PNL-6004
UC-85

PNL--6004

DE87 011106

FACSIM/MRS-1: CASK RECEIVING AND CONSOLIDATION MODEL DOCUMENTATION AND USER'S GUIDE

T. L. Lotz
M. R. Shay

June 1987

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

DISCLAIMER

EXECUTIVE SUMMARY

The Pacific Northwest Laboratory (PNL) has developed a stochastic computer model, FACSIM/MRS, to assist in assessing the operational performance of the Monitored Retrievable Storage (MRS) waste-handling facility. This report provides the documentation and user's guide for the component FACSIM/MRS-1, which is also referred to as the front-end model. The FACSIM/MRS-1 model simulates the MRS cask-receiving and spent-fuel consolidation activities. The results of the assessment of the operational performance of these activities are contained in a second report, FACSIM/MRS-1: Cask Receiving and Consolidation Performance Assessment (Lotz and Shay 1987). The model of MRS canister storage and shipping operations is presented in FACSIM/MRS-2: Storage and Shipping Model Documentation and User's Guide (Huber et al. 1987).

The FACSIM/MRS model uses the commercially available FORTRAN-based SIMAN (SIMulation ANalysis language) simulation package (Pegden 1982). SIMAN provides a set of FORTRAN-coded commands, called block operations, which are used to build detailed models of continuous or discrete events that make up the operations of any process, such as the operation of an MRS facility. The FACSIM models were designed to run on either an IBM-PC or a VAX minicomputer.

The FACSIM/MRS-1 model is flexible enough to collect statistics concerning almost any aspect of the cask receiving and consolidation operations of an MRS facility. The MRS model presently collects statistics on 51 quantities of interest during the simulation. SIMAN reports the statistics with two forms of output: a SIMAN simulation summary and an optional set of SIMAN output files containing data for use by more detailed post processors and report generators.

CONTENTS

EXECUTIVE SUMMARY v

1.0 INTRODUCTION 1.1

2.0 MRS FACILITY DESCRIPTION 2.1

3.0 FRONT-END MRS MODEL AND ASSUMPTIONS 3.1

3.1 MRS MODEL DESCRIPTION 3.1

3.2 ASSUMPTIONS 3.3

4.0 INPUT DATA TO THE FRONT-END MODEL 4.1

5.0 COMPILING, LINKING, AND EXECUTING THE FRONT-END MODEL 5.1

6.0 SIMULATION OUTPUT FROM THE FRONT-END MRS MODEL 6.1

REFERENCES R.1

APPENDIX A - INPUT DATA, CODE LISTING, AND EXAMPLE OUTPUT A.1

APPENDIX B - QUEUES, STATIONS, AND VARIABLES IDENTIFICATION B.1

FIGURES

2.1 Integral MRS Facility 2.2

2.2 MRS Receiving and Handling Building 2.3

2.3 MRS Processing Cell Cask-Handling Area 2.4

2.4 MRS Processing Cell Disassembly and Consolidation Area 2.6

3.1 MRS Model 3.2

TABLES

3.1 MRS Model Process Station Parameters 3.4

1.0 INTRODUCTION

This report provides the documentation and user's guide for the model of MRS cask receiving and spent-fuel consolidation. This effort was undertaken as part of the U.S. Department of Energy (DOE) sponsored program at PNL.[a]

The FACSIM/MRS model consists of two modeling components. FACSIM/MRS-1 simulates the MRS cask-receiving and spent-fuel consolidation activities, whereas FACSIM/MRS-2 simulates the MRS storage and shipping operations. FACSIM/MRS-1 is also referred to as the front-end model, and the FACSIM/MRS-2 is also referred to as the back-end model. The model of storage and shipping operations is presented in FACSIM/MRS-2: Storage and Shipping Model Documentation and User's Guide (Huber et al. 1987).

FACSIM/MRS-1 provides the user with information about in-process lag-storage requirements, machine use, cask queues, welder queues, cask processing and cask turnaround times. The model can help determine the effect that the following activities have on operating efficiency: 1) receiving multiple cask shipments, when rail-cask or truck-cask shipments arrive at the facility in groups of two or more, and 2) operating the facility five days/week, three shifts/day or seven days/week, three shifts/day for any conditions. In addition, sensitivity to equipment failure frequency and the time needed for equipment repair can be studied. Information on the above operating characteristics may be obtained for any spent-fuel receipt rate, any split of shipments between truck and rail casks, or any fraction of the fuel receipts from a boiling water reactor (BWR) or a pressurized water reactor (PWR).

A brief description of the MRS facility, the receiving and handling (R&H) building and the front-end R&H operations is presented in Chapter 2.0. The front-end MRS model is described and model assumptions are detailed in Chapter 3.0. The input data for the model are described in Chapter 4.0, and the compiling, linking, and executing of the model are described in Chapter 5.0.

(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute.

The simulation output from the front-end MRS model is discussed in Chapter 6.0. Appendix A contains input data code listing and example output. In Appendix B, the queue numbers and station numbers used by the front-end simulation model are described, and the variables available for use in SIMAN are discussed.

2.0 MRS FACILITY DESCRIPTION

The proposed MRS facility is designed to receive, consolidate, and when needed, temporarily store spent fuel from U.S. commercial nuclear power plants. The MRS facility consists of multiple support and administrative buildings, a storage yard for dry storage of canistered fuel, and a receiving and handling (R&H) building. Figure 2.1 shows the layout of the proposed MRS facility. Spent fuel arrives at the inspection gate house of the MRS facility either as a rail- or truck-cask shipment. The shipment is inspected at the inspection gate house and sent to the R&H building, which is divided into two sides, each a mirror image of the other.

Each half of the R&H building contains a receiving and inspection area, two process cells, and a canyon cell with space for an in-building lag-storage vault for canistered, consolidated spent fuel. The north half of the building contains process cells 1 and 3, which handle primarily PWR spent-fuel assemblies; the south half of the building contains process cells 2 and 4, which handle primarily BWR spent-fuel assemblies. Each of the two receiving areas is serviced by a 150-ton-capacity crane and a mobile 40-ton-capacity crane. The 40-ton crane is used to lift smaller loads such as personnel barriers and impact limiters, whereas the 150-ton crane is used primarily for moving shipping casks. The receiving area is shown in Figure 2.2.

Once a shipment reaches the R&H building, the cask transporter (either a truck or a rail car) is positioned in front of a cask cart, and the cask is prepared for unloading. The cask is then placed onto the cask cart with the 150-ton crane. Each process cell is serviced by two rail-mounted self-propelled carts that are used to move the shipping cask from the receiving area into position beneath a process-cell port. Each process cell has two ports, of which only one may be open at a time. Once the cask is in the cask handling and decontamination room, the cask is prepared for unloading and moved to the cask unloading room and mated with the process cell port. Figure 2.3 shows the movement of a shipping cask from a transporter, to a cask cart, and to the process-cell port. The required shielding is put into place, the entry port is opened, and the cask is unloaded using the process cell's 20-ton crane.

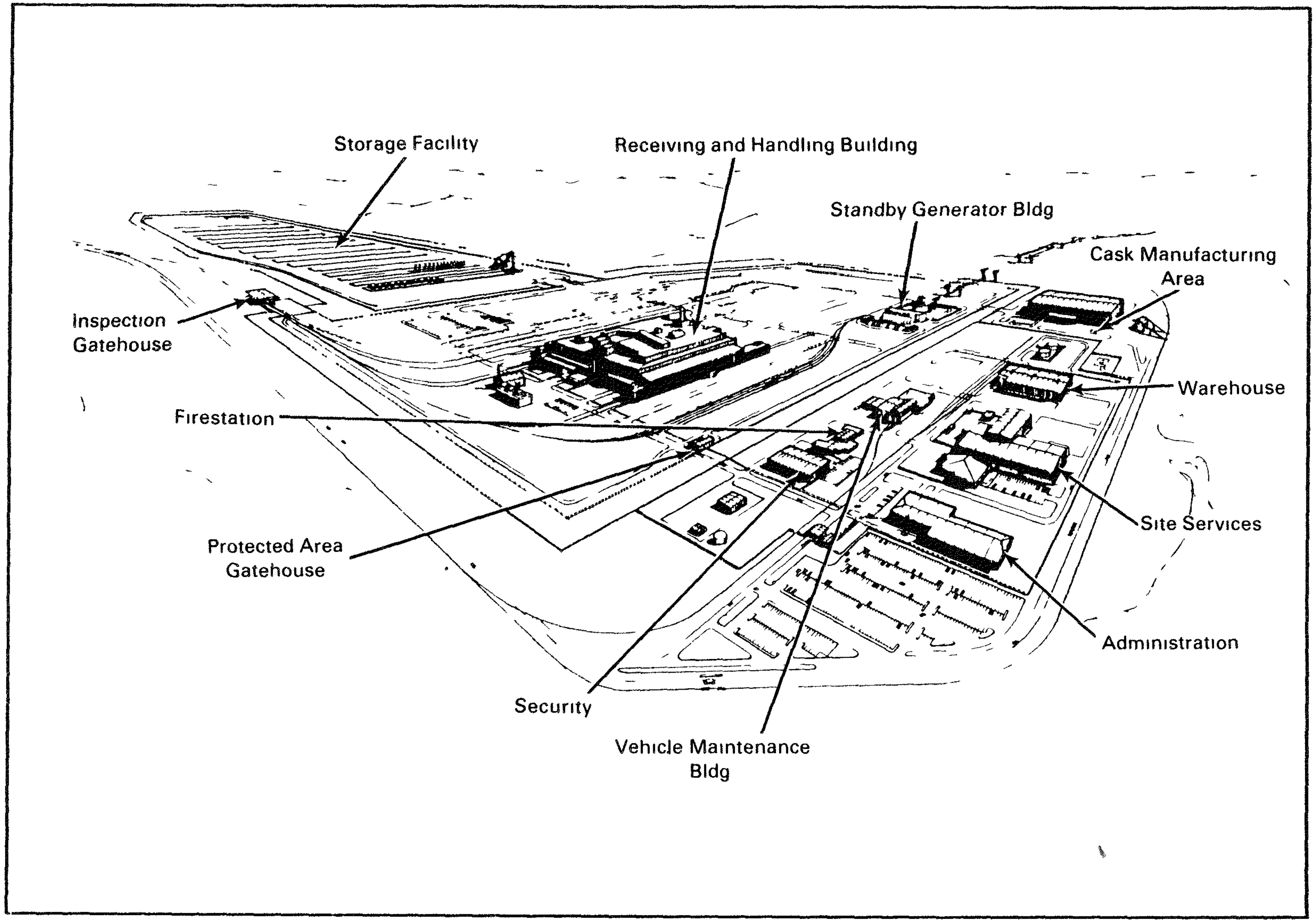

FIGURE 2.1. Integral MRS Facility (Parsons 1985)

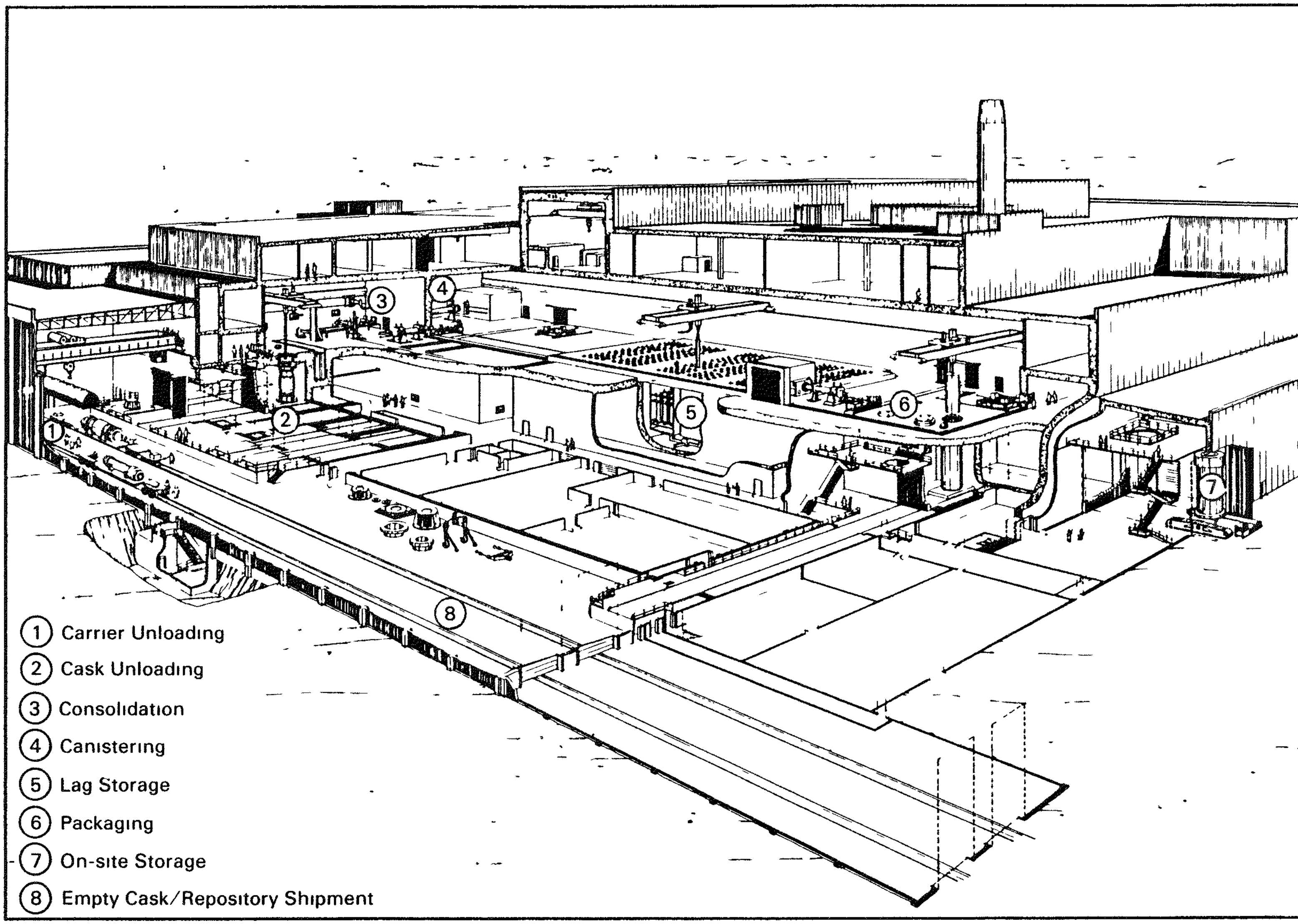

FIGURE 2.2. MRS Receiving and Handling Building (Parsons 1985)

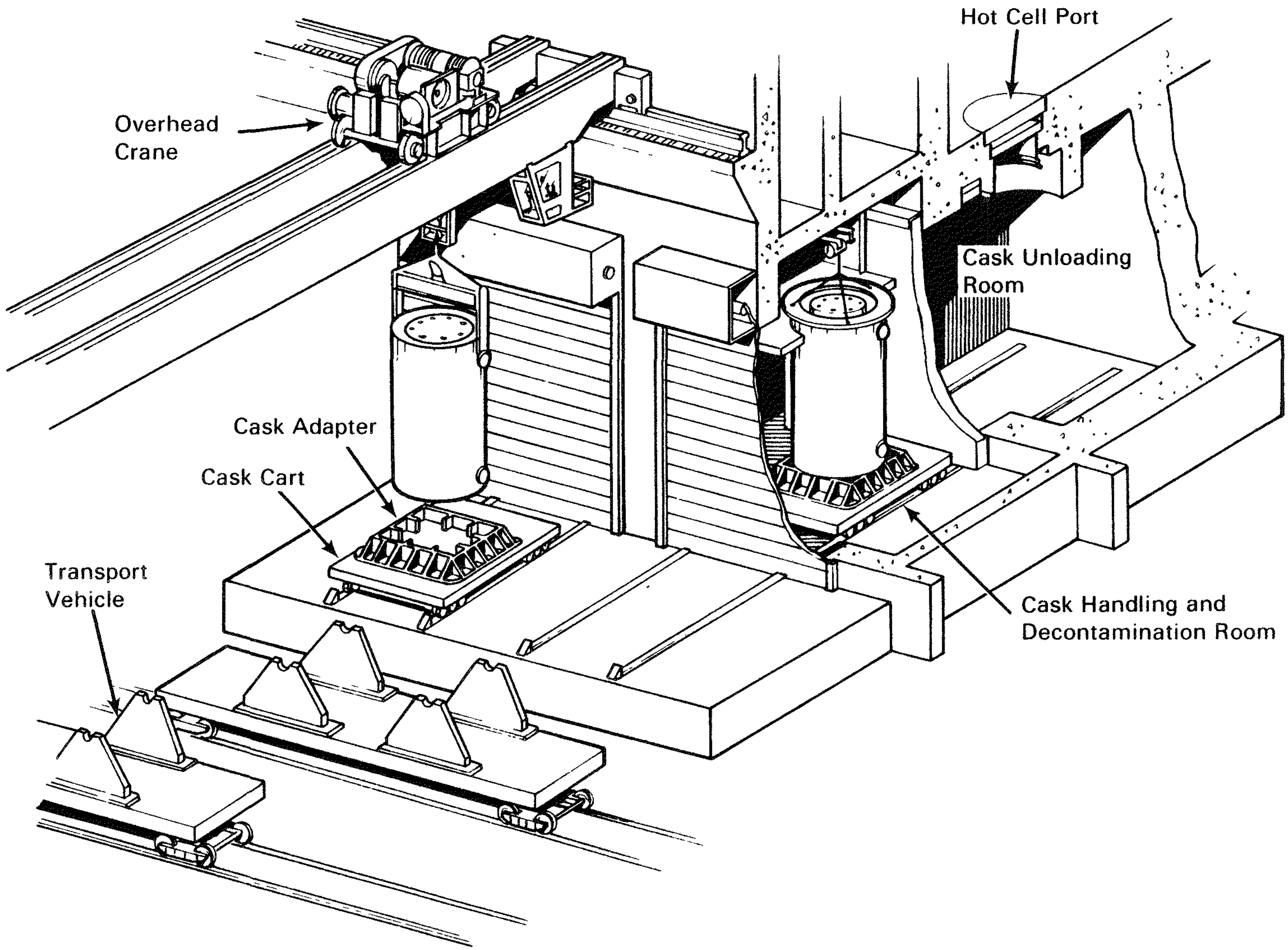

FIGURE 2.3. MRS Processing Cell Cask-Handling Area

Each process cell contains a 20-ton bridge crane, an in-process lag-storage vault, and a disassembly/consolidation station which consists of a spent-fuel disassembly table, a spent-fuel-rod puller assembly, and a rod reordering system. Consolidated spent-fuel rods are passed through one discharge port to be placed into canisters; intact spent-fuel assemblies are passed through the other discharge port. The process cells can handle either PWR or BWR spent fuel, but must be tooled correctly for each type of fuel. In the base MRS design, each disassembly table may handle either three PWR spent-fuel assemblies or seven BWR spent-fuel assemblies concurrently. The in-process lag storage has a capacity of 180 intact PWR spent-fuel assemblies or 320 intact BWR spent-fuel assemblies. Figure 2.4 illustrates the unloading of a shipping cask and the interior of a process cell.

Once unloaded, spent-fuel assemblies are placed either into the in-process lag-storage vault, if the disassembly table is being used, or onto the disassembly table, if the table is not being used. Although all process cells can process intact spent-fuel assemblies using independent equipment, most spent-fuel assemblies are consolidated. Once the assemblies are placed into the in-process lag-storage vault or onto the disassembly table, the process cell port is closed, the required shielding is removed, and the cask is moved back to the cask handling and decontamination room, where the cask outer lid is replaced and the outer surface decontaminated, if required. The cask is then moved to the receiving area and loaded onto the transporter using the 150-ton crane. The tiedowns, impact limiters, and personnel barriers are then replaced, and the transport leaves the facility. All process cell activities are performed with remote equipment.

Once the spent-fuel assemblies are placed on the disassembly table by the process cell crane, the assemblies' end fittings are cut away to facilitate the removal of the spent-fuel rods. The rod-puller assembly then pulls the spent-fuel rods from the assemblies and places them into the rod reordering system. The assemblies' remaining nonfuel-bearing components are removed from the spent-fuel assembly table, shredded, drummed, and removed from the process cell. From the rod reordering system, the spent-fuel rods are pushed into a canister.

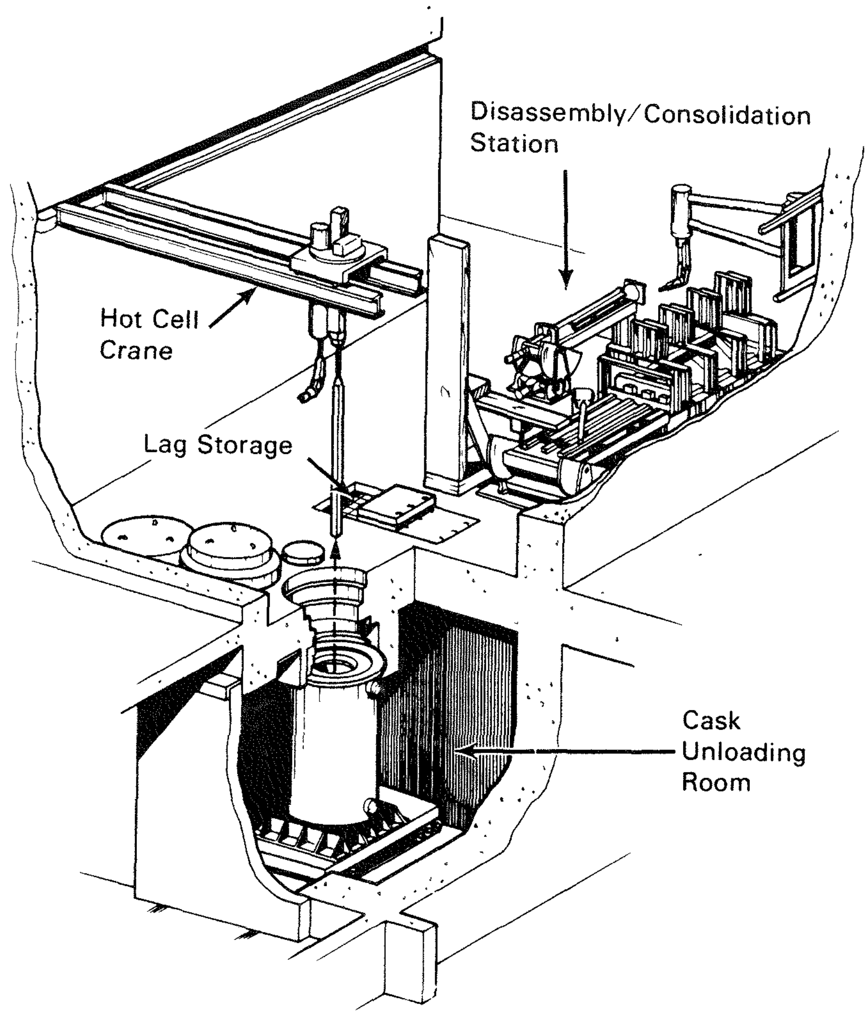

FIGURE 2.4. MRS Process Cell Disassembly and Consolidation Area

Each half of the R&H building has one welding station that handles the canisters produced by the two adjacent process cells. Two canister upenders, mounted on a common set of rails, are used first to position empty canisters to accept spent-fuel rods from the process cells, and then to move the canisters to the welding station. At the welding station, the canister is evacuated, filled with inert gas, sealed by a welded lid, and the outer surface decontaminated. If a welder fails, an access door with a rail-mounted cart between the two welding stations is used to pass canisters to the other welder until the failed welder can be repaired.

The welded canister then goes through the weld inspection station and is placed by one of the two 35-ton bridge cranes into the in-building lag-storage vault, or outloaded to yard storage or to repository shipment. The in-building lag-storage vault in each half of the building has 374 positions for canisters of spent-fuel rods. The first 35-ton crane is used primarily to move canisters from the welder to in-building lag storage. The second 35-ton crane is used primarily to move canisters out of in-building lag storage to canister outloading. The canister waits in in-building lag storage until it is required for either shipment to the repository or for placement into yard storage.

3.0 FRONT-END MRS MODEL AND ASSUMPTIONS

The MRS front-end model simulates the activities of the spent fuel from cask arrival to discharge from the welding machine. For long simulations, a large amount of raw data may be generated. The structure of the model's logic and the basic assumptions made in creating the model are described in the following sections. Options within the model for determining which data are retained and which are discarded are discussed in Chapter 4.0.

3.1 MRS MODEL DESCRIPTION

Figure 3.1 is a flow chart for the MRS model. Included with the main model of the facility process stations are 1) a submodel that will simulate failure of a machine by simply turning it off for the time required to repair the machine, and 2) a submodel that will turn off all of the machines for two days in order to model a facility shutdown for the weekend. The weekend submodel will allow shipment arrivals during the weekends, but those arrivals will not be unloaded until the first shift of the week.

The failure submodel allows random failures and scheduled maintenance outages for the 150-ton and 20-ton cranes, the welding stations, and the disassembly consolidation equipment. The data for the different types of failures, frequency of occurrence, and time for repair are contained in Appendix A. Each failure is exponentially distributed about a mean frequency of failure and is assumed to be independent (Mendenhall 1981). If X1 and X2 are independent and have identically distributed exponential random variables with a mean of 1/z, then X1 + X2 is a gamma distribution with parameters 2 and z (Ross 1980). This may be expanded to N independent exponential probability distributions X1 + X2 + X3 + ... + XN, which produce a gamma distribution with parameters N and z.

The erlang distribution is a special case of the gamma distribution in which k exponential distributions with the same mean are folded together. The parameters for the erlang distribution are the mean and the number (k) exponential distributions which were folded together. The exponential distributions

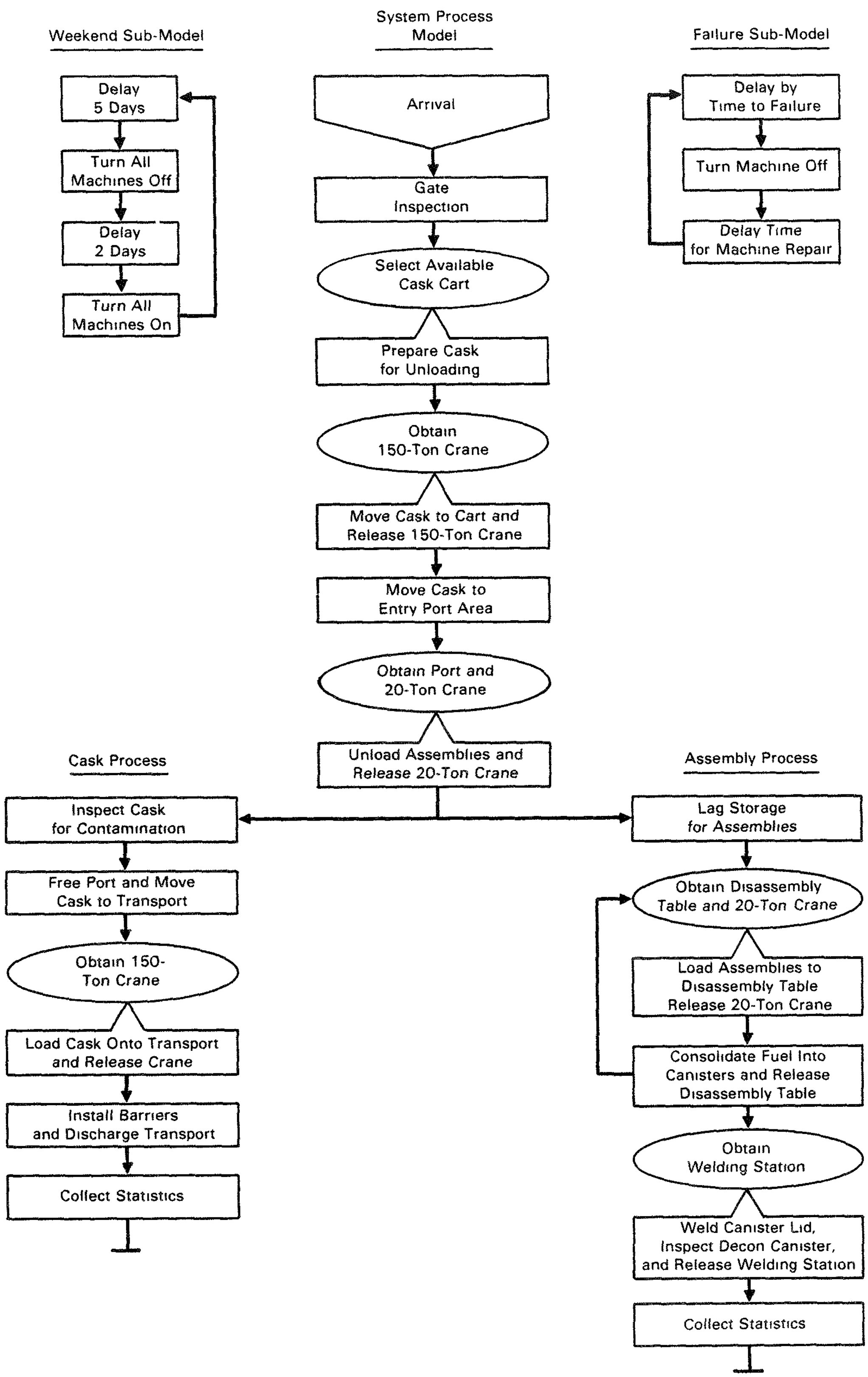

FIGURE 3.1. MRS Model

for machine failure frequency were folded together to produce erlang distributions with frequency parameters of 1 month, 3 months, 6 months, 1 year, and 5 years. Each machine station thus has a single failure mode for each of the above frequencies. For each failure mode, the associated repair time is obtained by sampling from an exponential distribution. The mean time of repair used with the exponential distribution is the average of the average times for repair of each failure mode that was folded into the erlang distribution. Thus, each machine is down for repair for the expected number of hours on the average each year. Scheduled outages for disassembly table maintenance were modeled as an equipment failure with a frequency of two weeks. Each failure mode is independent of the others and is modeled individually.

The MRS facility is modeled by appropriately grouping a series of operations into process stations. These groupings are illustrated in Table 3.1. The average process times were obtained from Conceptual Design Report (The Ralph M. Parsons Company, Volume VI, Book I, 1985). Because very few data on process times are available, the above average process times were used with estimated minimum and maximum process times as parameters for a triangular distribution. A detailed listing of the MRS model and input is provided in Appendix A. The average process times from the Parsons report are given in Table 3.1 and are grouped according to each process station that the MRS model uses. Also given are the parameters used for the triangular distributions to determine each station's processing delay time. All times listed in the table are in minutes.

3.2 ASSUMPTIONS

The following assumptions are made when the model default input values are used:

1. Only spent-fuel consolidation is considered. All arriving spent-fuel assemblies are consolidated into canisters of spent-fuel rods.

2. The facility will operate 3 shifts/day for 365 days/year when processing rates are equal to or greater than 3,600 metric ton of uranium (MTU)/yr, and will operate 3 shifts/day, five days/week when processing rates are less then 3,600 MTU/yr.

TABLE 3.1 MRS Model Process Station Parameters

Station Number	Process Description	Time Parameters (minutes) Parson's est.[a] Truck	Rail	Triangular Param. Truck	Rail
1	Position transport for inspection	5	5		
	Conduct gate inspection	12	18	MIN: 82	93
	Move transport to R&H building	8	8	MODE: 92	103
	Begin washdown process and drying	67	72	MAX: 102	113
2	Position transport in front of cask cart	10	15		
	Remove tiedowns, personnel barriers, impact limiters	45	60	MIN: 60	90
				MODE: 75	105
	Complete preparation for cask unload	20	30	MAX: 90	120
3	Position cask-lifting yoke for 150-ton crane			MIN: 32	32
	Rotate cask to vertical position	35	35	MODE: 35	35
	Place cask onto cart			MAX: 39	39
4	Remove cask valve covers, install gas venting system, take gas samples, remove cask outer cover, install shield barrier adapter, untorque inner closer bolts	95	20	MIN: 140	175
	Move cask to unloading cell, engage contamination barriers	20	20	MODE: 145	180
	Remove cell entry port, remove cask inner closure	30	40	MAX: 160	190
5	Unload cask:				
	PWR assembly	40	240	MIN: 35	225
				MODE: 40	240
				MAX: 50	270
	BWR assembly	75	480	MIN: 70	460
				MODE: 75	480
				MAX: 90	560
6	Inspect cask, replace inner closure, replace port shield	45	75	MIN: 40	70
				MODE: 45	75
				MAX: 52	83

TABLE 3.1. (contd)

Station Number	Process Description	Time Parameters (minutes): Parson's est.[a] Truck	Parson's est. Rail	Triangular Param. Truck	Triangular Param. Rail
7	Open shield door, disengage contamination barrier, move cask to decontamination area	20	20	MIN: 130	155
	Complete inner closure installation, remove shield adapter, install outer cover, decontaminate exterior, survey for decontamination	120	150	MODE: 140	170
				MAX: 155	190
8	Move cask to transport (with 150-ton crane), rotate to horizontal position, place on transport	35	35	MIN: 32	32
				MODE: 35	35
				MAX: 39	39
9	Install cask tiedowns, impact limiters, personnel barriers	45	60	MIN: 55	75
	Complete preparation for cask and transporter discharge	20	30	MODE: 65	90
				MAX: 80	110
10	Load fuel assemblies to the disassembly table from lag storage	45	105	MIN: 40	95
				MODE: 45	105
				MAX: 52	120
11	Disassemble fuel assemblies	150	325	MIN: 225	425
	Consolidate fuel rods	70	95	MODE: 235	435
	Load fuel rods into canister	15	15	MAX: 260	480
12	Rotate canister, place in welder	5	5	MIN: 25	25
	Evacuate canister and backfill with inert gas, weld lid to canister.	20	20	MODE: 30	30
				MAX: 40	40

(a) The Ralph M. Parsons Company (1985).

3. The facility operates four process cells: two cells to handle only PWR spent fuel and two cells to handle only BWR spent fuel.

4. The process cells are not retooled to handle the other fuel types. However, the MRS facility must handle different sizes of PWR and BWR fuel assemblies. The disassembly tables within each process cell will need to be recalibrated to handle each designated variety of fuel assembly. Thus, a process cell outage for recalibrating the disassembly tables has been modeled as a machine failure with a frequency of two weeks.

5. The average BWR spent-fuel assembly contains 0.186 MTU, and the average PWR spent-fuel assembly contains 0.462 MTU.

6. Truck-cask shipments contain 2 PWR or 5 BWR spent-fuel assemblies.

7. Rail-cask shipments contain 12 PWR or 32 BWR spent-fuel assemblies.

8. Truck/rail splits listed in this report are independent of fuel type. For example, a truck/rail split of 10/90 for PWR means 10% of PWR MTU will be shipped by truck cask; 90% of PWR MTU will be shipped by rail cask.

9. Shipment interarrival times are exponentially distributed. Process station times are determined by sampling from triangular distributions. Repair times are determined by sampling from exponential distributions. Time to failure for a machine station is determined by sampling from an erlang distribution.

10. If the capacity of the in-process lag storage is exceeded, the cask is assigned to the other process cell. If the fuel-assembly lag storage of both process cells is exceeded, the cask must wait until space is available to hold the required number of assemblies.

11. If the 20-ton crane servicing a process cell is down for repair, the cask is assigned to the other process cell.

12. In-process lag storage for each process cell handling the same type of fuel is managed such that the number of assemblies stored is always within 20% of the number of assemblies in the other process cell.

13. Each transport leaves the facility with the same cask it arrived with.

14. The transport occupies the unloading/loading space in front of the cask cart station while its cask is being processed.

15. Cracked, bent, or ruptured spent-fuel rods do not affect the unloading parameters and distributions used for the model. These events are assumed to occur at the end of the distributions and in the shipments that take the longest time to process.

16. Assemblies are loaded directly into the in-process lag storage from a shipping cask.

17. The disassembly table is loaded directly from the in-process lag storage only. When a disassembly table is ready to be loaded, the 20-ton crane servicing that process cell is interrupted to load the table and then allowed to resume its previous task.

18. Seven BWR and three PWR spent-fuel assemblies are loaded onto the disassembly table, cut, pulled, consolidated, and loaded into a canister before the disassembly table is free to be reloaded with spent-fuel assemblies. (This is the model default and may be changed by the user as described in the model input, Chapter 4.0). The disassembly and the consolidation processes have been considered as occurring simultaneously. It was determined that this would not always be the case, and so the default time parameters used for this station reflect times which are longer than if the two steps were completely parallel.

19. When a welder failure occurs, canisters are not transferred to the other welding station. Within the model, the user has the option of allowing canisters to queue up until the welder is repaired and able to process the backlog. This option allows a determination of how

long the canister queues would become, and thus assesses the need for canister transfers or in-process lag storage.

20. Any canister that fails the weld inspection can be rewelded without delaying or holding up any part of the system (assumption of infrequent weld failure).

21. The process steps that occur after the welding station have little or no effect on the events occurring up to and including the welding station.

22. The only machine failures that have a major impact on processing shipments are the failures for the 150-ton bridge cranes, the 20-ton process cell cranes, the disassembly and consolidation equipment, and the welding stations. Other failures occur too infrequently or are repaired quickly enough so that they have a small impact on the system.

23. When the facility is operating on a five days/week schedule, shipments may arrive on the weekend. However, these shipments are not unloaded until the first shift of the following week.

24. The performance assessment presented in the FACSIM/MRS-1 report ends with the completion of canister welding. The assessment of shielded canyon cell operations presented in FACSIM/MRS-2 (Huber et al. 1987) begins with the placement of welded canisters in canyon vault lag storage. This performance assessment does not include the inspection and decontamination of welded spent-fuel canisters. Neglecting canister inspection and decontamination is not expected to significantly impact the findings contained within these documents, and was not included because of the relatively low expected utilization rate of inspection and decontamination equipment.

Many of the above assumptions are merely the assumptions used for establishing the default values for the model input. The user will need to change the values for any given simulation scenario. These options are explained in detail in Chapter 4.0.

4.0 INPUT DATA TO THE FRONT-END MODEL

All input to set up a particular MRS simulation is contained in the SIMAN experimental framework. A listing of a typical experimental framework is given in Appendix A. The first three images must be a BEGIN card, a PROJECTS card identifying the output of the simulation, and a DISCRETE card, which sets the limits on the number of active entities in the system, number of attributes an entity may have, the number of queues within the model, and the number of stations within the model, in that order. The rest of the input cards, described below, may follow these three in any order.

REPLICATE,RNS,TBEG,TRN,ISYS,ISTAT;

- RNS - number of simulation runs to be performed
- TBEG - starting time of the simulation
- TRN - ending time of the simulation
- ISYS - option to keep or re-initialize all system variables
- ISTAT - option to keep or discard the statistics between each replicated run.

TALLIES,N,ID,NUNIT;

- N - the number of the TALLY register. These numbers must be listed sequentially beginning at one and must match the tally number in the model frame.
- ID - option to identify each of the tally variables in the output (20 character title).
- NUNIT - the number of the output file containing the individual observations for each tally variable for use in the SIMAN output processor. If a number for NUNIT is not given, the file of the form output.nunit is not created and the raw data are not saved. A value is generated for the SIMAN summary output in either case.

DSTAT,N,DVAR,ID,NUNIT;

N - the number of the DSTAT register. These numbers must be listed sequentially beginning at one.

DVAR - option to identify the variable for which time varying statistics are to be collected.

ID - option to identify each of the DSTAT variables in the output (20 character title).

NUNIT - the number of the output file containing the individual observations for each DSTAT variable.

Information concerning how to specify a DSTAT or TALLIES card and the variables that may be used is provided in Appendix B.

PARAMETERS:N,DATA;

N - the parameter set number used by the model to access the data that are entered. The numbers must be listed sequentially beginning at one.

DATA - the required data for a parameter set. They are entered with commas separating each data item.

The variables of greatest importance are contained in the parameters statement in the MRS experimental framework. The parameters statement given in the experimental frame is provided with defaults that are the same values as those given in Table 3.1. The parameter set is listed in Appendix A with the experimental frame and is filled with zeros, which indicate that the default values for all data will be used. These parameter sets should not be deleted because the model will need the parameter set numbers to reference the needed data. Thus, the user should view the PARAMETERS card as a template with which to set up simulations. To use data other than the given defaults, the user simply replaces the zero in the appropriate parameter set with the desired data; the model will then use that data. All time parameters should be entered with the units of days. The information contained in each parameter set is given below with the default values in parentheses.

1. Fraction of shipments PWR (0.5), fraction of shipments BWR (0.5), fraction of shipments by truck cask (0.5), fraction of shipments by rail cask (0.5), annual receipt rate in MTU (3600).

2. Number of PWR assemblies carried by a truck cask (2), number of BWR assemblies carried by a truck cask (5), number of PWR assemblies carried by a rail cask (12), number of BWR assemblies carried by a rail cask (32).

3. Initial number of assemblies in process cell lag storage for process cell 1 (0), process cell 2 (0), process cell 3 (0), process cell 4 (0).

   When a processing cell is not to be operated, entering a negative number of -1 or less for the initial number of assemblies in a process cell's lag storage will disable that process cell. Thus, no spent-fuel assemblies will be processed in that cell during the entire simulation. Example: if parameter set 3 is 3,0,0,0,-5:, then process cell number 4 will not operate during the simulation.

4. Number of assemblies which each disassembly table may handle concurrently for process cell 1 (3), process cell 2 (7), process cell 3 (3), process cell 4 (7).

5. Work (0), truck group (1), rail group (1), FPLAG (none), FBLAG (none).

   Work - If greater than zero, simulate weekend shutdown. If equal to or less than zero, then simulate 7 days/week, 3 shifts/day operation.

   Truck group - Truck cask arrivals will occur in groups of the given number.

   Rail group - Rail cask arrivals will occur in groups of the given number.

   FPLAG - PWR lag storage management variable. The number of assemblies in the two PWR (cells 1 and 3) lag-storage vaults will always be within FPLAG of the other. If the user wished each lag storage to be within 20% of the other, FPLAG would be entered as 0.2.

FBLAG - Same as FPLAG, but controls the BWR (cells 2 and 4) lag-storage vaults.

FPLAG and FBLAG provide a means of managing the process cells in order to maintain an even pressure on each cell to process spent-fuel assemblies or to purposely place more pressure on one cell. If no lag managing is desired by the user, entering -1 will disable the feature.

Example: if parameter set 5 is 5,0,0,0,.15,-1:, then the number of spent-fuel assemblies in one PWR cell lag storage will not be larger than 15% of the other PWR cell lag storage. For the BWR shipments, the relationship of the two BWR cell lag-storage vaults is not considered when a cask cart is obtained for unloading.

6. Position for mean truck cask interarrival time (calculated for the user from the above information; user does not need to indicate a value).

7. Position for mean rail cask interarrival time (calculated for the user from the above information; user does not need to indicate a value).

8. MIN, MODE, MAX - time parameters for gate inspection, washdown, and (0.0569,0.06389,0.07083) movement to the R&H building for a truck cask.

9. MIN, MODE, MAX - time parameter for gate inspection, washdown, and (0.06458,0.07153,0.07847) movement to the R&H building for a rail cask.

10. MIN, MODE, MAX - time parameter to prepare a truck cask to be loaded (0.04167,0.05208,0.0625) onto a cask cart (tiedowns, etc.).

11. MIN, MODE, MAX - time parameter to prepare a rail cask for unloading (0.0625,0.07292,0.08333) onto a cask cart (tiedowns, etc.).

12. MIN, MODE, MAX - 150-ton crane unload/load time parameter to place (0.0222,0.0243,0.02708) a cask onto a cask cart.

13. MIN, MODE, MAX - time parameter for truck cask preparation and movement into (0.07639,0.07986,0.09028) a process cell.

14. MIN, MODE, MAX - time parameter for rail cask preparation and movement into (0.09375,0.09722,0.10774) a process cell.

15. MIN, MODE, MAX - time parameter for removal of PWR assemblies from (0.04514,0.04861,0.0556) a truck cask.

16. MIN, MODE, MAX - time parameter for removal of BWR assemblies from (0.06944,0.07292,0.0833) a truck cask.

17. MIN, MODE, MAX - time parameter for removal of PWR assemblies from (0.18403,0.19444,0.21528) a rail cask.

18. MIN, MODE, MAX - time parameter for removal of BWR assemblies from (0.3472,0.3611,0.4147) a rail cask.

19. MIN, MODE, MAX - time parameter for decontamination of the inside of (0.01944,0.02083,0.02431) a truck cask.

20. MIN, MODE, MAX - time parameter for decontamination of the inside of (0.03819,0.04167,0.04722) a rail cask.

21. MIN, MODE, MAX - time parameter for replacement of plug shield in (0.00972,0.01042,0.01181) the process cell.

22. MIN, MODE, MAX - time parameter for movement to transport and preparing (0.09028,0.09722,0.10764) a truck cask for loading onto the transport.

23. MIN, MODE, MAX - time parameter for movement to transport and preparing (0.10764,0.11806,0.13194) a rail cask for loading onto the transport.

24. MIN, MODE, MAX - time parameter for preparing to discharge a truck (0.03819,0.04514,0.05556) cask (tiedowns, etc.).

25. MIN, MODE, MAX - time parameter for preparing to discharge a rail (0.05208,0.0625,0.07639) cask (tiedowns, etc.).

26. MIN, MODE, MAX - time parameter to load disassembly table from lag (0.02778,0.03125,0.03611) storage for process cell 1. (If parameter set 4 is changed, the user need not alter parameter set 26 because the model will calculate the new values.)

27. MIN, MODE, MAX - time parameter to load disassembly table from lag (0.06597,0.07292,0.08333) storage for process cell 2. (If parameter set 4 is changed, the user need not alter parameter set 27 because the model will calculate the new values.)

28. MIN, MODE, MAX - time parameter to load disassembly table from lag (0.02778,0.03125,0.03611) storage for process cell 3. (If parameter set 4 is changed, the user need not alter parameter set 28 because the model will calculate the new values.)

29. MIN, MODE, MAX - time parameter to load disassembly table from lag (0.06597,0.07292,0.08333) storage for process cell 4. (If parameter set 4 is changed, the user need not alter parameter set 29 because the model will calculate the new values.)

30. MIN, MODE, MAX - time parameter for processing and consolidating PWR (0.15625,0.16319,0.18056) assemblies into canisters for process cell 1. (If parameter set 4 is changed, the user need not alter parameter set 30 because the model will calculate the new values.)

31. MIN, MODE, MAX - time parameter for processing and consolidating BWR (0.29514,0.3021,0.3333) assemblies into canisters for process cell 2. (If parameter set 4 is changed, the user need not alter parameter set 31 because the model will calculate the new values.)

32. MIN, MODE, MAX - time parameter for processing and consolidating PWR (0.15625,0.16319,0.18056) assemblies into canisters for process cell 3. (If parameter set 4 is changed, the user need not alter parameter set 32 because the model will calculate the new values.)

33. MIN, MODE MAX - time parameter for processing and consolidating BWR (0.29514,0.3021,0.3333) assemblies into canisters for process cell 4. (If parameter set 4 is changed, the user need not alter parameter set 33 because the model will calculate the new values.)

34. MIN, MODE, MAX - time parameter for weld and inspection of weld (0.01736,0.02083,0.02778).

35. MEAN, N - (30.5, 3)
36. MEAN, N - (91.5, 2)
37. MEAN, N - (183, 7)
38. MEAN, N - (365, 8)

Parameters for failure frequency of the disassembly tables.
MEAN - average time between failures for a mode of failure.
N - The number of exponential distributions which were folded into the erlang distribution.

39. MEAN, N - (91.5, 2)
40. MEAN, N - (183, 4)
41. MEAN, N - (365, 4)

Parameters for failure frequency of the welding stations.
MEAN - Average time between failures for a mode of failure.
N - The number of exponential distributions which were folded into the erlang distribution.

42. MEAN, N - (30.5, 4)
43. MEAN, N - (183, 2)
44. MEAN, N - (365, 2)
45. MEAN, N - (1830, 6)

Parameters for failure frequency of the 150-ton and 20-ton cranes.
MEAN - Average time between failures for a mode of failure.
N - The number of exponential distributions which were folded into the erlang distribution.

46. RMEAN - 1-month frequency failure mode (1.8333)
47. RMEAN - 3-month frequency failure mode (1.3333)
48. RMEAN - 6-month frequency failure mode (7.167)
49. RMEAN - 1-year frequency failure mode (5.833)

Parameters for the mean time for repair of the disassembly tables.
RMEAN - The mean time for repair.

50. RMEAN - 3-month frequency failure mode (0.3333) 51. RMEAN - 6-month frequency failure mode (2.00) 52. RMEAN - 1-year frequency failure mode (5.667)	Parameters for the mean time for repair of the welder stations. RMEAN - The mean time for repair.
53. RMEAN - 1-month frequency failure mode (0.6667) 54. RMEAN - 6-month frequency failure mode (0.6667) 55. RMEAN - 1-year frequency failure mode (1.00) 56. RMEAN - 5-year frequency failure mode (24.306)	Parameters for the mean time for repair of the 150-ton and 20-ton cranes. RMEAN - The mean time for repair.

57. NUM, ID

NUM - The number of machine failures which follow on this card.

ID - The machine ID number (which may be obtained from the RESOURCES card described below) for which the user is supplying additional failure modes.

The parameter sets 35 through 56 correspond on a one-to-one basis. For example, if the user alters parameter set 34, the associated time for repair in parameter set 46 must be checked for the required value. If the user wishes to include additional failure modes in the simulation, the user simply indicates in parameter set 57 the number of additional failure modes to be added followed by the machine ID for which the failure mode is meant. If more than one failure mode for a single machine is to be added, the user must repeat the machine ID for each associated failure mode. The data for each failure mode are then entered by creating a pair of parameter sets for each failure mode beginning with parameter sets 58 and 59. In the first parameter set, the user provides the failure frequency data in the same form as for parameter sets 35 through 45. In the second parameter set, the user provides the time for repair data for the failure mode in the same form as parameter sets 46 through 56. For example, if the user wished to add one failure mode for machine 20, the end of the PARAMETERS card would be:

57,1,20:58,25,5:59,4.896;

The required machines for the MRS model are created with the RESOURCES card. The machine stations are indexed by a resource card called MACH(1-20). The user will rarely need to alter any of the data included on this card.

RESOURCES:N,RNAME,NCAP;

N - resource set number, which must begin with one and increase sequentially.

RNAME - the resource to be used in the simulation.

NCAP - number of units of the resource to be available during a simulation.

The resource index number corresponds to the following machine stations within the MRS model:

1. pwr cart (2)
2. bwr cart (2)
3. pwr cart (2)
4. bwr cart (2)
5. pwr 150 crane (1)
6. bwr 150 crane (1)
7. hc-1 20 crane (1)
8. hc-2 20 crane (1)
9. hc-3 20 crane (1)
10. hc-4 20 crane (1)
11. hc-1 entry port (1)
12. hc-2 entry port (1)
13. hc-3 entry port (1)
14. hc-4 entry port (1)
15. hc-1 table (1)
16. hc-2 table (1)
17. hc-3 table (1)
18. hc-4 table (1)
19. pwr welding station (1)
20. bwr welding station (1)

The DISTRIBUTIONS card specifies the type of distribution that each process station uses to determine processing time delays.

DISTRIBUTIONS:N, TYP;

N - the distribution set number, which must begin with one and increase sequentially.

TYP - the type of distribution, which the model will use when it references the distribution set number.

A few of the distributions are written directly into the model, such as the exponential distributions for shipment arrivals and the failure model distributions. The DISTRIBUTIONS card contains all of the triangular distributions required for the process stations and are identified by position below. The parameter sets that the DISTRIBUTIONS card accesses are given for each distribution set number in parentheses.

1.	TRUCK	- preparation for unloading cask from transport (10)
2.	RAIL	- preparation for unloading cask from transport (11)
3.	TRANSFER	- used for movement between stations (should not be changed)
4. - 5.	PWR or BWR	- crane unload or loading (12, 12)
6. - 9.	TRUCK	- process cells 1, 2, 3, and 4 unload assemblies from cask (15, 16, 15, 16)
10.	TRUCK	- cask preparation time for movement into entry port area (13)
11.	RAIL	- cask preparation time for movement into entry port area (14)
12. - 15.	RAIL	- process cells 1, 2, 3, and 4 unload assemblies from cask (17, 18, 17, 18)
16.	TRUCK	- survey cask for decontamination (19)
17.	RAIL	- survey cask for decontamination (20)
18.	TRUCK	- movement of cask from entry port area back to transport (22)

19. RAIL - movement of cask from entry port area back to transport (23)

20. TRUCK - prepare transport to be discharged from the facility (24)

21. RAIL - prepare transport to be discharged from the facility (25)

22. PWR - load assemblies from lag storage to the disassembly table for process cell 1 (26)

23. BWR - load assemblies from lag storage to the disassembly table for process cell 2 (27)

24. PWR - load assemblies from lag storage to the disassembly table for process cell 3 (28)

25. BWR - load assemblies from lag storage to the disassembly table for process cell 4 (29)

26. PWR - disassemble and consolidate fuel rods for process cell 1 (30)

27. BWR - disassemble and consolidate fuel rods for process cell 2 (31)

28. PWR - disassemble and consolidate fuel rods for process cell 3 (32)

29. BWR - disassemble and consolidate fuel rods for process cell 4 (33)

The SEQUENCES card defines the order in which a cask and spent-fuel assemblies go through the process stations in the MRS model.

SEQUENCES :N,IN,PORT,CC,TBL,OUT,WELD;

N - sequence set number, which must begin with one and increase sequentially.

IN - option to identify the 150-ton crane station number that the arriving cask shipment is to use.

PORT - indicates which cell port to use.

CC - indicates which cell 20-ton crane to use.

TBL - indicates which cell disassembly table to use.

OUT - option to identify the 150-ton crane which an empty cask is to use when it is to be placed back on the carrier.

WELD - option to identify which welder to use.

Sequences set numbers 1 and 3 are for the PWR process cells 1 and 3, respectively, and sequence numbers 2 and 4 are for the BWR process cells 2 and 4, respectively. For more information on the use of station ID numbers, see Appendix B. The SEQUENCES card defines the layout or physical structure of the MRS facility. The default R&H building is a two-sided structure with two process cells on each side of the building. For example, if the user wished to place all of the process cells on the same side of the building and use only one 150-ton crane, the user would simply direct two of the process cells to the other 150-ton crane and thus only use one 150-ton crane. Therefore, IN and OUT would indicate the same station number for all four process cells.

As a more complicated example, consider the problem of modeling a one-sided MRS facility (in that only one 150-ton crane is to be included) which has only three process cells: one for PWR spent fuel and two for BWR spent fuel. The user must 1) disable process cell 3 (the second PWR cell) as described in the PARAMETERS card for parameter set 3, 2) in parameter set 5, set FPLAG to -1 so that incoming PWR shipments will not consider the second PWR cell's lag storage, and 3) change the sequence set number 1 so that IN and OUT indicate the same 150-ton crane as sequence set numbers 2 and 4. Sequence set number 3 will never be used but should not be removed from the card because the set number must be included. Therefore, three process cells are modeled completely and each has access to the only 150-ton crane. If the user, in addition to the above conditions, wishes to dedicate the third cell to handle only difficult consolidations, such as bent or ruptured fuel assemblies, the user must also alter the disassembly table station time parameters for the third process cell (in this case cell number 4 because cell number 3 has been disabled) to reflect that more time is needed to consolidate those spent-fuel assemblies. The model is not limited to modeling the above scenarios, which are only examples of the flexibility of the MRS model.

Also included in the experimental frame is the RANKINGS card, which determines where in a queue a cask is to be placed when the cask must wait for a machine to become available. The user should never have to deal with this card, and should not alter it. If more information about these input cards is desired, the user is referred to Introduction to SIMAN (Pegden 1985).

For most system situations that the user may wish to simulate, the user will need to adjust only a few of the parameter sets, usually sets 1 through 5. The user will also need to specify which statistics are to be stored in SIMAN output files that are created with the DSTAT and TALLIES cards for later use with the SIMAN output processor OUTPT or with other software packages for manipulating data or for plotting data. The time units for all process times are days. SIMAN allows fractional time steps to provide more accurate information about system synchronization.

5.0 COMPILING, LINKING, AND EXECUTING THE FRONT-END MODEL

After the data are input into the experimental frame, the user is ready to compile, link, and execute the front-end MRS model. The model has a FORTRAN extension named MPRIME, which handles setting up the default parameters and the initial set up of the simulation. To execute the simulation on the PC, the user must first have MICROSOFT FORTRAN version 3.3 and make sure that the MICROSOFT meta commands $NODEBUG and $STORAGE:2 are included at the beginning of MPRIME.FOR. These meta commands are needed for the internal workings of SIMAN. The user then links MPRIME.OBJ and SIMAN.OBJ with the 8087.LIB, FORTRAN.LIB, and the SIMAN.LIB with the /SEGMENTS:256 option included in the link command. The user then has a MPRIME.EXE file. The VAX user must compile MPRIME.FOR and link MPRIME.OBJ with the SIMAN object files SMAIN.OBJ, RA.OBJ, SUTIL.OBJ, and SIMAN.OBJ to obtain the executable MPRIME.EXE.

For both the PC and VAX cases, the user will encounter the warning "SUBROUTINE PRIME MULTIPLY DEFINED" during the FORTRAN link. This occurs because SIMAN includes a dummy subroutine called PRIME for use when no FORTRAN extensions to SIMAN models are used. This warning is normal and should not cause concern. For this reason, when linking MPRIME on the VAX, MPRIME must be the first object file in the link command. Once the user has an executable version of MPRIME, it will not be necessary to recompile and relink MPRIME.FOR again.

The user must now use the SIMAN model compiler to compile the MRS model framework. Once the user has a compiled version of the model (usually referred to as MRS.M if the model file is MRS.MOD), the model will not have to be recompiled again under normal circumstances. The user must now use the SIMAN experiment compiler to compile the experiment file, which contains all of the user-specified information for the simulation. The next step is for the SIMAN linker to link the compiled versions of the model and experiment to obtain an executable simulation model. The user will recompile the experiment file and link it to the compiled model file each time a different simulation (any change in the experiment file) is to be created.

To begin the execution of a simulation, the PC user executes MPRIME.EXE with the file name of the executable simulation model as a parameter. The VAX user executes a simulation by invoking the SIMAN command file SIM.COM with the file names of the executable simulation model, the FORTRAN extension, and an E (to indicate that the FORTRAN file is an executable) as parameters. These commands are given below in the proper sequence for the PC and VAX minicomputer versions of SIMAN. The file containing the MRS model is MRS.MOD, and the file containing the user's experiment data is MRS.EXP.

PC VERSION OF SIMAN	VAX VERSION OF SIMAN
1) MODEL MRS.MOD MRS.M	1) MOD MRS
2) EXPMT MRS.EXP MRS.E	2) EXP MRS
3) LINKER MRS.M MRS.E MRS.P	3) LNK MRS MRS
4) MPRIME MRS.P	4) SIM MRS MPRIME E

In the PC version, the user needs to specify the file name of the compiled model, experiment, and linked model, whereas the VAX version creates a .M file for the compiled model, an .E file for the compiled experiment, and a .P file for the linked simulation model automatically. It is strongly recommended that the PC user follow the same nomenclature to avoid confusion with all references to the use of the SIMAN simulation language. The model file name and the experiment file name need not be the same.

6.0 SIMULATION OUTPUT FROM THE FRONT-END MRS MODEL

The MRS model is flexible enough to collect statistics concerning almost any aspect of the cask-receiving and consolidation operations of an MRS facility. The MRS model presently collects statistics on 51 quantities of interest during the simulation. SIMAN reports the statistics with two forms of output: a SIMAN simulation summary and an optional set of SIMAN output files containing data for use by more detailed post processors and report generators.

The first section of the first type of output contains information concerning TALLY variables. These variables provide information about cask processing and turnaround times. Information on truck and rail cask processing and turnaround times is provided for each individual process cell, for the facility as a whole, and also specified as BWR or PWR truck and rail for the facility as a whole. Information concerning the length of time needed to process a spent-fuel assembly and the frequency with which a canister comes from the welder is also produced. All tallies currently in the model are listed in Appendix A.

The second section of the first type of output contains information concerning the DSTAT variables that provide information on time-dependent quantities. The first entries indicate the time average for a number of assemblies stored in each process cell lag-storage pit, along with the maximum and minimum number of assemblies during the simulation. Information on the time average, minimum, and maximum number of transports waiting for a cask cart, and the number of canisters waiting for the welding station to become available is generated as the next entries. The final entries provide information on all process station uses, which include the 150-ton cranes, 20-ton cranes, welder stations, and the disassembly consolidation station. All the DSTAT variables in the model are listed in Appendix A.

The second type of output is in the form of SIMAN output files which contain all of the raw data collected and are used to generate the SIMAN summary output. These files are created when a file number is included in the TALLIES or DSTAT cards, and the file name in the form, output.#, where # is the file number the user indicates on the input card. Each of the entries contained in the SIMAN summary output can have a SIMAN output file containing all of the observations and chronological history generated by the simulation. The SIMAN output files that are retained are specified by the user in the MRS model experimental frame using the TALLIES and DSTAT cards. These files may then be used by the SIMAN output processor OUTPT to generate distributional data and reports. These include plotted histories of a process cell lag storage or a queue size. Histograms may be generated from the data generated by the TALLY variables. SIMAN output files may also be exported by the SIMAN output processor as DIFF or ASCII files for the user to use with other software packages or to enable the user to perform his/her own statistical manipulations.

Results from an example simulation are included in Appendix A. The model and experimental frames are also listed. The sample output provided is for a MRS facility that would operate 3 shifts/day, 7 days/week at a receipt rate of 3600 MTU/year. Shipment arrivals were 50% PWR by weight and 50% truck cask by weight of the fuel shipped. A listing of the SIMAN summary output is provided, along with an example of the graphics that may be obtained from the SIMAN output files which contain the raw data for the simulation. This is only an example, not a complete listing of the data that may be obtained from the SIMAN output files. More information may be obtained from the output files by using the SIMAN output processor.

REFERENCES

Huber, H. D., et al. 1987. FACSIM/MRS-2: Storage and Shipping Model Documentation and User's Guide. PNL-6003, Pacific Northwest Laboratory, Richland, Washington.

Lotz, T. L., and M. R. Shay. 1987. FACSIM/MRS-1: Cask Receiving and Consolidation Performance Assessment. PNL-6002, Pacific Northwest Laboratory, Richland, Washington.

Mendenhall, W. 1981. Mathematical Statistics with Applications. Duxbury Press, Boston, Massachusetts.

Pegden, D. C. 1985. Introduction to SIMAN. Systems Modeling Corporation, State College, Pennsylvania.

Ross, S. M. 1980. Probability and Mathematical Statistics. Academic Press, Inc., New York, New York.

The Ralph M. Parsons Company. 1985. Conceptual Design Report. Available from the Technical Information Center, Springfield, Virginia.

APPENDIX A

INPUT DATA, CODE LISTING, AND EXAMPLE OUTPUT

APPENDIX A

INPUT DATA, CODE LISTING, AND EXAMPLE OUTPUT

Section A.1 lists the failure frequency and repair data used to form the failure submodel. The SIMAN block commands that form the model of an MRS facility are listed in Section A.2. Section A.3 shows an example of the template used to set up a particular MRS facility scenario for simulation. Section A.4 lists the FORTRAN extension to the MRS model which initializes the simulation variables. An example of a SIMAN summary report generated by a simulation is presented in Section A.5.

A.1 FAILURE FREQUENCY and REPAIR DATA

The following are the raw data used to form the failure submodel.

Disassembly and Consolidation Equipment

Activity Description	Equipment	Component	Frequency	Repair (hr)
Laser cut and trim	Laser	1) Table assem.	6 Mo.	24
		2) Cutter and head	1 Mo.	16
		3) Focusing dev. and sensors	1 Mo.	8
		4) Power pkg. and drive assem.	1 Yr.	16
Secondary waste handling	Disassem. and waste robot	1) Gripper effector	3 Mo.	8
		2) Ball screw	1 Yr.	16
		3) Power pkg.	1 Yr.	16
		4) Arms/extenders	3 Mo.	24
Extract spent-fuel element (SFE) and group SFE for reordering	Fuel consol. equip.	1) Vert. and horz. combs and drive assem.	6 Mo.	24
		2) Lowering strap	6 Mo.	24
		3) Forming dies	6 Mo.	24
		4) Pneumatic	1 Yr.	16
		cylinder	1 Yr.	16
		5) Grippers	1 Mo.	20
		6) Pull mech.	6 Mo.	20

		7) Elec. and pneumatic conn.	1 Yr.	1
		8) Ball screw	1 Yr.	16
Upender module	Upender equip. (designed for unit removal)	1) Pivot assem.	6 Mo.	16
		2) Gear galling	1 Yr.	20
		3) Clamping blocks	6 Mo.	40
		4) Misc. cables and tubing	1 Yr.	16
		5) Bearings	5 Yr.	25
		6) Upender table	1 Yr.	24

Welder Station Failures

Activity Description	Equipment	Component	Frequency	Repair (hr)
Receive SFE from extraction (canister handling)	Upender	1) Drive rollers	5 Yr.	80
		2) Bearings and drive pkg.	5 Yr.	80
		3) Canister clamps	6 Mo.	8
Secure canister and weld lid and test	Air tube and lid deliv.	1) Service conn.	3 Mo.	8
		2) Weld equip.	6 Mo.	16
		3) Lid supply equip.	6 Mo.	8
		4) Helium leak detector	6 Mo.	16
		5) Locking/ restraining devices	1 Yr.	16
		6) Drive rollers	1 Yr.	48

Crane Equipment Failures

Component Failure	Frequency	Repair (hr)
1) Major breakdown or planned overhaul	5 Yr.	168
2) Hook fails	5 Yr.	120
3) Break slips/locks	1 Yr.	24
4) Control malfunction	6 Mo.	16
5) Motor problems	5 Yr.	48
6) Travel malfunction	5 Yr.	168
7) Drum wear	5 Yr.	72
8) Power supply	5 Yr.	8
9) Remote monitor inst.	1 Mo.	4
10) TV optics	1 Mo.	4
11) Audio	1 Mo.	4
12) Lights	1 Mo.	4
13) Inspections and mandatory checks	1 Yr.	72

A.2 MRS SIMAN SIMULATION MODEL

The following is a listing of the SIMAN block commands which form the model of an MRS facility.

```
BEGIN,10,10;
;****************************************************************
;        STATION 1 SHUTS A PROCESSING CELL DOWN FOR THE
;        DURATION OF THE SIMULATION IF THE USER WISHES.
;****************************************************************
         STATION,1;
         ALTER:MACH(A(1)),-2:DISPOSE;       REMOVE CELL CASK CARTS
;*****************************************************************
;
;
;    THE FOLLOWING IS THE SUB-MODEL  TO MODEL MACHINE BREAK DOWNS
;
;*****************************************************************
         STATION,18;
BREAK    DELAY:ER(A(1),4);                  OPERATE UNTIL FAIL TIME
BRK      BRANCH,1:
            IF,MR(A(3)).EQ.0,KLL:
            ELSE,DEST;
KLL      DELAY:1:NEXT(BRK);
DEST     ALTER:MACH(A(3)),-1;               REMOVE FAILED MACH FROM SYS
         DELAY:EX(A(2),3);                  FOR REPAIR TIME
         BRANCH,1:
            IF,MR(A(3)).EQ.1,BREAK:
            ELSE,TNON;
TNON     ALTER:MACH(A(3)),+1:NEXT(BREAK);   PLACE MACH BACK IN SYS.
;*****************************************************************
;
;
;   THE FOLLOWING IS A SUB-MODEL TO SHUT DOWN THE FACILITY ON WEEKENDS
;
;*****************************************************************
WK       QUEUE,58;                      WORK FOR 5 DAYS - 24 HRS/DAY
         SCAN:X(22).EQ.0;
CNTROL   BRANCH,1:
            IF,X(22).EQ.1,WK:
            IF,MR(A(1)).EQ.0,FAILCH:
            ELSE,SHDWN;
FAILCH   DELAY:0.2:NEXT(CNTROL);        FAIL MODEL HAS CONTROL
SHDWN    ALTER:MACH(A(1)),-1;
WKEND    QUEUE,60;                      SHUT DOWN FOR WEEKEND
         SCAN:X(22).EQ.1;
         BRANCH,1:
            IF,MR(A(1)).EQ.1,WKBR:
            ELSE,TURNON;
TURNON   ALTER:MACH(A(1)),+1;           RESTORE MACH AND WORK FOR WEEK
```

```
WKBR     QUEUE,57;
         SCAN:X(22).EQ.1:NEXT(WK);
         CREATE;
WKON     ASSIGN:X(22)=1;               SET SCAN CONDITION TO OPERATE
         DELAY:4.7;                    FOR 5 DAYS
         ASSIGN:X(22)=0;               THEN SET TO OFF FOR
         DELAY:2.3:NEXT(WKON);         2 DAYS - THEN TO ON FOR 5
;                                     (IT TAKES 0.3 DAYS TO SHUT DOWN)
;*****************************************************************
;     CREATE ARRIVING SHIPMENTS,ASSIGN SHIPMENT TYPE, AND
;     ROUTE TO THE GATE OF THE MRS FACILITY
;*****************************************************************
         CREATE,X(9):EX(6,1):MARK(4);
         ASSIGN:A(1)=1:NEXT(TRK);      TRUCK ARRIVALS A(1)=1
         CREATE,X(10):EX(7,3):MARK(4);
         ASSIGN:A(1)=2;                RAIL ARRIVALS  A(1)=2
TRK      ASSIGN:A(2)=DP(3,2);          ASSIGN AS PWR(1) OR BWR(2)
         ASSIGN:A(5)=A(2)+(A(1)*2)-2;  FIND PROPER INDEX
         ASSIGN:A(3)=P(2,A(5));        # OF ASSEM IN SHIPMENT
         ASSIGN:A(5)=A(1)+7;
         ASSIGN:J=A(2)+1;
         ROUTE:TR(A(5),1),J;           SEND TO R & H BLDG.
;*****************************************************************
;
;
;      WAIT FOR NEEDED HOT CELL TO BECOME AVAILABLE. IF LAG
;    STORAGE FOR A HOT CELL IS .GT. 400 THE SHIPMENT WAITS FOR
;    ANOTHER HOT CELL OR FOR THE LAG STORAGE TO DECREASE
;
;*****************************************************************
         STATION,2-3;                  GET HC ASSIGNMENT
WAIT     QUEUE,M;
         SELECT,SNB:HC1:HC2;           SELECT LEAST BUSY HC
HC1      SEIZE,3:MACH(M-1):NEXT(CHECK);
HC2      SEIZE,3:MACH(M+1):NEXT(CHK);  GET CART AT HC
CHECK    ASSIGN:A(5)=1;
         BRANCH,1:
            IF,X(M-1).GT.290,REQUE:
            IF,MR(M+7).EQ.0,CON:
            IF,(X(M-1)).GT.(X(M+38)*(X(M+1)+1)),REQUE:
            ELSE,CON;                   IF OVER LAG LIMIT REASSIGN
CHK         ASSIGN:A(5)=2;
            BRANCH,1:
            IF,X(M+1).GT.290,REQUE:
            IF,MR(M+5).EQ.0,CONT:
            IF,(X(M+1)).GT.(X(M+38)*(X(M-1)+1)),REQUE:
            ELSE,CONT;                 IF HC2 LAG FULL WAIT TO UNLOAD
REQUE    BRANCH,2:
             ALWAYS,CART:
             ALWAYS,WAIT;
```

```
CART     DELAY:0.01;                       TO AVOID AN INFINITE LOOP
         BRANCH,1:
             IF,A(5).EQ.1,REASS:
             ELSE,REAC;
REAC     RELEASE:MACH(M+1):DISPOSE;
REASS    RELEASE:MACH(M-1):DISPOSE;
CON      ASSIGN:NS=M-1:NEXT(R);           SEQUENCE FOR HC1 & HC2
CONT     ASSIGN:NS=M+1;                   SEQ FOR HC3 & HC4
R        ASSIGN:J=A(1):MARK(6);           DELAY UNLOAD PREP.
         ROUTE:ED(J),SEQ;
;****************************************************************
;
;    STATION 4-5 OBTAIN THE CORRECT 150 TON CRANE FOR UNLOADING.
;  STATION 10-13 GET CONTROL OF THE PARTICULAR HOT CELL'S PORT.
;  STATION 6-9 GET CONTROL OF THE PARTICULAR HOT CELL'S 20 TON
;  CRANE TO UNLOAD THE ASSEMBLIES FROM THE CASK. WHEN UNLOADING
;  IS FINISHED, WE MOVE TO STATION 14-17 DEPENDING ON THE HC.
;
;******************************************************************
         STATION,4-9;                     CRANE OPERATIONS
         QUEUE,M;
         SEIZE,3:MACH(M+1);               GET 150 OR 20 CRANE
         BRANCH,1:
            IF,M.LT.6,TRAN:
            IF,A(1).EQ.1,TRAN:
            IF,A(1).EQ.2,CASK;
TRAN     DELAY:ED(M):NEXT(PR);             DELAY TRUCK CASK UNLOAD/150CR.
CASK     DELAY:ED(M+6);                     DELAY RAIL CASK UNLOAD
PR       RELEASE:MACH(M+1);
         BRANCH,1:
            IF,M.LT.6,OUTR:
            ELSE,INR;
OUTR     ASSIGN:J=A(1)+9:NEXT(RED);        CHOOSE PROPER DELAY TIME
INR      ASSIGN:J=3;
RED      ROUTE:ED(J),SEQ;
;******************************************************************
;  OBTAIN THE HC PORT
;******************************************************************
         STATION,10-13;                   CLOSE PROPER PORT
         QUEUE,M;
         SEIZE,3:MACH(M+1);               GRAP PORT
         ROUTE:0.0,SEQ:MARK(7);           TIME TO CLOSE THEN NEXT STA.
;*******************************************************************
;
;   WHEN THE DISSASSEMBLY TABLE IS AVAILABLE, THE 20 TON CRANE
; IS PREEMPTED TO LOAD MORE ASSEMBLIES TO THE TABLE. THE WORK
; THAT WAS INTERRUPTED IS SENT TO PREM WITH THE PROCESS TIME
; REMAINING IN ATTRIB. 5. THE 20 TON CRANE THEN FINISHES THE
; WORK AND THE PIECE IS RETURNED TO THE PROPER STREAM.
;
;*****************************************************************
```

```
PREM     BRANCH,1:
            IF,M.LT.11,ONE:
            ELSE,TWO;
ONE      QUEUE,M+21;
         SEIZE,2:MACH(M+1);
         DELAY:A(5):NEXT(PR);
TWO      QUEUE,M+17;
         SEIZE,2:MACH(M-7);
         DELAY:A(5):NEXT(OT);          PREEMPTED ITEM, FINISH PROC.
;*****************************************************************
;
;   STATION 14-17 SERVES TWO PURPOSES. 1) TO FINISH THE PROCESS
; OF RETURNING THE CASK TO THE TRANSPORT, AND 2) TO SPLIT THE
; CASK INTO ASSEMBLIES TO BE CONSOLIDATED.
;
;*****************************************************************
         STATION,14-17;
         BRANCH,5:
            ALWAYS,RCASK:
            ALWAYS,LAG:
            IF,A(1).EQ.2,DUP:
            IF,A(1).EQ.2,DUP:
            ALWAYS,DUP;                 SPLIT INTO CASK AND ASSEM.
;*****************************************************************
;    RCASK COMPLETES THE RETURN OF THE CASK TO THE TRANSPORT
;
;*****************************************************************
RCASK    ASSIGN:J=A(1)+15;
         DELAY:ED(J);                   DECON INSIDE OF CASK
         QUEUE,M;
         SEIZE,2:MACH(M-7);             GET 20 CRANE
         DELAY:TR(21,2);                REPLACE PLUG SHIELD
OT       RELEASE:MACH(M-7);
         RELEASE:MACH(M-3);             OPEN PORT OF HOT CELL
         ASSIGN:J=A(1)+17;
         DELAY:ED(J);                   MOVE TO TRANSPORT & INSPEC.
         ASSIGN:A(5)=M;
         ROUTE:0.0,SEQ;
         STATION,19;
         QUEUE,1;
         SEIZE,3:MACH(5):NEXT(LOAD);    GET PWR 150 CRANE
         STATION,20;
         QUEUE,18;
         SEIZE,3:MACH(6);               GET BWR 150 CRANE
LOAD     DELAY:TR(12,8);                DELAY LOAD TIME
         RELEASE:MACH(M-14);            RELEASE PROPER 150 CRANE
         ASSIGN:J=A(1)+19;
         DELAY:ED(J);                   TIEDOWN CASK ON TRANSPORT
         ASSIGN:M=A(5);
         RELEASE:MACH(M-13);            RELEASE CART
```

```
;****************************************************************
;  THE FOLLOWING TALLY STATEMENTS KEEP TRACK OF THE NEED STATS
; ON PROCESSING TIMES OF THE CASKS. THEY ARE IDENTIFIED IN THE
; EXPERIMENTAL FRAME.
;****************************************************************
         BRANCH,1:
            IF,TNOW.LT.00,DISP:
            ELSE,TALL;                     DISCARD TRANSIENT DATA
DISP     ASSIGN:J=1:DISPOSE;
TALL     TALLY:17,INT(4);
         TALLY:18,INT(6);
         BRANCH,1:
            IF,A(1).EQ.1,TSTAT:
            ELSE,RSTAT;
TSTAT    TALLY:M-13,INT(4);
         TALLY:19,INT(4);
         TALLY:21,INT(6);
         ASSIGN:J=A(2)+22;
         TALLY:J,INT(4);              TR PWR/BWR TURN AR
         ASSIGN:J=A(2)+24;
         TALLY:J,INT(6);              TR PWR/BWR PROC TIME
         TALLY:M-5,INT(6):DISPOSE;
RSTAT    TALLY:M-9,INT(4);
         TALLY:20,INT(4);
         TALLY:22,INT(6);
         ASSIGN:J=A(2)+26;
         TALLY:J,INT(4);              RA PWR/BWR TURN AR
         ASSIGN:J=A(2)+28;
         TALLY:J,INT(6);              RA PWR/BWR PROC TIME
         TALLY:M-1,INT(6):DISPOSE;
;****************************************************************
;   LAG PERFORMS THE DISASSEMBLY PROCESS ON THE ASSEMBLIES TO BE
; CONSOLIDATED. THE DISSASSEMBLY TABLE WAITS UNTIL THE CORRECT
; NUMBER OF ASSEMBLIES IS AVAILABLE, A PARTIAL LOAD IS NOT DONE.
;****************************************************************
LAG      ASSIGN:X(M-13)=X(M-13)+A(3);     ADD ASSEM. TO LAG STORE
DUP      QUEUE,M+5,60;
         SEIZE,2:MACH(M+1);               GET TABLE TO LOAD
         BRANCH,1:
            IF,X(M-13).LT.X(M-9),NOPROC:
            ELSE,PROC;
NOPROC   RELEASE:MACH(M+1):DISPOSE;        NOT ENOUGH ASSEM.
;
PROC     QUEUE,M+9;
         PREEMPT,3:MACH(M-7),5,PREM;      GET 20 CRANE
         ASSIGN:J=M+8;
         DELAY:ED(J);                     LOAD TABLE
         ASSIGN:X(M-13)=X(M-13)-X(M-9);   REDUCE LAG BY LOADED ASSEM.
         RELEASE:MACH(M-7);
         ASSIGN:J=M+12;
         DELAY:ED(J);                     PROCESS ASSEM. ON TABLE
```

```
        RELEASE:MACH(M+1);
        ROUTE:0.0,SEQ;
        STATION,21-22;
WLD     QUEUE,M+14;
        SEIZE,2:MACH(M-2)                GET WELDING STATION
        DELAY:TR(34,7);                  PROCESS THE CANISTER
        RELEASE:MACH(M-2);
;*******************************************************************
;   KEEP STATS ON THE TIME FOR PROCESSING A SHIPMENT FROM THE TIME
; THE SHIPMENT REACHES THE GATE UNTIL A CANISTER IS SENT FOR THE
; WELDING STATION.
;*******************************************************************
        BRANCH,1:
           IF,TNOW.LT.00,DISPSE:
           ELSE,TLLY;                     DISCARD TRANSIENT DATA
DISPSE  ASSIGN:J=1:DISPOSE;
TLLY    TALLY:31,INT(4):DISPOSE;          TRACK CASK-IN-CAN-OUT TIME
END;
```

A.3 USER EXPERIMENTAL FRAME INPUT

The following is an example of the template which the user will use to set up a particular MRS facility scenario to simulate. The user will usually enter only those parameters which change in the PARAMETERS and the PROJECTS cards. The rest of the cards should rarely need to be altered.

```
BEGIN,10,10;
PROJECT,TEST 36 bat 11      ,tl lotz,12/11/85;
DISCRETE,1100,7,75,20;
PARAMETERS:1,0,0,0,0,0:      2,0,0,0,0:       !RECEIPT RATE DATA & CASK CAP
           3,0,0,0,0:     4,0,0,0,0:       !INT. # ASS. IN LAG & TABLE CAP.
           5,0,0,0,.2,.2:  6,0: 7,0:       !CASK ARRIVAL DATA
           8,0,0,0: 9,0,0,0: 10,0,0,0: 11,0,0,0:  !PROCESS TIME PARAM. POS.
          12,0,0,0:13,0,0,0: 14,0,0,0: 15,0,0,0:
          16,0,0,0:17,0,0,0: 18,0,0,0: 19,0,0,0:
          20,0,0,0:21,0,0,0: 22,0,0,0: 23,0,0,0:
          24,0,0,0:25,0,0,0: 26,0,0,0: 27,0,0,0:
          28,0,0,0:29,0,0,0: 30,0,0,0: 31,0,0,0:
          32,0,0,0:33,0,0,0: 34,0,0,0:
          35,0,0: 36,0,0: 37,0,0: 38,0,0: 39,0,0: 40,0,0: !FAIL FREQ PARAM
          41,0,0: 42,0,0: 43,0,0: 44,0,0: 45,0,0:
          46,0: 47,0: 48,0: 49,0: 50,0: 51,0: 52,0:       !REPAIR TIME PARAM
          53,0: 54,0: 55,0: 56,0:
          57,0;                                 !ADDITIONAL USER FAIL. DATA
```

```
TALLIES:1,HC1 TR TURN AR  :2,HC2 TR TURN AR  :3,HC3 TR TURN AR  :
      4,HC4 TR TURN AR   :5,HC1 RA TURN AR   :6,HC2 RA TURN AR   :
       7,HC3 RA TURN AR   :8,HC4 RA TURN AR   :9,HC1 TR CSK PROC   :
      10,HC2 TR CSK PROC   :11,HC3 TR CSK PROC   :12,HC4 TR CSK PROC   :
      13,HC1 RA CSK PROC   :14,HC2 RA CSK PROC   :15,HC3 RA CSK PROC   :
      16,HC4 RA CSK PROC   :17,AVE CSK TURN AR   :18,AVE CSK PROC   :
      19,AVE TR TURN AR   :20,AVE RA TURN AR   :21,AVE TR CSK PROC   :
      22,AVE RA CSK PROC   :23,AVE PWR TR TN AR,29:
      24,AVE BWR TR TN AR,30:25,AVE PWR TR PROC,31:
      26,AVE BWR TR PROC,32:27,AVE PWR RA TN AR,33:
      28,AVE BWR RA TN AR,34:29,AVE PWR RA PROC,35:
      30,AVE BWR RA PROC,36:31,CASK IN CAN OUT   ;
DSTAT:1,X(1),HC1 LAG STORE,11:2,X(2),HC2 LAG STORE,12:
   3,X(3),HC3 LAG STORE:4,X(4),HC4 LAG STORE:5,NQ(2),# FOR PWR CART,13:
      6,NQ(3),# FOR BWR CART,14:7,NR(7),HC1 CR20 UTIL   :
      8,NR(8),HC2 CR20 UTIL   :9,NR(9),HC3 CR20 UTIL   :
      10,NR(10),HC4 CR20 UTIL   :11,NR(5),PWR CR150 UTIL   :
      12,NR(6),BWR CR150 UTIL   :13,NR(15),HC1 TABLE UTIL   :
      14,NR(16),HC2 TABLE UTIL   :15,NR(17),HC3 TABLE UTIL   :
      16,NR(18),HC4 TABLE UTIL   :17,NR(19),PWR WELD UTIL:
      18,NR(20),BWR WELD UTIL:19,NQ(35),PWR WELD QUEUE,15:
      20,NQ(36),BWR WELD QUEUE,16;
DISTRIBUTIONS:1,TR(10,1):2,TR(11,2):3,CO(57):4,TR(12,1):5,TR(12,2):
       6,TR(15,3):7,TR(16,4):8,TR(15,8):9,TR(16,6):10,TR(13,7):
       11,TR(14,8):12,TR(17,9):13,TR(18,1):14,TR(17,2):15,TR(18,3):
       16,TR(19,4):17,TR(20,1):18,TR(22,6):19,TR(23,7):20,TR(24,8):
       21,TR(25,9):22,TR(26,1):23,TR(27,2):24,TR(28,1):25,TR(29,2):
       26,TR(30,3):27,TR(31,4):28,TR(32,3):29,TR(33,4);
RESOURCES:1-20,MACH,2,2,2,2,1,1,1,1,1,1,1,1,1,1,1,1;
REPLICATE,1,0,4015;
SEQUENCES:1,4/10/6/14/19/21:2,5/11/7/15/20/22:3,4/12/8/16/19/21:
          4,5/13/9/17/20/22;
RANKINGS:2-3,HVF(4):37-38,HVF(4):71-72,HVF(4);
END;
```

A.4 FORTRAN INITIALIZATION ROUTINE

The following code is a listing of the FORTRAN extension to the MRS model which initializes the simulation variables. The array PARA contains all of the default values for the PARAMETERS card in the user's experimental frame input. The array is arranged such that PARA(POS, PSET) is the default value for position POS in parameter set number PSET.

```
      SUBROUTINE PRIME

      COMMON / SIM/ D( 50), DL( 50), S( 50), SL( 50), X( 50)
     *            , DTNOW, TNOW, TFIN, J, NRUN

      REAL PARA(3,100), MTU(2), TEMP(5), TIME, WORK, TP, TB,
     *  RP, RB, TRA, RAA, CAP(5)

      DATA TRA / 0/, RAA / 0/, RB / 0/, RP / 0/, TB / 0/, TP / 0/,
     *  WORK / 0/, TIME / 0/, TEMP / 5*0/, MTU / 0.462 , 0.186/
      DATA CAP /5*0/, PARA / 21*0,
     *        0.0569, 0.06389, 0.07083, 0.06458, 0.07153, 0.07847,
     *        0.04167, 0.05208, 0.0625, 0.0625, 0.07292, 0.08333,
     *        0.02222, 0.0243, 0.02708, 0.07639, 0.07986, 0.09028,
     *        0.09375, 0.09722, 0.10774, 0.04514, 0.04861, 0.0556,
     *        0.06944, 0.07292, 0.08333, 0.18403, 0.19444, 0.21528,
     *        0.3472, 0.3611, 0.4167, 0.01944, 0.02083, 0.02431,
     *        0.03819, 0.04167, 0.04722, 0.00972, 0.01042, 0.01181,
     *        0.09028, 0.09722, 0.10764, 0.10764, 0.11806, 0.13194,
     *        0.03819, 0.04514, 0.05556, 0.05208, 0.0625, 0.07639,
     *        0.02778, 0.03125, 0.03611, 0.06597, 0.07292, 0.08333,
     *        0.02778, 0.03125, 0.03611, 0.06597, 0.07292, 0.08333,
     *        0.15625, 0.16319, 0.18056, 0.29514, 0.3021, 0.3333,
     *        0.15625, 0.16319, 0.18056, 0.29514, 0.3021, 0.3333,
     *        0.01736, 0.02083, 0.02778, 30.5, 3, 0, 91.5, 2, 0,
     *        183, 7, 0, 365, 8, 0, 91.5, 1, 0, 183, 4, 0, 365, 4, 0,
     *        30.5, 4, 0, 183, 1, 0, 365, 1, 0, 1830, 6, 0,
     *        1.8333, 0, 0, 1.3333, 0, 0, 7.167, 0, 0, 5.833, 0, 0,
     *        0.3333, 0, 0, 2, 0, 0, 5.667, 0, 0, 0.6667, 0, 0,
     *        0.6667, 0, 0, 1.0, 0, 0, 24.306, 0, 0, 132*0/

      NRUN = 1
      X(22) = 1.0
C
C                 SET UP TRUCK AND RAIL CASK CAPACITIES
C
      IF( P(2,1).EQ.0) THEN
                     CALL SETP(2,1,FLOAT(2))
                     CAP(1) = 2
              ELSE
                     CAP(1) = P(2,1)
                     PARA(2,15) = ( P(2,1)*20.0 )/ 24
                     PARA(1,15) = PARA(2,15)*0.9
                     PARA(3,15) = PARA(2,15)*1.18
            ENDIF
      IF( P(2,2).EQ.0) THEN
                     CALL SETP(2,2,FLOAT(5))
                     CAP(2) = 5
```

```
             ELSE
                    CAP(2) = P(2,2)
                    PARA(2,16) = ( P(2,2)*20.0 )/ 24
                    PARA(1,16) = PARA(2,16)*0.9
                    PARA(3,16) = PARA(2,16)*1.18
           ENDIF
      IF( P(2,3).EQ.0) THEN
                    CALL SETP(2,3,FLOAT(12))
                    CAP(3) = 12
              ELSE
                    CAP(3) = P(2,3)
                    PARA(2,17) = ( P(2,3)*15.0 )/ 24
                    PARA(1,17) = PARA(2,17)*0.9
                    PARA(3,17) = PARA(2,17)*1.18
           ENDIF
      IF( P(2,4).EQ.0) THEN
                    CALL SETP(2,4,FLOAT(32))
                    CAP(4) = 32
              ELSE
                    CAP(4) = P(2,4)
                    PARA(2,18) = ( P(2,4)*15.0 )/ 24
                    PARA(1,18) = PARA(2,18)*0.9
                    PARA(3,18) = PARA(2,18)*1.18
           ENDIF
C
C                  INITIALIZE LAG STORAGE OF EACH PROCESSING CELL
C
      X(1) = P(3,1)
      X(2) = P(3,2)
      X(3) = P(3,3)
      X(4) = P(3,4)
      DO 5 I = 1, 4
            IF( X(I).LT.0 ) THEN
               CALL CREATE( L)
               CALL SETA(L, 1, FLOAT(I))
               CALL ENTER( L, 1)
               X(I) = 0.0
             ENDIF
    5  CONTINUE
C
C                  SET UP PROCESS CELL DISASSEMBLY TABLE CAPACITY
C
      IF( P(4,1).EQ.0) THEN
                     X(5) = 3
               ELSE
                     X(5) = P(4,1)
                     PARA(2,26) = (X(5)*15)/24
                     PARA(1,26) = PARA(2,26)*0.9
                     PARA(3,26) = PARA(2,26)*1.15
                     PARA(2,30) = (( X(5)*50)+85)/ 24
```

```
                    PARA(1,30) = PARA(2,30)*0.95
                    PARA(3,30) = PARA(2,30)*1.17
         ENDIF
      IF( P(4,2).EQ.0) THEN
                    X(6) = 7
               ELSE
                    X(6) = P(4,2)
                    PARA(2,27) = (X(6)*15)/24
                    PARA(1,27) = PARA(2,27)*0.9
                    PARA(3,27) = PARA(2,27)*1.15
                    PARA(2,31) = (( X(6)*50)+110)/ 24
                    PARA(1,31) = PARA(2,31)*0.95
                    PARA(3,31) = PARA(2,31)*1.17
         ENDIF
      IF( P(4,3).EQ.0) THEN
                    X(7) = 3
               ELSE
                    X(7) = P(4,3)
                    PARA(2,28) = (X(7)*15)/24
                    PARA(1,28) = PARA(2,28)*0.9
                    PARA(3,28) = PARA(2,28)*1.15
                    PARA(2,32) = (( X(7)*50)+85)/ 24
                    PARA(1,32) = PARA(2,32)*0.95
                    PARA(3,32) = PARA(2,32)*1.17
         ENDIF
      IF( P(4,4).EQ.0) THEN
                    X(8) = 7
               ELSE
                    X(8) = P(4,4)
                    PARA(2,29) = (X(8)*15)/24
                    PARA(1,29) = PARA(2,29)*0.9
                    PARA(3,29) = PARA(2,29)*1.15
                    PARA(2,33) = (( X(8)*50)+110)/ 24
                    PARA(1,33) = PARA(2,33)*0.95
                    PARA(3,33) = PARA(2,33)*1.17
         ENDIF
C
C              CALCULATE INTER-ARRIVAL PARAMETERS
C
      WORK = P(5,1)
      X(9) = P(5,2)
      IF( X(9).EQ.0 ) X(9) = 1
      X(10) = P(5,3)
      IF( X(10).EQ.0 ) X(10) = 1
      X(40) = P(5,4) + 1
      IF( X(40).LE.0 ) X(40) = 1000
      X(41) = P(5,5) + 1
      IF( X(41).LT.0 ) X(41) = 1000
```

```
      DO 10 I = 1, 5
         TEMP(I) = P(1,I)
         IF( TEMP(I).EQ.0 ) TEMP(I) = 0.5
   10  CONTINUE
      IF( TEMP(5).EQ.0.5 ) TEMP(5) = 3600

      CALL SETP( 3,1,TEMP(1))
      CALL SETP( 3,2,FLOAT(1))
      CALL SETP( 3,3,1.0)
      CALL SETP( 3,4,FLOAT(2))

      TP = (( TEMP(5)*TEMP(1))*TEMP(3)) / ( MTU(1)*CAP(1))
      RP = (( TEMP(5)*TEMP(1))*TEMP(4)) / ( MTU(1)*CAP(3))
      TB = (( TEMP(5)*TEMP(2))*TEMP(3)) / ( MTU(2)*CAP(2))
      RB = (( TEMP(5)*TEMP(2))*TEMP(4)) / ( MTU(2)*CAP(4))
      TRA = ( 365/(TP+TB) )*X(9)
      RAA = ( 365/(RP+RB) )*X(10)

      CALL SETP(6,1,TRA)
      CALL SETP(7,1,RAA)
C
C              CHECK FOR NEW PROCESS TIME PARAMETERS
C
      DO 15 I = 8, 34
         DO 15 J = 1, 3
            TIME = P(I,J)
            IF ( TIME.EQ.0 ) CALL SETP(I,J,PARA(J,I))
   15  CONTINUE
C
C              SET UP WEEKEND SHUT DOWN MODEL
C
      IF ( WORK.GT.0 ) THEN
            DO 20 I = 5, 20
               IF ( I.GT.10 .AND. I.LT.15 ) GOTO 20
               CALL CREATE(L)
               CALL SETA(L,1,FLOAT(I))
               CALL QUEUE(L,58)
   20  CONTINUE
       ENDIF
C
C              CREATE CONTROL ENTITIES FOR FAILURE SUB MODEL
C       CRANES:
C
      DO 25 I = 5, 10
          J = 42
          K = 53
          DO 25 M = 1, 4
             CALL CREATE( L)
             CALL SETA(L,1,FLOAT(J))
             CALL SETA(L,2,FLOAT(K))
             CALL SETA(L,3,FLOAT(I))
```

```
              CALL ENTER(L,18)
              J = J + 1
              K = K +1
   25   CONTINUE
C
C
C       DISASSEMBLY TABLES AND WELDERS
C
      DO 30 I = 15, 20
          IF ( I.GE.19) THEN
               J = 39
               K = 50
            ELSE
               J = 35
               K = 46
           ENDIF
          DO 30 M = 1, 4
              IF ( I.GE.19 .AND. M.EQ.4 ) GOTO 30
              CALL CREATE(L)
              CALL SETA(L,1,FLOAT(J))
              CALL SETA(L,2,FLOAT(K))
              CALL SETA(L,3,FLOAT(I))
              J = J + 1
              K = K + 1
              CALL ENTER(L,18)
   30    CONTINUE
C
C                  CHECK FOR ADDITIONAL FAILURE DATA
C
      I = P(57,1)
      IF ( I.GT.0 ) THEN
          DO 35 K = 2, I+1
              M = P(57, K)
              N = 56
              CALL CREATE( L)
              CALL SETA(L,1,FLOAT(N+K))
              CALL SETA(L,2,FLOAT(N+K+1))
              CALL SETA(L,3,FLOAT(M))
              CALL ENTER(L,18)
              N = N + 2
   35      CONTINUE
        ENDIF
C
C                   PLACE DEFAULT FAIL PARAMETERS INTO PLACE
C
      DO 40 I = 35, 45
          IF( P(I,1).EQ.0 ) CALL SETP(I,1,PARA(1,I))
          IF( P(I,2).EQ.0 ) CALL SETP(I,2,PARA(2,I))
   40  CONTINUE
      DO 45 I = 46, 56
          IF( P(I,1).EQ.0 ) CALL SETP(I,1,PARA(1,I))
```

```
45  CONTINUE
    CALL SETP(57,1,FLOAT(0))

    END
```

A.5 EXAMPLE OUTPUT FROM THE MRS MODEL

The following is an example of a SIMAN summary report generated by a simulation.

SIMAN Summary Report
Run Number 1 of 1

Project: WKEND 361 T R 5 5
Analyst: TL LOTZ
Date: 8/23/1985

Run ended at time: .4015E+04

Tally Variables

Number	Identifier	Average	Standard Deviation	Minimum Value	Maximum Value	Number of Obs.
1	HC1 TR TURN AR	.61001	.31308	.44629	6.11572	5658
2	HC2 TR TURN AR	.85990	.86830	.47351	14.01965	5510
3	HC3 TR TURN AR	.61877	.40379	.44617	7.78516	5087
4	HC4 TR TURN AR	.88492	1.04841	.47241	15.92480	5239
5	HC1 RA TURN AR	.87652	.34920	.69995	4.77405	870
6	HC2 RA TURN AR	1.33910	.99452	.88757	14.52429	848
7	HC3 RA TURN AR	.87164	.46674	.69434	8.00269	812
8	HC4 RA TURN AR	1.32653	.95850	.88330	11.97888	868
9	HC1 TR CSK PROC	.44005	.13796	.38379	3.33716	5658
10	HC2 TR CSK PROC	.50935	.16042	.40857	3.80908	5510
11	HC3 TR CSK PROC	.44144	.13054	.38574	4.96033	5087
12	HC4 TR CSK PROC	.51608	.16800	.41211	4.04443	5239
13	HC1 RA CSK PROC	.68035	.11502	.62622	2.23145	870
14	HC2 RA CSK PROC	.94473	.16373	.81256	2.82959	848
15	HC3 RA CSK PROC	.68350	.16609	.62085	4.95776	812
16	HC4 RA CSK PROC	.96255	.19778	.80432	3.30573	868
17	AVE CSK TURN AR	.79265	.75358	.44617	15.92480	24892
18	AVE CSK PROC	.52343	.20139	.38379	4.96033	24892
19	AVE TR TURN AR	.74315	.73636	.44617	15.92480	21494
20	AVE RA TURN AR	1.10575	.78543	.69434	14.52429	3398
21	AVE TR CSK PROC	.47668	.15433	.38379	4.96033	21494
22	AVE RA CSK PROC	.81917	.21251	.62085	4.95776	3398
23	AVE PWR TR TN AR	.61415	.35892	.44617	7.78516	10745
24	AVE BWR TR TN AR	.87210	.96035	.47241	15.92480	10749
25	AVE PWR TR PROC	.44071	.13450	.38379	4.96033	10745
26	AVE BWR TR PROC	.51263	.16418	.40857	4.04443	10749
27	AVE PWR RA TN AR	.87416	.41005	.69434	8.00269	1682

28	AVE BWR RA TN AR	1.33274	.97620	.88330	14.52429	1716
29	AVE PWR RA PROC	.68187	.14195	.62085	4.95776	1682
30	AVE BWR RA PROC	.95374	.18192	.80432	3.30573	1716
31	CASK IN CAN OUT	2.557733	.44374	.46509	28.57080	29401

Discrete Change Variables

Number	Identifier	Average	Standard Deviation	Minimum Value	Maximum Value	Number of Obs.
1	HC1 LAG STORE	2.53	3.22	.00	28.00	4015.00
2	HC2 LAG STORE	20.34	20.99	.00	149.00	4015.00
3	HC3 LAG STORE	2.65	3.85	.00	39.00	4015.00
4	HC4 LAG STORE	20.63	21.05	.00	152.00	4015.00
5	# FOR PWR CART	.02	.26	.00	9.00	4015.00
6	# FOR BWR CART	.04	.33	.00	11.00	4015.00
7	HC1 CR20 UTIL	.19	.39	.00	1.00	4015.00
8	HC2 CR20 UTIL	.34	.47	.00	1.00	4015.00
9	HC3 CR20 UTIL	.17	.38	.00	1.00	4015.00
10	HC4 CR20 UTIL	.34	.47	.00	1.00	4015.00
11	PWR CR150 UTIL	.15	.36	.00	1.00	4015.00
12	BWR CR150 UTIL	.15	.36	.00	1.00	4015.00
13	HC1 TABLE UTIL	.36	.48	.00	1.00	4015.00
14	HC2 TABLE UTIL	.75	.43	.00	1.00	4015.00
15	HC3 TABLE UTIL	.33	.47	.00	1.00	4015.00
16	HC4 TABLE UTIL	.74	.44	.00	1.00	4015.00
17	PWR WELD UTIL	.08	.27	.00	1.00	4015.00
18	BWR WELD UTIL	.08	.28	.00	1.00	4015.00
19	PWR WELD QUEUE	.03	.38	.00	13.00	4015.00
20	BWR WELD QUEUE	.04	.71	.00	23.00	4015.00

Stop - Program terminated.

Figures A.1 through A.8 were generated by LOTUS using the SIMAN data files created with the TALLIES and DSTAT cards. The raw data generated were compressed to yield time averages based on quarters of a year for the DSTAT variables using a user-programed routine. The histograms were generated using the SIMAN output processor OUTPT, and the resulting files were then used by LOTUS to generate the plots.

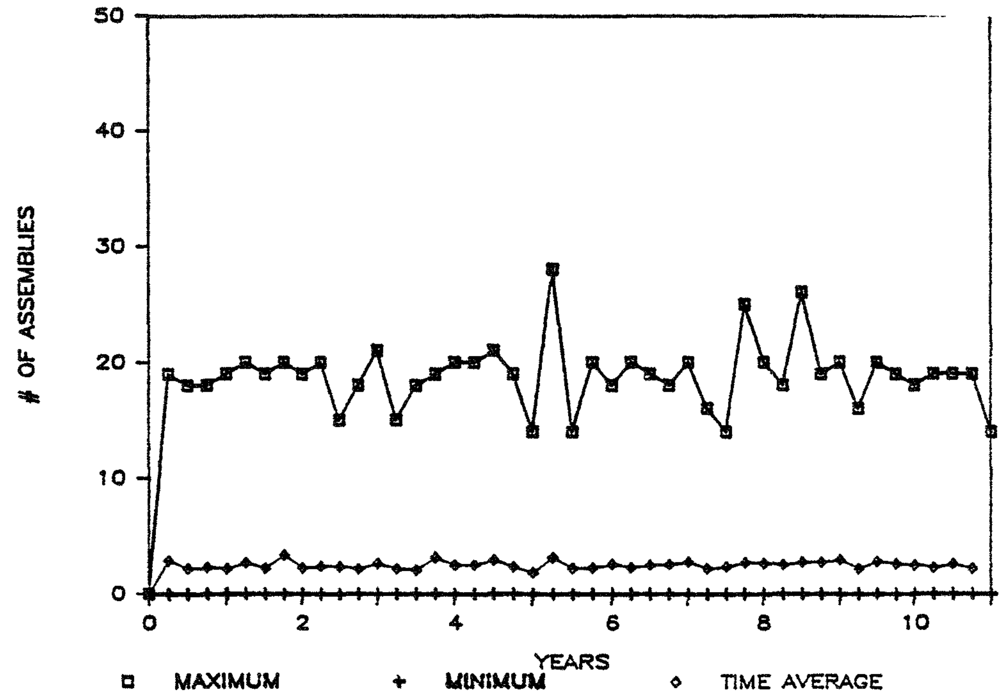

FIGURE A.1. PWR Lag Storage: 3600 MTU/yr, Truck/Rail Split - 50/50

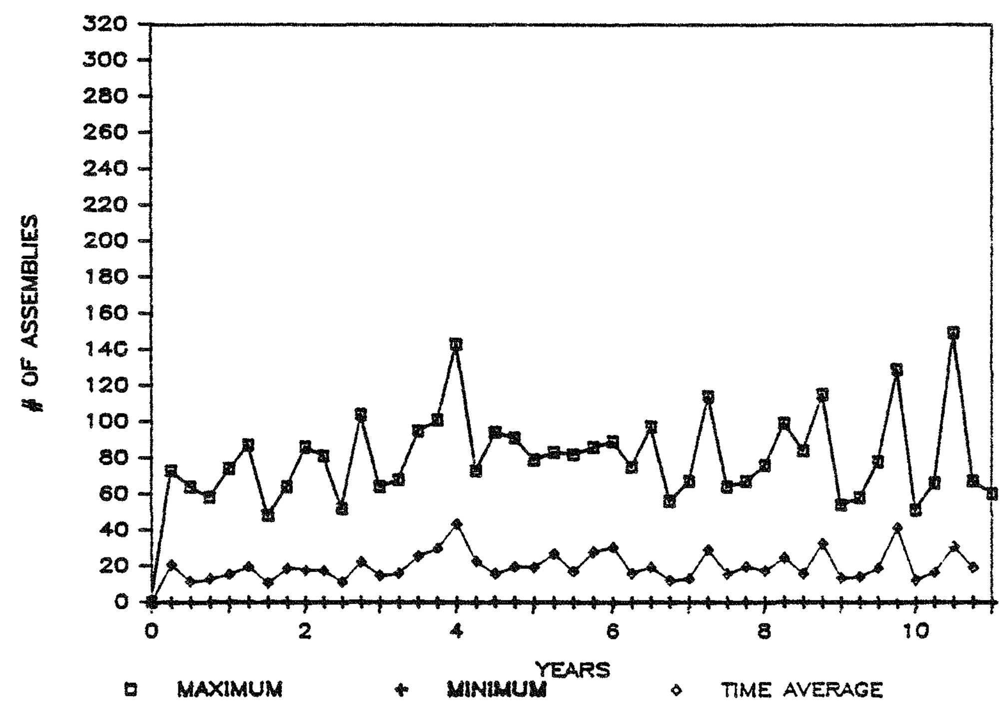

FIGURE A.2. BWR Lag Storage: 3600 MTU/yr, Truck/Rail Split - 50/50

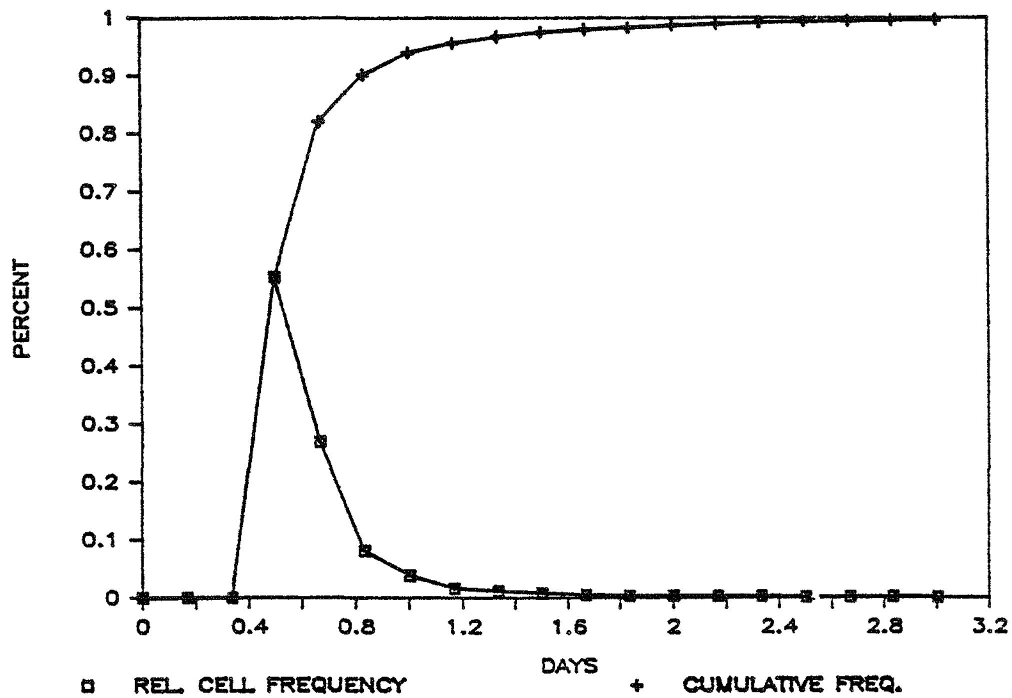

FIGURE A.3. PWR Truck Turnaround: 3600 MTU/yr, Truck/Rail Split - 50/50

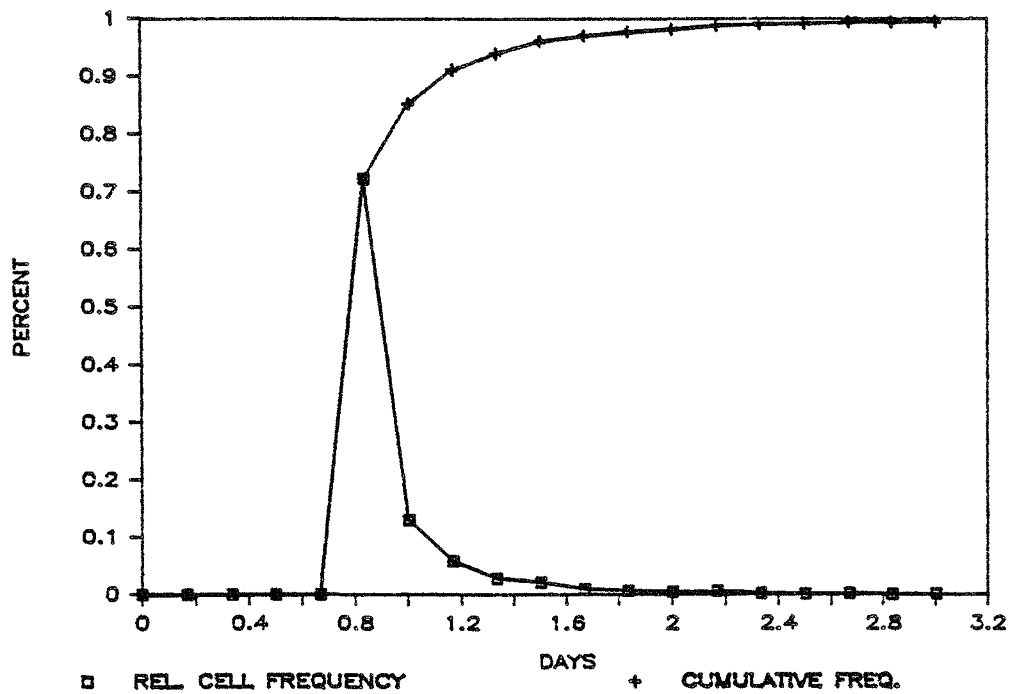

FIGURE A.4. PWR Rail Turnaround: 3600 MTU/yr, Truck/Rail Split - 50/50

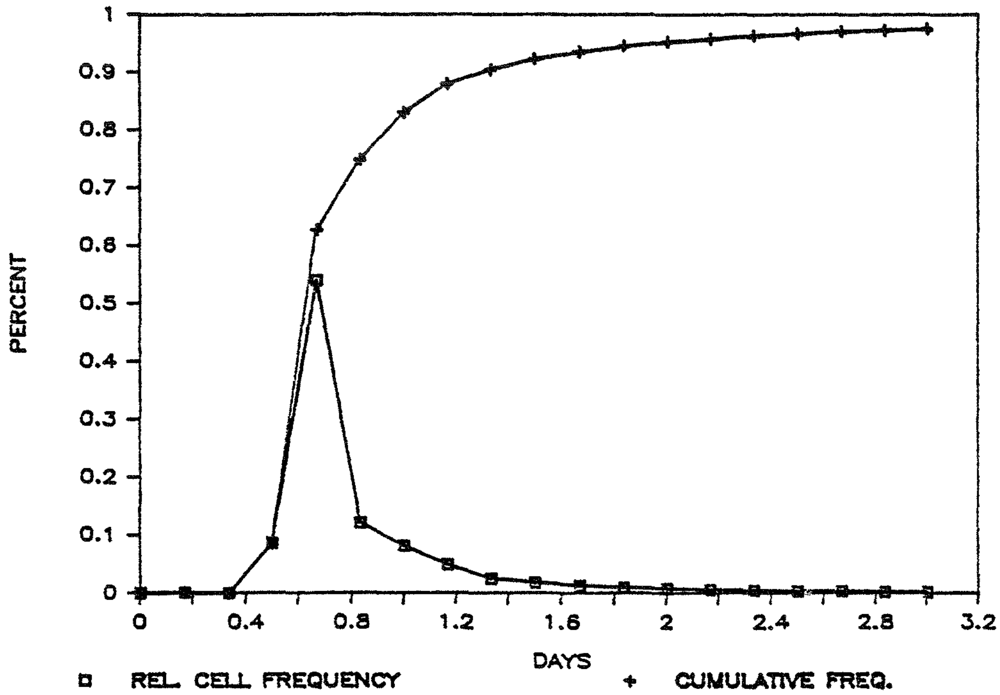

FIGURE A.5. BWR Truck Turnaround: 3600 MTU/yr, Truck/Rail Split - 50/50

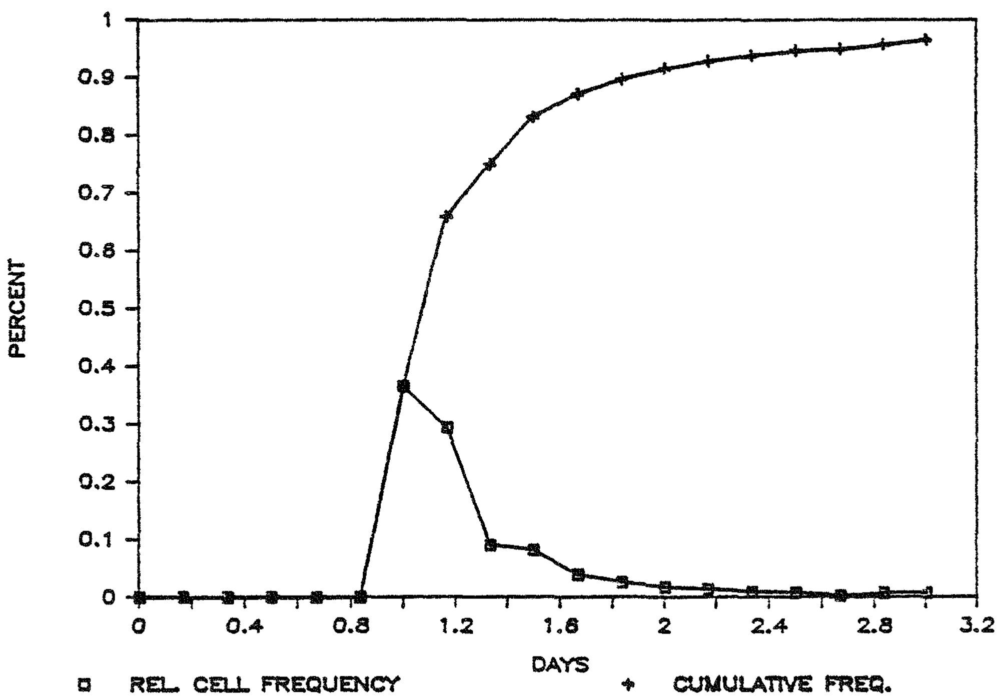

FIGURE A.6. BWR Rail Turnaround: 3600 MTU/yr, Truck/Rail Split - 50/50

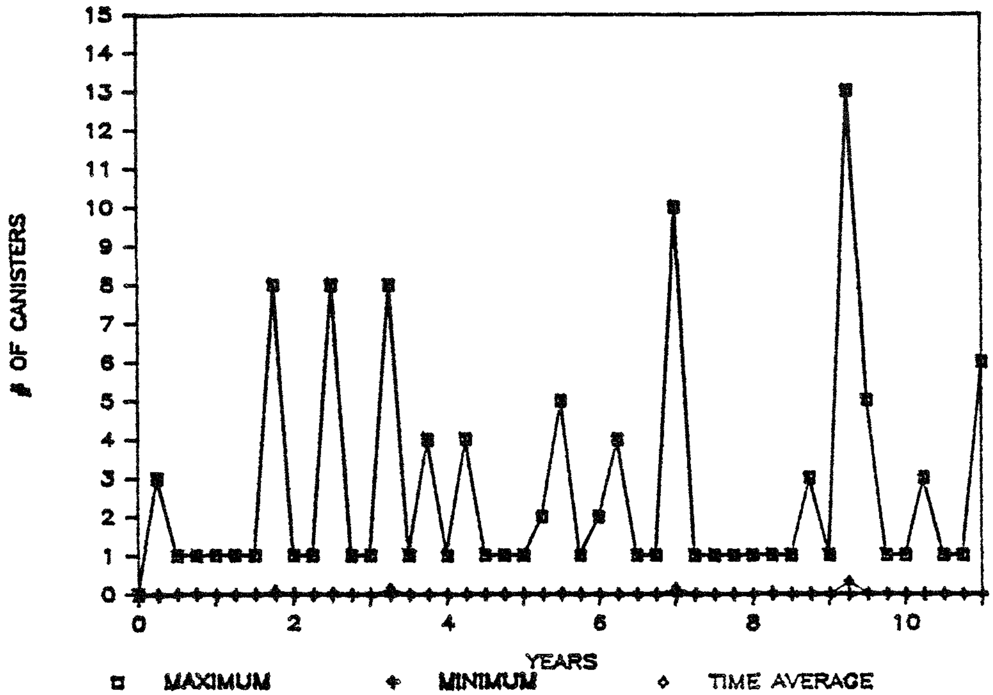

FIGURE A.7. PWR Welder Queue: 3600 MTU/yr, Truck/Rail Split - 50/50

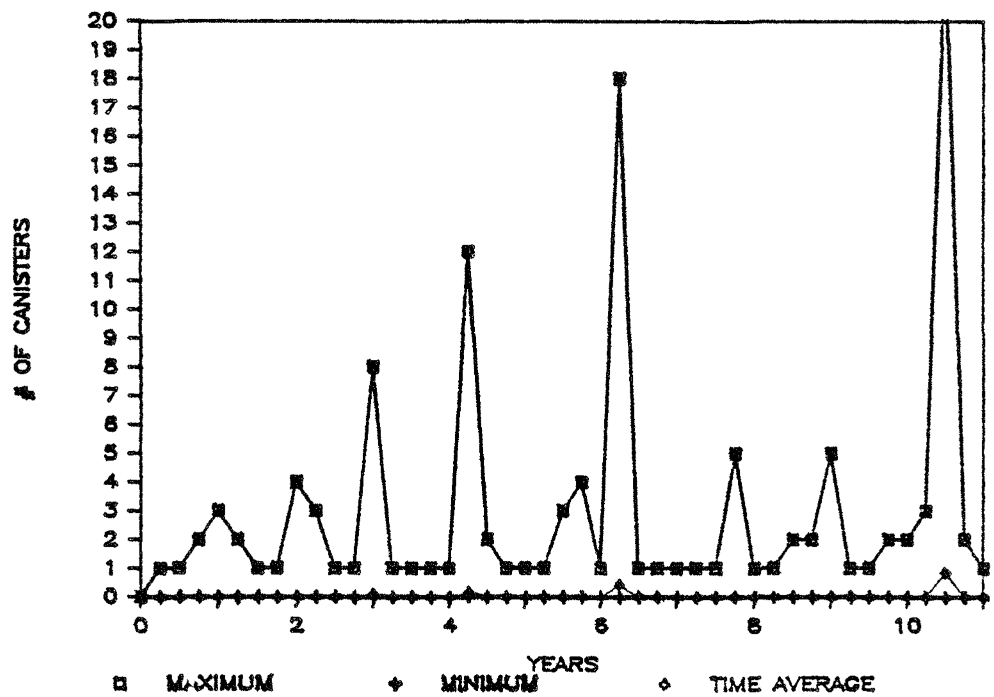

FIGURE A.8. BWR Welder Queue: 3600 MTU/yr, Truck/Rail Split - 50/50

APPENDIX B

QUEUES, STATIONS, AND VARIABLES IDENTIFICATION

APPENDIX B

QUEUES, STATIONS, AND VARIABLES IDENTIFICATION

In the following sections, the queue numbers and station numbers used by the front-end simulation model are described. Also, the variables available for use in SIMAN are discussed.

B.1 QUEUES

Within a model, SIMAN provides blocks which hold items waiting for a condition to be realized, such as a machine becoming available for use. These blocks are called queues and are identified by a register number which SIMAN associates with the block. Queue numbers of interest in the MRS model are listed below. Not all queue numbers have been listed. The user should never need to have access the queues within the weekend or failure submodels.

Description of Queue		Queue Number
Casks waiting for carts from process cells 1 & 3		2
Casks waiting for carts from process cells 2 & 4		3
Casks waiting to be loaded onto a cart with the 150-ton crane which serves cells 1 & 3		4
Casks waiting to be loaded onto a cart with the 150-ton crane which serves cells 2 & 4		5
Casks waiting for the 20-ton crane to unload spent-fuel assemblies into process cell lag storage:	cell 1	6
	cell 2	7
	cell 3	8
	cell 4	9
Casks waiting for the single entry port door to close for processing cell:	cell 1	10
	cell 2	11
	cell 3	12
	cell 4	13

Description of Queue	Queue Number
Canisters waiting for the PWR welder	35
Canisters waiting for the BWR welder	36

B.2 STATIONS

In the model, SIMAN provides blocks which act as markers or labels so that items may easily be routed through a series of processes with the SEQUENCES card in the experimental frame. These blocks are called stations and are identified by an integer number. The station numbers used by the MRS model are given below with a description of the station.

Description of Station		Station Number
The process cells which the user specifies as inactive in the experimental frame. The user should NEVER route to this station.		1
Receiving area for process cells 1 & 3. The user does not have to route shipments to station 2 because the model handles all arriving shipments automatically.		2
Receiving area for process cells 2 & 4. The user does not have to route shipments to station 3 because the model handles all arriving shipments automatically.		3
PWR (cells 1 & 3) 150-ton crane lifts casks onto cask carts.		4
BWR (cells 2 & 4) 150-ton crane lifts casks onto cask carts.		5
Unloading of spent-fuel assemblies from shipping casks using the 20-ton crane in process cell:	cell 1	6
	cell 2	7
	cell 3	8
	cell 4	9
Obtaining the single unloading door so that cask unloading may occur for process cell:	cell 1	10
	cell 2	11
	cell 3	12
	cell 4	13

Description of Station		Station Number
Return of the cask to cart and the sending of spent-fuel assemblies to the disassembly station for process cell:	cell 1	14
	cell 2	15
	cell 3	16
	cell 4	17
Failure submodel. The user should NEVER route a shipment to this station.		18
PWR (cells 1 & 3) 150-ton crane lifts a cask from a cask cart to a cask carrier.		19
BWR (cells 2 & 4) 150-ton crane lifts a cask from a cask cart to a cask carrier.		20
PWR canister welding station		21
BWR canister welding station		22

B.3 GENERAL VARIABLES

SIMAN has a few general-purpose variables available to the user. The MRS model uses the X array variable. Other variables are available with the model and if more information is desired, refer to Introduction to SIMAN (Pegden 1985). The MRS model uses the following X variable to track the number of spent-fuel assemblies in lag storage:

X(1) - Process cell 1 spent-fuel-assembly lag storage
X(2) - Process cell 2 spent-fuel-assembly lag storage
X(3) - Process cell 3 spent-fuel-assembly lag storage
X(4) - Process cell 4 spent-fuel-assembly lag storage

B.4 USE OF THE SEQUENCES, DSTAT, AND TALLIES CARDS

The SEQUENCES card is easily used if the user has the information on identifying the stations through which a shipment may be routed (Section B.2). However, an assembly which enters a processing cell must undergo all processing steps within the same process cell. To set up a routing sequence, simply place the station numbers, in the order in which the stations are to be visited, into each of the sequence set numbers on the SEQUENCES card. All shipments are moved into the receiving area of the R&H building by the model. The user then chooses which 150-ton crane, which process cells, and which welder the cask and its cargo will use.

The DSTAT card is used to keep track of time-varying statistics. Several system status variables are available for use in SIMAN. Those directly usable by the MRS model are listed below. If the user wants more information concerning what SIMAN has available, refer to Introduction to SIMAN (Pegden 1985).

NE(N) - Number of items enroute to station number N

NR(N) - Number of busy units of resource number N (The resource number of a particular machine is obtained from the RESOURCES card.)

NQ(N) - Number of items residing in queue number N

X(N) - Value of array variable X(N) [X(1) through X(4) is used to hold the current number of assemblies in process cells 1 through 4, respectively.]

When NR(N) is used to obtain a machine use, and the number of machines with the resource number N is greater than one, the value reported in the SIMAN summary must be divided by the number of machines in order to obtain an average machine use. In SIMAN, machine use is defined as any time a machine is not idle. Thus, if a machine is down for repair, the time is accounted for as busy time. The percentage of that time a machine is idle is obtained from: [1-(utilization)]*100.

The TALLIES card is entered as simply stated in Chapter 4.0 into the experimental frame by the user. The user must also enter into the model frame a TALLY block at the point in the model that the information is available. The user then recompiles and links the model and experiment as described in Chapter 5.0. The TALLY block has the syntax:

TALLY:N, VAR;

N - Tally set number, which the information corresponds to on the TALLIES card in the experimental frame.

VAR - The variable or, if some calculations need to be performed, an expression which has a value to be observed.

DISTRIBUTION

No. of Copies

OFFSITE

J. H. Carlson
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

H. J. Hale
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

K. A. Klein
U.S. Department of Energy
1000 Independence Avenue, SE
Washington, DC 20585

E. L. Wilmot
U.S. Department of Energy
1000 Independence Avenue, SE
Washington, DC 20585

C. Boggs-Mayes
Chicago Operations Office
U.S. Department of Energy
9800 S. Cass Avenue
Argonne, IL 60439

2 Oak Ridge Operations Office
U.S. Department of Energy
Oak Ridge, TN 37830
Attn: P. J. Gross
S. S. Perkins

W. D. Woods
Ralph M. Parson Co.
100 West Walnut St.
Pasadena, CA 91124

No. of Copies

P. J. Steffan
Westinghouse Electric Corp.
Waste Technology Services Div.
P.O. Box 286
Madison, PA 15663

J. W. Cashwell
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185

30 DOE Technical Information Center

ONSITE

5 DOE Richland Operations Office

J. P. Collins
M. S. Karol
D. E. Kenyon
D. C. Langstaff
J. J. Sutey

No. of Copies

40 Pacific Northwest Laboratory

G. H. Beeman
A. J. Boegel
J. L. Braitman
A. D. Chockie
L. L. Clark
J. W. Currie
J. F. Fletcher
R. M. Gale
R. E. Heineman
C. J. Hostick (3)

No. of
Copies

H. D. Huber
T. L. Lotz (5)
P. N. McDuffie
R. W. McKee
G. W. McNair
P. T. Otis
M. R. Shay (5)
R. I. Smith
R. A. Sovers
M. B. Triplett
R. C. Walling
M. K. White
T. W. Wood
Publishing Coordination MH (2)
Technical Information (5)