TIME AND MOTION SIMULATION OF THE WRAP MODULE 1 FACILITY

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ABSTRACT

A Time and Motion simulation model was developed for the Waste Receiving and Processing (WRAP) Module 1 Facility which will be located at the U.S. Department of Energy (DOE) Hanford site. The simulation model was developed using the WITNESS computer program licensed from AT&T ISTEL. The model simulates the movement of 6,825 drums per year of transuranic (TRU) and low level waste (LLW) through the WRAP 1 Facility.

In the WRAP 1 Facility, four main areas were modeled: Receiving, Non-Destructive Examination/Non-Destructive Assay (NDE/NDA), Waste Process and Shipping. Movement of waste drums through the plant is accomplished with forklifts, roller conveyors, two automated guided vehicles (AGV's), lift tables, jib cranes and pallet transfer carts. In-plant drum storage is provided by an automated storage and retrieval system (ASRS) for palletized drums in the Receiving/Shipping areas, a 12-drum storage carousel in the NDE/NDA area and a 24-drum storage carousel in the Waste Process area.

The process simulation model has been able to confirm that in excess of 6,825 drums per year of TRU and LLW waste can be processed in the WRAP 1 Facility. The WRAP 1 Time and Motion simulation model incorporated a 70% facility availability to account for equipment failures and maintenance downtime. The availability factor was required by the facility design requirements documents. In addition to determining the facility throughput, the maximum throughputs for each of the individual areas: Receiving, NDE/NDA, Waste Process and Shipping have been determined based on simulation runs of area operations that have been isolated from the rest of the facility.

To assess the plant availability, the Time and Motion simulation model incorporates a Reliability, Availability and Maintainability (RAM) analysis for the plant. Each key equipment item in the model was assigned a mean-time-between-failure (MTBF) and a mean-time-to-repair (MTTR) value, based upon historic data of similar equipment. The RAM model confirmed that the overall plant availability factor of 70% and the facility throughput requirements could be achieved.

The process simulation models use a color graphic display of plant operations to show drum (or pallet) movement throughout the plant. Actual speeds of vehicles, conveyors and forklifts are simulated in the model as well as machine cycle times, delay times, and stop times. Vehicle load and unload times, and acceleration and deceleration are included in the model. Distributions for the arrival of trucks delivering pallets or trucks leaving with waste drums or pallets are included in the model. Random numbers for distributions are assigned to determine the effect of variability on plant performance. The simulation program generates a full range of reports that allows users to determine the plant throughput under a wide variety of conditions. Typically a warm-up period is run to allow drums to complete travel through the system until "steady-state" operation is achieved. The model is then run at these steady-state conditions for several days, weeks or even years, depending on the complexity of the model.

BACKGROUND

United Engineers and Constructors Inc. (UE&C) is performing the Definitive Design of the WRAP Facility Module 1 for the Department of Energy at Richland, Washington. The A/E design effort consists of an integrated design team of UE&C, British Nuclear Fuels (BNFL Inc.) and Engineering Design Services (EDS). UE&C as the prime contractor, has provided the overall project management and A/E design services for the project. BNFL Inc. has provided a team of senior solid waste management personnel from their United Kingdom operations to provide TRU solid waste process technologies. EDS is an engineering firm providing the specialized TRUPACT shipping container design expertise. The integrated project team is located at UE&C's Denver, Colorado offices. Technical oversight and equipment development support to the project is provided by Westinghouse Hanford Company (WHC) personnel.

The WRAP 1 Facility is being designed to certify contact-handled waste for disposal. The waste will be contained in 55-gallon drums, 55-gallon drums overpacked in 85-gallon drums, and Standard Waste Boxes (SWB's). WRAP 1 will accept both newly-generated waste and waste retrieved from storage. WRAP 1 will provide the capability to open, sort and sample contact-handled drums of TRU, TRU mixed waste, LLW, and LLW mixed waste. The WRAP 1 Facility will provide limited treatment for certain corrosive materials, loose particulate, and free liquids; provide volume reduction of waste amenable to reduction; and repackage the waste to meet current waste disposal criteria.

FACILITY GENERAL DESCRIPTION

The WRAP 1 Facility will be located in Benton County, Washington, in the 200-West area of the Hanford site. This area has been designated by the U.S. DOE as the Hanford Central Waste Complex. The facility will be housed in a metal building structure with approximately 51,700 square feet of floor space. Figure 1 illustrates the facility floorplan and identifies the four process areas.

The WRAP 1 Facility will have a reception area, waste receiving and shipping area, non-destructive examination and non-destructive assay area, alpha confinement enclosures for opening and sorting drums, a restricted waste management area for waste treatment, and a sample management area. The administrative and reception areas will contain restrooms, change rooms, offices, office equipment and space necessary for administrative work and visitor control.

Key design features of the facility include an automated drum stacker/retriever system (ASRS) in Shipping and Receiving, state-of-the-art NDE/NDA equipment, LLW, TRU and Restricted Waste Management (RWM) glovebox suites that house the sorting/sampling/volume reduction equipment, and Automated Guided Vehicles (AGV's) that service the NDE/NDA and Waste Process areas. Waste data acquisition and manipulation is handled with a data management system which will interface with existing Hanford waste data management systems. Supervisory control of the plant operations is provided by a distributed control computer system.

FACILITY MISSION

The primary mission of WRAP 1 is to characterize and certify LLW/TRU solid waste for disposal. A secondary mission is to provide limited treatment for non-compliant wastes to meet disposal requirements.

FACILITY FEED

WRAP 1 will receive contact-handled waste (i.e., less than 200 mrem/hr at contact) mainly in the form of drums (both 55-gallon and 85-gallon), and also SWB's. Waste will be either LLW or TRU waste, and will be either newly-generated or retrieved.

The WRAP 1 Facility will receive 6,825 drums and 70 SWB's of contact-handled waste annually to be processed in 175 uninterrupted operating days/year (assuming a 70% facility availability for the 250 available operating days/year), operating one (1) eight hour shift/operating day. The annual drum feed will consist of 2,625 retrieved 55-gallon drums and 4,200 newly-generated 55-gallon waste drums. Both retrieved and newly-generated drummed wastes are estimated at 50% TRU and 50% LLW. Retrieved 55 gallon waste drums will be placed in 85-gallon overpack drums prior to shipment to WRAP 1. Wastes contained in SWB's will be comprised of newly-generated suspect TRU waste.

PLANT PROCESS SIMULATION MODELS

Two time-and-motion simulation models were developed for the WRAP 1 Facility. The development of the first model had two major objectives: 1) to confirm the throughput requirements of 6,825 drums and 70 SWB's per year in 175 uninterrupted operating days per year and 2) to determine the maximum throughput for the four main areas of the plant: Receiving, NDE/NDA, Waste Process and Shipping. The second model was based on extensive modification of the first model and the main objective for developing this model was to confirm the plant availability of 70% could be achieved after providing for the random breakdown and repair of key equipment in the model. This reliability, availability and maintainability (RAM) analysis model was very useful in determining how the lag or buffer storage areas (pallet and drum storage) could best be utilized when equipment breakdowns did occur.

WRAP 1 BASE TIME AND MOTION MODEL

Model Description

A flow diagram for the WRAP Module 1 Facility is shown in Fig. 2. The WRAP 1 Facility has four main areas: Receiving, Shipping, NDE/NDA and Waste Process. The flow rates shown are in drums per day equivalents, even though drums may be present as individual drums, drums on pallets or pallets on trucks. The drum flow rates are specified in the facility design requirements documents to meet the 6,825 drums per year in 175 operating days per year, assuming a plant availability of 70% for the nominal 250 days per year the plant is available to work. The standard waste boxes were not modeled in as much detail as the drummed waste due to the relatively small size of the box feed stream.

The model used a variety of vehicles, conveyors and cranes to move the drums throughout the plant. Five vehicles are used in the model: a fork truck (FORK) is used in the Shipping and Receiving areas to move pallets of drums, the automatic stacker/retriever system (ASRS) is used to move pallets to incoming pallet storage (LAGIN) or outgoing pallet storage (LAGOUT) in the Shipping and Receiving areas, two jib cranes to palletize and depalletize waste drums, a bridge crane (BRIDGE) in the Shipping area to move TRUPACT pallets to the TRUPACT loading area, and two automated guided vehicles (AGV's) to 1) move individual drums in the NDE/NDA area and between NDE/NDA and the Shipping and Receiving areas (AGV1) and 2) to move drums within the Waste Process area (AGV2). Each vehicle in the model is given speeds for unloaded and loaded conditions, an unloading time and a loading time and a time delay to account for vehicle acceleration or deceleration. The speeds and times were based on vendor information.

The four plant areas utilize three different operating shift durations that are incorporated in the model, which include:

- Shipping and Receiving (SF1) 6.0 hours per day
- NDE/NDA (SF2) 7.0 hours per day
- Waste Process (SF3) 5.5 hours per day

In the model, a day was defined as seven hours (420 min) because 1) the plant will only operate one shift per day and 2) a maximum of seven hours of work is done by any one of the three operating times. For shifts SF1 and SF3 that operate less than seven hours, all machines and conveyors stop (including the forklift) during 1 and 1.5 hour rest periods, respectively.

In addition to modelling the equipment required to operate the WRAP 1 facility, the Time and Motion simulation model also evaluated the 18 units of labor that comprise the manpower requirements for WRAP 1. The allocation of labor for the three process operators at the TRU enclosure was equalized as much as possible to optimize TRU enclosure (glovebox) throughput and thereby minimize storage of drums waiting for processing. The allocation of labor for the three

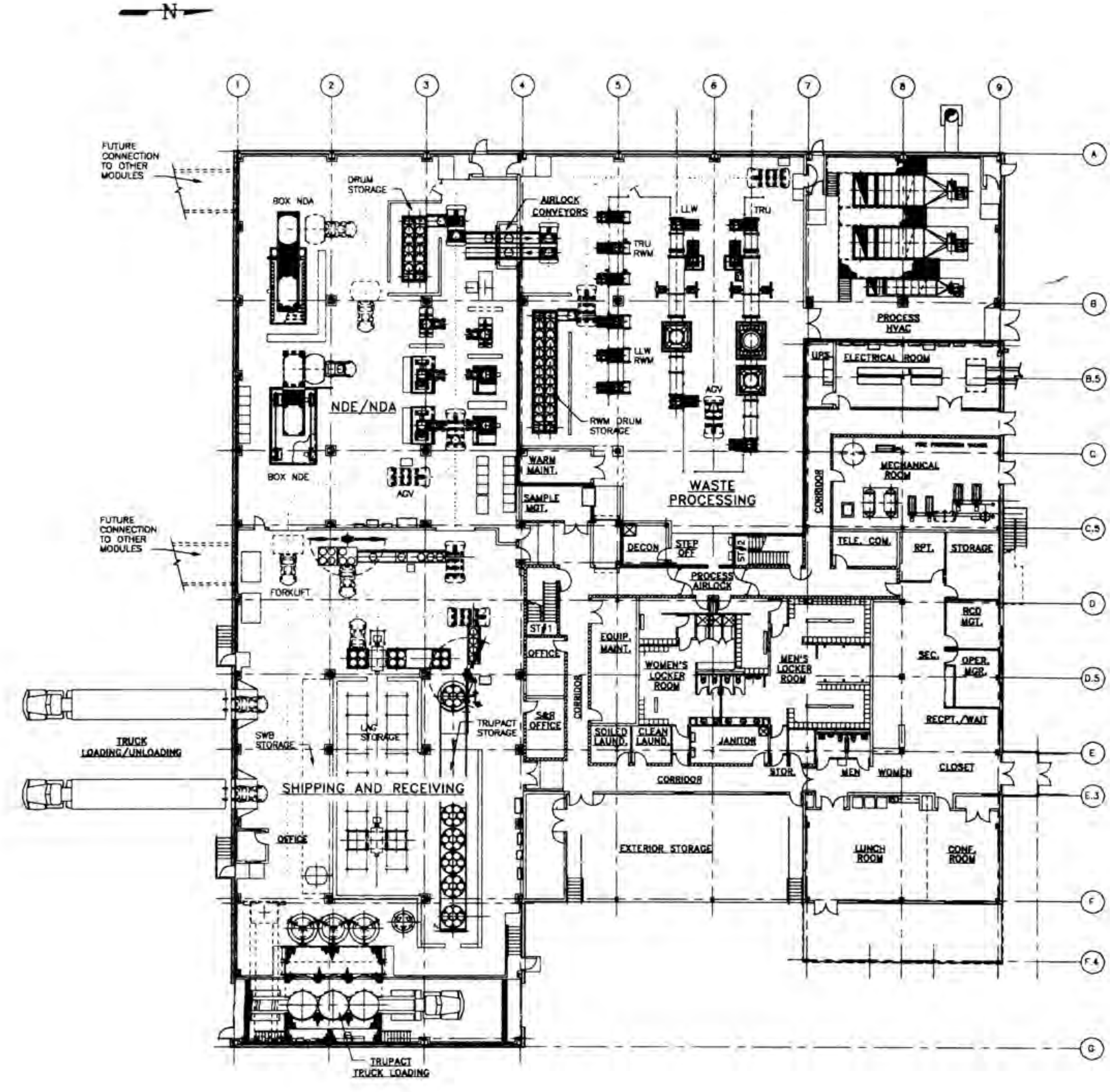

Fig. 1. Wrap module 1 - floor plan - ground level.

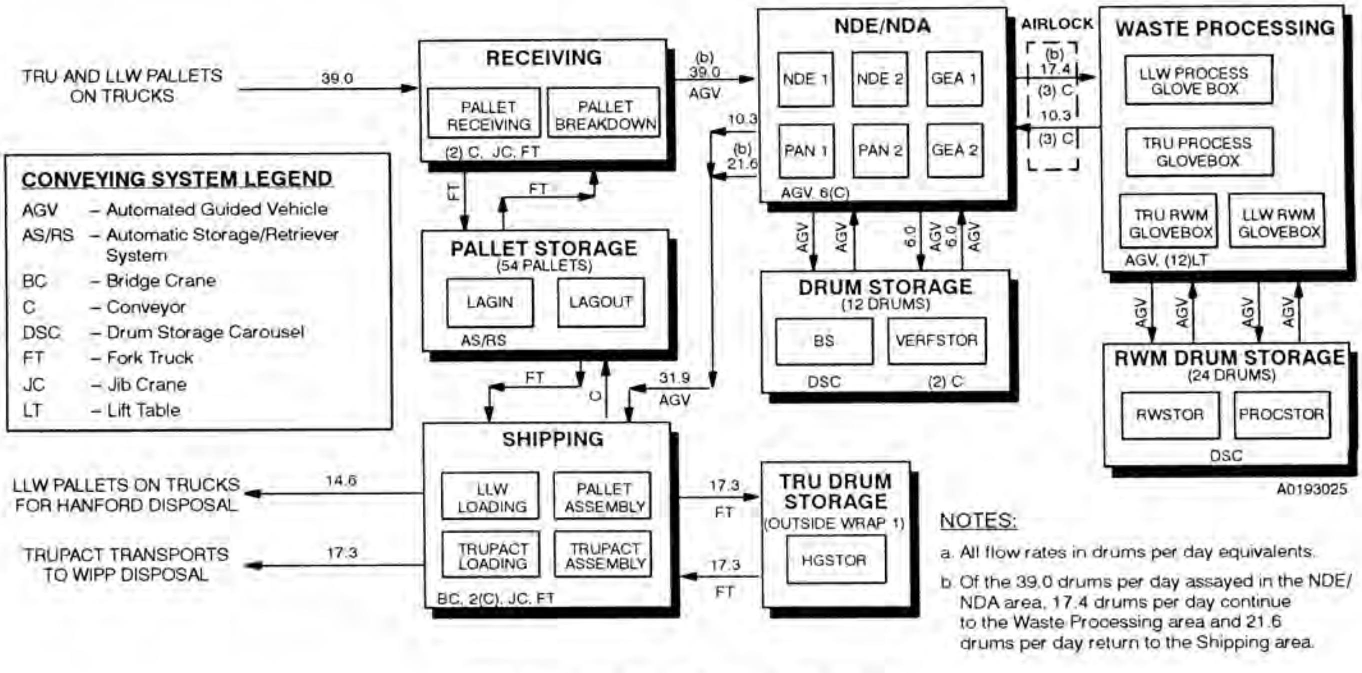

Fig. 2. WRAP module 1 flow diagram.

process operators at the LLW enclosure was likewise equalized to optimize LLW enclosure throughput.

Other peripheral manpower such as a sample management technician or a Health Physics monitor in the Waste Process area were not modeled since they do not have a direct impact on the production operations. Operators that monitor the NDA equipment and the material handling system are not directly involved with the operations unless off normal conditions occur and these were not modeled. The peripheral operators are important to the overall facility, but in normal cases these operators would not impact the waste throughput operations of the facility and were excluded.

In the model, drums are received on trucks which carry five pallets of four drums per pallet, or a total of 20 drums per truck. Two trucks per day (a total of 40 drums per day) arrive on a random arrival pattern. Pallets are removed from the trucks by a fork lift truck, surveyed and temporarily stored in the automatic pallet storage/retrieval system (LAGIN via the ASRS vehicle). Pallets are retrieved from LAGIN storage via the ASRS and are transported to the pallet breakdown area where the drums are removed from the pallets, bar code labels applied, placed on a roller conveyer and weighed. The total pallet storage capacity for both incoming and outgoing pallets is 54 pallets.

Individual drums are picked up by an AGV that services the NDE/NDA and Receiving and Shipping areas. Drums are transported by AGV1 from the Receiving area roller conveyor to one of two Non Destructive Examination (NDE) machines and then to one of two Passive-Active Neutron (PAN) machines and finally to one of two Gamma Energy Analysis (GEA) units. The NDE units use Real-Time Radiography technology (RTR) to determine the contents of the drum, i.e., whether the drum contains any non-compliant waste such as particulate, HEPA filters, free liquids, aerosol cans, compressed gas cylinders or other non-compliant items requiring waste processing. Assay results obtained for the PAN and GEA units are used in conjunction with sampling and characterization data to develop isotopic inventories of the waste drums which will support their certification and disposal.

All of the retrieved TRU and LLW drums and 10% of the newly-generated TRU and LLW drums (a total of 17.4 drums per day) that exit one of the two GEA units are transported by AGV1 to three roller conveyors in series that pass through an airlock that separates the NDE/NDA area from the Waste Process area. The remaining 90% of the newly-generated TRU and LLW waste (21.6 drums per day) is transported by AGV1 to a roller conveyor in the Shipping area.

Processed waste returning from the Waste Process area (10.3 drums per day) is again assayed in the NDE/NDA area before moving to the Shipping area. Processed drums containing stabilized and immobilized TRU or LLW restricted waste items must pass through the NDE, PAN and GEA units before being transported to the Shipping area. The remaining waste drums are assayed by the PAN and GEA units.

A priority "call" system with a first-in/first-out (FIFO) handling of equal priority calls is used to direct the movement of the NDE/NDA AGV. A call can be illustrated by the following example: When a drum reaches the end of a conveyor, a call is issued for an AGV to pick up the drum and deliver the drum to a second location (conveyor, machine, etc). Drums leaving the GEA machines have the highest priority, followed by the PAN units and finally the NDE units, the S/R infeed roller conveyor, the roller conveyor returning processed drums to the NDE/NDA area and the 12-drum storage carousel. The priority assignments were determined by running the model with varying priorities assigned to the equipment and comparing the resulting throughput. A "flag" system is used when calls are made to prevent the AGV from delivering one drum to two competing units (say both NDE units) or from delivering two different drums to the same unit. A flag is an integer with a value of zero or one. Each potential call is given a "flag" with a normal value of zero (when no call is being made. When the call has been made and is being executed, the flag is set to one. The flag is reset to zero after the call has been completed. A call is allowed to be made when the following conditions are satisfied:

- A drum is available to be picked up by the AGV.
- A machine and attached transfer conveyor is idle (available to accept a drum).
- All flags from all other potential competing calls are equal to zero.

The call is then placed on the AGV demand list in the order received (if priorities are equal) or based on the priority of the call. The call is executed only when the call is at the top of the demand list and all three conditions are met, i.e. all previous competing calls have been completed (all flags equal zero) and therefore the AGV is available to make the call.

The call and flag system was also used to direct the AGV in the Waste Process area (AGV2) which interfaces with numerous conveyors and the Shipping/Receiving forklift (FORK) which interacts with trucks containing incoming and outgoing waste pallets and the ASRS unit.

The NDE/NDA area also has a 12-drum storage carousel which is primarily used to temporarily store processed drums returning from the Waste Process area awaiting a second pass through the NDE/NDA area. In case the Waste Process area equipment is broken down and cannot receive drums from the NDE/NDA area, the storage carousel can also be used to temporarily store these drums.

The PAN and GEA units capability to properly assay waste matrices is checked twice daily. Two background drums and two verification drums enter the modelled assay equipment at the beginning of each operating day. At the end of the day, the two verification drums enter the model a second time to perform verification checks on the assay equipment. This in effect adds six drums per day to the NDA throughput requirements.

The primary functions of the Waste Processing area are to provide characterization, volume reduction, limited non-compliant waste stabilization, treatment, certification and repackaging capabilities for retrieved TRU and LLW waste (schematically shown in Fig. 3), in order that such wastes can be safely disposed of in accordance with approved waste disposal criteria. The Waste Processing area consists of four enclosures, or gloveboxes: TRU Process glovebox, LLW Process glovebox, TRU RWM glovebox and LLW RWM glovebox. The Waste Processing area has a 24-drum storage carousel used to hold RWM drums for a two week period awaiting sample analysis and to temporarily hold drums from the NDE/NDA area that are waiting to be processed.

Incoming drums are picked up from the airlock conveyor line leaving the NDE/NDA area by the Waste Processing AGV (AGV2), which is identical to the NDE/NDA AGV. Drums are delivered to either the TRU or LLW Processing glovebox, where process operations are essentially identical, except the LLW enclosure does not have a girth (diameter reduction) compactor. About 75% of the drums are delidded and the contents spread on sorting tables to remove non-compliant items and to sample the waste. About 25% of the waste is not spread but is sent directly to compaction. Non-compliant items are verified by a package X-ray machine in the glovebox. After verification, the non-compliant waste packet is placed in a transfer drum with several other non-compliant items and the drum is transferred via AGV to the respective (TRU or LLW) RWM glovebox. Compliant items are returned to the empty feed drum by tipping the sorting table contents into the drum. The drum is relidded, girth compacted (TRU only) and supercompacted into a "hockey puck". Pucks will be stored in each glovebox and loaded into a new drum depending on weight, fissile content or height of the waste in the drum. The product drum containing multiple pucks is relidded and picked up by the AGV for transport to the airlock conveyor line which returns processed drums to the NDE/NDA area.

The two RWM enclosures perform identical operations. Drums are opened, and the contents are sampled and the items returned to the drum. These drums are then relidded and sent to the RWM drum storage carousel for two weeks awaiting sample results. Some items sent to the RWM gloveboxes are actually compliant items and these are returned by drum to the respective TRU or LLW RWM enclosure. When sample results are received, the RWM drums are returned by the AGV to the respective TRU or LLW RWM enclosure and the non-compliant items are neutralized and immobilized depending on the specific waste item. Treated waste items are repacked in a drum and the drum is moved by the Waste Process AGV to the airlock conveyor line for transfer back to the NDE/NDA area.

In the Shipping area, TRU or LLW processed drums are delivered by the NDE/NDA AGV to a roller conveyor where the drum is bar code labeled, weighed and surveyed for surface contamination. Drums are placed on pallets by type (TRU or LLW). The LLW pallets are sent to the ASRS until a truck is available to pick up five pallets. These LLW drums will be disposed of at the Hanford site. TRU drums are palletized and sent to a storage building (HGSTOR) separate from the WRAP 1 building for a two week period while waiting for sample results, head-gas sampling, and acceptance of the waste for shipment. Once the certified TRU drums are accepted for shipment by the Waste Isolation Pilot Plant (WIPP), 14 drums that may be assembled into a single TRUPACT II payload are returned on pallets of four to the WRAP 1 Facility. The drums are removed from the pallets and assembled into a 14-drum TRUPACT II payload. TRUPACT payloads are moved by a conveyor and bridge crane to the TRUPACT loading area, where three TRUPACT payloads are placed in TRUPACT II casks, sealed, leak checked and readied for shipment to the WIPP facility. These trucks will deliver the TRUPACT's to the WIPP in New Mexico for ultimate disposal.

Model Results

Operation of the process simulation model indicates the WRAP 1 Facility will meet the throughput requirements as specified in the WRAP 1 design requirements documents. Table I summarizes the throughput requirements as well as the maximum throughputs generated by the model. In each area, the maximum throughput estimated by the program exceeds the design requirements.

Operation of the integrated model with all four areas using random arrival times for incoming trucks confirms that the design throughput of 6825 drums per year will be achieved. Buffer storage areas to do not show a consistent buildup of drums, indicating that all areas of the plant are meeting design requirements.

TABLE I
WRAP 1 Annual Throughput
(Time and Motion Study)

WRAP 1 Operating Area	Design Requirements		Throughput Estimated by WITNESS Time & Motion Program	
	Per Day[a]	Per Year[a]	Per Day[a]	Per Year
Receiving	39.0	6825	49.8	8715
NDA/NDE	49.3 55.3[b]	8632 9682	62.7	10973
Waste Process				
Entering	17.4	3045	21.4	3745
Leaving	10.3	1803	12.5	2188
Shipping	31.9	5587	51.2	8960

Notes: a. Based on 175 uninterrupted operating days per year.
b. Includes two background and four verification drums per day that pass through the PAN and GEA machines.

drums, indicating that all areas of the plant are meeting design requirements.

WRAP 1 RELIABILITY, AVAILABILITY AND MAINTAINABILITY TIME & MOTION MODEL

Model Description

A second model was developed by extensively modifying the initial process simulation model to perform a Reliability, Availability and Maintainability (RAM) Analysis. The revised model included changes to account for plant wide equipment breakdowns and repairs, vehicle breakdowns and repairs, and equipment (including machines and conveyors) breakdowns and repairs. Numerous changes were also made to the logic commands to direct the flow of drums around failed equipment (primarily in the NDE/NDA area) or more commonly to either 1) direct the flow of drums to the buffer storage areas or 2) stop the flow of drums when buffer storage areas exceed their capacities or have failed.

The RAM model includes 87 machines that simulate equipment or system breakdowns. Fifty five of these machines existed in the base Time and Motion simulation model and were modified by adding MTBF and MTTR values. Thirty-two of the 87 machines were added to the Time and Motion model to: 1) simulate plant wide failures, 2) simulate equipment items not modeled in the base model (some of the Time and Motion simulation steps involved multiple pieces of equipment, each with its own MTBF and MTTR values), and 3) simulate the breakdown of vehicles (which do not breakdown in the WITNESS model). When the latter occurs, drums or pallets leaving machines or conveyors are held until the vehicle servicing those elements is repaired.

Based on vendor information, the two Automated Guided Vehicles (AGV's) have been estimated to have a failure frequency of once every 100 cycles (tasks) with a MTTR of 0.20 hours. At 100 tasks per hour, the AGV's would have a MTBF of 1.00 hour. A task is defined as a discrete operational step or control command (e.g., four tasks are: go to conveyor, load drums, move drum to station, off-load drum). The MTTR is small because in most cases the AGV can be made operational by resetting a control button on the on-board computer. This is not caused by a hardware failure, but a failure to complete a task due to a slight misalignment, dusty sensors, etc.. Most of these failures can be corrected by the local operator trained to perform simple AGV adjustments. These adjustments typically take a few minutes. The 12 minute (0.2 hour) MTTR includes all repairs, minor and major, averaged over the life of the AGV.

In the WITNESS model, the MTBF for equipment used the negative exponential distribution because that is the distribution which tends to most accurately reflect real equipment breakdowns. The MTTR also uses a random distribution with the repair time distribution based on the mean value of an Erlang distribution with a K value of 2. Again, WITNESS uses the Erlang distribution because that is the distribution which tends to most accurately reflect real repair times. A random number generator is used with each distribution to generate the random patterns for breakdowns and repair times. As an alternate, WITNESS allows the actual time to be used for the MTBF and MTTR. Availability of an equipment item used in the RAM analysis can be calculated using the equation:

$$A = \frac{MTBF}{MTBF + MTTR}$$

For repairs within a waste processing enclosure, a 5.5 hour administrative delay was added to all MTTR values. For standard commercially available equipment outside of containment, a 2.5 hour administrative delay was assumed. For repairs requiring temporary "greenhouse" construction to confine the spread of contamination when a glovebox would be opened, additional time for greenhouse assembly/disassembly has been added as part of the repair time. The repair of process equipment at the LLW or TRU glovebox requiring the construction of a temporary "greenhouse" will result in the shutdown of both gloveboxes until the repair has been completed (AGV travel path is blocked by the greenhouse). The same is true for the LLW RWM and TRU RWM gloveboxes. Equipment repairs are conservatively assumed to be performed only during the regular operating shift.

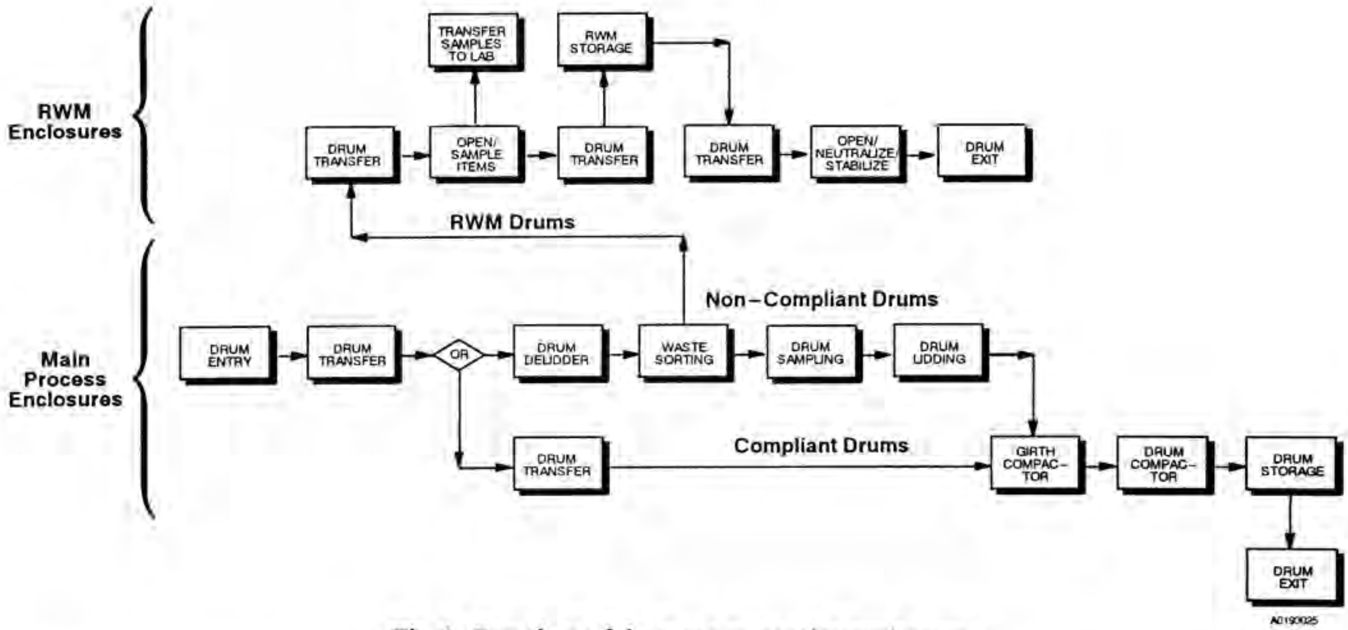

Fig. 3. Functions of the waste processing enclosures.

Elapsed time (clock hours) was used as the basis for establishing mean-time-between failure (MTBF) equipment parameters with one notable exception: both of the AGV's have MTBF's based on number of cycles (discrete tasks) rather than number of elapsed hours based on advice from the vendor.

Natural disasters, labor disruptions, sabotage, initial facility startup, failure of external utilities and facility damage from accidents are excluded from the RAM analysis. The effect of human error is only included to the extent that it has already been incorporated into published failure rates for equipment.

Model Results

The simulation model was run for 750 days, or a three operating years warm-up period followed by 1,250 days, or five operating years of steady-state operation: During the warm-up period, 68 of the 87 machines (78%) broke down and 28 of the 28 conveyors (100%) broke down.

During the five years of steady-state operation, a total of 36,885 drums were processed in the model (as noted by the number of drums reaching the drum infeed conveyor CT3) or an average of 7,377 *drums per* year. This compares favorably with the design requirement of 6,825 drums per year as shown in **Table II**.

The variability in throughput during the five years of production for twelve key areas of the plant is due to the random pattern of equipment breakdowns and repairs produced by the simulation model. In each case, the yearly throughput for that part of the facility exceeds the design requirements shown in the last column of **Table II**. The model results also show that the maximum capacity of the drum storage carousels is not exceeded. This is a key point, since exceeding the capacity of any storage area would invalidate the model results. The Box NDE values verify that 70 boxes per year pass through plant. During the time the Box NDE machine is in operation, the NDE2 machine cannot operate, since the two machines share the same display console. The 7,377 drums per year is equivalent to a plant availability factor of 76%.

During the five years of steady state operation, 71 of the 87 machines (82%) broke down and 27 of the 28 conveyors (96%) broke down. Including the three year warm-up period, 80 of the 87 machines (92%) broke down and 28 of the 28 conveyors (100%) broke down. Of the seven machines that did not breakdown, six of the machines had high MTBF values of 25,000 hours or more.

During the five years of steady state operation, the AGV in the NDE/NDA area (AGV 1) averaged 1,750 shutdowns per year which lasted 12 minutes each, or a downtime of 1.40 hours per day (20.0% of the seven hour operating day by this AGV). During this same five year period, the AGV in the Waste Process area (AGV2) averaged 529 shutdowns per year which also lasted 12 minutes each or a downtime of 0.42 hours per day or 6.0% of the seven hour operating day of this AGV.

SIMULATION MODELING BENEFITS

The WITNESS Time and Motion simulation model developed for the WRAP 1 Facility confirmed plant throughput under an assumed plant operating availability of 70%. The RAM model also showed that facility throughput requirements could be met assuming a 250 day operating year and providing for random equipment failures modelled with mean-time-between- failure (MTBF) and mean-time-to-repair (MTTR) data. Some other benefits to be gained from simulation modeling are:

- Plant operations can be optimized, especially in directing the movements of the automated guided vehicles to avoid unnecessary repetitive motion between two pick up or two drop off stations. This information will be beneficial in developing the plant control software.

are included in the model. In fact, using the pallet storage area and the two drum storage carousels to their maximum capacities only becomes apparent when equipment breakdowns are included in the model.

- The simulation model can be used in developing equipment specifications, especially the automated components requiring control logic.
- The models can be used for personnel training since the color graphic display shows how drums and pallets move through the plant using fork trucks, AGV's, cranes, stacker/retrievers, and conveyors. The RAM model also shows how the buffer storage areas are utilized when equipment failures occur.
- The models can be used in "what if?" situations when a plant modification is planned and the potential effect on plant throughput needs to be estimated. By saving the model under several names, a family of models can be developed for a variety of plant operating conditions.
- The model can be continually updated as changes are made to the facility and is, in effect, a living document for the life of the facility.
- The model can be used to facilitate maintenance planning and estimate personnel dose accumulations

TABLE II

Wrap 1 Throughput Comparisons (Time and Motion and RAM Analysis Using 250 Available Days Per Year)

		T2-RAM-6 Model Results with 3-Year Warmup					
Witness Code	Operation Title	1st Year of Production	2nd Year of Production[a]	3rd Year of Production[a]	4th Year of Production[a]	5th Year of Production[a]	SDRD REQMNT (Table I Annual Rates)
CT2	Receiving	6995	7771/14766	7387/22153	6997/29150	7735/36885	6825
NDE1 & NDE2	NDE	7206	7997/15203	7616/22819	7223/30042	7959/38001	7014
GEA1 & GEA2	NDA	9993	11068/21061	10498/31559	10024/41583	11052/52635	[c]9678
BOXNDE	Box NDE	70	70/140	70/210	70/280	70/350	70
BS	Buff Storage	12 max	12 max	12 max	12 max	12 max	12 max
BC11	LLW Glovebox	590	652/1242	612/1854	592/2446	640/3086	564
BC12	TRU Glovebox	1134	1257/2391	1150/3541	1164/4705	1211/5916	1054
TRUNC	TRU RWM	160	167/327	166/493	160/653	166/819	144
LLWNC	LLW RWM	178	205/383	191/574	184/758	199/957	175
RWSTOR	RWM Storage	15 max	17 max	17 max	17 max	17 max	24 max
PROCSTOR	TEMP Storage	24 max	24 max	24 max	24 max	24 max	24 max
(HGSTOR x 4)	TRU Drums to HGSTOR	3264	3480/6744	3260/10004	3144/13148	3420/16568	3037
CT3	DISCH Conveyor	8487	9429/17916	8926/26842	8501/35343	9352/44695	8069
(REMOVE2 x 4)	TRU Drums Out	3128	3476/6604	3268/9872	3152/13024	3392/16416	3037
(LLWPLLT x 4)	LLW Drums Out	2628	2900/5528	2756/8284	2592/10876	2880/13756	2550
(E83PLLT x 4)	Empties Out[b]	2780	3052/5832	2904/8736	2764/11500	3048/14548	2482

Notes:

a) XXXXX/YYYYY numbers show the particular year's throughput/cumulative years' throughput.

b) Assumes all waste entering the process enclosures are overpacked, i.e., generated empty 85 gallon drums.

c) Includes two background drums and four verification drums per day that pass through the PAN and GEA machines.