base operations, limiting transfers to a single MCO/cask at one time. A learning curve profile is assumed, allowing a linear ramp of six months to attain full system production capacity from the KW basin. The KE basin startup lags KW basin startup by three months, but is allowed three months to attain full production capacity. Based on these startup scenarios, staffing of a single CVD station during the first three months of

operation will support processing activities. The remaining CVD stations become important to maintain the overall system capacity in months four through six after startup.

The fuel retrieval system limits the FY 98 Base Case rate of fuel removal from the basins. A parametric evaluation was performed to identify the process sub-system that limits the system capacity should the fuel retrieval system exceed design throughput expectations by about 40%. Increasing the number of cask/transport trailers from five to seven allowed the overall system capacity to increase. An increase in the number of cask/transport trailers beyond seven was not effective in improving the overall capacity. However, utilizing a second receiving pit at the CSB, in combination with seven casks, was found to nearly return the fuel retrieval system to the rate limiting process step. These types of changes would be predicted to reduce the time to remove fuel from the basins by four to six months. It is also noted that, increasing the overall system throughput increases the importance of the fourth CVD station as a queue between basin and transport activities.

A final parametric evaluation was completed investigating the impact of operating the FY 98 Base Case configuration with the transport crew limited to a single shift, and CSB operations limited to two shifts, per day 5 days/week. This operating scenario significantly increased the time required to complete fuel removal from the basins.

ENGINEERING REPORT

SPENT NUCLEAR FUEL PROJECT DESIGN BASIS CAPACITY STUDY

Spent Nuclear Fuel Project

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SPENT NUCLEAR FUEL PROJECT DESIGN BASIS CAPACITY STUDY

1.0 INTRODUCTION

The mission of the Spent Nuclear Fuel Project (SNFP) is to repackage the fuel from the 100K Area fuel storage basins and transfer the fuel to a safe, dry storage facility in the 200E Area plateau. The Multi-Canister Overpacks (MCO) are filled with fuel rods retrieved from the 100K East and 100K West wet storage basins, moved into a vacuum drying process line, transported to staging at the Canister Storage Building (CSB), sampled, sealed, and placed into dry storage in the CSB.

A process simulation model that depicts the architecture of the Spent Nuclear Fuel (SNF) process systems was developed. The model is a basic high-level model that includes the fuel retrieval system (FRS), cask loadout station, transportation to the vacuum drying stations, cold vacuum drying (CVD) stations, transportation to the CSB, the MCO handling machine, validation test station, the MCO weld stations, and transportation of the empty cask to the basin. The model can be modified as needed to evaluate a variety of SNF operating scenarios.

2.0 SUMMARY

2.1 Method

Witness -TM (TRADEMARK) is a discrete simulation software used by manufacturing industries to determine equipment capability, capacity, efficiency, and utilization; and to investigate system queues, bottlenecks, and other parameters. Witness models are flexible and allow different scenarios to be developed and tested quickly and efficiently. Witness extends the analytical capability of an industrial engineer, by enabling him to perform repeated random experiments on a system.

Revision zero of this document, released September 10, 1996, details the original thirteen cases that were modeled and evaluated. That revision can be retrieved from archives. Details from four additional cases were transmitted to Westinghouse Hanford Company on September 6, 1996, correspondence number SCS-W-96-1597, and details from another eight cases were transmitted on September 30, 1996, correspondence number SCS-W-96-1672. Case 14 from correspondence number SCS-W-96-1597 was used as a base model for the cases evaluated in this document.

The FY 96 case includes the Hot Conditioning stations. The Hot Conditioning System (HCS) was part of the operating strategy in 1996, but has been removed from the FY 98 case and replaced with the validation and weld stations. The MCO's are periodically sampled at the

validation station; if they pass the validation criteria they are sent to the weld stations for final sealing.

2.2 Assumptions

The following assumptions were made in developing the Witness model.

- Analysis results based on the utilization of the Witness software will not affect health or safety of the personnel engaged with the SNF Project.
- Process cycle times of the model were based upon triangular distributions. These distributions are characterized with a low, high, and mode cycle time for production of an MCO. The low value is the minimum time to process an MCO, the high value is the maximum time to process an MCO, and the mode value is the most likely time required to process an MCO.
- The supply of MCO's will satisfy the processing requirements, either an adequate inventory of MCO's will exist or delivery of the MCO's will be just-in-time to satisfy any rate or production requirement.
- 200 MCO's from each basin will be enough to completely remove all of the spent nuclear fuel.
- All processes are based on working 7 days per week, 18 hours per day except the CVD which operates 7 days per week, 24 hours per day.
- All subsystems except the transportation system are not labor resource limited or restricted. There is an unlimited labor pool available for the required operation and repairs.
- The system runs long enough to achieve a steady-state condition, the probability law governing the behavior of the real system will stabilize.
- Once a loaded MCO is in the system it may not leave the queue.
- Cycle times of the MCO Handling Machine (MHM) and CSB load-in/load-out crane are independent. Interferences between the two were not modeled.

2.3 Results

Results in this report are based on process cycle times determined from input by the sub-project design authorities. The results should not be taken as absolute answers but should be used as guides in decision making. Some key areas examined in this report are: time to empty the basins, time to finish final sealing of the MCO, number of operations of cold vacuum drying, and the number of casks used. The results, and a comparison of the differences between cases,

are listed in Table 2.3. Descriptions of each case, and various operational details are listed in Sections 4.1 to 4.7.

Completion times for the FY 96 case using cycle times that reflect the current operating parameters, and for the FY 98 base case using the new CSB configuration are about the same as Case 14 in correspondence number SCS-W-1597.

Completion times for FRS in Case I and Case II are less than the FY 98 base case but, FRS and CVD develop substantial blockage. Additional impromptu parametric studies were performed to determine what could be done to eliminate the blockage from the FRS. The percentage of blockage continued to decrease by adding additional shipping casks. Adding more than 7 casks did not reduce FRS blockage therefore the optimum number of casks for additional studies was determined to be 7.

Using unlimited labor for the transportation activities, by eliminating the need for a single crew between the different transportation tasks, did not have any effect on FRS blockage.

Using 6 CVD stations cleared the blockage at the FRS but, increased the blockage at CVD. The additional bays created a larger queue at CVD but was not the root of the blockage in the system.

Operating all SNF systems at 100% reduced the blockage at FRS but, considerably increased the blockage at the basin loadin/loadout stations and at the CVD.

Operating the CSB cask loading crane on an 24 hour effective work day did not have any effect on FRS blockage but, slightly reduced the CVD blockage.

Reducing cycle times on the CSB cask loading by 5 hours and reducing cycle times of the MHM by 1 hour did not have any effect on FRS blockage but, slightly reduced the CVD blockage

Operating the CSB crane and the MHM on 24 hour effective work day and reducing the cycle times of the CSB crane by 5 hours and the MHM cycle times by 1 hour did not have any effect on FRS blockage but, slightly reduced the CVD blockage.

Using 100% efficiency on the CSB crane and MHM and reducing the cycle times of the CSB crane by 5 hours and the MHM cycle times by 1 hour did not have any effect on FRS or CVD blockage.

Adding a second CSB crane reduced the blockage of almost all the systems. The FRS West, CVD, and basin cask load-in/load-out blockage was almost completely eliminated. FRS East still had 13% blockage, but Witness gives preference to the first machine in a series so actual FRS blockage would be spread between KE and KW. Detailed results of using a second CSB crane can be found in Section 4.7.

Table 2.3. Results and comparison of studies.

Case	Time to finish (yrs)			CVD Operations				Notes
	KW	KE	Weld	CVD1	CVD2	CVD3	CVD4	
FY 98 base case	2.15	2.26	2.48	139	125	106	30	Completion times for the new configuration are about the same as for the FY 96 base.
Case I	1.73	2.21	2.48	138	127	98	37	KW finished 0.42 years earlier than in FY 98 base case and KE finished about 20 days earlier. Weld stations finished at the same time.
Case II	1.70	2.02	2.44	120	112	91	77	KW finished 0.45 years earlier and KE finished 0.24 years earlier than in FY 98 base case. Weld stations finished 15 days earlier than FY 98 base case.
Case III	2.20	3.72	4.61	159	130	66	45	KW finished 18 days later than in FY 98 base case and KE finished 1.46 years later. Weld stations finished 2.13 years later.
Case IV	1.57	1.90	2.40	121	111	96	72	KW finished 0.58 years earlier and KE finished 0.36 years earlier than the FY 98 base case. Weld stations finished 29 days earlier than FY 98 base case.

The finish times between K West (KW) and K East (KE) basins may be skewed by the Witness solution routine. When both basins experience blockage, Witness gives preferential treatment to KW because it is the first of two machines. The finish times of the two basins would probably be closer to an average of the two, with KW finishing slightly earlier than KE.

3.0 RECOMMENDATIONS

3.1 System Model Refinement

The Witness model uses the FY 98 base configuration and cycle times to evaluate the flow of spent nuclear fuel from retrieval to storage. Comparison cases were performed using different operating configurations or cycle times to determine the effects on throughput and schedule. Additional sensitivity analyses can be run to evaluate the effects of changing other parameters.

There is a need to verify the consistency of data for each element of the model with the responsible design authority, and to review the development of the cycle times to ensure common assumptions and limitations, and definitions of terms.

3.2 Cask Handling and Transportation Crew

Additional studies can be performed to analyze the cask handling and transportation system to determine how many trucks and crews will be required. This can most easily be done by decomposing the main processes into functions performed by the fixed crew and functions performed by the traveling crew, then apportioning the cycle times to these sequences of functions. The process simulation model can be modified to incorporate these changes and further refine the system capacity.

3.3 CSB Operations

There are a number of uncertainties in the process cycle times for the CSB, which could cause distortions in results and conclusions. This is compounded by the fact that there are several pieces of equipment that are single items with no identified work-arounds, and because of schedule conflicts when some of this equipment is competing for common space. Receiving, inspecting, and rework/testing of empty MCO's is not addressed in the model. Schedule interferences between the cask handling function of the overhead crane and the loading/unloading function of material handling machine, working in the same common space, is not currently addressed in the model.

3.4 Labor Resource Allocation

The Witness model assumes that there is an unlimited supply of labor resources available, whenever and wherever needed. This deficiency detracts from the validity of the results, and should be addressed in the model. Accurately allocating labor resources within the model will require the development of process flow charts, precedence network diagrams, time standards and work allowances, and line balancing and manpower models. A process flow chart provides graphic representation of the work performed on a product as it passes through each stage of a process, including quantity, distance moved, type of work done, and equipment used. A precedence network diagram graphically depicts the discrete tasks within each work element, the predecessors, successors, restrictions, and limitations on each task, and logically connects them in parallel or series to show how the work could be structured. Time standards can then be developed for each task by using K Basins studies, industrial engineering handbooks and texts, and Department of Defense work measurements and standards. Work allowances are applied to cover the use of personnel protective equipment, personnel fatigue and mental stress, radiation exposure and environmental conditions, etc. Then the line balancing and manpower modeling optimizes the work process and allocates the labor resources. This information can be incorporated into the Witness model to further improve the accuracy of the simulation and validity of the results.

Figure 4.1.1. Illustration of a One-Line, One Server Queuing system

4.0 DETAILED DISCUSSION

4.1 General Witness Modeling

Witness is a simulation programming language used to build computer models of queuing systems. The SNF project simulation is a closed system with a set amount of serving devices moving through a series of processes. Each of these processes may be seen as a simple queuing model. Each of these simple models consist of a single process containing a piece or group of equipment performing a service on demand. "Customers" come up to this "server" at random times, wait their turn (if necessary) for service, are served on a first-come-first-served basis, then leave. This situation is depicted schematically in Figure 4.1.1 in which the row of circles represents waiting customers, the square represents the server, and the circle within the square represents the customer currently being served.

The line formed by those waiting for service is termed a "queue". The configuration consisting of the server, the customer being served, and those waiting to be served, is termed a "queuing system".

The simple system shown in Figure 4.1.1 is characterized by two independent random variables. The time between consecutive arrivals of customers to the system, often called the "interval time," is a random variable. The time required for the server to perform a service is also a random variable and termed "service time". The distributions followed by these two independent random variables influence system properties and are listed below.

1. Number of customers who arrive for service during a given time span.
2. Number of customers who are able to go immediately into service when they arrive.
3. Average time customers spend in the queue.
4. Average length of the queue.
5. Maximum length of the queue.
6. Server's utilization; that is the fraction of the time that the server spends providing service during a given time span. System properties such as these are of special interest when economic considerations or project milestones are involved.

The SNF Project Witness model is composed of a series of simple models that are integrated into a larger system, adding complexity because of the interaction between each model. Additional constraints are added because of the interaction with the queuing system, consequently increasing its complexity.

Discrete simulation occurs when the dependent system variables change at specific points in simulated time. The time variable may be either continuous or discrete in such a model, depending on whether the discrete changes in the dependent variable can occur at any time or only at specified times.

Running a discrete simulation model on a computer is in essence a complex sampling experiment. Thus, the procedures for designing and analyzing simulation runs are similar to the techniques used in other scientific experiments. The main difference is that the simulation analyst has greater control over the experimental conditions. An appropriate statistical analysis is necessary to (1) use simulation-generated data efficiently in the estimation of system performance measures and (2) reveal the scope and limitations of the conclusions based on the data.

It is necessary to characterize the random variables of a system by particular probability distributions when formulating a simulation model. When selecting an appropriate distribution for an input process, the analyst must understand some of the basic properties of common distributions and the circumstances in which those distributions arise. Initially a uniform distribution was used to examine the system response. This distribution is often used as a first approximation when the real quantity varies between two values but little else is known. Following the initial model development, a triangular distribution was selected because of confidence that a minimum, maximum and a most likely value - (mode) could be established.

The schematic of the SNFP operating system shown in Figure 4.1.2, and process cycle times and efficiencies from Table 4.1.3 were used to develop the FY 96 base model. Startup of KE basin is delayed three months from the startup of KW Basin. The weld stations in the CSB have a nine month delayed start from the start of KW Basin. The CVD has a staged startup procedure where only one process bay is available when the fuel removal process begins and the other three bays come online in one month increments. Table 4.1.3 lists each process involved, a description of what's included in the cycle time, the operating efficiency, the cycle time distribution for each process, and the hours work per week.

All cases have a learning curve factored into the model. The learning curve is 3 months for KE and 6 months for KW. Table 4.1.1 and Table 4.1.2 shows a breakdown of the hours worked per day for each month of the learning curve.

The FY 98 base case and cases I, II and III are modeled using the SNF operations schematic in Figure 4.1.3, the detail schematic of CSB operations shown in Figure 4.1.4, and the process cycle times and efficiencies from Table 4.1.3. The learning curves and sequence of operation startups are the same as the FY 96 base.

Figure 4.1.2. Spent Nuclear Fuel Operations Schematic

Table 4.1.1. Ramp-up cycle for K West basin.

Month	1	2	3	4	5	6	7
Hrs work	2	5	8	11	14	17	18
Hrs Rest	22	19	16	13	10	7	6
Hrs delay	0.00	720	1440	2184	2904	3624	4368

Table 4.1.2. Ramp-up cycle for K East basin.

Month	1	2	3	4	5	6	7
Hrs work	0.00	0.00	0.00	3	9	15	18
Hrs Rest	0.00	0.00	0.00	21	15	9	6
Hrs delay	0.00	NA	NA	2184	2904	3624	4368

Table 4.1.3. Spent Nuclear Fuel Process Cycle times

Process Name	Cycle Time Description	Operating Efficiency	Dist. Type min/mode/max	Work Week
Transport new MCO from CSB to K Basin	Time to transfer new MCO cask from just outside the CSB to just outside the Basin Loadout Area door.	70%	Triangular 0.5 / 1 / 4	7 days/week 3 shifts/day
Fuel Retrieval	Time to produce the equivalent of one MCO of fuel baskets placed in the basin queue.	70%	Triangular 28.88 / 43.32 / 57.76	7 days/week 3 shifts/day
K Basin Cask Loadin/Loadout	Time basin loadout area is occupied by a single MCO/Cask. Includes transport entering basin loadout area door, placing cask in loadout pit, loading baskets in MCO, placing shield plug on MCO, returning MCO to transport, removing transport form loadout area, and preparing to receive next empty cask/MCO at basin.	70%	Triangular 12 / 16.9 / 26	7 days/week 3 shifts/day
Transport MCO from Basin to Cold Vacuum Drying	Time to transfer MCO/Cask from just outside basin door to just outside entry point of a Vacuum Drying station within the 100K Area.	70%	Triangular 0.1 / .25 / .5	7 days/week 3 shifts/day
K Basin Cold Vacuum Drying	Time a single Vacuum Drying station is occupied by a MCO. Includes time to bring MCO/Cask from entry point into station, secure MCO/Cask in station, complete pre-processing attachments, complete the actual drying cycle, test for free water removal, remove the dried MCO/Cask from the station to just outside the drying station entry point, and prepare the drying station to receive another MCO/Cask.	70%	Triangular 64 / 72 / 82	7 days/week 3 shifts/day
Transport MCO from 100K to 200E Area	Time to move the MCO/Cask from just outside a Vacuum Drying station located in the 100K Area to a point just outside the Canister Storage Building entry point located in the 200E Area.	70%	Triangular 0.5 / 1 / 4	7 days/week 3 shifts/day
CSB MCO/Cask Loadin/Loadout	Time the CSB cask loadin/loadout area is occupied by a single cask. Includes transport entering the building with a loaded MCO/Cask from just outside the CSB entry point, off loading the cask to the service pit, removal of MCO from the cask by the MHM, insertion of a new MCO in the cask, returning the cask to the transport, ready the transport for hookup, and any preparations of the CSB loadin/loadout area for receipt of the next cask.	95%	Triangular 17.63 / 19.58 / 22.25	7 days/week 3 shifts/day
MCO/MHM Transfer for Validation Process, from CSB Service Pit to Storage Tube	Time the MHM is occupied with the transfer of a MCO to a storage tube. Includes the MHM transfer of a MCO from the CSB service pit to placement in a storage tube. Does not include waiting period during storage.	90%	Triangular 3.45 / 3.83 / 4.58	7 days/week 3 shifts/day
MCO/MHM Transfer for Validation Process, from Storage Tube to Weld Station	Time the MHM is occupied with the transfer of a MCO to the weld station for validation activities. Includes the MHM retrieval of a MCO from a storage tube and transfer to the weld station.	90%	Triangular 3 / 3.33 / 4.08	7 days/week 3 shifts/day
MCO Validation Process (Only for first 12-24 MCOs)	Time the MCO completes one cycle of the Validation Process. Includes leak checking of the MCO and gas sampling and pressure testing for validation process requirements. Does not include waiting period during storage.	70%	Triangular 7.5 / 10.5 / 15	7 days/week 3 shifts/day
MCO/MHM Transfer from the CSB Service Pit to the Weld Station	Time the MHM is occupied with transfer of a MCO from the CSB service pit to placement in a weld station. Includes moving the MHM to a position over the cask in the service pit for removal of a MCO, removal of the MCO from the cask, moving the MHM/MCO to a weld station, placing the MCO in the station, and any other time the MHM is used to support placing that specific MCO in the station until it is free to move another MCO.	90%	Triangular 3 / 3.33 / 4	7 days/week 3 shifts/day
MCO at the Weld Station in the CSB	Time a single weld station is occupied by a MCO. Includes time to leak test MCO ports, inspect and clean MCO surface in preparation for weld, weld first pass and inspect, weld final passes and inspect, weld cover cap and inspect, repair any weld failure as is found, and finally leak test the weld and remove equipment.	70%	Triangular 24.17 / 31.33 / 35.83	7 days/week 3 shifts/day
MCO/MHM Transfer from Weld Station to Storage	Time the MHM is occupied with transfer of a MCO from a weld station to an interim storage tube. Includes moving the MHM to a weld station, removal of the MCO from the station, moving the MHM/MCO to an interim storage tube, placing the MCO in the tube, and any other time the MHM is used to support placing that specific MCO in interim storage until it is free to move another MCO.	90%	Triangular 3.17 / 3.67 / 4.03	7 days/week 3 shifts/day

Figure 4.1.3. FY 98 Equipment Operating Schematic

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4.2 FY 96 Base

The FY 96 base operates 3 shifts/day, 7 days/week with an effective work day of 18 hours for all processes except the CVD and HCS which operate on an effective work day of 24 hours. Operating efficiencies are 95% for the CSB crane, 90% for the MHM and 70% for all other systems. There are five transportation casks and four CVD stations. Cycle times have been updated to reflect the current operating parameters. The HCS cycle times are the same cycle times used in WHC-SD-SNF-RPT-011, Rev. 0.

The system is limited to a single crew to support transportation activities. The crew operates the KE & KW basin cask loadin/loadout pits, the transportation from the loadin/loadout pits to the cold vacuum drying, the transportation from CVD to the CSB, and the transportation of the cask and empty MCO back to the basins. Only one of the five systems can operate at a time.

The transporters between the basins and the CVD and between the CVD and the CSB are assigned the highest priority and can preempt other operations. The basin loadin/loadout pits have the next highest priority and the transporter between the CSB and the basins has the lowest priority. It is assumed that after an MCO is unloaded at the CSB the cask and empty MCO are stored out of the way until the crew is available to transport them back to the basins.

Figure 4.2.1. is the percentage of time that each machine was busy processing the fuel, blocked and waiting to release a MCO, or broken down and waiting for repairs.

Figure 4.2.1. FY 96 Base Case Machine Usage

Figure 4.2.2 is the frequency of which a specific number of casks is in use. Approximately 85% of the time all 5 casks are in use. Fewer than 5 casks are in use during startup and after KW basin has emptied.

Figure 4.2.2. FY 96 Base Cask Usage

Figure 4.2.3 shows the time to empty each basin and the time to complete hot conditioning.

Figure 4.2.3. FY 96 Base Time to Complete Operations

4.3 FY 98 Base Case

FY 98 base case operates 3 shifts/day, 7 days/week with an effective work day of 18 hours for all processes except the CVD which operates on an effective work day of 24 hours. Operating efficiencies are 95% for the CSB crane, 90% for the MHM and 70% for all other systems. There are five transportation casks and four CVD stations.

The system is limited to a single crew to support transportation activities. The crew operates the KE & KW basin cask loadin/loadout pits, the transportation from the loadin/loadout pits to CVD, the transportation from CVD to the CSB, and the transportation of the cask and empty MCO back to the basins. Only one of the five systems can operate at a time.

The transporters between the basins and the CVD and between the CVD and the CSB are assigned the highest priority and can preempt other operations. The basin loadin/loadout pits have the next highest priority and the transporter between the CSB and the basins has the lowest priority. It is assumed that after an MCO is unloaded at the CSB the cask and empty MCO are stored out of the way until the crew is available to transport them back to the basins.

Table 4.3 is a break down of the number of CVD operations per month for each station. The Witness solution routine gives operating preference to stations in descending order of 1 to 4. If station one is available then the part will be shipped to that station, station four has the lowest priority. The number of operations per station could be more evenly distributed through administrative controls.

Table 4.3. FY 98 base case CVD Operations per Month.

Month	CVD Station 1	CVD Station 2	CVD Station 3	CVD Station 4	Total per Month
1	0	0	0	0	0
2	3	0	0	0	3
3	3	0	0	0	3
4	5	1	0	0	6
5	5	4	2	0	11
6	5	5	4	1	15
7	6	5	5	1	17
8	6	6	6	0	18
9	6	5	5	1	17
10	5	5	5	3	18
11	5	6	4	1	16
12	6	5	5	2	18
13	6	5	4	2	17
14	5	6	5	2	18
15	6	5	6	1	18
16	5	6	6	1	18
17	6	6	5	0	17
18	5	5	5	2	17
19	6	6	4	2	18
20	6	5	5	1	17
21	6	6	6	0	18
22	5	6	5	2	18
23	6	5	4	2	17
24	5	6	5	1	17
25	6	5	4	3	18
26	5	5	5	2	17
27	5	4	1	0	10
28	1	2	0	0	3
Total Operations	139	125	106	30	400

Figure 4.3.1. Is the percentage of time that each machine was busy processing the fuel, blocked and waiting to release a MCO, or broken down and waiting for repairs.

Figure 4.3.1. FY 98 Base Case Machine Usage

Figure 4.3.2 is the frequency of which a specific number of casks is in use. Approximately 87% of the time all 5 casks are in use. Fewer than 5 casks are in use during startup and after KW basin has emptied.

Figure 4.3.2. FY 98 Base Case Cask Usage

Figure 4.3.3 shows the time to empty each basin and the time to complete MCO welding.

Figure 4.3.3. FY 98 Base Case Time to Complete Operations

4.4 Case I Maximum Fuel Retrieval Rate with 5 Casks

Case I has the same operating parameters as the FY 98 base case except the operating efficiency of the fuel retrieval lines in both KE and KW are 100%.

Table 4.4 is a break down of the number of CVD operations per month for each station. The Witness solution routine gives operating preference to stations in descending order of 1 to 4. If station one is available then the part will be shipped to that station, station four has the lowest priority. The number of operations per station could be more evenly distributed through administrative controls.

Table 4.4. Case I CVD Operations per Month

Month	CVD Station 1	CVD Station 2	CVD Station 3	CVD Station 4	Total per month
1	1	0	0	0	1
2	3	0	0	0	3
3	5	1	0	0	6
4	3	4	1	0	8
5	6	5	4	0	15
6	6	6	5	2	19
7	6	5	6	2	19
8	6	5	5	3	19
9	5	6	5	3	19

Month	CVD Station 1	CVD Station 2	CVD Station 3	CVD Station 4	Total per month
10	6	5	5	2	18
11	6	6	4	3	19
12	5	6	6	1	18
13	5	5	4	3	17
14	6	5	5	3	19
15	5	6	5	2	18
16	6	5	4	3	18
17	6	6	4	3	19
18	5	6	5	2	18
19	6	5	5	1	17
20	5	6	6	2	19
21	6	5	5	2	18
22	5	6	5	0	16
23	6	4	3	0	13
24	5	5	2	0	12
25	5	5	2	0	12
26	5	5	1	0	11
27	4	4	1	0	9
Total Operations	138	127	98	37	400

Figure 4.4.1 Is the percentage of time that each machine was busy processing the fuel, blocked and waiting to release a MCO, or broken down and waiting for repairs.

Figure 4.4.1. Case I Machine Usage

Figure 4.4.2 is the frequency of which a specific number of casks is in use. Approximately 78% of the time all 5 casks are in use. Fewer than 5 casks are in use during startup and after KW basin has emptied.

Figure 4.4.2. Case I Cask Usage

Figure 4.4.3 shows the time to empty each basin and the time to complete MCO welding.

Figure 4.4.3. Case I Time to Complete Operations

4.5 Case II Maximum Fuel Retrieval Rate with 6 Casks

Case II has the same operating parameters as the Case I except six transportation casks are used.

Table 4.5 is a break down of the number of CVD operations per month for each station. The Witness solution routine gives operating preference to stations in descending order of 1 to 4. If station one is available then the part will be shipped to that station, station four has the lowest priority. The number of operations per station could be more evenly distributed through administrative controls.

Table 4.5. Case II CVD Operations per Month.

Month	CVD Station 1	CVD Station 2	CVD Station 3	CVD Station 4	Total per month
1	1	0	0	0	1
2	3	0	0	0	3
3	5	1	0	0	6
4	3	4	1	0	8
5	5	5	4	0	14
6	6	6	5	4	21
7	6	5	5	6	22
8	5	6	5	4	20
9	5	5	5	6	21
10	5	5	5	4	19
11	5	5	4	5	19
12	5	5	5	5	20
13	6	5	5	5	21
14	5	6	5	5	21
15	5	5	5	5	20
16	5	5	5	4	19
17	5	5	5	5	20
18	6	5	4	4	19
19	5	5	5	5	20
20	5	6	5	5	21
21	5	5	5	5	20
22	6	5	3	0	14
23	5	5	3	0	13
24	6	5	1	0	12
25	2	3	1	0	6
Total Operations	120	112	91	77	400

Figure 4.5.1 is the percentage of time that each machine was busy processing the fuel, blocked and waiting to release a MCO, or broken down and waiting for repairs.

Figure 4.5.1. Case II Machine Usage

Figure 4.5.2 is the frequency of which a specific number of casks are in use. Approximately 80% of the time all 6 casks are in use. Fewer than 6 casks are in use during startup and after KW basin has emptied.

Figure 4.5.2. Case II Cask Usage

Figure 4.5.3 shows the time to empty each basin and the time to complete MCO welding.

Figure 4.5.3. Case II Time to Complete Operations

4.6 Case III Single Shift Transportation Crew to CSB

Case III has the same operating parameters as the FY 98 base case except the shifts of transportation crew from the CVD to the CSB and the CSB activities. The transportation crew works a single day shift five days a week. The single shift represents a six hour effective work day. CSB operations work two shifts per day, five days per week with an effective work day of 12 hours.

Table 4.6 is a break down of the number of CVD operations per month for each station. The Witness solution routine gives operating preference to stations in descending order of 1 to 4. If station one is available then the part will be shipped to that station, station four has the lowest priority. The number of operations per station could be more evenly distributed through administrative controls.

Table 4.6. Case III CVD Operations per Month

Month	CVD Station 1	CVD Station 2	CVD Station 3	CVD Station 4	Total per Month
1	0	0	0	0	0
2	3	0	0	0	3
3	3	0	0	0	3
4	5	2	0	0	7
5	4	4	2	1	11
6	4	3	2	1	10
7	3	2	3	3	11
8	3	2	2	1	8

9	4	3	2	2	11
10	4	3	3	2	12
11	3	3	1	2	9
12	2	3	3	1	9
13	3	3	2	2	10
14	3	2	2	2	9
15	5	2	2	2	11
16	2	3	3	2	10
17	3	3	1	2	9
18	3	2	3	2	10
19	3	2	2	3	10
20	5	2	2	1	10
21	2	3	3	1	9
22	3	3	1	2	9
23	4	2	2	2	10
24	3	2	3	2	10
25	3	3	2	1	9
26	3	3	3	2	11
27	3	3	2	3	11
28	3	2	3	1	9
29	4	2	2	2	10
30	3	4	2	0	9
31	4	4	0	0	8
32	4	4	1	0	9
33	5	4	0	0	9
34	4	5	0	0	9
35	4	4	1	0	9
36	5	2	2	0	9
37	4	5	0	0	9
38	5	4	0	0	9
39	4	4	0	0	8
40	4	5	0	0	9
41	4	4	0	0	8
42	5	3	1	0	9
43	3	4	2	0	9
44	4	3	1	0	8
45	4	4	0	0	8
Total Operations	159	130	66	45	400

Figure 4.6.1 is the percentage of time that each machine was busy processing the fuel, blocked and waiting to release a MCO, or broken down and waiting for repairs.

Figure 4.6.1. Case III Machine Usage

Figure 4.6.2 is the frequency of which a specific number of casks is in use. Approximately 62% of the time all 5 casks are in use. The number of times 5 casks are in use is less than the previous cases. The transportation crew bottleneck slows the system and reduces the number of times 5 casks are in use.

Figure 4.6.2. Case III Cask Usage

Figure 4.6.3 shows the time to empty each basin and the time to complete MCO welding.

Figure 4.6.3. Case III Time to Complete Operations

4.7 Case IV Maximum Fuel Retrieval Rate with 5 Casks and 2 CSB cranes.

Case IV has the same operating parameters as the FY 98 base case except the operating efficiency of the fuel retrieval lines in both KE and KW are 100%, 7 casks are being used, and the CSB has two loadin/loadout stations.

Table 4.7 is a break down of the number of CVD operations per month for each station. The Witness solution routine gives operating preference to stations in descending order of 1 to 4. If station one is available then the part will be shipped to that station, station four has the lowest priority. The number of operations per station could be more evenly distributed through administrative controls.

Table 4.7. Case IV CVD Operations per Month

Month	CVD Station 1	CVD Station 2	CVD Station 3	CVD Station 4	Total per Month
1	0	0	0	0	0
2	4	0	0	0	4
3	4	1	0	0	5
4	5	3	1	0	9
5	5	6	4	1	16
6	5	5	6	5	21
7	6	6	6	5	23
8	6	6	5	5	22
9	7	5	5	6	23

10	6	6	5	5	22
11	5	6	5	5	21
12	6	6	7	5	24
13	6	6	5	6	23
14	5	6	6	5	22
15	6	5	5	6	22
16	5	6	6	5	22
17	6	6	5	5	22
18	6	6	5	6	23
19	6	5	5	5	21
20	6	5	5	1	17
21	5	5	2	0	12
22	5	5	3	0	13
23	6	6	1	0	13
24	0	0	0	0	0
Total Operations	121	111	92	76	400

Figure 4.7.1 Is the percentage of time that each machine was busy processing the fuel, blocked and waiting to release a MCO, or broken down and waiting for repairs.

Figure 4.7.1. Case IV Machine usage

Figure 4.7.2 is the frequency of which a specific number of casks are in use. Approximately 77% of the time all 7 casks are in use. Fewer than 7 casks are in use during startup and after KW basin has emptied.

Figure 4.7.2. Case IV Cask Usage

Figure 4.7.3 shows the time to empty each basin and the time to complete MCO welding.

Figure 4.7.3. Case IV Time to Complete Operations

4.8 SNF Process Cycle Times

The following discussion describes the basis for cycle time estimates used to model the production of an MCO by each process element. These cycle times represent the peak throughput of each process element, or the actual work time needed to produce an MCO. Potential system down time from equipment failure or operating environment inefficiencies, is included as a separate model input parameter.

Fuel Retrieval

Fuel retrieval cycle time estimates are based on peak capacity testing per the Final Report - SNF Retrieval System Fuel Handling Development Testing (PNNL-11666, 9/97). Capacity estimates for a single fuel retrieval line are estimated at 7-8 canisters/day average and 12 canisters/day peak. Based on fuel retrieval testing times, 94 minutes were required to load one fuel basket and one scrap basket from the process table, with an additional 20 minutes for miscellaneous related activities. With 3.8 canisters per basket and four baskets per MCO (the scrap basket is included in the time estimate), 28.88 hours is required for producing an MCO. With a 1.5 inefficiency factor for a mode time, and twice the load time for a maximum, this results in a triangular distribution with minimum time of 28.88 hours, mode time of 43.32 hours, and maximum time of 57.76 hours.

Cold Vacuum Drying

The cycle time for a cold vacuum drying station is derived from the SNF Project Cold Vacuum Drying Facility Operations Manual (HNF-2356, Rev. A) and yields 64 hours to produce an MCO. The CVD process times start with backing the cask trailer into the process bay, and ends with driving the tractor away from the facility with a dried MCO/Cask. The cycle times are expected to vary based on the condition of the fuel and therefore how much drying is required. The minimum time for drying is 64 hours, assuming the fuel is dried on the first cycle. The mode time estimates that one additional drying cycle is required. The maximum time is estimated as a result of a longer drying period. The two additional cycles of drying, and draining and drying of the cask annulus (stated as a parallel action, conservatively assumed as additional time) is estimated to take up to an additional 18 hours. These estimates result in a triangular cycle time distribution with a minimum time of 64 hours, mode time of 72 hours, and a maximum time of 82 hours.

Canister Storage Building

Time cycle estimates for the cask load-in/load-out and MCO Handling Machine (MHM) transfer activities within the Canister Storage Building were derived from the CSB Operational Sequence Block Flow Diagram (H-2-123400, Rev. D). The sequence is broken down into distinct actions, with a time estimate assigned to each action. The blocks are further assigned to specific movements within the CSB; such as cask load-in/load-out, MHM transfer, MCO welding, process validation, etc.

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Based on the task time estimates, 19.58 hours is required to complete cask loadin/loadout. The tasks are shown on the flow diagram (H-2-123400, Rev. D, Blocks 2-1 to 2-21, 2-28 to 2-40, and 6-1 to 6-7) in sequential order, however some tasks may be completed in parallel with other tasks. Therefore, a minimum time for completing cask load-in/load-out was estimated assuming a 10% reduction in the nominal or mode time due to parallel activities. A maximum time was estimated assuming that additional tasks are required to respond to a detection of pressure in the shipping cask (Blocks 5-1 to 5-1). These additional tasks take 2.67 hours. These assumptions result in a triangular distribution estimate for CSB cask loadin/loadout with a minimum time of 17.63 hours, mode time of 19.58 hours, and maximum time of 22.25 hours.

Based on the task time estimates in the Operating Sequence Flow Diagram, 3.33 hours is estimated to be required to complete activities using the MHM to transfer a MCO from the cask loadin/loadout pit to the welding station (H-2-123400, Rev. D). This includes 115 minutes to transfer the MCO to the MHM in the cask load-in/load-out area (Blocks 2-22 to 2-27), and 85 minutes to position the MCO at the welding station and return the MHM to the staging area (Blocks 3-1 to 3-5). A minimum time for completing the transfer with the MHM was assumed to be 3 hours, based on a 10% reduction due to efficiency in operations. A maximum time for completing the transfer was assumed to be 4 hours, based on assuming the MHM transfer to the weld station would take an additional 15 minutes, and positioning the MCO at the weld station would take an additional 25 minutes. These assumptions result in a triangular distribution estimate for the MHM transfer of a MCO with a minimum time of 3 hours, mode time of 3.33 hours, and maximum time of 4 hours.

MCO Welding

The cycle time for welding, based on the CSB Operational Sequence Block Flow Diagram (H-2-123400, Rev. D, Blocks 3-6 to 3-47), is estimated to be 24.17 hours for an MCO with no weld failure. It is estimated that if minor weld failure repair is required, then an additional 3.58 hours is needed (Blocks 10-1 to 10-6). If major weld failure repair is required, then 4.5 hours is needed (Blocks 11-1 to 11-5). The welding tasks start with removal of the pit cover for access to the MCO at the weld station, and ends with replacing the pit cover at the weld station upon completion of welding. With three welds to inspect for each MCO, the mode time assumes two of the welds will require minor repair. The maximum weld time assumes that two of the welds require minor repair, and the third weld requires major repair. These assumptions result in a triangular distribution estimate for the welding operation of an MCO with a minimum time of 24.17 hours, mode time of 31.33 hours, and maximum time of 35.83 hours.

The CSB Operational Sequence Block Flow Diagram shows that 3.17 hours is required to move the MCO from the weld station to a storage tube for interim storage (H-2-123400, Rev. D, Blocks 3-48 to 3-51 and 4-3 to 4-8). This time includes the MHM removing the welded MCO from the weld station, moving to the interim storage area, removing the tube plug cover, transferring the MCO to the storage tube, and returning the MHM to the staging area. A similar operation occurs when the MHM removes the MCO from the sampling station after process validation activities and returns the MCO to the storage tube. There is a slight difference in time for removal of the MCO from the station. For validation activities, the time required is 105 minutes (Blocks 12-15 to 12-19). The more conservative time for removing the MCO from the

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sampling station will be used for the mode time. Assuming a 10% operating factor on the high end of the transfer time provides a triangular cycle time distribution time of 3.17 hours minimum, 3.67 hours mode time, and 4.03 hours maximum.

Basin Cask Loadin/Loadout and Transportation

A preliminary exposure evaluation of the basin cask load-in/load-out activities was used as a basis for estimating the cycle time for basin cask load-in/load-out activities (Transnuclear, nd). The exposure evaluation estimated a total cycle time of 10.9 hours to prepare the cask for MCO loading (cask load-in), load the MCO, and loadout the cask. Additional conservatism was added to this cycle time estimate by increasing the MCO basket loading from 1 to 4 hours, increasing the MCO shield plug decontamination time from 0.5 to 1.5 hours, and increasing the final cask survey and decontamination time from 0.1 to 2.1 hours. The conservatism increases the load-in/load-out cycle time to 16.9 hours, which was used as the mode time of a triangular distribution for the cask cycle time.

A minimum cycle time was estimated at two shifts of operating time, or 12 hours. A maximum cycle time was estimated by tripling the time required for installing the shield plug and decon/survey activities, resulting in increasing the cask load-in/load-out time to 26 hours. These assumptions result in a triangular distribution estimate for the basin cask load-in/load-out with a minimum time of 12 hours, mode time of 16.9 hours, and maximum time of 26 hours.

Transportation time estimates are based on allocations based on the approximate distance traveled. The transfer from just outside the door at a basin to the cold vacuum drying location is approximately 1,000 feet. Based on discussion with the transportation design authority, a triangular distribution with minimum time of 0.1 hour, mode time of 0.25 hour, and maximum time of 0.5 hour was used to model the transfer from the basin to just outside a cold vacuum drying station.

The transport distance from the Cold Vacuum Drying Facility to the Canister Storage Building is approximately 7 miles. Based on discussion with the transportation design authority, a triangular distribution with minimum time of 0.5 hour, mode time of 1 hour, and maximum time of 4 hours was used to model the transportation time required to move an MCO from just outside the cold vacuum drying station to just outside the Canister Storage Building. This triangular time distribution was also used to model the time required to return a cask loaded with an empty MCO back to the basin.

Process Validation

Process Validation is intended to confirm nominal process operations consistent with analytical predictions (models, testing, sampling). The first 12 to 24 MCOs will undergo process validation, which means that, upon entry in the CSB, the MCOs will be immediately staged in a storage tube rather than proceeding directly to the weld station. After one month and then every 6 months, the MCOs will then be removed from the storage tube and moved to the weld station for gas sampling and monitoring. This will happen approximately three times over the course of one year for each validation MCO (1st month, 6th month, 12th month). Upon completion of the

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monitoring period and favorable results, the MCO will then be moved to the weld station for welded closure and back to the storage tube for final interim storage.

The MHM transfer of the MCO for validation process activities are divided into two blocks of time: one block for transfer to the weld station, and one block for return to the storage tube. Waiting time during storage is not addressed in either block.

Based on the task time estimates in the Operating Sequence Flow Diagram (H-2-123400, Rev. D), 3.83 hours is required to transfer the MCO from the cask loadin/loadout pit to a storage tube awaiting validation activities. This includes 115 minutes to transfer the MCO to the MHM in the cask loadin/loadout area (Blocks 2-22 to 2-27) and 115 minutes to place the MCO in the storage tube and return the MHM to the staging area (Blocks 4-3 to 4-8). A minimum time to complete this MHM transfer process was assumed to be 3.45 hours, due to a 10% reduction in time for operating efficiency. The maximum time assumes an additional 15 minutes is required for the transfer itself, and an additional 30 minutes is required to position the MCO in the storage tube. This results in a triangular distribution of 3.45 hours minimum, 3.83 hours mode time, and 4.58 hours maximum.

Based on the task time estimates in the Operating Sequence Flow Diagram (H-2-123400, Rev. D), 3.33 hours is required to transfer the MCO from a storage tube to the weld station for validation activities. This includes 115 minutes to retrieve the MCO from the storage tube with the MHM and transfer it to the weld station (Blocks 14-3 to 14-8) and 85 minutes to position the MCO at the weld station and return the MHM to the staging area (Blocks 3-1 to 3-5). A minimum time to complete this MHM transfer process was assumed to be 3 hours, due to a 10% reduction in time for operating efficiency. The maximum time assumes an additional 30 minutes is required to remove the MCO from the storage tube, and an additional 15 minutes is required for the transfer itself. This results in a triangular distribution of 3 hours minimum, 3.33 hours mode time, and 4.08 hours maximum.

Based on the task time estimates in the Operating Sequence Flow Diagram (H-2-123400, Rev. D), 7 hours is estimated to complete gas sampling and monitoring requirements of each validation MCO at the Weld Station. This includes 195 minutes to leak test the MCO after placement in the weld station (Blocks 3-6 to 3-11), and 255 minutes to complete gas sampling and monitoring (Blocks 12-1 to 12-14). This was assumed to be the minimum time to complete the monitoring activities. The mode time was estimated assuming that the leak checking takes an additional 150 minutes, and gas sampling takes an additional 30 minutes. The maximum time is estimated to be twice the minimum time. These assumptions result in a triangular distribution estimate for the validation monitoring process of an MCO with a minimum time of 7.5 hours, mode time of 10.5 hours, and maximum time of 15 hours.

5.0 REFERENCES

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APPENDIX A

VALIDATION REQUIREMENTS

Witness is a commercially available off-the-shelf software for which validation requirements are covered under WHC-CM-4-2 *Quality Assurance Manual* and WHC-CM-3-10 *Software Practices*. The software is not modified and will not be incorporated into the development of other software. The use of this software does not invoke or address any health or safety issues.

Validation of this software addresses only the SNF process model and is not intended as overall software validation. Other groups using this software will need to validate their particular applications.

Software requirements

This software is intended to be used as a simulation program to model the SNF project and subprojects. The simulation program must be capable of performing "what if" scenarios when analyzing method or process alternatives, performing time and motion studies, determining queuing sizes and frequencies, determining problem elimination or learning curves, evaluating flow restrictions and plant and work station layout, incorporating machine breakdown cycles and repair times, and including workstation staffing.

User documentation

Modeling for this application was based on the flow diagram shown in figures 4.1.3 and 4.1.4 and the operating efficiencies and cycle times listed in table 4.1.3. Each machine or queue was input into the model along with the proper logic ties to create a representation of the SNF project.

Appendix B in revision 0 is the input file for the FY 96 base used in this study.

Test case specification

There was no formal test case specification prepared for this study. In various meetings with the software administrator, design authorities and responsible engineers it was decided that the design authority and responsible engineers would review input to the model and determine if the desired results were obtained.

Test procedure specification

As new items or features were added to the base model the output was checked to see if the expected results were obtained. Both the responsible engineer and the design authority checked the output against the SNF operating baseline. If the output didn't represent the proposed SNF

processes, the logic was examined and revised to achieve expected system operations. A couple of examples follow of how modeling didn't represent the base system and how it was changed.

In one example, the cold vacuum drying stations released an MCO to the transporter to the CSB. The transporter would take the MCO to the CSB and unload it. In looking at the output, it was found that if the CSB load-in/load-out pit was busy or blocked the truck would wait until it was open then release the MCO, in effect making the truck into a queue. In the proposed system the cold vacuum drying is the queue and will not release an MCO if the CSB is blocked or busy so the logic was modified to reflect actual system operations.

A second example is the learning curve ramp-up cycle. The ramp-up cycle was created by defining sub-shifts with the hours worked per day for each month during the ramp-up and hours worked per day for steady state operations. Each month was a combination of sub-shifts with the steady state condition for the final month. Instead of repeating the steady state month after the ramp-up was complete, the completed ramp-up cycle was repeated for the duration of the project. New logic had to be written giving the shifts a variable name and changing that name after steady state was achieved to simulate the proper shift schedules.

Test results

Test results were not documented. The final version of the FY 98 base model was reviewed by the design authority and the responsible engineer and was found to accurately represent the overall SNF project.

Software configuration control plan

The computer program is controlled in accordance with WHC-CM-3-10 Software Practices. The electronic data files are retained by Maple Lee, the computer programmer, who keeps a separate data file of the input and the output for each case.

DISTRIBUTION SHEET

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